Master thesis Offshore & Dredging Engineering

Delft University of Technology

TOTAL
COMMITTED TO BETTER ENERGY

The application of marine access for Total Exploration and Production Netherlands

Joost Middelburg

Chair
Delft University of Technology – Faculty of Civil Engineering: F. Sliggers

Supervisors
Delft University of Technology – Faculty of Civil Engineering: F. Renting
Delft University of Technology – Faculty of Civil Engineering K.N. van Dalen
Total Exploration & Production – Development & Planning Department: J. Ducray
Total Exploration & Production – Logistic Department: H. Giesberts

Executive summary

Why is Total exploring a marine access solutions?

The gas production of a field in the decline phase combined with maturing assets and an especially low commodity prices result in a challenge regarding operational costs. The incentive to focus on activity optimization is to establish a long-term cost reduction. Many activities require physical access to the structure for which a specific logistic transportation means is required. The contribution of the logistic costs to the total costs of servicing a platform makes evaluating this process logical. All transportation means come at a cost, depending on the accessibility desired. The objective is cost reduction, and therefore exploring marine access solutions instead of the current air access solution. To support a potential operational decision between marine or air access solutions, the process is modelled in a process flow diagram.

Maintenance on Total's satellite platforms in the North Sea?

Satellite platforms are the un-manned platforms that are key to the production of natural gas. This research will only address the maintenance visits to these platforms to keep the scope manageable. The location of the platforms is key, because Total's platforms are closely together but far offshore, this should be considered when selecting a marine approach. This research makes a distinction within the maintenance activities: *preventive* or *corrective maintenance.* The chosen focus is on the preventive maintenance requirements of 14 satellites in the North Sea.

At what point to start this study?

Currently, a high visitation frequency is characterizing the logistic deployment of a helicopter. The helicopter is used for personnel transfer in combination with a supply vessel for equipment transfer. The conducted marine access requirement analysis workshop gives requirements and constraints as a starting point.

Does marine access provide an operational cost saving?

The means of accessing a satellite, from a cost perspective, needs to be investigated to see if new opportunities arise. Since the brownfield under consideration is reaching end of life this limits capex. The components linked to the access manner, a generalized approach for all assets, and the high cost of offshore activities are considered in this research. The importance of the work scope, especially the PM hours, becomes clear since the required visit frequency has much to do with the required flexibility. The access to a platform comes at a cost, the higher the accessibility (frequency of visits) the higher the costs involved. Selecting a marine access means that takes this into account requires a detailed evaluation of system components.

Logistic scenarios: how to choose?

All marine access solutions consist of 3 general components: vessel, mooring method and transfer mechanism. The vessels are considered by type: crew transfer vessel, offshore support vessel and jack up vessel. The mooring method is directly linked to the type of vessel; 2 methods are considered: a surfer- or dynamic positioning method. The transfer principle is bounded by operational requirements limiting the use of some transfer principles. These constraints limiting the amount of options can be internal (company requirements) or external (out of control of TEPNL). The platform, the transportation means or operating requirements set the boundaries. The assessment of options has resulted in 4 key scenarios: helicopter & supply vessel, walk to work vessel, crew transfer & supply vessel and a jack up vessel. To compare the different access scenarios a common unit is required, chosen is to make the comparison based on costs.

How to model different scenarios?

In the evaluation of the operational costs of offshore logistics and access solutions both means of transporting people and equipment need to be considered. The rather complex influence relations and significance of many of the cost driving variables of marine access have been captured in a cost comparison model. The mathematical expressions of the total cost functions for all of the scenarios are given based on the same variables. The model is described in a process flow diagram, which is used to compare various scenarios. For each scenario, a total cost function is determined.

Cost driving variables?

By using different evaluation techniques, the dominant variables for cost modelling are obtained. The cost comparison model is based on the key variables:

- travel time
- workday
- personnel on board
- wait on weather time (W.o.W.)
- rates of labor and logistic means

The travel time is particularly important for a helicopter since cost function is a based-on flight time. The maintenance workday offshore is linked to the duration on the platform, on its term is dependent on the means used and the required work scope of the platform. The size of the maintenance team is both restricted by the platform constraints and capacity of the used transportation means. The impact of the weather specifically the wave conditions result in wait on weather time which is costly considering the rate of the required logistic means. Finally, the labor and logistic rate are cost contributors to the operating costs.

Findings

Some of the pre-assumed cost drivers are determined less significant when making the cost comparison. The desired cost saving from operational optimization are realized by the reduction in transportation means and do not result from change in labor. To optimize offshore operations in the North Sea, the focus should be on simultaneous servicing, reducing the frequency of platform visits, increasing the duration of the visits, and taking benefit from the seasonal environmental conditions. The evaluation shows the cost saving from route of team optimization are less significant.

Change of shift?

The behavior of a scenario versus the current case (starting point) is graphically evaluated by a cost vs. time curve comparison. The visitation by a team results in small steps in cost curve, till the workday requires an additional trip, the is the larger cost steps.

Conclusion: for marine access, operating mode changes necessary?

The conclusions obtained from this research result in the confirmation that TEPNL is currently using the most cost effective logistic means, considering their current operating mode. As proven in this research, interchanging the current air access means by a sole marine access solution, under the same operational strategy, would not lead to the desired cost savings. However, Total could financially benefit from using a marine access solution over an air access solution, but only if the operating mode changes too: changing the workload, reducing the visitation frequency and profit of the environmental conditions per season.

The marine access means best suitable for operating TEPNL's assets in the North Sea, would be an offshore service vessel with a motion compensated gangway solution (a walk to work vessel). Motion compensated technology increases the accessibility by W.o.W. time. To make sure the capacity of a walk to work vessel will be fully utilized, two platforms need to be serviced simultaneously. This means the vessel transports two groups of maintenance personnel to two platforms on the same day.

Obtaining the highest level of accessibility should not be the objective of the selection of an access method. The most important focus should be the required way of access instead of the desired way of access. As thoroughly discussed in the report a work scope should drive the way of access. Before being able to select the most suitable solution, the frequency of visits in combination with the durations is of key interest (main drivers).

Re-design operating strategy

Recommended is to fundamentally change the operating mode. It is proposed that further study based on the outcome of this research should be carried out to assess cost attractive options for changes in operating mode for TEPNL. The key recommendations are to determine the exact work scope, focus on the workload distribution and explore the required bedding for a future operating mode.

Keywords: marine access, accessibility, transfer, operation and maintenance, platform, vessel

List of Abbreviations

- TEPNL = Total E&P Netherlands
- DPD = Development & Planning Department
- LD = Logistics Department
- TCs = Treating Centers
- O&M costs = Operational and Maintenance Costs
- SNS pool = Southern North Sea pool
- SCE = Safety Critical Elements
- BCE = Business Critical Elements
- PM = Preventive Maintenance
- CM = Corrective Maintenance
- ETD = Estimated Time of Departure
- ETA = Estimated Time of Arrival
- HoTT = Hands on Tool Time
- GS = General Specifications
- HSE = Health Safety and Environment
- CFD = Cumulative Frequency Distribution
- HAT = Highest Astronomical Tide
- LAT = Lowest Astronomical Tide
- MHWN = Mean High Water Neap
- MHWS = Mean High Water Spring
- MLWN = Mean Low Water Neap
- MLWS = Mean Low Water Spring
- MSL = Mean Sea Level
- SWL = Still Water Level
- E&P = Exploration and production
- CAPEX = Capital expenditure
- OPEX= Operational expenditure
- O&G = oil and gas
- WO = Work Orders
- TBO = Total Black Out
- LSP = Long Term Service Provider
- CTV = crew transfer vessel
- DC = daughter craft
- DP = dynamic positioning
- ERRV = Emergency response and rescue vessel
- FRC = Fast Rescue vessel
- SBV = standby vessel
- IS = Installation Supervisor
- IOM = Offshore Installation Manager

List of Figures

List of Tables

Definitions

Logistic means	The means for travelling to a specific location; for this research either by air or by sea.
Accessibility	The percentage of time that a(n) (offshore) structure can be approached. Evidently the accessibility depends upon the equipment used.
Availability	The probability that the system is operating satisfactorily. This probability is usually determined as a percentage of time.
Satellite entrance / access points	The physical access point or points, where the safe transfer of personnel can be executed.
Flexibility	Flexibility reflects the ability of a system to change or react with little penalty in time, effort, cost or performance. (Grigore, 2007)
Cost elements	The parameters fixed and variable that drive the total cost functions of marine access.
Cost Influence factor	A factor that influence the cost price of goods or services. *(Investopidia , 2016)*
Cost drivers	An activity cost driver is a factor that influences or contributes to the expense of certain business operations. (investopedia , 2016)
Cost components	The costs from a cost estimate are assigned to cost elements and cost components. Cost components are used to specify that costs should be included in a relevant valuation. *(SAP, 2016)*
Cost function	A mathematical formula used to predict the cost associated with a certain action or certain level of output. (*businessdictionary, 2016*)
Vendor	A vendor is a party in the supply chain that makes goods or services available to companies or customers. *(Investopedia, 2016)*

Table 1. Key definitions marine access study

Table of Contents

Module A: Research objective

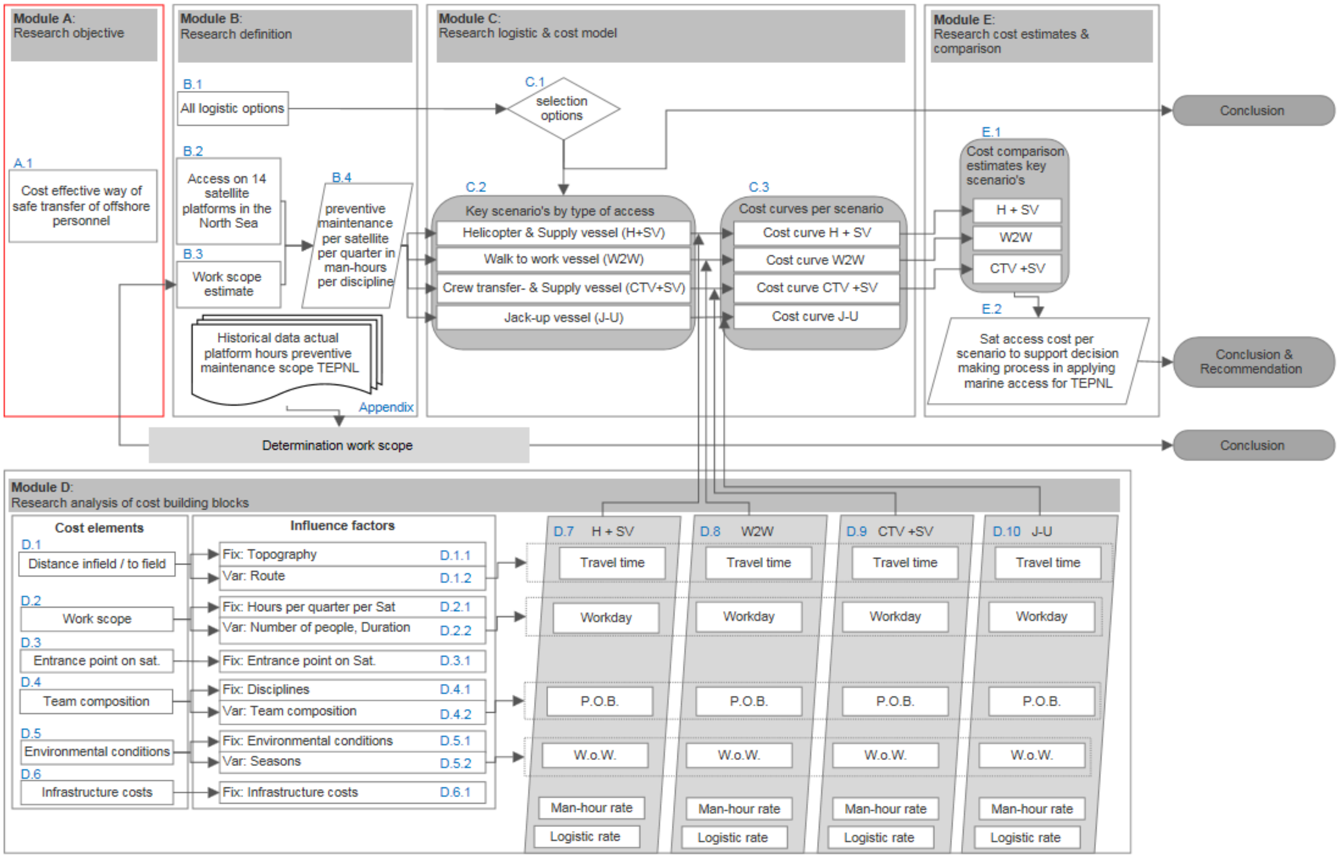


Figure 1. Process flow diagram marine access with the emphasis on research module A.

Chapter 1: Introduction

This chapter will firstly explain the reason why this study will be conducted (1.1). Thereafter the process of satellite access is stated (1.2). Thirdly, the objective and focus of this research will be explained (1.3). Finally, this chapter will state the academic relevance and show the layout of the report based on the process flow diagram (1.4 &1.5).

1.1 Cost focus on offshore operations

Total is a world-class operator in natural gas and oil exploration &production, refining and petrochemicals with approximately 100.000 employees all over the world. The oil and gas industry in general is currently coping with decreasing energy prices, which makes it a more challenging field of expertise. But since the estimated global energy demand will grow 30% in 2035 compared to 2010 (BP Global, 2014), Total's exploration and production are crucial to fulfill the society's demand. Oil and gas will play a key role in the energy supply of the future. Therefore, Total is developing innovative processes, enabling aging platforms to maintain their availability and performance levels.

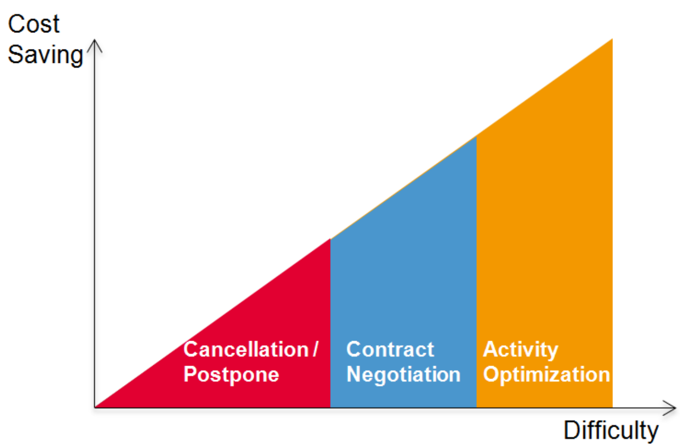


Figure 2. Cost saving opportunities found in a study.

When determining cost saving opportunities, the level of difficulty can be plotted against the amount of savings in a linear curve (McKinsey&Company, 2014). The easiest savings are gained by simply postponing activities or the cancellation of activities. A more sustainable cost saving is by contract (re)negotiation and the most effective cost saving opportunity is introduced by activity optimization.

The most difficult but also most rewarding way to create cost savings is to focus on the optimization of activities rather than postponing activities or the (re)negotiation of contracts. The cost saving opportunity in the North Sea according to McKinsey & Company Oil & Gas Practice are expressed in the figure above (McKinsey&Company, 2014). By expressing cost savings as a function of operational difficulty the impact of the activity is shown. In the articles "Meeting the challenge of increasing North Sea costs" & "Tackling the asset production efficiency crisis in the North Sea" the opportunities of sustainable cost saving are evaluated (McKinsey&Company, 2014).

The drivers to more sustainable costs in the North Sea are considered to be: firstly, an increased productivity in current operating assets, secondly improving the economics of new investments through standardization and simplification, and finally the collaboration of industry. The first driver will be the starting point. The most difficult but rewarding costs savings are based on the execution of offshore activities. The considered solution is; a reduction in non-value adding activities thereby improving hands on tool time, leading to less time offshore and finally a cost saving.

In the article; The oil industry needs a work reality check (The Herald, 2015) a concern about the North Sea oil industry is expressed. The managing director of The Wood Group said: "the industry has been working too inefficiently for too long", "Half of the employees work two on, three off offshore rotation which is effectively 20 weeks a year". This research is bounded by the regulations of the offshore unions and is focused on using the offshore time as effectively as possible.

With declining energy prices, the emphasis is on cost reduction. (Deloitte , 2015). New strategies are adopted e.g.; Integrated Projects delivery, Advanced analytics, Lean projects management, Talent management, A shift towards the digital oilfield, Modular approaches.

The concerns of increased cost savings are felt in the whole industry. Total E&P's CEO Patrick Pouyanné addressed this topic by saying (Wall Street Journal, 2016):

> Our profits fall. They will fall a little more than 20% while the oil price falls 50% (CEO Total Patrick Pouyanné)

Before the to the drop in oil-price by the end of 2014, Total has focused to reduce OPEXand CAPEX, similar to increase oil output, to overcome the impact of the low prices on the overall results. These measures will not last in the long run so a more sustainable solution has to be found to reduce the costs. Initiatives to tackle this problem rise throughout the industry.

Examples of trends that can be seen in cost reduction are studies on minimizing maintenance costs by reducing platform facilities and combining services to save mobilization costs. The specific example leading up to the increased interest of Total in marine access was the contribution to the workshop (EBN , 2015) about low cost development and maintenance, in which the following topics have been discussed: "Reducing OPEX with wave compensated equipment" and "synergy between E&P and Wind". These subjects are intertwined with the research in the application of marine access.

1.2 Platform access comes at a cost

Currently the access method to enter a platform in the North Sea is by helicopter. The biggest advantage of this way of access is the high accessibility despite the harsh North Sea conditions. The high transit speed of a helicopter provides a large coverage of satellite visits and a high flexibility in visits. There is also a downside to all these advantages. The load a helicopter can carry is limited and the means come at a high price.

Besides the use of helicopters there are other alternatives available which have been blossoming because of the development in the offshore wind industry. The innovations in the offshore vessels, DP systems, motion compensated gangways etc., have led to a means that can challenge the existing helicopter transfers. Especially the surplus of vessel due to postponed offshore activities create interesting opportunities.

A large variety of logistic means is available for crew and equipment transfer besides a helicopter. Generally speaking, the larger the means to more robust the access method. Depending on the accessibility level required a specific transportation means can be chosen.

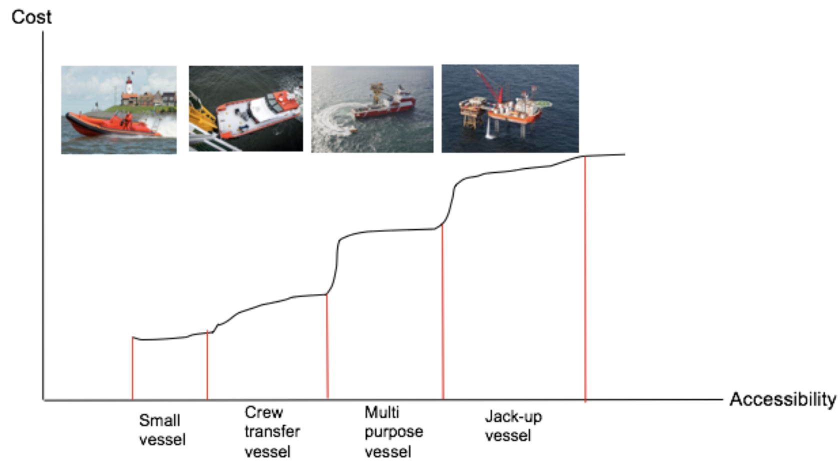


Figure 3. Marine accessibility against cost of access means

The figure illustrates that the level of accessibility can be expressed in costs. Only the feasible marine access methods are evaluated in this research.

The main activity of an operator is to produce its assets as economically as possible. For production, there are many reasons why these platforms require manual labor, despite the control room already been located onshore. Keeping the production, availability of the platforms, as high as possible requires constant supervision but also many activities for which the structure needs to be entered, Accessibility, a key question in this research is the relation between access method and cost.

Definition (van Brussel & Zaaijer):

- Accessibility is the percentage of time that a (offshore) structure can be approached. Evidently the accessibility depends upon the equipment used.
- Availability is the probability that the system is operating satisfactorily. This probability is usually determined as a percentage of time.

Due to the many factors that can be considered in the whole operating and servicing of the field the research scope needs to be narrowed. A preliminary assumption made in this research is to focus only on unmanned platforms (satellites) and their corresponding activities.

Satellite access, has many different factors which can be further examined.

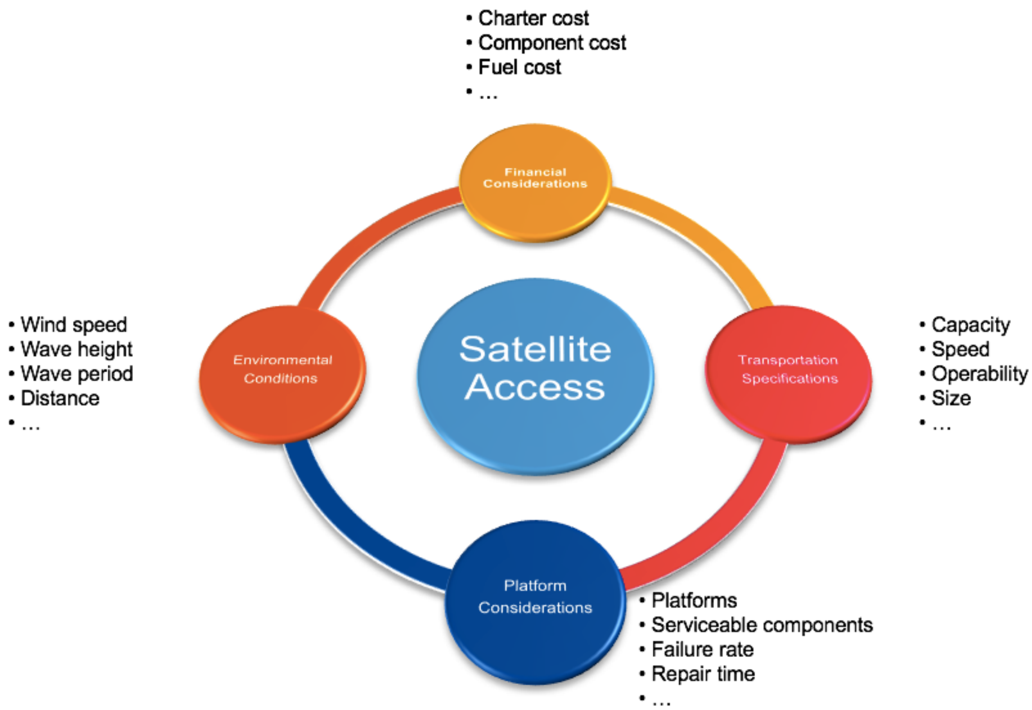


Figure 4. Satellite access selection

To illustrate a few factors that drives the way of access such as; transportation specifications, platform considerations, and environmental conditions and the corresponding financial considerations. By determining the main factors that influence the operational cost a decision in applying marine access can be supported. (Dalgic, Lazakis, & Turan, 2014)

Most studies done on accessibility are primarily focused on achieving the highest level of access. This research however investigates this topic from an operational perspective. Many ship-owners, access system providers and service companies who have specialized in this field have published the benefits that come with access by vessel. From an operator's point of view achieving higher accessibility then necessary would be unbeneficial since accessibility comes at a cost.

Important is to note, that accessibility or workability, is dependent on many variables. One of the factors is the interaction of vessel with the environmental conditions (the type of vessel, its size, the position of an access system and the access point on the structure are all factors that influence the accessibility). Besides that, the available data on the market and in-house knowledge will be used to verify different cases.

Air access is defined as the access of personnel to an offshore structure by helicopter. By considering only helicopter flights all other means of transport, planes, drones etc., by air are excluded. Besides the means of transportation itself, the resulting requirements for the means are also included in this research. When considering solely helicopters the transfer is limited to only personnel. Many of the activities offshore require tools & equipment so air access is always combined with some kind of marine means.

A more general definition is applied for marine access; the access of an offshore structure by boat. The general specifications (GS) from Total Personnel transfer between watercrafts and between watercrafts and offshore structures by logistics and operational support (Total, 2015), defines the conditions and methods required by the company for transfer of personnel at sea.

1.3 Research goal and objective

1.3.1 Research Challenge

"Total is searching for a way to access its satellite platforms in the most cost effective manner, without compromising on safety."

1.3.2 Research Goal and Objective

Total's main goal on the long run is service its satellite platforms more cost effective. The organization's goal regarding platform access on the short run is to reduce costs and increase cash flow. The main aim of this research is to find an appropriate marine access scenario, as an alternative to air access, which serves as input for a pilot study to check whether the costs will be reduced in practice.

Therefore, a two-folded outcome is needed: a clear evaluation of the current available access methods, and subsequently delivering a model that optimizes the maintenance and inspection costs by marine access. The objective of the study is to obtain an optimization model which supports the decision making in the design of the logistical infrastructure.

1.3.3 Research Question & Sub Questions

"Which means of marine access can create new opportunities to be able to service the existing satellite platforms more cost effectively?"

1. Which serviceable components of existing satellite platforms are critical for the accessibility by air or by sea?
2. Can a generalized marine access approach be developed without large modifications to the existing satellite jacket structure?
3. How can the effective working time at a satellite platform be increased, regarding optimized logistic processes?

1.4 Academic relevance

This research addresses the operational part of offshore engineering. The many variables which need to be considered in an offshore operation demand an understanding of all topics associated with this field of expertise. A thorough understanding of environmental, safety, structural and personnel constraints are required to determine possible optimizations in the current way of operating.

Although the oil and gas industry and its technology are very advanced, the logistic cost modeling deserves more research. The transportation to an offshore location is a cost intensive action which deserves more attention since the revenues are under pressure due to fluctuations in the gas-prices.

The offshore access market has developed rapidly due to technological innovations and the higher demand for transfers since the Offshore Wind industry has taken off. The contribution of this research to the operational part is interesting due to the absence of models which focus on the combination of both personnel and equipment transfer. The optimization of the access means by focusing on a workload in combination with the external conditions has not been done to my knowledge. Individual studies regarding either helicopter access or vessel access for personnel transfer have been conducted. However, the combined crew and equipment transfer have not been addressed.

1.5 Thesis outline

The research procedure is divided into 5 modules, which are explained in ascending order (fFgure 5). By consecutive going through the different modules the required information is gained to support an operational decision regarding marine access and come to the required conclusions for Total Exploration & Production Netherlands. This report is constructed around the process flow diagram to support all decisions and explain all key findings. A more detail description is given below.

Marine access research flow char

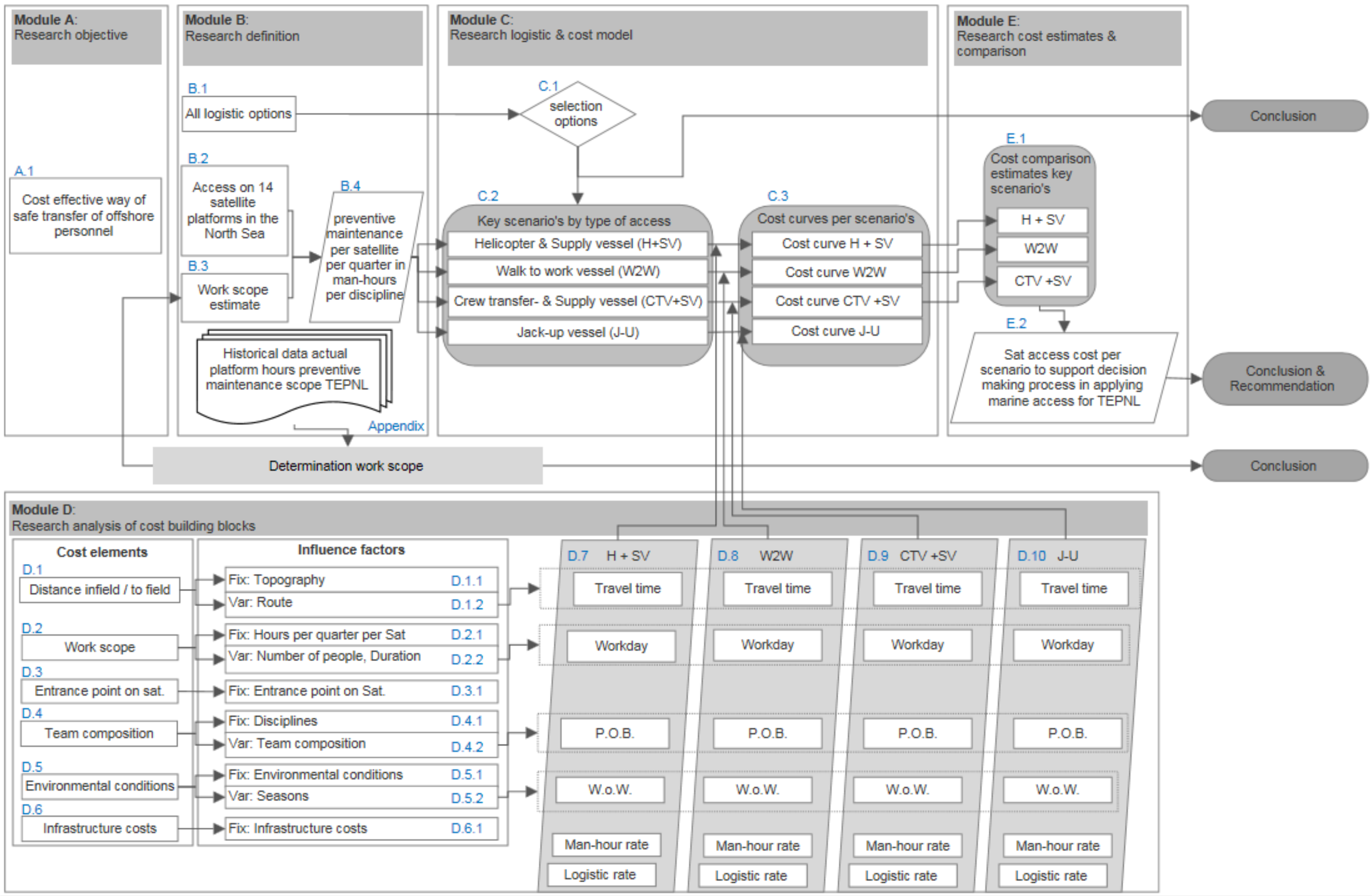


Figure 5. Holistic Process Flow Diagram marine access study TEPNL

The procedure of the evaluation of the applicability of marine access for TEPNL is done by a holistic process flow diagram (PFD), Figure 1. The symbols below (figure 2) are used to indicate the different functions in the PFD.

Figure 6. Symbols Process Flow Diagram

The procedure is divided into 5 modules, and explained in ascending order. The relationship between the different components and its findings are clarified all within the research scope.

The first module is the introduction of the topic and defines the objective of this research: Find out if marine access could help TEPNL to optimize offshore operation and if so, which marine access means is the most suitable for operating its North Sea assets (Fig 1 A.1). The focus is on the cost aspects of operation and maintenance without compromising on safety. The field-layout, assets and current way of operating are defined with respect to platform access.

From this descriptive module, the foundation for the definition module is obtained (Fig 1 B.) Stating the research question, sub questions and framing the research scope, the operational research is limited to a manageable size. The process of determining all possible options (Fig 1 B.1), established and innovative, identifies the access methods by type of means. Next to these logistic options, the process behind the incentive for these visits needs to be defined (Fig 1 B.2). The scope confines the research interest to the 14 satellite platforms in the North Sea, and their individual preventive maintenance (PM) requirements. Since PM is periodic and driven by requirements, safety or production, it is a major interest for Total. The diversity of the routine activities requires specialized personnel. The boat logistics offshore operations are influenced by the environment and variation in work scope, a seasonal distinction is required. To determine the preventive maintenance per satellite platform per quarter in man-hours per discipline, the required work scope needs to be available. A work scope estimate is used based on manuals and interviews, since the historical data and other sources led to contradictions (Fig 1 appendix).

The module, logistic & cost, (Fig 1 C.) uses both the logistic options and PM work scope to generate scenarios of interest for TEPNL (Fig 1 C.2). The reduction in logistic options is based on company restrictions and feasibility of concepts (Fig 1 C.1). The scenario analysis is based on the type of logistic transportation means, so not on a specific vessel. To make a proper comparison between the different means (Fig 1 C.3) it requires an extensive analysis of the cost components and their influence on the process. Before considering the key variables and describing how the cost comparison models (Fig 1 C.3) are constructed an explanation of the building blocks is defined.

The module: cost building blocks (Fig 1. D) describes the dominant variables behind the process of deciding on the marine access cost drivers. The cost elements are bundled into groups, which are on itself influenced by either fixed or variable factors. Since the purpose of this analysis is to obtain input for the comparison, the variables need to be recurring in the different scenarios and have a similar impact.

The distance infield and to-the-field is fixed by the topographic location; the route can be varied (Fig 1. D1). The travel time which is dependent on location and velocity is determined by a network flow diagram. Common practice is expressing the transit cost, by a defined unit rate multiplied by the travel time, by the type of means excluding the number of passengers.

The work scope entails the hours of work on a specific location. A satellite is an unmanned platform, so every physical activity requires a visit. The hours PM per quarter on a satellite are fixed. The workday hours however change with the access means (Fig 1. D2). The hands-on-tool-time is considered part of the actual manned time on the platform and varies also. The workday hours made on a location are based on the combination of the number of people and the duration of a visit.

A cost element that is considered purely fixed is the costs to the entrance point of a satellite (Fig 1. D3). The entrance points on the satellite are sunk costs and no significant PM work is directly allocated to one of these points. Corrective maintenance measures, as real structural changes, are not considered since the focus is on reducing OPEX without increasing CAPEX. Closely linked to the work scope and workday, is the team composition (Fig 1. D4). The compositions of people on platforms are restricted by safety measures. The activities on a platform are carried out by different trades. In this research, all activities are grouped by: production, mechanical, electricity & instrumentation, and safety.

The environmental conditions are obviously not fixed. The data used for this research are the average field specific operational data. The process of marine access is dominated by significant wave heights and wave peak periods. Especially when addressing motion-compensated-technology the significant wave height is the decisive factor (Fig 1. D5). The variable factor is the seasonality; the different seasons gives different costs.

When logistic means are used, additional costs arise to support these means: the infrastructure cost. The cost analysis of the different satellites indicates that the direct costs are insignificant and the indirect costs e.g. safety, hoisting, is greatly contributing to the overall costs (Fig 1. D6).

Before focusing on the cost curves per scenario, the different rates with time units are addressed. Each logistic means has a specific rate e.g. hourly- or day rate. This rate is of great impact on the total costs. The large impact due to the high rates of the logistic means is the underlying thought behind this research. Returning to these variables and their importance to the key scenarios, the cost equations will be derived. Chosen is to vary the work scope in a discrete step function to come to total cost functions. The expressions take the labor costs and the logistic costs into account.

Evaluating these different scenarios leads to the conclusion that interchanging the access means are not resulting into a significant cost savings. The benefits of operating with a vessel are diminished by the necessity of a different operating mode. Since the PFD gives a holistic overview, a set of recommendations are made to indicate how to benefit from marine access.

The incentive to focus on activity optimization is to establish a long-term cost reduction. The contribution of the logistic costs to the total costs of servicing a platform makes evaluating this process logical. For the platform access, specific logistical means are required. All means come at a cost, depending on the accessibility desired. The objective is cost reduction, shifting from desired to a required level of accessibility. To support an operational decision, the process is modelled in a process flow diagram. The context in which this decision needs to be made is will be addressed in the next chapter.

Chapter 2: Context

The aim of this chapter is to provide the reader with the required knowledge and background information to understand the challenges connected to this topic. Starting with a brief description of the field and its production assets (2.1), whereupon the maintenance structure (2.2), time dependency (2.3), planning and scheduling will be addressed subsequently (2.4).

2.1 Field layout & Satellite platforms

TEPNL's 22 platforms are located in the North-Sea in a range of 80 to 150 km north-west of Den Helder. 5 of the 22 platforms are manned treating centers (TCs), as well as personnel hubs. Helicopters are used for personnel transport, while supply vessels are used for transport of goods and equipment. The field layout indicates that the platforms are close together however relative far offshore.

The orientation of the field, layout and distance offshore, needs to be considered when determining the feasibility of accessing the structure by vessel. The port based or offshore based operational logistics need to be evaluated by the distance to the field. When all satellite locations are plotted on a scale with the absolute distance from the port it becomes clear that process should be evaluated in 2 phases:

- Distance to the field
- Inter-field distance

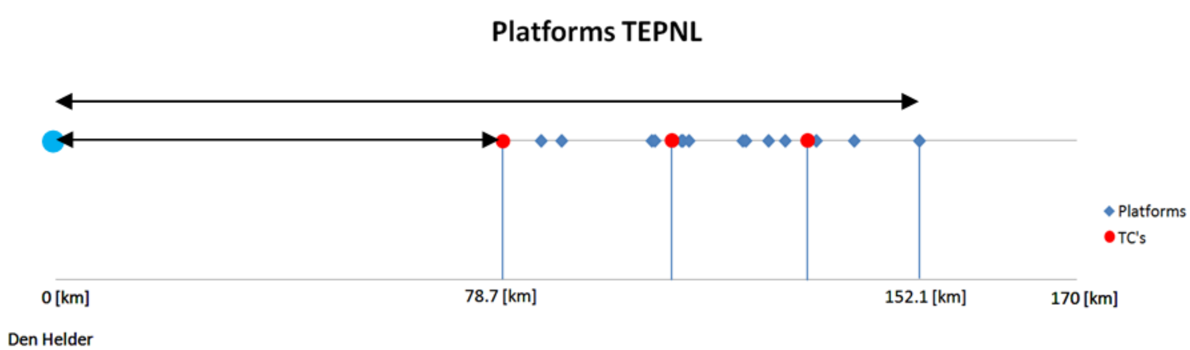


Figure 7. Distance to the field vs. inter-field distance

The red dots are the treating centers while the blue dots represent the satellite platforms. The relative large distance from shore makes a port based operation difficult for a vessel since the transit speed is low. Even with a helicopter TEPNL is currently working with a hub for offshore accommodation.

The influence of the logistic means regarding the flexibility in servicing locations needs to be considered in current and possible operating modes. A helicopter can fly approximately 200 km/h, a vessel is limited to 20 km/h.

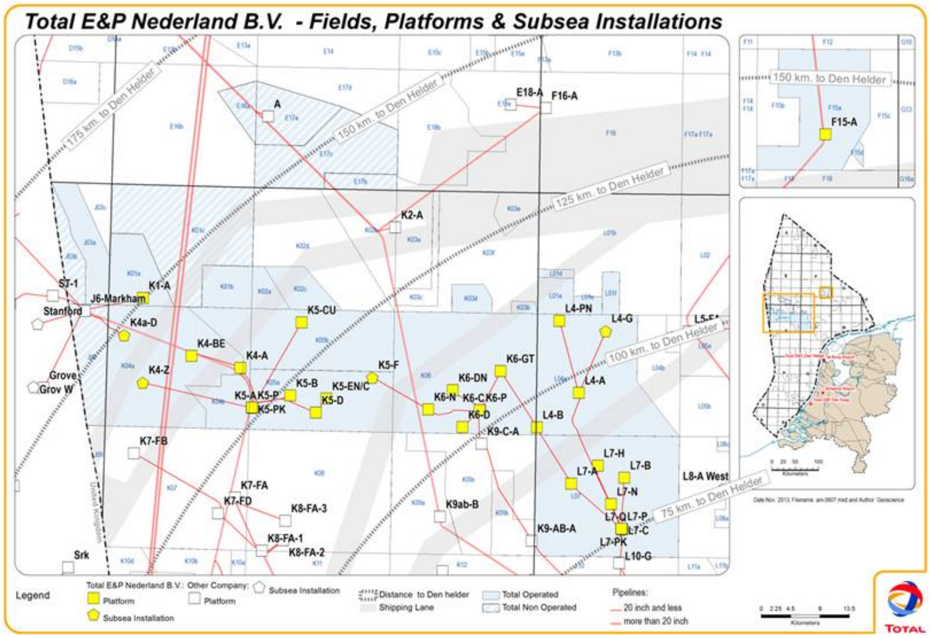


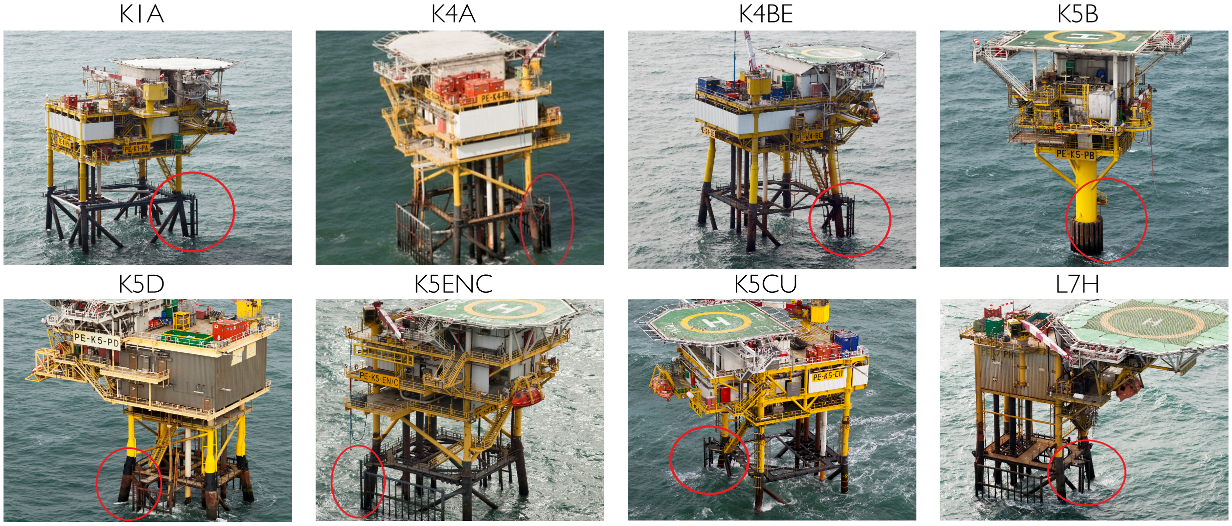
Figure 8. Total E&P Nederland Field layout

All Totals assets, treating centers, satellite platforms and subsea installations, in the North Sea are shown in the figure. The radii indicate the distance in km from Den Helder.

The 14 satellite-platforms considered in this research are listed below:

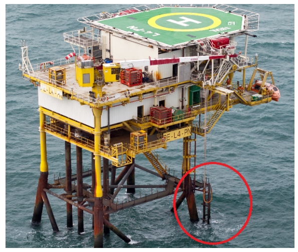
Satellite Platforms Total NL

K1A K4A K4BE K5B



K5D K5ENC K5CU L7H

L7B L4NP K6D K6N

K6GT K6DN


Table 2. Satellite Platform Scope

The 14 considered satellite platforms have been installed over the years and are different in design. The platforms illustrated in the table are equipped with helicopter deck, but there are also several access points on the structure which can be reached form the sea. The platforms producing this brownfield are in the declining phase, therefore no large modification (CAPEX restrictions) are considered.

Each satellite platform has a specific layout; the design of the structure requires an optimal strategy to enter a site. The geographical factors; distance offshore but also required availability and accessibility play part. The most important factors that contribute to the suitability of the access method according to a position paper published by Tennet (Tennet , 2015) are:

- Safety
- Accessibility (weather and sea-state dependent)
- Available access method
- Direct costs
- Required response time

2.1.1 Description of satellites entrance points

The 13 jacket structures and 1 monopole are located in approximately the same water depth and relatively close to each other. All structures are equipped with a helicopter deck and all have some sort of access point on the waterline leading or lowest deck. The selection of locations to enter the structures is done by an evaluation of internal documents. The identification of the optimal access location is considered without large CAPEX modifications. The structural capacity of the access location and its associated hazards for crew transfer needs to be determined.

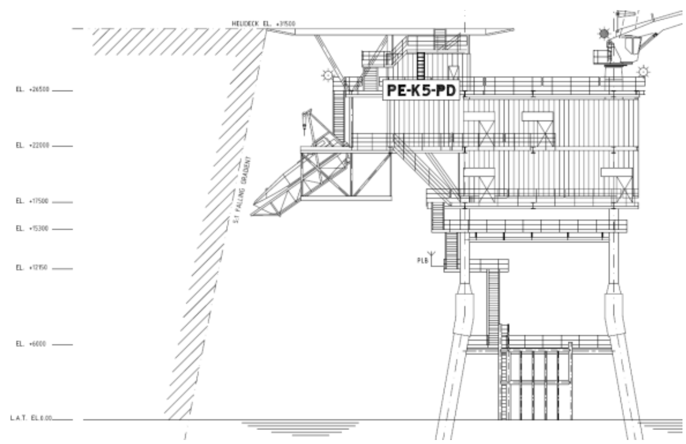


Figure 9. K5D platform North view

The visitation frequency is important when selecting an access point on a structure. Dependent on whether the structure requires a visit once a year or once a week. The key responsibility of TEPNL is safety, so the intention is to reduce the risk as much as possible. Platform access is considered a risky operation and therefore deserves a lot of attention. The entrance to a structure by one of the decks is preferred over climbing ladders. A risk is defined as the probability times a consequence. The probability is linked to the frequency of visits resulting in the number of people transferred, while the consequence can be linked to the most convenient way of accessing a structure. An assessment of the layout of all platforms is done to determine all entrance points *(Appendix: Access points).*

The decks from the bottom up are named: spider deck, maintenance deck, cellar deck, main deck, and helicopter deck. Besides entering directly on the deck the staircases between the different decks is a feasible option. The lowest deck, spider deck, is the tertiary escape route and should be accessible. The North Sea conditions can be severe due to storms; the grating and structure in the surf zone should endure a lot. Besides the deck height the structural loading restrictions should be considered as well *(Appendix: boat landings*). The physical interface with either a surfer solution or gangway induces additional forces on the structure.

2.2 Maintenance

To determine the visits for maintenance activities in line with the maintenance policy the company's maintenance Philosophy needs to be considered. The philosophy is based on both external: industrial maintenance, maintenance function and offshore reliability data OREDA (Offshore and onshore Reliability Data Handbook, 6th edition, SINTEF, 2015), and internal documents.

The focus on supply chain optimization, getting the materials at the right time on the right place in a cost-effective manner, is of high interest. The way in with a field is operated needs to be intertwined with the maintenance requirements.

Operating (Total) & Maintenance philosophy (TEPNL , 2015) – confidential

To keep the competitive advantage many changes have been made already in the way the operations are done e.g.:

- Minimizing the personnel on treating centers to reduce the potential risks and making the production more cost effective

- Asset integrity management
- Minimum maintenance requirements

The 24/7 onshore control room has substituted many operations which used to be carried out offshore. The lean focus on asset integrity management by implementing and monitoring the four P's; Plant, People, Process and Performance, shows the progressiveness applied (Total , 2014).

- Plant: the installation and physical condition of equipment
- People: the responsibility and competence involved
- Process: procedures and techniques used by disciplines
- Performance: measuring and reporting of performance

The determination of the optimal level of maintenance to reach the required availability is one of the most important steps to reduce operational costs. Therefore, the minimum requirement is the lowest boundary for the activities that must be carried out. The requirements established per class of equipment have been studied by Total in minimum maintenance requirements (Total , 2016). The preventive maintenance described is aiming at: guaranteeing the availability of the production program, maintain the fitness over the fields expected lifetime, the prevention of incidents (personnel or equipment) end minimize operational cost.

The objectives of the Total Group are:

- Safety and health of personnel and assets
- Care for the environment
- Sustained operation and performance of the installations over time
- Economic optimization

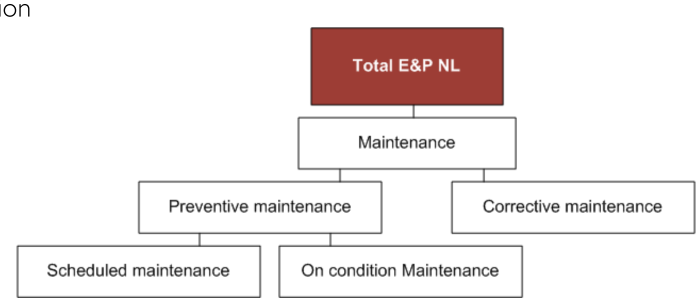


Figure 10. Maintenance structure

The maintenance within TEPNL is structured by a distinction between preventive and corrective maintenance. More information about PM and CM (Appendix: Maintenance)

2.2.1 Preventive maintenance

Preventive maintenance (PM) involves scheduled and proactive repair. Scheduled maintenance is planned on a predetermined time interval. The substitution of components subjected to wear based on experience is on condition maintenance.

2.2.2 Corrective maintenance

The opposite of planned is reactive or corrective maintenance (CM). No action is taken before the failure of a component. Often this kind of maintenance is called "break-down" maintenance. Depending on the well performance this event could be very undesirable.

Many of the maintenance activities offshore are based on a specific skill or certification. A maintenance team consists of different disciplines. An electrical engineer is responsible for the work on the electrical installations and instrumentation on the platform. For rotational equipment, such as pumps of engines a mechanical engineer is required. The responsibilities that go along with production of natural resources require constant supervision of an operator but also strict safety regulations of a HSE person. The composition of maintenance team for this research is based on:

- Production
- Mechanical
- Electrical & Instrumentation
- Safety

On addition to the fixed crew in the satellite team, one must consider vendors as well. A vendor, in supply chain management is considered a person who provides a product or service to a company. In this research vendors are highly specialized people who are contracted to do a specific task (Investopedia, 2016). The satellite (SAT) team for preventive maintenance is based on a combination of fixed crew and vendors.

A recent change in maintenance strategy is the project based approach regarding maintenance. By managing the maintenance as a project the schedule and budgets are all value driven.

Preventive maintenance can be divided in: Safety critical (SC) and Business critical (BC) components. Safety critical component are of the highest priority for HSE reasons. Business critical components are directly linked to the company's profit. The ratio preventive maintenance to corrective maintenance has been studied to a great extend (Call, 2007) *(Appendix: Maintenance)*

2.3 Time dependency & Work day

The required work on an offshore location, seen from a preventive maintenance perspective, needs to be carried out by several people with specific equipment. To indicate the interconnectedness of the access means and work hours a typical working day offshore can be assessed.

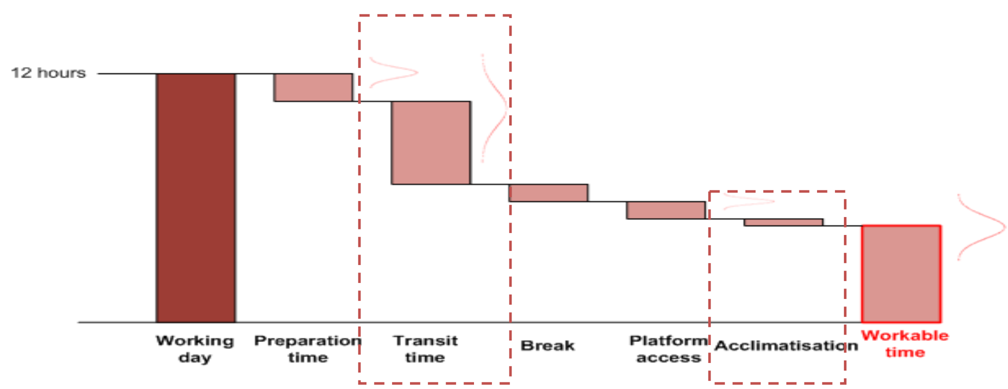


Figure 11. A breakdown of a typical work day offshore

To illustrate the composition and inefficiency of offshore maintenance activities the different activities are shown. Increasing the affectivity (Dong Energy , 2012), (Damen , 2015) of offshore personnel is getting a lot of attention due to the developments in the wind industry and the focus on cost of oil and gas operators.

The efficiency of work offshore is dependent on many logistical factors. By evaluating a 12-hour working day offshore, a breakdown into time components can be made. The transit-time, the waiting time (check-in/out), the preparation time, a lunch break all reduce the effective working time. The visitation frequency is a critical factor in optimizing the efficiency of the work done offshore.

One of the industry demands that have led to the increased use of vessels is required increase in effective working time. Since the vessel is on location, work can start by dawn and end at dusk. This would maximize the time at which work can be done on the platform. By increasing the effectiveness of the maintenance activities, the logistic cost is reduced.

By means of a example the inefficiency of offshore work will be explained based on a field experts opinion. This illustration only serves to clearify the considerations that have to be taken into account.

In this case only crew transfer by helicopter is described. By using a 12 hour workday, starting at 7 a.m. in Den Helder the first maintenance crew is flown to a hub. From here Satellite-team A with a specific composition for Satellite (A) is selected and transferred to location. Upon arriveal the crew is dropped of and the helicopter flighs flies back to the hub to pick up Sat-team (B). Sat team (A) has to change, switch emergency suite, prepare all work permits and collect tool and equipement. After 50 min of preparation they are ready to work. Sat-team (B) has to follow the same procedure, but are one hour behind since the helicopter had to fly back and forth. For Sat-team (A) and (B) there is a required coffee break and lunch time. During the short break in the afternoon, the pick up time is announced. Depending on the work there is time to store tools, sign work permits and change into survical suites again before being transferred back to the hub. Without looking at specific disiplines, and taking into account delays in transportation or irreregular activities in this example, the effective working time can be considered.

$$T_{trans} + T_{Prep} + T_{HoT} + T_{break} + T_{HoT} + T_{lunch} + T_{HoT} + T_{break} + T_{HoT} + T_{prep} + T_{trans} = T_{day} \qquad \text{Eq 1}$$

$$\frac{\sum Hands\ on\ Tool\ Time}{Workday\ Offshore} = Effective\ working\ time \qquad \text{Eq 2}$$

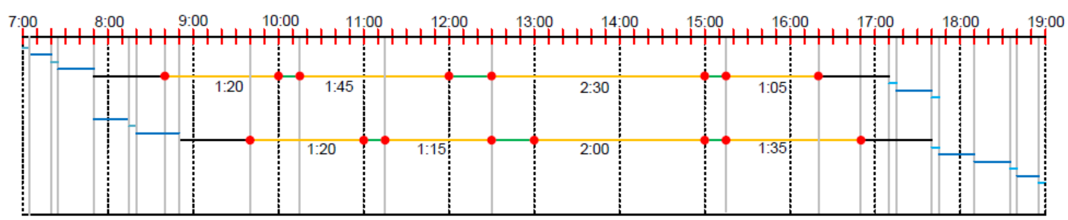


Figure 12. Example of offshore work time schedule

This practical example illustrates how inefficiency of offshore activities can lead to a low effective working time.

This demonstrates the efficiency of a workday, Sat team (A) has 6,6 hrs HoTT and Sat team (B) has 6,2 hrs HoTT. The low efficiency is resulting amongst others by the quantity of means, transit time limitations and preparation time caused by safety requirements.

This research focuses on cost reduction, without compromising on safety. To illustrate one of the safety considerations when accessing the platform by vessel an example will be given. The primary evacuation method changes depending on its access means. The vessel could function as a standby vessel which could lead to an increase in maintenance crew, because the lifeboats present would not be the limited factor anymore. Another advantage would be that the access by one of the decks could also increase the efficiency on executed offshore work by a change in distribution of a workday.

2.4 Planning & scheduling

Based on project management terminology there is a big difference between planning and scheduling. "A schedule is obtained by doing additional work on the initial plan, so that resources needed to carry out all the project activities are considered" (Lock, 2007). Work preparation determines what it takes; number of people, skill, parts, materials, tools and equipment. To ensure the correctness of this process the work is entered into SAP. The process path is indicated below:

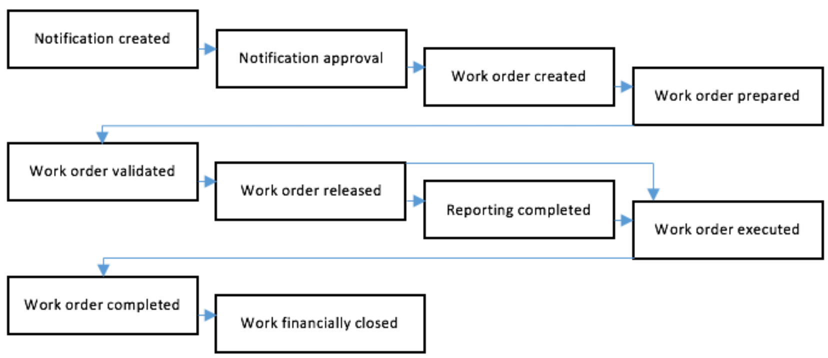


Figure 13. Flow work order preparation

For every step a notification and work order status is appointed. The IS (Installation Supervisor) or the IOM (Offshore Installation Manager) is responsible for verifying new notifications to ensure relevancy and necessity for safety and production. The maintenance and inspection scheduling principles are based on priority (prio) assigned in the SAP, a system designed to manage business operations, from a centralized database.

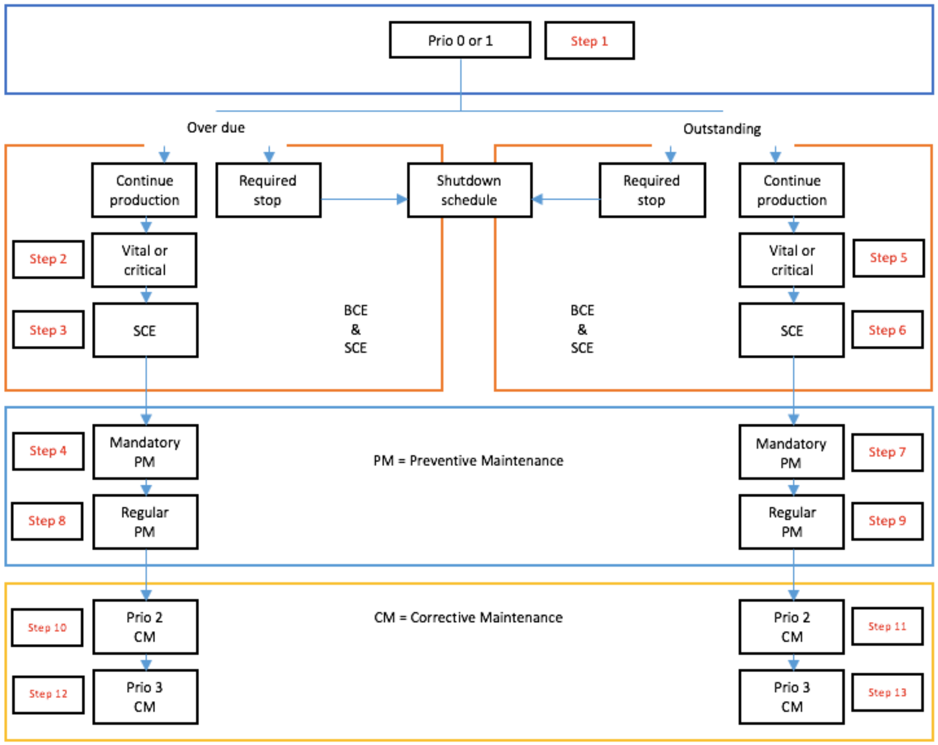


Figure 14. Maintenance and inspection scheduling principles

The sequential steps illustrate the importance in scheduling. The first notifications have a priority description, 0 immediate safety, 1 production impact, 2 production / safety risks and 3 all other defects, that is the dominant factor. Secondly the decision is based on time; overdue or outstanding. Thirdly the level of criticality (Appendix: Criticality work orders) is considered. In this second layer the safety critical elements (SCE) & business critical elements (BCE) are described. The strategy from which this distinction has evolved is summarized (Appendix: SCE & BCE). After the layer SCE & BCE, there are two layers; a preventive and a corrective maintenance. This research focuses on the PM activities, but the satellite access is also required for CM activities. A set ratio PM vs. CM leads visitation frequency.

The context in which an operational decision is made is of importance to understand the underlying arguments. The satellite access by vessel is dependent on the field layout, configurations of platforms and operational requirements. The required level of access is based on physical activities on the platform. The maintenance activities can be subdivided in preventive or corrective maintenance, both resulting in visits. The logistic means used for platform visits are linked to the duration of activities; the considerations regarding a workday offshore and resulting inefficiencies illustrated. The wish of cost reduction in a considered context still requires a reference point of the current situation. The present situation of logistical means and its corresponding costs will be addressed.

Chapter 3: Current situation case study TEPNL

This chapter explains the present way of operating to have a benchmark to make a comparison of marine access against. A base case is selected at the start of this research and will remain the focus. The current way of operating will be discussed (3.1), with the different logistic means: Helicopter (3.1), Supply Vessel (3.2) and Jack-up Vessel (3.3). Operational research is dealing with real-life situations that are constantly changing hence a point of reference.

As mentioned in the previous chapter Totals assets are in blocks L4, L7, K6, K5, F15 in the southern part of North Sea. Presently the general way to access the platforms is by means of helicopter. This is considered a safe, effective and industry accepted way to reach remote platforms. To give an impression to the extent of visits the figure below are given.

CONFIDENTIAL

Figure 15. Helicopter landings on 14 satellite platforms

The amount of helicopter landings on the 14 satellite platforms are shown above. This figure illustrates the high visitation frequency of what are supposed to be unmanned platforms. The monthly helicopter landings on the different sites need to be divided by 2 to translate it to day visits. Besides the helicopter visits for personnel transfer the boat visits of supplies need to be addressed.

CONFIDENTIAL

Figure 16. Boat landings on 14 satellite platforms

Chosen is to use the current situation of helicopter landings and boat visits, by taking 2015 as reference point. When interpreting this data noticeable is the high frequency of visits. For this research a distinction between the different quarters is made since the work scope is addressed per quarter.

CONFIDENTIAL

Figure 17. Satellite helicopter visits per quarter 2015

The satellite data gives insight in the distribution per quarter. This is done since a season outlier, or major activity at a location could explain the high frequency. The satellite visits make no distinction between preventive of corrective maintenance activities.

A decision based on air access, marine access or a combination of both, have profound implications. Resulting from this decision on how to access a platform, many advantages and disadvantages arise, not only the direct but also indirect.

3.1 Requirements and constraints TEPNL

The requirements and constraints regarding marine access of TEPNL have been determined in a functional and performance requirements joint development session based on a system engineering principle *(Appendix: Requirement analysis)*.

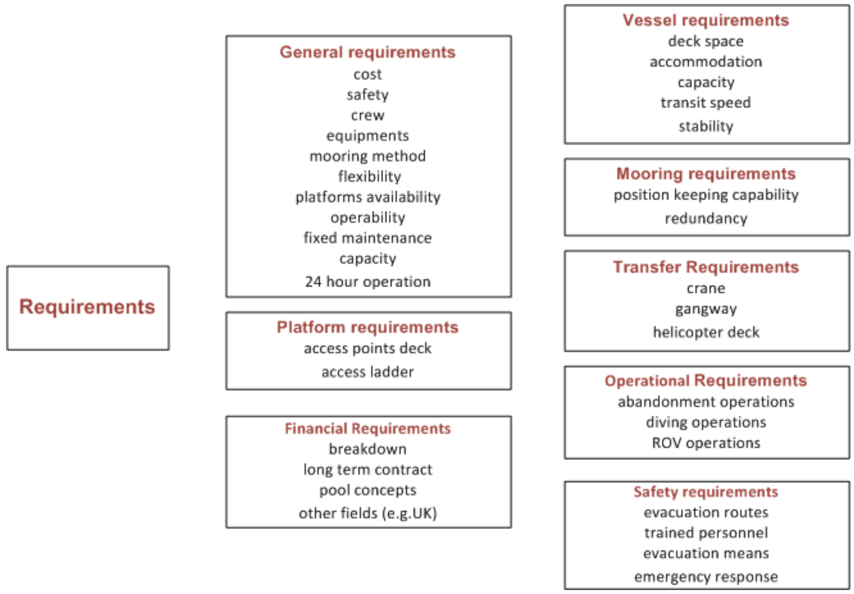


Figure 18. Outcomes requirements based on workshop "marine access requirements"

By collectively discussing this topic in a joint requirements development session a common view is obtained of the requirements of any form of marine access. All requirements can be broken down in 3 key requirements for this research: general requirements, platform *requirements and financial requirement. The combination of vessel, mooring and transfer requirements follow form the general requirements. The safety requirements induced by the company result in many of the following constraints.*

In a similar manner as the requirement the constraints have also be investigated during the workshop.

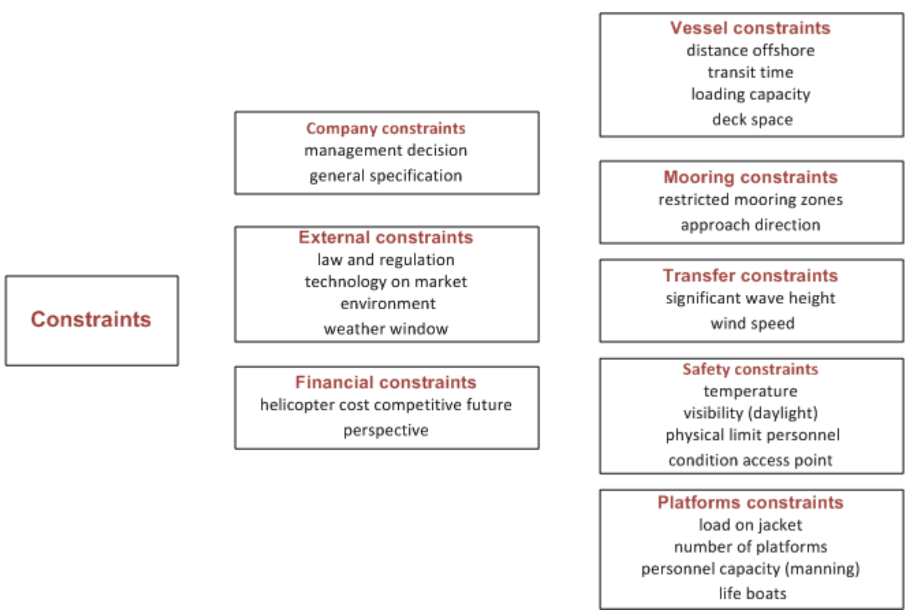


Figure 19. Outcomes constraints based on workshop "marine access requirements"

The constraints discussed are based on company rules. The high safety standard is imposing internal restrictions, while external restriction is influenced nature and financial markets.

3.2 Transportation means TEPNL

As mentioned the combination of helicopter and supply vessel is used. The harsh North Sea conditions make this a quick and flexible solution to transfer personnel to remote locations. All logistic means come at a cost, TEPNL is using logistic service providers to transfer its personnel. All service providers use contracts based a unite rate, often a day-rate, but sometimes hourly rate. To make a cost comparison model the cost of the current logistic means are expressed.

3.2.1 Helicopter

CHC provides air transport by an AW139 helicopter *(Appendix: CHC Helicopters)*. Due to the quantity and necessity of the flights one helicopter is dedicated to service Totals personnel. The helicopter contract is set up that there is a standing fee, $\mathbf{c_{fix\ heli}}$ and a marginal cost for every filght hour $\mathbf{c_{var\ heli}}$. The $\mathbf{c_{var\ heli}}$ is composed of the flight time so fuel and helicopter pilots, and of a landing fee on Den Helder airport. By determining the total cost curves of a helicopter a reference point is established. The helicopter rate is expressed in:

$$rate_{\ heli} = c_{fix\ heli} + c_{var\ heli}, \qquad \text{Eq 3}$$

where the rate is expressed in euros per flight hour. The current way of operating is based on the usage of a single helicopter at a time. The helicopter has an average flight time of 4 hours a day, resulting in an average flight time capacity of 120 hours. Operations above the 120 hour require the rent of additional means.

Cost component	Description	Cost [€]	Unit
$c_{fix\ heli}$	$standing\ fee$	-	$\frac{€}{per\ month}$
$c_{var\ heli}$	$flight\ time$	-	$\frac{€}{flight\ hour}$
	$landings$	-	$\frac{€}{per\ landing}$
	$ad\ hoc\ rate\ additional\ helicopter\ time$	-	$\frac{€}{flight\ hour}$

Table 3. Helicopter cost components estimates

The prices used to make this cost estimation are provided by the head logistics TEPNL. This cost approximation is based on the current helicopter service contracts. The explanation of the total cost of one single helicopter designated for use is formulated above. The designated chopper has a flight time of 120, after which one must be rented against spot market price.

Interval I	$0 < t_{\text{flight time}} < 120$	Designated helicopter Total
Interval II	$t_{\text{flight time}} > 120$	Ad hoc hours rented

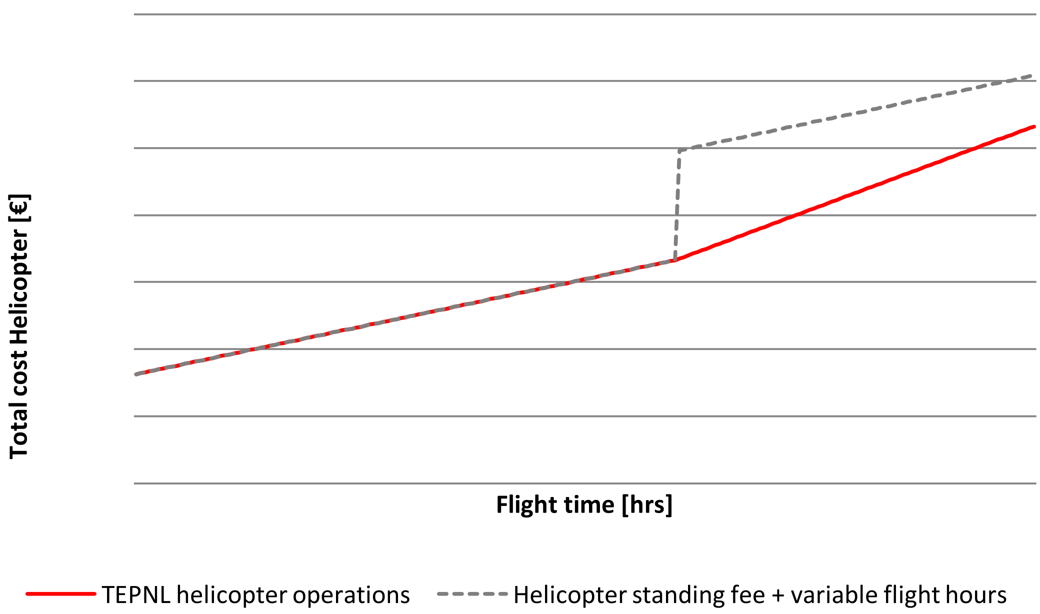


Figure 20. Helicopter cost estimates

The helicopter rates are based on a contract, with a fixed and variable part, or an ad hoc rate spot price. The gray dotted line represents the helicopter cost for 120 hours of flight time a month. Additional hours on top of the 120 limit are rent by the hour to eliminate the step caused by another standing fee for a second helicopter.

3.2.2 Supply Vessel

The supply vessels used by TEPNL comes from the sharing initiative; Southern North Sea pool *(Appendix: SNS-Pool)*. Multiple operators shear the vessels to optimize the use of deck space, and to reduce cost. A vessel can transport multiple containers, and bring equipment to different locations. Since this research is evaluating the logistic means especially for marine access, and supplies are based on preventive maintenance requirement the supply vessel is evaluated by a day rate.

Cost component	Description	Cost [€]	Unit
$Fixed\ Cost_{Supply\ Vessel}$	$Dayrate, Fuel + habour\ fees$	$-$	$\frac{€}{per\ day}$

Table 4. Supply vessel cost components estimates

The supply vessel costs are estimated by a fixed day rate. Additional costs caused by, the pool inefficiency, overhead TEPNL, fuel and harbor fees are included in the day rate of a vessel. For TEPNL in 2015 there were approximately 200 boat days (boat visits 2015).

3.2.3 Jack Up Vessel

To fully address current offshore operation of TEPNL all the means should be evaluated. Total has been in operation with a mobile accommodation unit for the last decades. Previous outstanding backlog and the requirement of additional accommodation and lifting capacity where decisive, is selecting this means.

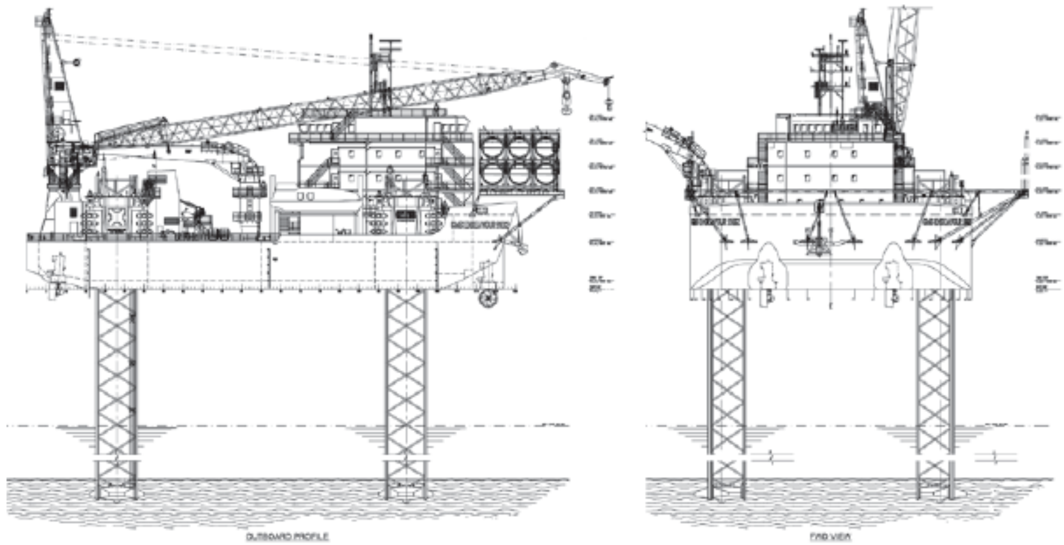


Figure 21. Jack up vessel GMS Endeavor

The mobile accommodation unit (MAU) the GMS endeavor is a self-propelled jack up. The cranes on the vessel make heavy lifts possible for large maintenance campaigns. The connecting gangway to a platform eliminate the constraints opposed by lifeboat limitation. With the vessel standing alongside 24-hours operations are conducted so no daylight restrictions apply.

To illustrate the exaggerated capacity of a jack-up and accompanying cost an example will be given. Since the jack up is located alongside of a platform and connected by a gangway the safety limitations can be disregarded. 24 hours' operations and additional manpower can fulfill the considered pm work scope within one day. Assume 2 shifts of 15 people working 10 hours a day results in 300 hours work which is more than the PM work scope on one platform for a quarter.

Currently, a high visitation frequency is characterizing the logistic deployment of a helicopter. The helicopter is used for personnel transfer in combination with a supply vessel for equipment transfer. An additional means to TEPNL disposal in the current operating mode is a jack-up. The conducted marine access requirement analysis workshop gives requirements and constraints of the different departments, which will be used in Module B to define the research. The previous chapter supports the investigation into a cost-effective way of safe transfer.

Module B: Research definition

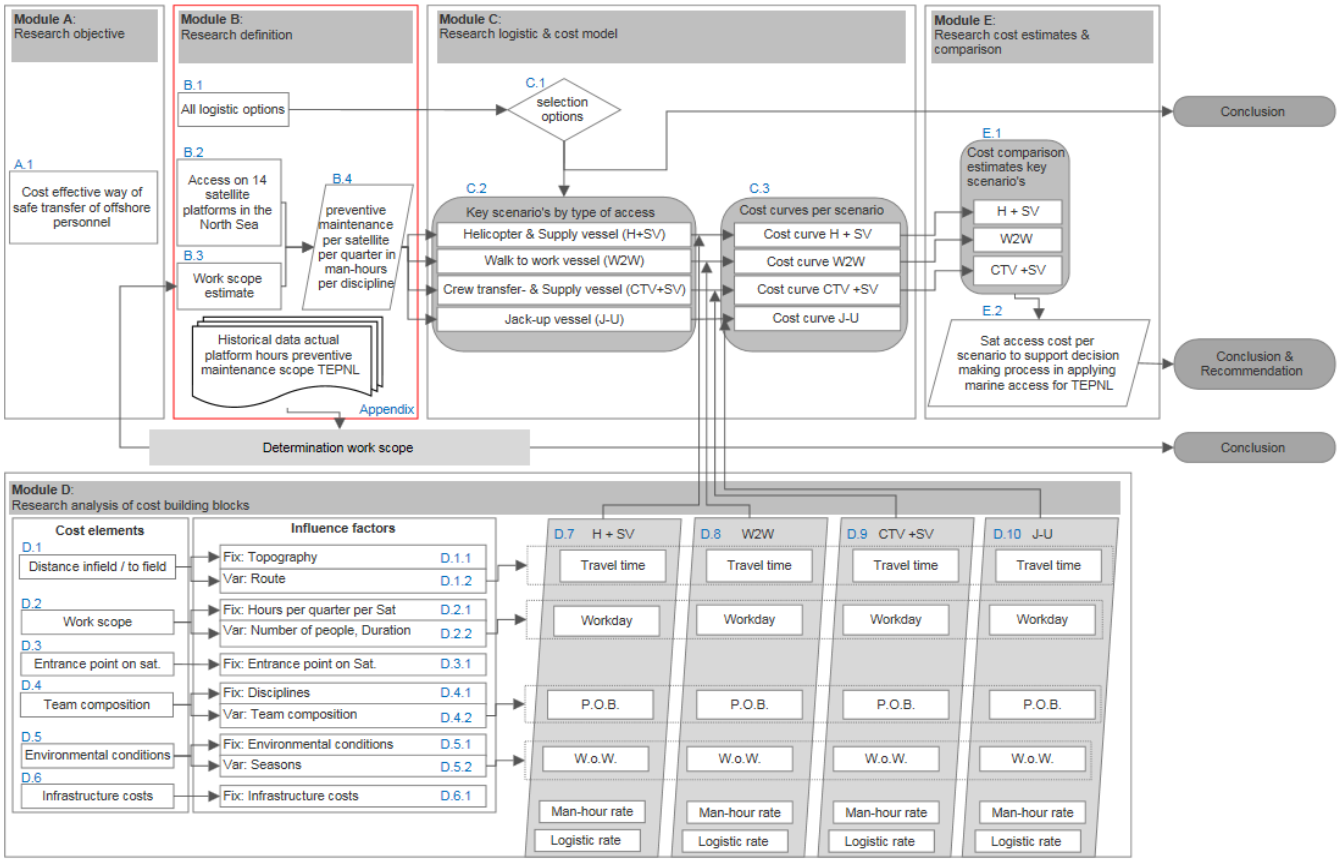


Figure 22. Process flow diagram marine access with the emphasis on research module B.

Chapter 4: Problem definition

The aim of this chapter is to define the problems addressed in this research. Starting with stating the main research question and the cause of this research (4.1). Subsequently, the associated sub questions are given to come to the answer of the main question (4.2).

This research is of exploratory nature. The objective of this study is to determine whether cost saving is applicable by visiting the satellites in a different way. The main research question is answered by subsequently exploring the related topics by answering the sub questions.

4.1 Main research question

"Which means of marine access can create new opportunities to be able to service the existing satellite platforms more cost effectively?"

The cost consciousness of offshore activities is clearly noticeable through the oil and gas industry (Analyst sees explorers growing more cost conscious, 2016). Studies to reduce operational expenditure without compromising on safety have captured the interest of many operators. This focus on cost is still in its infancy compared to other industries, due to the high returns of oil and gas fields in the past.

Especially with a gas field in the declining phase and the fact that the coherent assets are maturing, the financial benefits of large investments are due to its limiting lifetime very low. The cost saving opportunities that need to be considered are short term and sustainable for the field. The focus of this research is on the operational part of the inspection and maintenance activities of Totals satellites in the North Sea.

The inspiration for the way in which the structures are accessed cost effectively is obtained from the relatively young but quickly emerging offshore wind industry. Since the development of offshore wind farms is a cost intensive process, (The Operations & Maintenance (O&M) costs makes up 30% of the overall cost of energy (CoE) (Dinwoodie I. , McMillian, Revie, Lazakis, & Dalgic, 2013)), there has been great interest in quantifying O&M savings.

To indicate the parallels between the offshore wind industry and oil and gas production the following aspects are considered from a O&M perspective. (van Brussel, et al., 2013). The access methods in general are top priority, but more specifically access methods less sensitive to wind/wave conditions, should be developed. Great attention should be paid on the reduction of time required for offshore working. Difficult for a brown field, but worth investigating is the design for reduced maintenance; a reduction of overall components and simplistic design, modular design with possibility to interchange components, and use of high reliability components is today's credo. A special focus is on the appropriate maintenance strategy for service and repair. All aspects mentioned are beneficial for both the wind and the oil and gas industries to develop a cost-effective maintenance and inspection strategy.

When evaluating the opportunities to service the platforms more cost effectively an important question arises; more cost effective than what? The importance of a benchmark should be addressed when making a comparison. Offshore operations are and always have been considered expensive activities, the cost drivers are of great interest to many operators today. The impact of the rental of transportation and offshore equipment, as contribution to logistics, on the operational cost is considered significant.

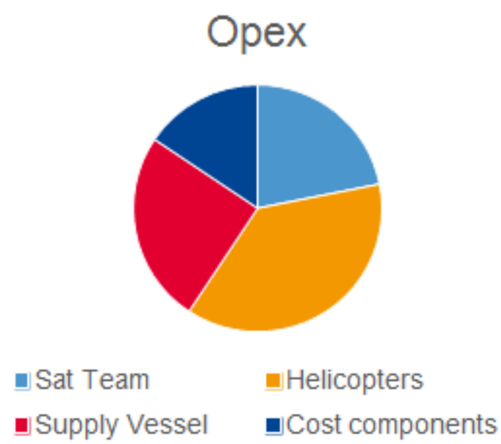


Figure 23. Distribution operational costs pm activities

The operational costs with respect to the preventive maintenance scope are approximately allocated as illustrated by the figure above. TEPNL is working with a preventive/corrective ratio of 60/40 which is used for cost allocation. The cost of the satellite-team are approximated by the estimations done on the required satellite work scope. Finally, the cost components are obtained from the SAP data and work orders.

The challenge in offshore access arises directly from the interactions of access means with the environmental conditions (DNV-GL, 2015). The different means, e.g. helicopter, crew-transfer vessel and offshore service vessel, have different operational limits. This weather window (Martins, Muraleedharan, & Sorares, Analysis on weather windows defined by significant wave height and wind speed , 2015), in which operations can take place, are set by the operator and evolve from the interaction of transport means and environmental conditions. A percentage of how much a structure can be accessed, the accessibility can be expressed in a percentage of transferable days. (van Brussel & Zaaijer). Accessibility comes at a cost. Before striving towards a maximum accessibility, the required accessibility should be determined.

The accessibility was based on the availability of the satellite. The availability, the amount of time the platform is producing, are not the only criteria of selecting the accessibility. The decreasing production volumes, lower gas price and high cost of personnel transfer should be taken in to consideration in the evaluation of the cost process.

4.2 Sub questions

The way of accessing a structure has many different effects on the structural infrastructure. Air access for example requires an emphasis on components related to the helicopter deck, but also firefighting and additional safety equipment. On the other hand, marine access requires an access point on the spider or cellar deck, a boat ladder and additional safety considerations for the physical transfer. The components critical to the way of access and their cost contribution can be evaluated directly.

1. Which serviceable components of existing satellite platforms are critical for the accessibility by air or by sea?

Besides the structural components related to access there are also a lot of safety requirements. Every satellite has its own safety system and is visited for maintenance and inspection. However, the safety means itself require also maintenance and inspection.

Some of the serviceable components are indirectly connected to the access method. The operational strategy requires these components to be present. In the current logistic process, the material and equipment, is delivered by supply vessel. Platform equipment such as a crane and lifeboats are part of the operational strategy.

The investigation towards an application of marine access is benchmarked against the current way of operating: a combination of helicopter access for personnel transfer and a supply vessel for equipment transfer. The specifications and operational procedures are fully developed and a lot of experience is gained since this is the general way of operating for many years now. All platforms are accessible and serviceable with this combination. A change in operational strategy should be more cost effective and not compromise on the safety standard. As previously explained the limited production life of the platform would make alternatives for which a high capital expenditure is required very unlikely.

The different satellites have been installed over the last decades, with a variety of equipment. This distinction in process equipment lead to a deviation in maintenance requirements. The required maintenance activities per satellite need to obtained from corresponding disciplines. The number of visits to a location needs to be considered when evaluating the way of access. Next to frequency, the distribution should be known to address the visitation requirements in more detail. All sites should be considered with the same access solution to avoid multiple means. Having multiple vessels with access solutions to reach the whole interval of access heights would never be economically beneficial due to the high day rates. Therefore, the next sub question addresses these points.

2. Can a generalized marine access approach be developed without large modifications to the existing satellite jacket structure?

The objective of maintenance activities offshore is to keep the desired production levels. "Service the existing satellite platforms" refers to the physical activities compulsory to keep up required production. The scope of work per location needs to be determined and an inventory of all hours needs to be calculated. When all hours at the different offshore locations are known, frequency and duration of visits is of key interest in determining the optimal access method. A variety of disciplines visit the satellites and contribute to the condition of the installation. A distinction in hours offshore should be made since scaffolding, mechanical, operators etc. are very diverse jobs. For many tasks, offshore specific qualifications are demanded, this automatically leads to a diverse group.

A combination of the number of visits, the discipline of the visitors, and the duration of the visit, needs to be considered to obtain the optimal access means for a specific work scope.

Every means comes at a specific cost; the duration drives the cost. What is the best means for a specific duration and is the rental time used efficiently? These questions require an investigation into the work day offshore. The interest in the efficiency of time related activities leads to the following sub question.

3. Can the effective working time at a satellite platform be increased, with respect to optimized logistic processes?

Every access means has its advantages and disadvantages. The objective is to determine consecutive steps which lead to an evaluation of the application of marine access. This report focuses on a specific field, but the same steps in a different situation can lead to another outcome.

The means of accessing a satellite, from a cost perspective, needs to be investigated to see if new opportunities arise. The brownfield under consideration limits capex due to a limited life time. The components linked to the way of access, a generalized approach for all satellites and aspect of time on a satellite are of great interest to evaluate the costs. The definition of the problem associated with assumptions will be addressed in the next chapter.

Chapter 5: Research demarcation

The operational character of this research requires a clear demarcation of the topic (5.1). By generally explaining the focus of satellite platforms and the preventive maintenance the scope results in a narrower scope. The market interest in access solutions at this moment with an operation and maintenance drive to reduce cost indicates the relevance of this topic (5.2). Finally, the boundary conditions on which this research is based are explained to describe the required assumptions (5.3 till 5.5).

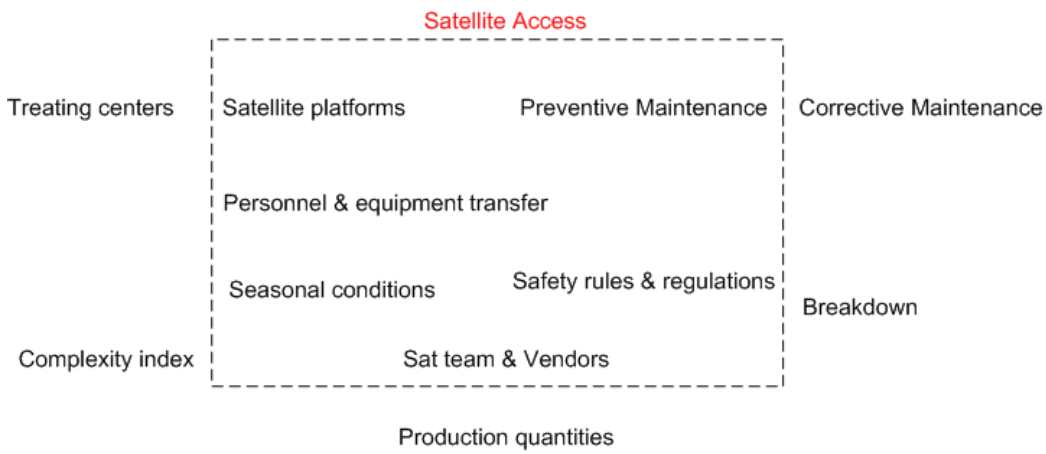


Figure 24. Research scope marine access

The research scope boundary is shown in the figure above by the dotted line. The focus is chosen by the researcher and the interests of the company. Due to the diversity and interconnectedness of variables related to this subject it is important to obtain a clear and narrower research scope.

The key stakeholders within TEPNL have delivered their input in a workshop to frame the common objective of marine access amongst the different departments. As described in System engineering fundamentals by the US department of defense a requirements analysis is the first step to analyze the process requirements for a system. To determine the functional and performance requirements the joint development session is based on a 15 task IEEE P1220 system engineering standard *(Appendix: Requirement analysis)*.

5.1 Demarcation subject

To limit the scope of this research a specific focus needs to be made. The research demarcation is based on the key interests of TEPNL. As indicated previously the company is actively looking for ways to adapt to the developments in the market, but also to cope with activities that correspond to the end of life of different locations.

Satellite platforms

The offshore assets in the North Sea can be divided into normally manned and unmanned locations. The focus of this research is limited by only looking at a specific group of unmanned satellite platforms. The satellite platforms are designed without accommodation. This results in transport to and from the location.

Maintenance and inspection

By investigating the effects of fixed preventive maintenance regarding crew and equipment transfer, a systematic pattern should be determined to evaluate the cost potentials of marine access. This eliminated the uncertainty of visits due to breakdown. Fixed maintenance and inspection is done periodically which therefore can lead to a sustainable cost saving.

Metocean conditions

The satellite platforms metocean conditions are available. Due to the given proximity of the platforms and similar water depth the same conditions are used for all platforms. The environmental conditions used for this research are the operational conditions.

Platform layout

The different structural layouts and orientations of the platforms will be considered. The access points and corresponding access related items will be considered; no specific focus will be on the production equipment on the platforms. By using an index which represents the platforms complexity based on equipment's, the frequency of visits and the requirement of containers can be quantified. Since a uniform means to servicing all platforms is required by the client no specific focus on one satellite is required.

Equipment and tools

When maintenance or inspection needs to be done often equipment and tools are required. In general, the equipment and tools can be divided in 2 categories; handhold or container. The equipment requirement has a large impact on the whole process and should be investigated in detail.

Rules & Regulations

All procedures within Total are defined in the General Specifications (GS) which are the internal guidelines based on the laws and regulations. When some activity deviates from this GS a request should be granted by Totals head office in Paris; a derogation. The application of some form of marine access is a change which needs to be considered in such a procedure. A close collaboration with the Health Safety and Environment (HSE) department is required when fundamentally changing the access method.

5.2 Access solution

The research conducted is focusing on the way of servicing the existing field for TEPNL. The access methods are discussed, but a detailed analysis e.g. vessel and transfer mechanism, should be supplied in a workability report from the marine solution provider. Currently offshore marine access market has seen more competition than ever before. A market analysis for totals framework has been done *(Appendix: marine access solutions 2016).*

5.3 Satellite work scope

The work scope of the satellites will be estimated in hours. This is done because the specific work orders per satellite contain too much detail. The diversity and quantity of all different activities require a high-level approach.

5.4 O&M strategies

The main activity for offshore logistics regarding O&M focuses on transporting technicians and equipment to different locations. (Anderberg, 2015) To determine the operational strategy the main factors are (Bard, J.; Thalemann, F. ORECCA, 2011):

- Distance from shore
- Average sea state
- Number, size & reliability of platforms
- Environmental conditions, important if wave heights, wind speed, and currents effects on operability of the vessel, safety of personnel, accessibility

- Distance between port and sat, transit speed given journey time, actual work time on site

5.5 Boundary conditions

The boundary conditions considered are based on both practical and regulatory restrictions. The practical restrictions which are considered logistic means are listed below:

Boundary conditions	
Helicopter	One helicopter. The helicopter contracts are set up in a way that makes the usage only mornings and afternoons relatively expensive. The most effective use would be: flying out early with multiple helicopters to drop off and picking them up as late as possible, however this is not possible cost wise. This research uses the assumption that there is one helicopter dedicated for the use, and if exceeding the flight time ad hoc hours are bought.
Helicopter	12 PAX max. The helicopter used has the largest capacity within the constraints of all helicopter decks.
Helicopter	Helicopter flying: wind speed, visibility.
Helicopter	Crew transfers and break down visits are not considered but are done by helicopter.
Helicopter	Heavy and restricted material cannot be taken into helicopter. E.g. pressurized containers, fuel etc.
Vessel	One vessel. multiple vessels at the same time are not considered. A scenario that multiple vessels service the field in half the time are not included.
Vessel	4 quarters. The rent of a vessel is based on a quarterly rate. The market supply and demand in impacting the price.
Vessel	Vessel sailing: sea state
Platform	POB 4 < people < 13. All platforms have a minimum crew constraint due to the man-over-board requirements. The maximum crew constraint is based on the capacity of the life boat.
Platform	Shelter & accommodation present.
Platform	No detailed analysis of process equipment.

Table 5. Boundary conditions research demarcation

To limit the extent of the research a focus area is chosen. The preventive maintenance of 14 satellites in the North Sea are taken as a case study. The number and diversity of activities result in an interpretation of work scope expressed in hours. Besides the limitations imposed by selecting this scope there are also boundary conditions enforced by the logistic means. These boundary conditions are based on financial or operational requirements.

Chapter 6: Literature study

This chapter contains an overview of the literature framework on which this research is constructed. The literature that will be used is all related to the main topic of this inquiry: sea access of Total's platforms. The literature supporting this research has been divided into several topics. Firstly, the process flow chart has been described (6.1), after which the 3 levels of decision-making are discussed (6.2). Thirdly, there will be looked at the different logistic means related to scientific studies (6.3). Subsequently, the theories of optimization of maintenance and inspection are given (6.4).

6.1 Process Flow Chart

In this study, there is searched for the optimal decision-making model (see the process flow chart on page 2) for Total E&P's management, which is based on the old but established theory of Frank and Lillian Gilbreth. These two members of the American Society of Mechanical Engineers (ASME) founded the theory of the - what they called - 'flow process chart' in 1921, a new method to structure and document process flows (Gilbreth & Gilbreth, 1921). This way of structuring is used here to build a model, since "models enable decision-makers to filter out the irrelevant complexities of the real world, so that efforts can be directed towards the most important parts of the system under study" (Giaglis, 2001, p. 1).

6.2 Decision-making levels in logistics – operational focus

To build the model as mentioned in the previous paragraph, a certain perspective is used on the decision-making process regarding Total E&P's logistics. The many different aspects of logistical planning have been extensively studied. Recently a lot of research has been conducted in logistical systems, especially because of the amount of data that has been collected in the last decades. One of those researches focuses on the logistics regarding decision-making processes; according to Schmidt and Wilhelm (2000) decision-making processes in logistics networks can be classified into 3 levels:

- Strategic level: how the layout of the logistic field is built - number, location and size of network nodes
- Tactical level: how the nodes are connected - location of the resources and the products at the different sites
- Operational decisions: how the routing and scheduling between the nodes are structured

Mainly the operational view on decision-making for the logistics, as well as partially the tactical view, will be important in this research. When looking at this research's network in combination with the Decision-making Level Theory, the strategic level focuses on the locations within the field and its design. There will be no focus on this part, because no new investments are going to be made, due to the limited lifetime of the field. Looking at the second level, the tactical level, we see that it is partially of relevance here: because it focuses on the intermediate future and the material flows for maintenance. The third level, the operational level is the most important one in this research, because it describes the short-term schedules to ensure in-time delivery of maintenance employees (Schmidt & Wilhelm, Strategic, tactical and operational decisions in multi-national logistics networks: a review and discussion of modelling issues, 2000, p. 1513). This level is the main starting point for the decision-making model. One relevant side note: the decision-making levels are only focused on the logistics here, not on the management of decision-making. That would require another (strategic) level of decision-making.

The levels of decision making are inter-connected (Schmidt & Wilbert, Strategic, tactical and operational decision in multi-national logistics networks: a review and discussion of modelling issues, 2000). By choosing the right mix of strategic, tactical and operational decisions the overall cost can be minimized. Considering the different levels, the applicability of a different access solution should be supported by a decision support tool.

A decision support tool can be developed for all kinds of complex systems in which there is a strong dependence between variables. As stated in the research described in the article 'Developing a support system for transport of large systems for the oil and gas industry' (Sluimer, 2012), it is important to understand which factors influence the transport (see module D).

6.2.1 Decision support tool – equipment & personnel transfer

Before a tool can be developed that focuses on the transport, the existing literature on transport cost models is reviewed. Sluimer focuses on equipment transport by comparing the cost models of Gursoy's article 'A method for transportation mode choice (Gursoy, 2010), Kim 'Intermodal freight transport on the right track?' (Kim, 2010) and Min 'International intermodal choices via chance constrained goal programming' (Min, 1991). Like many other transportation related cost models, the focus of this article is on equipment (containers), its quantity and its transportation time between the network locations. In a logistical research those different locations in a network are called 'nodes'. These theories mainly focus on equipment only, while for this research equipment as well as personnel transfer are both important. Theory about personnel transfer will be discussed in paragraph 6.3.

6.2.2 Decision support tool – offshore activities

Before exploring the literature related to decision-making in offshore activities, the more general theory of decision support systems will be analyzed. A decision is a choice of action to reach a desired objective (Simon, The new science of Management Decision, 1960). Nevertheless, the decision-making process is not only the final stage but should also cover all activities starting at identifying the problem, obtaining the relevant information, consideration of alternatives with respect to the desired objective (Holsapple, 2008), as can also be seen in the process flow diagram (see page 2).

Offshore projects in particular, are sensitive for external factors, such as environmental conditions. Therefore the model should support the process of considering different scenarios. In a study conducted for Heerema, in which a decision support system for logistic planning is considered, there is the importance of the workability indicated (Egemen, 2011). As the different access means are evaluated the influence of the weather plays a key role in determining which means of access are suitable at a location. As described by Martins, Muraleedharan and Sorares (2015) there should be looked for a 'weather window' (the period of time when weather conditions are suitable for a specific work at sea is called a weather window), which is based on significant wave height and wind speed (Martins, Muraleedharan, & Sorares, Analysis on weather windows defined by significant wave height and wind speed , 2015, p. 91). This means that "to operate and maintain offshore marine renewables, the site has to be accessible for a certain period of time", as stated by Santos et al (2013 & 2015) ((Santos et al, 2013, 2015) cited in (Martins, Muraleedharan, & Sorares, Analysis on weather windows defined by significant wave height and wind speed , 2015, p. 91)). The weather window could also be defined by many more criteria, such as: peak wave period and wave heading et cetera (Sperstad, Halvorsen-Weare, Hofmann, Nonas, & Wu, 2014, p. 222). The article, A comparison of single-and multi-parameter wave criteria for accessing wind turbine in strategic maintenance and logistics models for offshore wind farms, illustrates that a single limiting significant wave height gives a similar result as a complex multi-parameter wave analysis. The decision support models related to offshore access are all developed for the offshore wind industry. One of the reasons that extensive research has been done in this field is because of the early focus on cost due to lower returns on investments.

6.3 Studies on the logistics means

The logistic means for the transfer of personnel offshore is documented by the international marine contractor's association (IMCA). The industry guide for transfer of personnel to and from offshore vessels and structures indicates all safe methods for transfer at sea. The key methods covered and thoroughly discussed in this research are: the transfer carrier basket, gangways, and surfer methods (IMCA, 2014).

The accessibility studies related to specific workability's, *Accessibility - Challenges of achieving a high accessibility in remote offshore wind farms* (Anderberg, 2015) are focusing on the highest availability. This research is searching for the most cost effective means.

When investigating alternative ways of accessing a structure the emphasis is put on cost reduction without compromising on the level of safety. A workshop with the G9 (the nine largest offshore wind developers) about the health and safety concerns associated with transfer offshore, has shed light on how this industry is dealing with marine transfer and safety (Energy Institue , 2015). The crew transfer ladder is common practice in the offshore wind industry and topics like; boat landing/ladder design, access methodology, and the design of the CTV and access system are discussed.

Besides the joint industry initiative for the CTV, there has been a joint industry project for the gangway access solutions. The DNV GL led a project from which the W2W (Walk-to-work) guidance evolved (DNV-GL, 2015). The term walk to work is used to describe manning of the platform. The transfer of personnel by vessel via a gangway rather then, helicopter, basket or boat landing, provides improved manning flexibility, reduced life cycle cost and improved safety.

When accessing an offshore structure the environmental conditions are limiting. For air access the wind and visibility needs to be considered, but also sea state for helicopter survival. On the other hand, for marine access the waves are dominant, but there are wind limitations for personnel transfer and hoisting of equipment. The specific criteria on which the accessibility is determined depends on many factors. The interest in the wind industry has also stimulated the research and development in the offshore access market.

Previously the significant wave height was used as the only criteria in a strategic decision support tool. Research has been to determine if multiple parameters, e.g. peak wave period or heading do influence the accessibility offshore. In the article: A comparison of single- and multi-parameter wave criteria for accessing wind turbines in strategic maintenance and logistics models for offshore wind farms. (Sperstad, Halvorsen-Weare, Hofmann, Nonas, & Wu, 2014), was stated that by comparing the single limiting and multi parameter criteria a similar result was obtained. They also confirm that no established method has been developed to estimate the limiting significant wave height rather than by expert knowledge and testing procedures.

The operator can draw boundaries and to determine the operational guidelines based on safety standards. Total has developed specific guidelines and manuals to ensure the safety of all technicians.

The general principles for working in adverse weather describe environmental conditions, which may affect people, equipment or facilities, to an extent that precautionary measures are necessary. The specific limits are linked to a location, place of work, nature of the work, and time required securing the worksite before adverse weather. The consideration of a mix of environmental limitations should be evaluated. Especially, secondary limitations may form a restriction in operations.

- Wind speed limit, restricts external personnel movement

- Sea state limit, restricts launching of fast rescue craft
- The weather conditions, limits watercraft or helicopter activities.

Analysis on weather window defined by significant wave height and wind speed (Martins, Muraleedharan, & Guedes Soares, Analysis on weather window defined by significant wave height and wind speed , 2015).

When accessing a platform the environmental conditions are limiting. The sea sate is the results of the interaction between wind generated waves and currents as described by L.H. Holthuijsen in Waves in Oceanic and Coastal waters. Based on hindcast data validated by in situ measurements Actimar Operational Oceanograpthy has mapped the metocean conditions which will be used for this research. The extreme & operational conditions for wind, wave, current, water level, sea and temperature are retrieved by this data.

6.4 Optimization theories of maintenance & inspection

The literature related to maintenance with respect to offshore activities is mainly based to corrective maintenance rather than preventive. The failure rates of components result in required maintenance visits. The reliability centered maintenance (RCM) is used within TEPNL to determine minimum visitation requirements (Total , 2016). The confidential Total general specification "minimum maintenance requirements" provide the basis for the development of a maintenance strategy, by type of equipment. Due to the diverse equipment chosen is to evaluate the maintenance process based on the work scope and required discipline. Below the literature is listed which is used throughout this research with respect to maintenance.

Title	Report/article	Published by:
"A model for optimization of maintenance support organization for offshore wind farms"	Paper	F.Besnard, K.Fischer, L Bertling IEEE Transaction on sustainable Energy
"on maintenance optimization for offshore wind farms"	Thesis for doctor of philosophy	Francois Bernard Gothenburg
Challenges of achieving a high accessibility in remote offshore wind farms	Master thesis	Christopher Anderberg Gothenburg
Operation & Maintenance	Presentation offshore wind farm design	Gerard van Brussels TU Delft
Development of a model to estimate O&M cost for onshore wind farms	Report	TU Eindhoven, MECAL, TU Delft
Lightning Damage of OWECS, parameter relevant for cost modeling	Report	ECN Wind Energy
Optimization of maintenance strategies for offshore wind farms, OMCE-calculator	Paper	R.P. van de Pieterman, H. Braan T.S. Obdam, L.W.M.M. Rademaker, T.J.J. van der Zee
Quantifying O&M savings and availability improvements form wind turbine design for maintenance techniques	Paper	J.Carroll, Ian Dinwoodie,Alasdair McDonanld, David McMillian
Advanced maintenance strategies for power plant operators – introducing inter-plant life cycle management	Paper	U.Graber
State of the Art and Technology trends for Offshore Wind Energy: Operation and Maintenance Issues	Paper	G.J.W. Van Bussel, A.R. Henderson, C.A. Morgan, B.Smith, R.Barthelmie, K.Argyriadis, A.Arena, G.Niklasson, E.Peltola
An integrated and Generic Approach for Effective Offshore wind farm Operation & Maintenance	Thesis	H. Koopsta, TU Delft

Table 6. Literature containing Optimization of maintenance and inspection

The literature related to this field of operations has a very diverse background. The decision making, environmental research, operational requirements, supply chain and financial modelling are all combined. The evaluation of logistics requires knowledge of routing (Appendix: literature) and financial modelling to find the most cost effective means.

A great interest throughout the oil and gas industry combined with offshore wind has led to the development of many new access solutions (Appendix: Marine access solutions 2016).

Chapter 7: Logistic scenario's analysis for marine access

To give insight in marine access in general the 3 basic components of a marine access solution will be addressed (B1of the process flow diagram). The argument for a comparison by type is supported by the evaluation of the cost of a logistic means. Different logistic scenarios are considered based on type of access (7.1). A scenario analysis method shows the response to a change in a variable. The vessel characteristics and workability are provided by the shipbroker and are not considered in detail.

7.1 Assessment of logistic process (B.1)

The transfer of personnel can be divided into, on the one hand a helicopter (air access) on the other hand a watercraft (marine access). The logistic process considered in this research needs to address both, because the platform demands equipment and personnel. As discussed there are advantages and disadvantages when choosing an access principle.

Table 7. Air vs. marine access

Offshore access is greatly dependent on the environment and the nature of a task. Helicopters in general are designed for personnel transport, and vessels are often designed for carrying load. Nowadays ships with all different kinds of purposes have been made. This research limits the vessel investigation to types specifically designed for personnel transport.

The large variety of vessels designs and specifications for personnel and/or equipment transport lead to a selection based on type. All types of solutions combine three basic components: a vessel, a mooring method and some physical transfer mechanism.

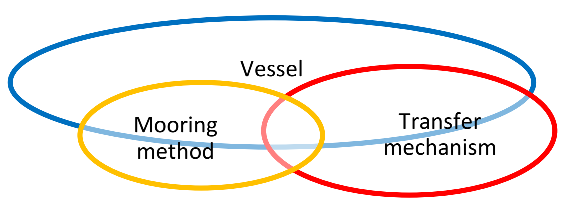


Figure 25. Basic components marine access

All forms of marine access require any combination of the 3 components; a vessel, mooring system and the transfer mechanism. The "best mixture" of these 3 components is not only dependent on how the systems interacts with each other but also what is required and how it is operated by the end user.

7.1.1 Vessel

The vessels are considered by type since their main purpose will be the transport of personnel and material. This research generalizes the type of vessels by splitting all vessels into 3 groups:

1. Crew transfer vessels

A crew transfer vessel is considered a small vessel solely used to transport personnel to offshore locations. The vessels are carried out in single and dual hull, but for this research no distinction is made. The capacity of maintenance crew is 24 and their service speed is considered at 25 knots on average. The deck space does not allow normal sized containers. The accommodation requirements are minimal, 24 forward facing seats, day/mess room and no beds available.

2. Offshore service vessels / Multipurpose vessel

The larger size vessel is described as an offshore service/ multipurpose vessel. The vessels are specially designed for the logistical servicing of offshore platforms. The comfort class on these vessels is higher than on crew transfer vessel, all facilities are present and beds are available for the crew op to 50. Their service speed is lower, approximately 12 knots.

3. Jack-up vessels

A MAU, mobile accommodation unit, is the least flexible alternative. The jack up considered is a DP2 vessel, no tugs are required to move it through the field. The service speed is 6 knots and the jacking time including preloading makes this a relative slow alternative. However, all required accommodation is present.

	Vessel information			
	Supply vessel (& Helicopter)	Crew transfer vessel (& supply vessel)	Offshore service vessel	Jack-up vessel
• Capacity (P.O.B)	$[-]$	24	50	100
• Service speed	$12\ [kts]$	$25\ [kts]$	12 [kts]	$6\ [kts]$
• Dimensions, Length	$70\ [m]$	$20\ [m]$	$100\ [m]$	$70\ [m]$
• Complexity of activity	$-+$	$--$	$+-$	$++$

Table 8. Vessel type key characteristics

7.1.2 Mooring method

Depending on the size of the vessel an appropriate mooring system is installed. The mooring procedure can be done by contact with the structure or keeping its position alongside. The contact method is called; the surfer method. By applying a forward thrust against the structure, the friction between the tip of the vessel and the V-shapes access point, a ladder access is possible. The platform boat landing restrictions are carefully explained in the design rules (Total, 2015).

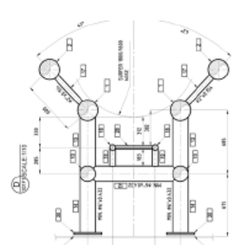


Figure 26. Structural drawing V-shape landing

The configuration above has been used in the offshore industry for decades, the much younger offshore wind industry has also implemented this as a standard. A ladder which is inclined between 2 bumpers to protect the person making the transfer, but also a point to push against to remain in contact with the structure.

7.1.3 Transfer mechanism

The logistic process is considered within the framework of the rules and safety regulations of Total. The foundations of the company's General specifications are based upon international guidelines. Due to the risks involved in personnel transfer it is practice within Total to do a Risk Assessment. Internal factors like the necessity and frequency of transfer are evaluated, but also external factors like environmental conditions, and its effects on the vessels movements. The operability and corresponding constraints are managed in this way.

The satellite entrance possibilities are studied from both the structural and logistical point of view *(Appendix: access points)*. This ensures the interaction between the entrance and the structural requirements. All possible solutions are considered and examined in detail on feasibility and applicability within the company's operational boundaries. The different methods for personnel transfer throughout the industry are listed.

Satellite entrance methods	Operational specifications TEPNL
Transfer by helicopter	• The transfer by helicopter requires a certified helicopter deck. • Necessary safety and alarm equipment. • The structure is accessed from the top down, putting the emphasis on the condition of the top side.
Transfer by boat landing	• Every platform has a v-shaped structure with a ladder in between to access the structure. • Necessary safety protocols required. • The structure is accessed from the bottom up, putting the emphasis on the condition of the lower part of the structure, especially spider deck and staircase.
Transfer by personnel transfer carrier basket *Not allowed by Total in the North Sea*	• The transfer by basket requires a crane certified for man riding. • Necessary safety procedures. • The structure is accessed from the top down, putting the emphasis on the condition of the crane and landing area.
Transfer by gangway	• Transfer by gangway has developed since the introduction of motion compensated technology, active and passive. • Necessary safety consideration due to interaction with environmental conditions. • The structure is accessed from the bottom up, putting emphasis on either the lower part of the structure or the topside since an access height should be chosen.
Transfer by swing rope *Not allowed by Total in the North Sea*	• One of the oldest and riskiest methods, generally considered an out dated approach. • Very limited by the environmental conditions. • The structure is accessed from the bottom up, putting the emphasis on the condition of the lower part of the structure, especially spider deck and staircase

Table 9. Marine entrance solution comparison methodology

The table above shows all practiced transfer mechanisms. The environmental conditions at a specific location force the operator to restrict the use of a specific access method. Total has provided guidelines for all affiliates. The use of swing rope, an outdated but still effective method in some regions, is not allowed in the North Sea. The transfer by carrier basket requires a specific certified man riding crane which is not present on the satellites. These 2 marine entrance solutions will not be explored further in this report. (note more information can be found in appendix: access mechanisms).

7.2 Access on 14 satellite platforms in the North Sea (B.2)

The structural layout as described in section 2.1.1 is determined by the platform elevation drawings. With the support of the marine specialist of TEPNL all access points on each platform have been indicated. All platforms have one or multiple points of entrance. The orientation of the platform, and respectively hazardous components e.g. risers etc. need to be considered with the vessels position *(Appendix: Access points).* (note: inventory access points & risk assessment marine access.)

7.3 Work scope estimate (B.3)

To develop a methodology that allows for an evaluation of the application of marine access, data on which conclusions can be drawn needs to identified. A lot of data is available in the extensive computerized maintenance management system (CMMS). Key is finding the most relevant or best data available to support any future decisions.

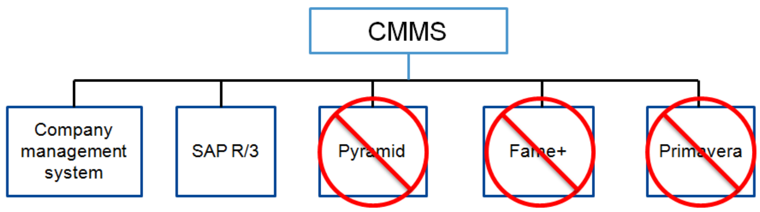


Figure 27. Computerized maintenance management system Total

The figure indicated that the company's restrictions and guidelines are combined with the SAP database to create a comparison on which Total can base its decision for the application of marine access.

The Company management system (CMS) is used for this research since it provides a framework of policies, standards, processes and procedures within Total. To include safety regulations and operational restrictions this source is used.

To obtain information about the assets SAP is used. The whole process from notifications till the financial closing of a work order is described in the maintenance and inspections manual (M&I). This source of data is used to evaluate the components related to access and to calculate hours offshore.

Pyramid & Fame+ are both custom tools too I have not used them since they are focusing on the process itself, rather than supplying data.

Finally, Primavera is a useful planning which can be helpful to set up a schedule based on input from SAP. I have not included Primavera data in this research because it has not been fully implemented and contains backlog leading to a distorted view of PM work scope.

Besides the CMS there are also many tools available for the different departments linked to SAP or a production database.

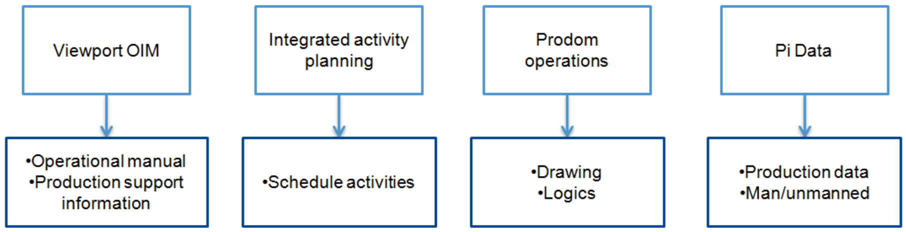
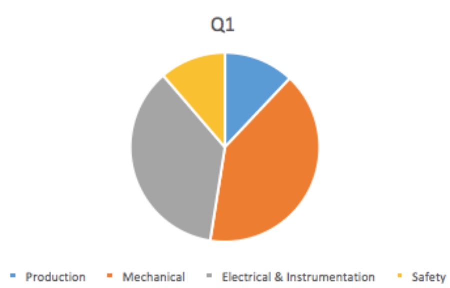


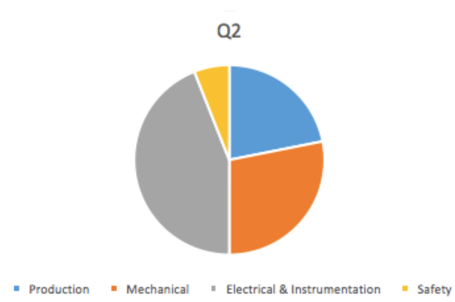
Figure 28. Available company tools TEPNL

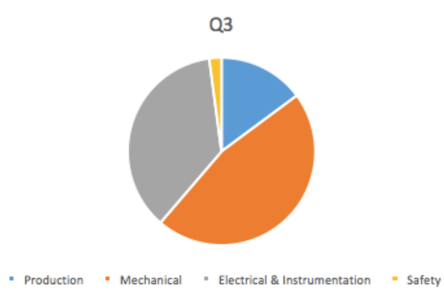
The combination of resources available make it possible to interpret all sorts of data and compare their outcomes. The figure above indicated the data source used for this research. The date used like procedures and drawings are not changing over time, however it is important to state that in operational research the external factors have a big influence. The impact of the gas price has far-reaching effects.

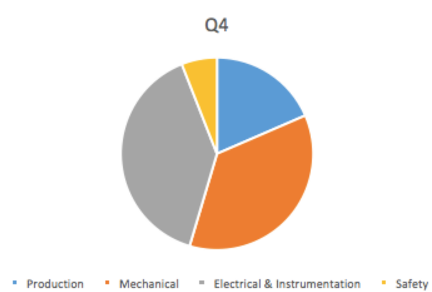
7.4 PM per satellite per quarter in man-hours per discipline (B.4)

As expressed above the preventive maintenance hours per location are estimated based on various sources. The best approximation of the actual pm work scope is based on: a minimum visitation study, interviews and a SAP analysis supplied by methods.









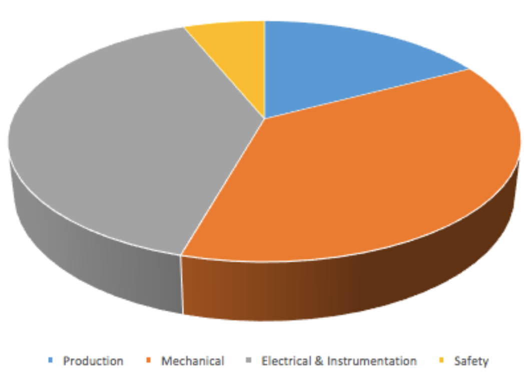


Table 10. Overview PM discipline work scope

The table above indicated the workload per discipline per quarter on all satellites. Since all platforms have different processing equipment the hours per discipline per location varies. As visible in the table above the hours mechanical and electrical & instrumentation make up the largest share of work. When taking the annual average of the different disciplines the bottom distribution can be made.

When studying an individual satellite rather than a whole field the distinction between the different locations can be made. The table below shows the pm hours at one location, the Appendix: PM hours per location per discipline gives the distribution per site.

CONFIDENTIAL

Table 11. Hours PM based on minimum visitation requirement study K1A per discipline per quarter.

A more extensive table is visible in appendix: PM hours per location per discipline.

All marine access solutions consist of 3 components: vessel, mooring method and transfer mechanism. The vessels are considered by type: crew transfer vessel, offshore support vessel and jack up vessel. The mooring method is directly linked to the type of vessel; 2 methods are considered: a surfer- or dynamic positioning method. Finally, all transfer mechanisms are evaluated combined accompanied with the other 2 components. The entrance points are mapped and the work scope per discipline per location is evaluated on marine access possibilities. The inventory is required for the selection of the suitable marine access options.

Module C: Research logistic & cost model

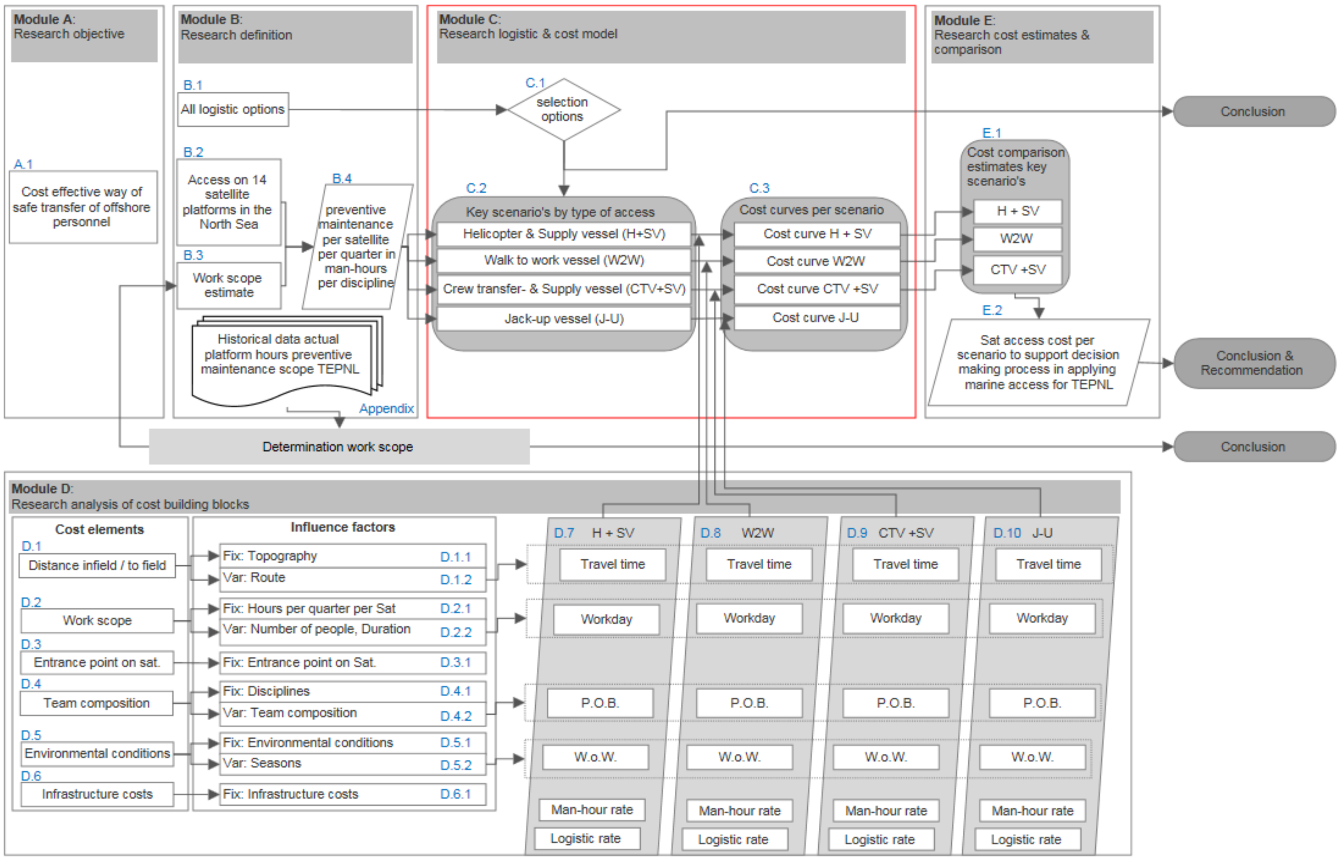


Figure 29. Process flow diagram marine access with the emphasis on research module C.

Chapter 8: Selection marine access options

The logistic scenarios that are evaluated are based on the type of access means. The choice of type is based on company restrictions and applicability in the focus area. A deductive reasoning results in a limited number of access options (8.1). Starting by reducing the logistic scenarios based on internal or external constraints, by platform, transportation means or operational requirements. After which the key scenario's will be elaborated upon in more detail (8.2).

8.1 Reducing logistic scenario's (C.1)

The number of means to service the field with respect to the transfer of personnel and equipment is limited. These limitations or constraints are either internal or external. The internal constraints are factors that are under the control of the company yet interfere with its ability to make decisions that are in its own best interest, according business case study LLP. External constraints are factors outside control of the company and may open or close the possibilities in achieving its targets (thefacts, 2016).

All operational processes a bounded by constraints. The constraint theory is a method of determining the most important factor that limits the process of achieving the goal. In production and manufacturing this constraint is called the bottleneck or weakest link. The key constraints are shown in the table below.

	Internal constraints	External constraints
Platform	• Personnel capacity on platform • Crane not suitable for man riding • Swing rope not suitable in North Sea conditions	
Transportation means	• Sea state limitations (Total, 2015)	• Personnel capacity of transportation means • Available in the market
Operational	• Supervisory attendance company personnel	• Environmental conditions for transfer; significant wave height & wave period • Rotational period of two weeks offshore 3 weeks onshore.

Table 12. Internal and external constraints

The table shows the most important constraints either induced by the company itself or by factors which cannot be controlled. Totals key priority is safety and has therefore created strict rules and regulations for the offshore operations. All options considered in this report are within the operational restrictions.

8.2 Description key logistic scenario's (C.2)

All options illustrated in section 7.1 with the constraints from section 8.1 result in limited number of cases to consider. To make a comparison based on the type of access, it is chosen to compare the most applicable type of logistic means. The 4 key scenarios are briefly explained by type of access.

8.2.1 Scenario: Helicopter & Supply Vessel

The scenario of a helicopter and supply vessel represents the current way of servicing the satellite platforms. Only one helicopter is used and the flight time a day is between 3 and 4 hours (boundary condition from section 5.5). The helicopter is based in Den Helder and is flying every day to distribute the crew. The daily satellite visits always require 2 landings since the crew must be delivered and be picked up. The number of passengers range between 4 and 12 for a visit. The duration of a visit in effected by use of a single helicopter in combination with the visibility. The ratio HoTT versus NPT is effected by many additional requirements caused using a helicopter.

Figure 30. CHC helicopter landing on top of a helicopter deck

A supply vessel is designed to transport containers. The helicopter used is very limited in cargo space and lifting capability. The number of hours pm is linked to an average number of visits. The supply vessel requires a crane driver to lift the container from the vessel to the platform. The entrance of personnel to the structure is via the topside by landing on the helicopter deck.

8.2.2 Scenario: Walk to Work vessel

The W2W scenario is based on a vessel with a gangway access system, hence the name walk to work. The vessel is remaining offshore for 2 weeks, the longer transit to the field has not to be made daily, so this scenario would increase the duration at a location. The ratio HoTT versus NPT is better since activities could be done on the vessel. After transfer the vessel does not remain connected to the structure like the jack up scenario. The length of a vessel and the motion compensated technology *(Appendix: Marine transfer solutions 2016)* have widened the operational weather window to make is less dependent on environmental conditions.

Figure 31. Walk to work solution implemented by NAM

No supply vessel is needed since there is enough deck space to transport containers. Since a gangway is present the crane driver and the container are together, no additional effort needs to be done to bring the crane driver to the location. The entrance to the structure is dependent on the height and orientations with respect the dominant weather factor. The decks or staircases free from obstacles are the best place for transfer.

8.2.3 Scenario: Crew transfer vessel & Supply Vessel

The CTV scenario, popular in the windfarms, is a smaller vessel with no accommodation requirements. A crew transfer is the quickest of all considered vessels, but also the most effected by the environmental conditions. The daily transfer from the port and in-field the duration on the platform is under pressure.

Figure 32. Surfer landing by crew transfer vessel

This scenario is based on the same logistical challenge as the scenario with a helicopter. The big difference is however the level of accessibility, which is much higher with a helicopter. This is cause since the crew transfer is done with a surfer method on to the spider deck. The spider deck is the lowest deck and access to this deck is fully dependent on the weather conditions.

8.2.4 Scenario: Jack-up vessel

The jack-up scenario is based on a self-propelled mobile accommodation unit (MAU). The vessel is jacked up besides the platform and connected by a gangway. Since this configuration is fixed the operational requirements and constraints are otherwise specified.

Figure 33. Fixed gangway between jack-up and satellite

In the past the mobile platform has been flown on to crew change people and supplies are brought by vessel. Since the gangway is fixed to the structure the duration of people can be very high. The favorable ratio of HoTT results from the easy access to the MAU. For preventive maintenance as addressed in section 3.2 this means is an overkill in hours.

The argument for the evaluation of logistic scenarios is based on costs. A scenario analysis based on type of transportation results in a limited number scenarios. The limitations are imposed by both external and internal constraints. There are constraints linked to the platform, the transportation means or operating requirements. Since the evaluation is based on type, 4 key scenarios remain: helicopter & supply vessel, walk to work vessel, crew transfer & supply vessel and a jack up vessel. These different logistical means are evaluated based on cost which will be addressed in the next chapter.

Chapter 9: Mathematical description cost comparison

Firstly, a general description of the derivation of the cost functions used for the cost comparison model of the logistic means is given (9.1). The individual cost function for a scenario is explained in section 9.1.1 till 9.1.4., subsequently the inputs for the equations described (9.2), and finally the graphs supporting the cost function are given and interpreted (9.3).

This research makes a cost comparison between the different logistic means for satellite access. The process of deriving the final formula which describes the dominant cost drivers will be explained by starting with all significant cost components.

9.1 Mathematical expressions

The total cost function $f(s)$ is the summation of the cost terms c. The subscripts of c indicate the origin of the cost. The 3 general cost terms resulting in the total cost function are defined as:

- The labor costs c_{mh}, resulting from the multiplication of man-hours by an hourly rate
- The logistic costs c_l, based on a unit rate times a defined period
- The material costsc_m, following from maintenance activities.

The total cost function used in this research for the evaluation of the preventive maintenance cost per satellite per quarter is written as:

$$f(s) = c_{mh} + c_l + c_m. \qquad \text{Eq 4}$$

A different cost function $f(s)$ is defined for each of the 4 scenarios. The scenarios are described in the previous chapter and consist of a logistic means, or combination of logistic means. The means of transporting personnel to the platform influence the c_{mh}. The considered logistical means impact the workday due to different travelling times and capacity.

Important to state in this transportation problem is the large impact caused by a difference in marginal cost. The rates of the logistic means are relatively high compared to the rates of labor. This difference in rates with low quantities put the emphasis on the logistic costs. Depending on the capacity of a logistic means and its duration of platform time, the system is modeled by a discrete step function.

Since platform visits are considered a collective effort and the satellite team is staying together the hours on a platform are determined by an individual's longest task. The hours are assumed to be of an integer value. To clarify this, a required visit of 5 hours with a team of 12 people, results in all 12 people to stay 1 hour. A team composed of 12 people is making discrete steps of 12 hrs. An offshore workday of technical personnel as addressed in chapter 2 is divided into different intervals. The time in which physical work on the platform is done is called t_{HoT} which is given per hours.

The number of personnel is expressed by n with the index explaining the type of logistic means. By using a ceiling function: ⌈x⌉, the ceiling of x, the smallest integer greater than or equal to x (Harvard, n.d.), the step behavior can be expressed. By taking a ceiling function of the division of the t_{HoT} over n, and multiplying this by again n, the number of hours on the platform for the entire team are calculated.

To service the platforms in hours of work per year quarter, the number of people and their duration, D are varied. If for example 250 hrs of maintenance are required, an option to meet this requirement could be 5 people, 10 days for 5 hours or another option is 10 people, 5 days for 5 hours. To calculate the number of day visits, DV, the following ceiling function is used:

$$DV(\mathbb{Z}) = \left\lceil \frac{t_{HoT}}{(n*D)} \right\rceil. \qquad \text{Eq 5}$$

The variable D is chosen to consider inefficiencies that originate from the use of a specific transportation means. To illustrate such an inefficiency; changing time for survival suite into work cloths. The D indicated the length of an offshore workday and is expressed in hours.

After explaining the general assumptions behind the cost functions $f(s)$ a detailed expression for the different scenarios is specified.

9.1.1 Helicopter & supply vessel

Based on the preventive work scope (section 11.1), the average hours on a platform per quarter are approximately 250 hrs. The total cost equation for this scenario is assembled by combining the cost function of the helicopter and of the supply vessel.

$$\sum_{t_{HoT}=0}^{250} \left(\left(\left(\left\lceil \frac{t_{HoT}}{n_{heli}} \right\rceil * n_{heli} \right) * rate_{crew} \right) + \left(\frac{2\, d_{i,j}}{v_{heli}} \right) * rate_{\ heli} + (t_{WoW-wind} * rate_{\ heli}) + \left\lceil \frac{t_{HoT}}{\frac{250}{f_{boat}}} \right\rceil * rate_{\ means} \right.$$
$$\left. + \left((t_{WoW-Hs} \cup t_{WoW-W}) * rate_{\ supply\ vessel} \right) \right)$$

Eq 6

As expressed in the previous section the ceiling function of the t_{HoT} over n_{heli}, multiplied by n_{heli} gives the total number of hours on the platform. To obtain the labor cost as shown in Equation 4 the total number of hours is multiplied by hourly rate of the crew resulting in total cost of the crew on the platform.

As explained in chapter 3 the helicopter costs are based on flight time, rather than a day rate as such for a vessel. In order to consider the total time a helicopter is traveling: the individual distances between the platforms must be calculated, in combination with the speed of the helicopter. The roundtrip flight time, t_{ij}^{f} between two platforms is calculated by

$$t_{ij}^{f} = \frac{2\, d_{ij}}{v_{heli}}, \qquad \text{Eq 7}$$

where $t_{ij}^{f}$is the round-trip travelling time since there is no accommodation when using a helicopter, d_{ij} is the distance in km, $v_{heli}$is the average velocity of a helicopter in km/h. There the index $i, j = 1 \dots 14$ are the platforms, note$i \neq j$. The calculation of the distances is given in the next chapter. Since the rate of a helicopter is expressed in euros per flight time, multiplying t_{ij}^{f} with $rate_{\ heli}$ gives the first part of the logistic costs, c_1 .

The material cost for pm are removed from the cost equation, the material cost will approximately be the same. The only changes would be the infrastructure cost on the platform since another logistic means is used. The separate analysis that evaluated these material costs proves a minor costs contribution (Chapter 11).

The second part of the equation indicates the cost contribution by a supply vessel. The vessel is only transporting equipment and materials, so no labor cost needs to be considered. The logistic costs for a vessel require an expression in a different way, since the rate of a vessel is based on the day rate. A supplier is sailing from Den Helder based required supply. The supplies are dependent on the maintenance activities and are therefore linked to a number of hours. By varying the frequency, f_{boat}, a suppliers visits can be modeled by the similar ceiling function based on the same t_{HoT}. Multiplying the number of day visits by the day rate of the vessel a cost step function is created.

The second part of the logistic costs is connected to the environmental conditions. A supplier might not provide access directly to the structure, it's purpose is to supply equipment with require transfer by the crane on the satellite. Crane operations are limited by a defined weather window in a similar way as the transfer of people is limited. The time loss due to the weather, commonly referred to as: wait on weather time, t_{WoW} can be caused by many factors. The significant wave height H_s and wind speed V_w are used to consider additional cost due to weather by:

$$c_l = (t_{WoW-Hs} \cup t_{WoW-W})\ rate_{\ supply\ vessel}, \qquad \text{Eq 8}$$

where t_{WoW-Hs} is expressed in days. The probability obtained from the operational metocean data is provided by TEPNL. The t_{WoW-W} is also converted into days. The limits used to offshore operations are based on adverse weather working guidelines (Total, 2015).

Combining the different terms in a total cost function for this scenario and using the input from Module D: travel time, workday, person on board, wait on weather time both rates crew and logistic means, give a function with many variables to regard.

9.1.2 Walk to work vessel

The t_{HoT} of 250 hr per quarter per platform is the same as considered in the previous scenario. An important distinction between a larger vessel and helicopter is n_{W2W}. A limited of n_{heli} is 12 where a vessel can accommodate 30 n_{W2W}. The capacity restriction is shifted for the logistic means to the platform itself. Depending on how the w2w vessel is deployed this cost function can be obtained.

$$\sum_{t_{HoT}=0}^{250}\left(\left(\left\lceil\frac{t_{HoT}}{n_{W2W}}\right\rceil * n_{W2W}\right) * rate_{crew}\right) + \left(\frac{2\, d_{i,j}}{v_{w2w}}\right) * rate_{\ W2W} + (t_{WoW-Hs} * rate_{\ W2W})$$

Eq 9

9.1.3 Crew transfer vessel & supply vessel

To make an equal comparison the work scope on which the scenarios are evaluated is the same. The total cost equation $f(s)$ for this scenario is constructed in a similar manner as the helicopter and the supply vessel. The function is defined as:

$$\sum_{t_{HoT}=0}^{250}\left(\left(\left\lceil\frac{t_{HoT}}{n_{ctv}}\right\rceil * n_{ctv}\right) * rate_{crew}\right) + \left(\frac{2\, d_{i,j}}{v_{ctv}}\right) * rate_{\ ctv} + (t_{WoW-Hs} * rate_{\ ctv}) + \left\lceil\frac{t_{HoT}}{\frac{250}{f_{boat}}}\right\rceil * rate_{\ means}$$
$$+ \left((t_{WoW-Hs} \cup t_{WoW-wind}) * rate_{\ supply\ vessel}\right))$$

Eq 10

where the first term and last two terms are explained in the section above. The most important distinction from the first scenario is the impact of the logistic costs, both on shuttling time $t_{ij}^{s} = \frac{2\, d_{ij}}{v_{ctv}}$, and the limited operational window.

9.1.4 Jack-up vessel

$$\sum_{t_{HoT}=0}^{250}\left(\left(\left\lceil\frac{t_{HoT}}{n_{JU}}\right\rceil * n_{JU}\right) * rate_{crew}\right) + \left(\frac{2\, d_{i,j}}{v_{JU}}\right) * rate_{\,JU} + \left(t_{WoW-Hs} * rate_{\,JU}\right)$$

Eq 11

The cost curve derivation of a jack up is like the approach previously taken in section 9.1.2 of a walk to work vessel. The rate of a jack up is much higher and a jack up is considered less flexible in moving through the field. However, a jack up is connected by a fixed gangway and has the highest accessibility. As expressed in section 8.2.4 the 24-hour operations make this means highly effective if a lot of PM hours are required at a specific site.

9.2 Inputs – cost curve scenario

The cost comparison is based on the total cost functions explained in section 9.1. The influence factors impacting the cost functions are explained in chapter 10. A uniform way to model the different costs is to express them as a function of the work scope, so hours on platform. The input used to illustrate the general shape of the cost functions are given in the table below.

CONFIDENTIAL

Table 13. Input values scenario base case analysis

The key scenarios described in section 8.2 can all be modelled by specific cost function. To illustrate the behavior of the curves these values are chosen. The accessibility is the percentage of time the transfer is possible because the metocean conditions are not exceeding the operational limits. The logistic rates are expressed per time unit and are abbreviated as: Heli = helicopter, SV = supply vessel, OSV = offshore support vessel, TS = transfer system, CTV = crew transfer mechanism and JU = jack up. The number of passengers is limited by the design of the vessel. The duration on the platform is dependent on port or offshore based scenarios. The transit time is important for port based scenario's. And finally, the supply vessel, who is transporting the equipment.

9.3 Outputs - cost curve per scenario (C.3)

The values from table 12 give the input on which the output from figures 34 to 37 is generated. The total costs are expressed against required time on a satellite. The functions described in section 9.1 are discrete step functions.

9.3.1 Total cost curve helicopter & supply vessel

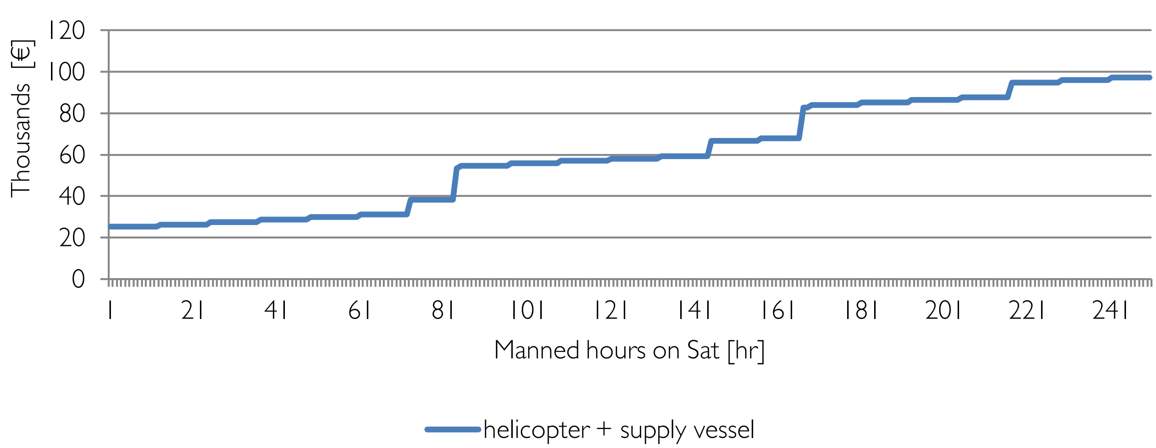


Figure 34. Total cost function scenario helicopter & supply vessel

The input from table 12 in Equation 6 from section 9.1.1 helicopter & supply vessel, gives the following figure. The total cost of a helicopter is modelled by a small step, for every additional hour the maintenance team is at the location, the larger step is the cost flight time. The total cost of the supply vessel is linked to the number of hours on a satellite before additional materials are required, this results in a similar step function. The combined step functions of the helicopter and supply vessel result in total cost function.

9.3.2 Total cost curve walk to work vessel

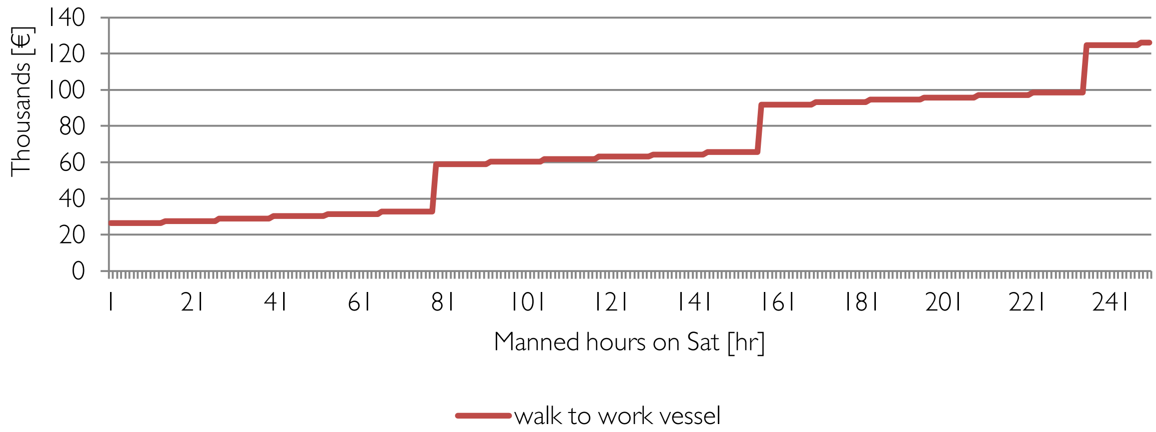


Figure 35. Total cost function scenario walk to work vessel

The input from table 12 in Equation 7 from section 9.1.2 walk to work vessel, shows a double step function. The large step is caused by the day rate of both vessel and access system. Since the vessel is at location the average duration on the platform goes up, an additional hour on the platform equals increase is effectiveness. The impact of the day rate of a vessel on the total cost can be clearly observed.

9.3.3 Total cost curve crew transfer vessel & supply vessel

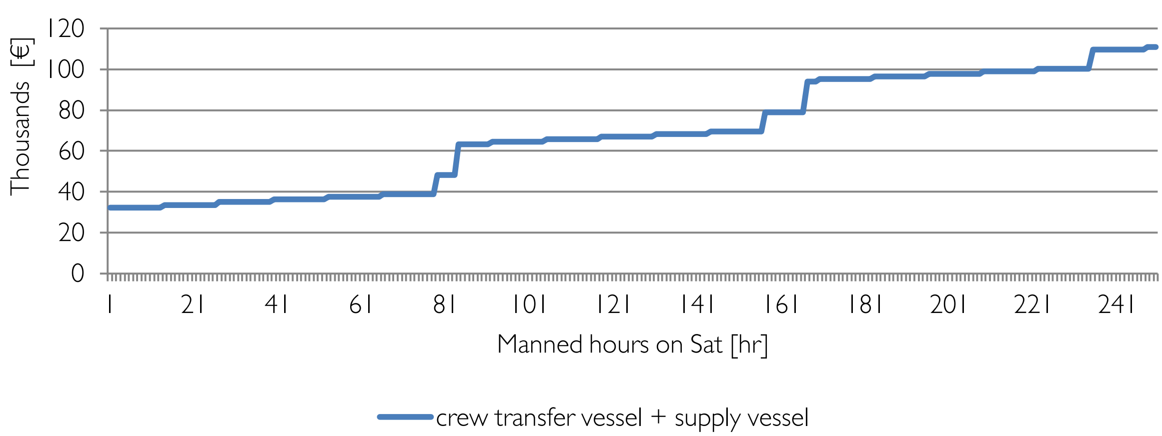


Figure 36. Total cost function scenario crew transfer vessel & supply vessel

The input from table 12 in Equation 8 from section 9.1.3 crew transfer vessel & supply vessel show a similar behavior as the helicopter and supply vessel in figure 31. The logistic means has the lowest cost per time unit of all vessels. This logistic means is considered most sensitive for the environmental conditions, not only the transit but also the access to the platform require calm sea conditions.

9.3.4 Total cost curve jack up

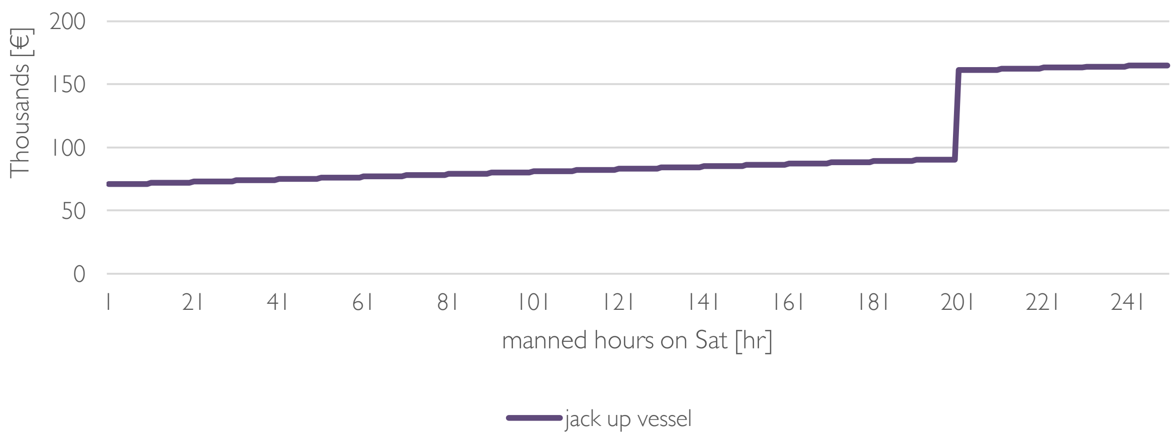


Figure 37. Total cost function scenario jack up vessel

The input from table 12 in Equation 11 from section 9.1.4 illustrates the cost curve of a jack up. The curve indicates the capability of delivering many hours on a specific site. When 24 hour operations are considered the preventive maintenance, scope can be met quickly. The figure clearly shows this means requires a much larger work scope to be used affectively. (note additional consideration need to be taken in to account when evaluating a jack up such as accommodation or lifting requirements).

The mathematical expressions of the total cost function for all for scenarios are given based on the same variables. To illustrate the shape of the total cost functions an input is used to generate an output. By evaluating the shapes and checking the responses to a change in variables insight is obtained in the cost related to satellite access. The decision of the variables chosen for the total cost function will be explained in the next chapter (module D).

Module D: Research analysis of cost building blocks

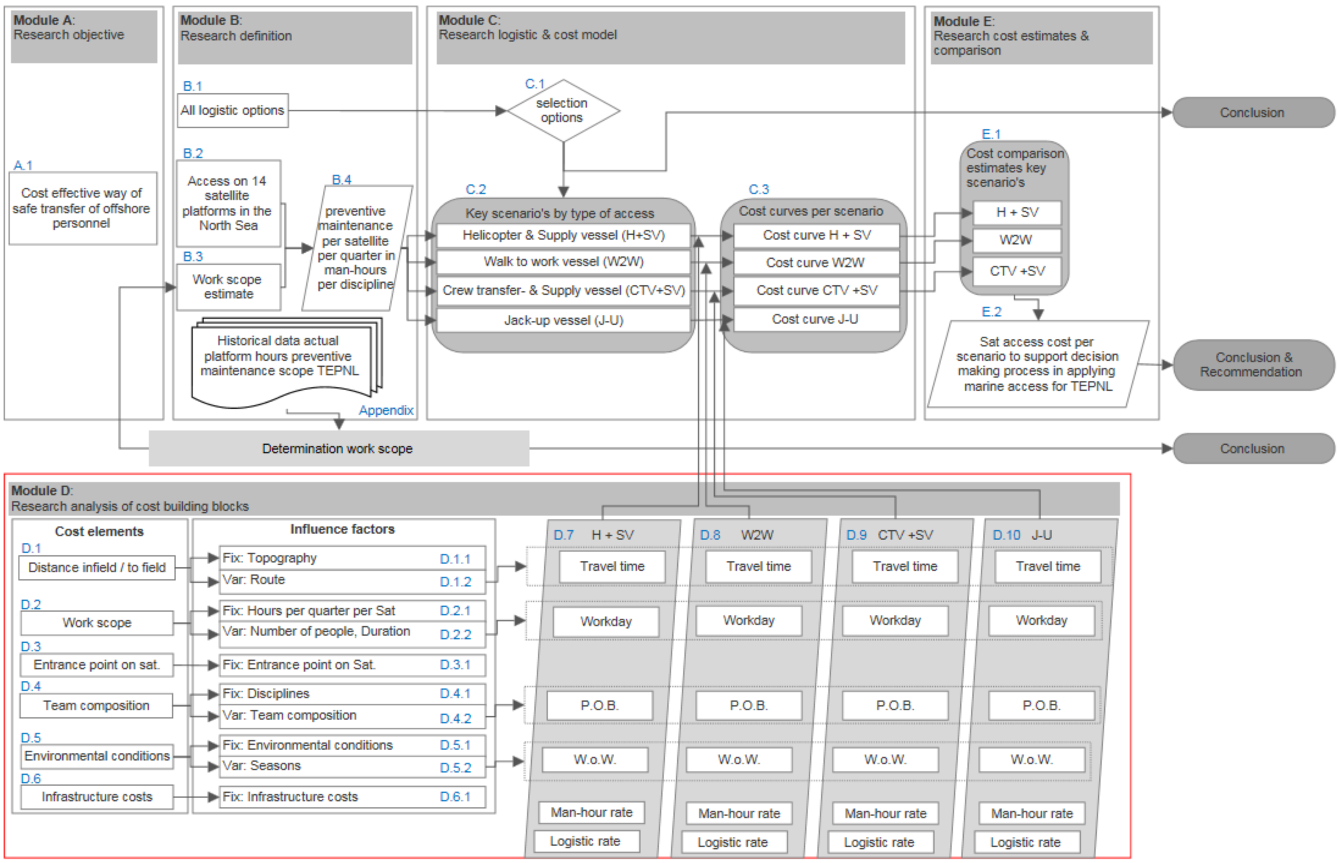


Figure 38. Process flow diagram marine access with the emphasis on research module D.

Chapter 10: Variables cost modeling

The cost curves per scenario (previously used in section 9.1) are based on a set of variables. The variables used for modelling these curves are discussed in this chapter. To determine the cost building blocks, figure 35 in module D, different methods will be used. Starting with section 10.1 by describing the cost elements and the objective behind selecting these. The cost elements considered are subjected by influence by factors either fixed or variable (section 10.2). Finally, after evaluating these factors the key variables used in each scenario are obtained (section 10.3).

10.1 Cost elements

The total cost function described in the previous chapter is expressed as a function of hours to service a platform PM requirements, but the functions are dependent on many variables. Based on cost accounting principles the basic elements of cost are: raw material, labor and expenses or overhead. The basic components labor and expenses/ overhead have been made more tangible by defining the following 6 cost elements: distance infield/to field, work scope, entrance point on satellite platform, team composition, environmental conditions and infrastructure costs.

Cost element	Objective
D.1 Distance	The objective of this analysis to obtain insight in the geographical layout of the field and to determine the relative travelling times between locations.
D.2 Work scope	The objective is to obtain an estimate of the hours by quarter and per discipline and location.
D.3 Entrance point	The objective is to estimate if there are any substantial savings being gained from a different way of access.
D.4 Team composition	The objective is to select a team with the best offshore performance.
D.5 Environmental condition	The objective is to consider the operational metocean conditions that impact marine access.
D.6 Infrastructure costs	The objective is to show the sensitivity of infrastructure cost on the model.

Table 14. Cost elements and coincide objectives

The objective of the cost elements indicates the goal of determining the contribution to the overall cost function. To determine the impact different methods are required to evaluate the cost elements.

10.2 Influence factors fixed or variable

The cost elements described in section 10.1 can be broken down in fixed or variable influence factors. The methods to investigate the impacts are presented below.

Topography (D.1.1)

The locations of the considered satellites are fixed. The geographical distance between two platforms is expressed as $\mathrm{d_{ij}}$ in km, where the indices $i, j = 1 \ldots 14$, and $i \neq j$. The d_{ij} is calculated by the GPS coordinates in $DD{:}MM{:}SS.SS$, and transformed in latitude lat_i and longitude lon_i in radians.

$$lat_i \vee lon_i \;= radians\,(\frac{D*3600+M*60+S}{3600}) \qquad \text{Eq 12}$$

$$d_{i,j} = acos\,(sin(lat_i)\,sin(lat_j) + cos(lat_j)\,cos(lat_i) * cos(lon_j - lon_i)) * \frac{180}{\pi*60} \qquad \text{Eq 13}$$

The earth's shape is approximated by a sphere, due to the proximity of all platforms this is a very accurate estimate.

A network diagram bases on the platforms locations (lat_i, lon_i) connects the nodes by the arcs d_{ij}.

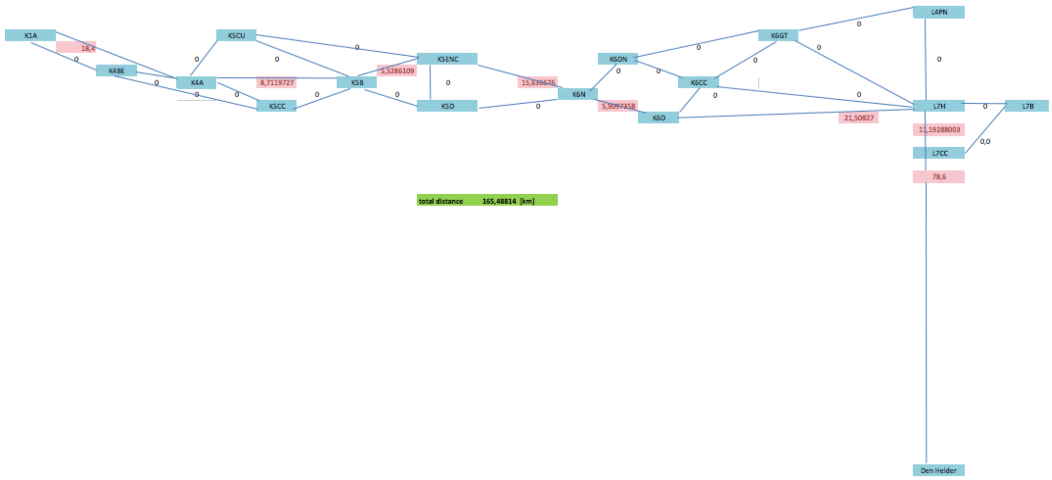


Figure 39. Network flow diagram based on TEPNL field layout.

The figure represents the TEPNL field with the blocks indicating the nodes (platforms), and lines the representing arcs (geographical distances). The network flow theory is used in transportation problems, like shortest path and vehicle routing problems (Appendix: Logistic network).

Route (D.1.2)

By using a network model with relative distances the shortest route amongst the different locations can be calculated. A linear solver gives the shortest path between the nodes by solving the defined balance equation.

$$(total\ flow\ in) - (total\ flow\ out) = specified\ net\ demand \qquad \text{Eq 14}$$

$$\sum_{(i,j)\in A} x_{i,j} - \sum_{(j,i)\in A} x_{j,i} = b_k \quad for\ all\ i\ \in V \qquad \text{Eq 15}$$

The shortest route calculation is done to obtain insight in the impact of the distance by using a different route. Since the distance to the field is approximately the same longest distance infield the impact of the route is not considered significant.

The d_{ij} matrix in km *(Appendix: Distance matrix)* obtained from these calculations is used to calculated the transit time between locations, $t_{transit,ij}$ in hours for the different logistic scenarios expressed in the previous chapter. Based on the average speed of the logistic means, v_h in km/hour, the time can be calculated by:

$$t_{trans,ij} = \frac{d_{ij}}{v_h} \qquad \text{Eq 16}$$

The research into the spacing between the locations however has led to the possibility of simultaneous servicing platforms. By visiting 2 or 3 satellites at a single workday more people can be distributed over the different assets. The decision is based on the response time and transit constraints. The use of simple geometry results in the evaluation of the geometric center to determine which platforms can be serviced simulations.

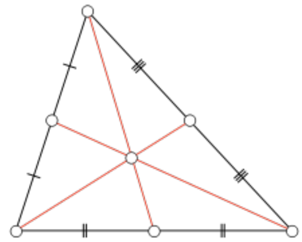


Figure 40. Three platforms triangle shape

The geometric center of a plane figure or centroid is the average position of all the points in the shape. This point is also the intersection of the triangles three triangle medians, and is always inside the triangle (Johnson 1929, p.249; Wells 1991, p.150) (Wolfram mathworld, 2016) .

The work scope or scope of work is the division of work to be performed under a contract typically broken out into specific tasks with deadlines (Businessdictionary, 2016). This research makes the division into; production, mechanical, electrical & instrumentation and safety. Since the enormous quantity of specific tasks chosen is to express the required activities in hours. To make a budgeting decision the manpower is a resource to complete defined work in terms of hours, the hours are converted into labor cost (U.S. Energy department). As discussed in the chapter 7.3 an approximation of the work scope is done by combining the resources available. The method used to analyze the data is both qualitative and quantitative. The qualitative aspects of understanding the context is of great importance. The impact of the difference between activities onshore and offshore are obtained by interviews. Both structured data, qualitative and interviews qualitative are used. The estimated taken and supported by experts within TEPNL is 250 hours pm per sat per quarter.

Hours per quarter per Satellite (D.2.1)

The method used to obtain an estimate is based on sorting data and comparing data sets. Section 7.4 illustrates the distributions per discipline over the quarters. The averaging of historical data over multiple years, different sites but similar installations is resulting in an approximation.

Number of people, Duration (D.2.2)

As previously expressed, the work scope is defined in hours. The size of a team results in a number of days that the work scope can be carried out. By evaluating the company rules the number of people are restricted by either man over board of lifeboat capacity. On the other hand, the transportation means do also have a defined capacity and operating time. Since no accommodation is present on the satellites technicians dropped off must be picked up. The workforce of people is considered uniform over the year, having people working for half a year is not considered in this research.

The duration on a platform is dependent on its logistic means. To determine the duration on a platform the planning a scheduling department is interviewed. The hours on a platform based on the helicopter use are evaluated by comparing them against a man-unmanned binary signal obtained from production. From the duration of a maintenance team on a platform the frequency distribution can be obtained.

Entrance point on sat (D.3.1)

The entrance height and position is determined by the structural layout. The company rules and CAPEX reduction lead to limited number of access points. To specify the heights from mean sea level (MSL) the following graph is given.

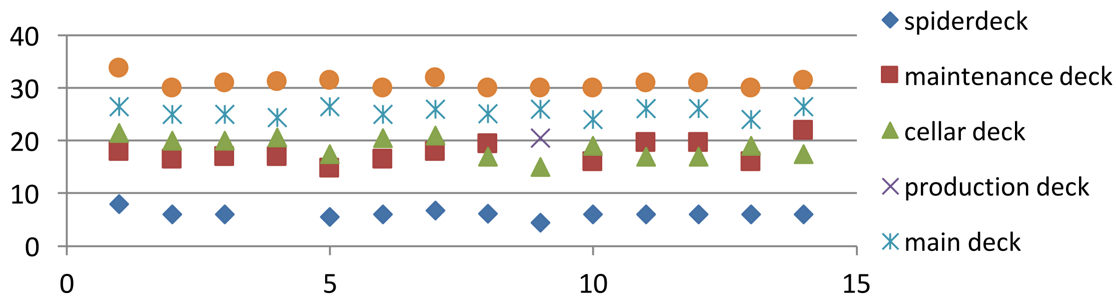


Figure 41. Deck height of TEPNL's satellite platforms in the North Sea.

The 14 satellite platforms (table 2) considered have different deck heights. All 13th jacket structure have a spider deck, only the mono-pile structure K5B has no spider deck, hence the missing blue dot. In the appendix: entrance points a thorough investigation of all entrance points is visible.

For satellite access 2 height-intervals can be used to enter all satellites. The higher the entrance height, the larger the means, which generally leads to an increase in costs.

Access points:

- Spider deck (range 6m – 8m)
- Horizontal part stairs (10m – 15m)
- Cellar/ Maintenance deck (16m – 22m)

The different access points require 2 different access solutions *(Appendix: Access points).*

Vessel range	
Smaller vessel + access system Range (6m – 12m)	Estimate: 15 K per/day
Larger vessel + access system Range (16m – 22m)	Estimate: 30 K per/day

Table 15. Entrance height intervals

The table shows the ranges in which the platforms can be divided. Besides the height of the access points, the orientation with respect to the wave direction needs to be considered as well. A safe access point is clear from obstacles and away from risers, tubes etc.

The combination of height of the vessel with access system and the length and inclination of the gangway define the interval of possible entrance heights.

$$H_{\max transfer} = H_{deck} + H_{access\ system} + H_{inclination\ gangway}$$

$$H_{\min transfer} = H_{deck} + H_{access\ system} - H_{inclination\ gangway}$$

$$H_{inclination\ gangway} = \sin(\theta) * l_{gangway}$$

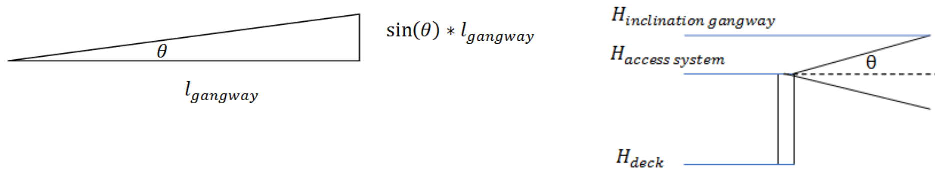


Figure 42. Access height estimate based on ship and access system

For all gangway solutions, the height intervals can be obtained by the supplier in a workability report. The vertical displacement is based on the ship motions and the ability to compensate by a motion compensated system. The higher the configuration, generally the larger the displacement in the tip will be.

	Inclination (degree)										
	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
Length gangway [m]											
15.0	1.3	1.6	1.8	2.1	2.3	2.6	2.9	3.1	3.4	3.6	3.9
16.0	1.4	1.7	1.9	2.2	2.5	2.8	3.1	3.3	3.6	3.9	4.1
17.0	1.5	1.8	2.1	2.4	2.7	3.0	3.2	3.5	3.8	4.1	4.4
18.0	1.6	1.9	2.2	2.5	2.8	3.1	3.4	3.7	4.0	4.4	4.7
19.0	1.7	2.0	2.3	2.6	3.0	3.3	3.6	4.0	4.3	4.6	4.9
20.0	1.7	2.1	2.4	2.8	3.1	3.5	3.8	4.2	4.5	4.8	5.2

Table 16. Gangway length with inclination to estimate operational interval

Changing the angle of the gangway result in larger window for operations. The change in angle however comes at a cost, it reduces the ability the compensate for motions.

Disciplines (D.4.1)

The maintenance team or sat-team is a group consisting of various technical disciplines. Due to safety regulations, a team needs to contain at least 4 people, since this is required for a man over board situation, and a maximum of 13 people, given the capacity of the lifeboats present. The upper and lower boundary of the team size is defined. However, within a team specific trades or disciplines are assigned to people since the work is specialized. (note the vendors, or highly specialized trades are excluded).

As described in section 2.2 the disciplines are grouped into: production, mechanical, electrical & instrumentation and safety. The number of people in a team, $n_{displine}$ can be varied with no limitation on available crew. This results in:

$$4 < n_{prod} + n_{mech} + n_{e\&i} + n_{safe} < 13, \qquad \text{Eq 17}$$

there is a constraint for the number of people on a specific satellite platform per quarter. As explained the pm hours of work scope, t_{HoT}, per satellite per quarter per discipline are estimated.

Team composition (D.4.2)

The work scopes in hours for a team demanded on an individual satellite are fulfilled by a visitation frequency, f_v and the duration of those visits, $D_{v\ sat\ i}$. Generally expressed as

$$Scope\ of\ work_{sat\ i} = f_{v\ \ sat\ i} * D_{v\ sat\ i}, \quad \text{Eq 18}$$

where, the f_v the number of times per quarter and $D_{v\ sat\ i}$ is expressed in hours. The duration is modelled by an accessibility factor, acc multiplied by the offshore work day. The t_{HoT} on a satellite per quarter is the product of the duration, the number of people and the number of days, DV.

This results in the following 4 equations:

$$T_{HoT\_mech} = D_{v\ sat\ i}.* n_{mech} * DV_{mech} \quad \text{Eq 19}$$

$$T_{HoT\_prod} = D_{v\ sat\ i}.* n_{prod} * DV_{prod} \quad \text{Eq 20}$$

$$T_{HoT\_E\&I} = D_{v\ sat\ i}.* n_{e\&i} * DV_{E\&I} \quad \text{Eq 21}$$

$$T_{HoT\_safe} = D_{v\ sat\ i}.* n_{safe} * DV_{safe.} \quad \text{Eq 22}$$

To calculate the labor cost per trade the t_{HoT} is multiplied by an hourly rate $P_{discipline}$. A solver is used to determine the optimal team composition given work scope estimate per discipline per satellite per trade by the objective function:

$$min\,TC = (D_{v\ sat\ i} * n_{mech} * DV_{mech} * P_{mech}) + (D_{v\ sat\ i} * n_{prod} * DV_{prod} * P_{prod}) + (D_{v\ sat\ i} * n_{e\&i} * DV_{E\&I} * P_{E\&I}) + (D_{v\ sat\ i} * n_{safe} * DV_{safe} * P_{safe})$$

Eq 23

The variables $n_{prod}, n_{mech}, n_{e\&i}, n_{safe,} DV_{prod}, DV_{mech}, DV_{E\&I}, DV_{safe}$ are shown with a constraint on $n_{displine}$ to be an integer since it considers people. By requiring the t_{HoT} per discipline to be larger than the assigned hours per discipline and the $n_{displine}, DV_{discpline}$ be larger than 1 to assure a minimization is coming to a trivial solution. (note, a minimum in cost is simply by not going).

To incorporate an operator's supervisory requirement, at least always 1 person from the discipline production present, the following constraint is used:

$$max\ (DV_{mech}, DV_{prod,} DV_{E\&I}, DV_{safe}) \leq DV_{prod.} \quad \text{Eq 24}$$

The max function uses the highest number of days of a discipline and constraints the number of days' production to be higher. This procedure gives the team composition for a assigned work scope.

An obvious next step to evaluate the team composition is to add the $\boldsymbol{transport\ costs}$ to the equation to determine the impact. By adding a vessel price to the number of days from the production discipline the total cost can be minimized. Due to the high cost of a vessel the solver is search for a minimum number of days rather than the most effective or efficient team composition.

The calculations result in to the finding that the gain of optimization of the maintenance team is small compared to the gain of reducing the vessel days.

Environmental conditions (D.5.1)

As indicated in chapter 9 the different logistic scenarios need to consider some form of downtime. This downtime or suspended use of a logistic means due to severe weather is defined as Wait on Weather time t_{WoW}. Different environmental factors influence the logistic process in a different way.

To illustrate the impact on the environment, a helicopter is generally restricted by wind and visibility. A vessel however, needs to consider downtime due to waves. A supply vessel needs to regard both, since lifting operations are considered. The operational oceanography data is evaluated by wind, wave and current conditions. The wind and wave data are considered the dominant criteria for the transfer process and will be used to determine the level of accessibility. The vessels dynamic positioning system will compensate the current and will be excluded from this research. The average wind speed v_{wind} in m/s and average significant wave height H_s in meters, are used to establish the probability of occurrence of these events. The cumulative probability of wind access per quarter $P_{w-a}\,(Q_n)$ as a dimensionless number, with $n = 1 \dots 4$, is multiplied by number of days as indicated by the waiting on weather time. This is calculated by:

$$t_{WoW-wind} = P_{w-a}\left(Q_n\right) * Q_n, \qquad \text{Eq 25}$$

where the probability is dependent on the quarter. The added cost of logistics due to this down time multiplied by a rate of a logistic means represents the wait on weather costs. In a similar manner, the t_{WoW-H_s} can be expressed, by using the cumulative probability of the average significant wave height per quarter $P_{H_s-a}\,(Q_n)$. Given by:

$$t_{WoW-H_s} = P_{H_s-a}\left(Q_n\right) * Q_n, \qquad \text{Eq 26}$$

the t_{WoW-H_s} indicates the numbers of days where no transit is possible. To increase the operational window that is limited by significant wave height, motion compensated technology has gained a lot of interest.

For the physical transfer process both the wind and wave conditions need to considered. The adverse weather working guidelines and general specification of personnel transfer between watercraft and offshore structure limit the transfer process (Adverse weather working guidelines, 2015) (Total, 2015). The operational guidelines use weather limits expressed in measurable quantities like: wind speed, restrict personnel movement, sea state: limits launching fast rescue crafts and weather conditions that limit or prevent watercraft of helicopter activities.

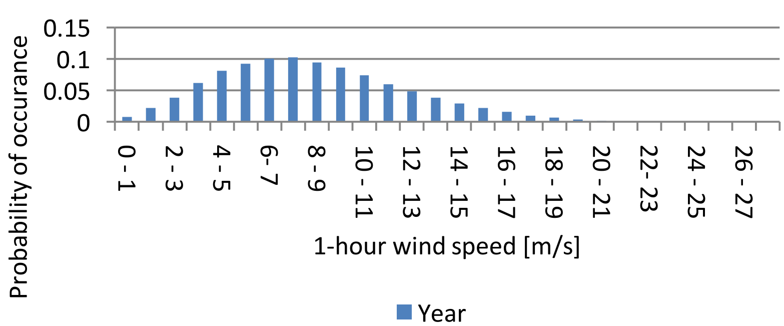


Figure 43. Annual one hour wind speed graph based on Actimar measurements

The wind is effecting the vessel, gangway, people and equipment transfer. The graph shows the distribution of the annual probability of occurrence of a 1 hour wind speed.

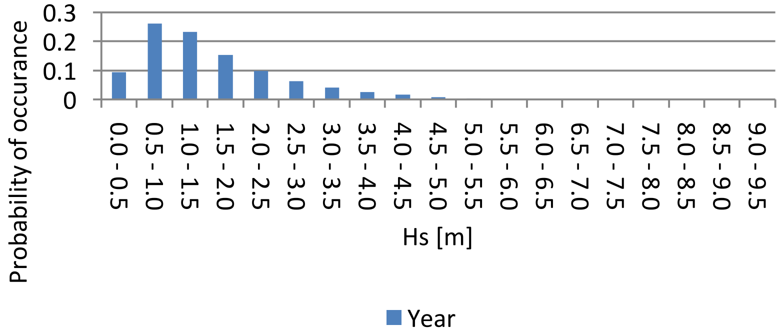


Figure 44. Annual significant wave distribution based on Actimar measurements

The annual distributions of wind speed and wave height give a first impression. The quarterly conditions used for the model give a better approximation. The company rules limit the transfer process not the technical performance of a gangway.

Seasons (D.5.2)

As discussed in section D.5.1. the wind and wave conditions are dominant due to company restrictions. The article "A comparison of a single- and multi-parameter wave criteria for accessing wind turbines in strategic maintenance and logistic models for offshore wind farms" expressed the importance of the significant wave height in the transfer process (Sperstad, Halvorsen-Weare, Hofmann, Nonas, & Wu, 2014). The environmental conditions vary strongly throughout the year. The operational metocean data at TEPNL's locations supplied by the company Actimar are therefore evaluated by season. To illustrate the impact of the season, the wind speed and direction of the months January and July shown.

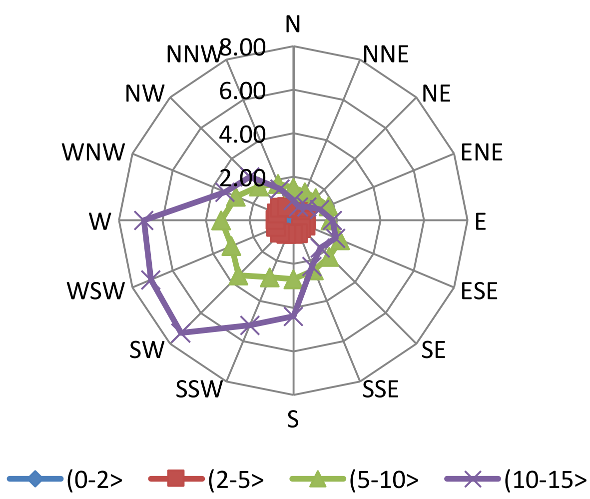


Figure 45. Wind speed and direction January based on Actimar data

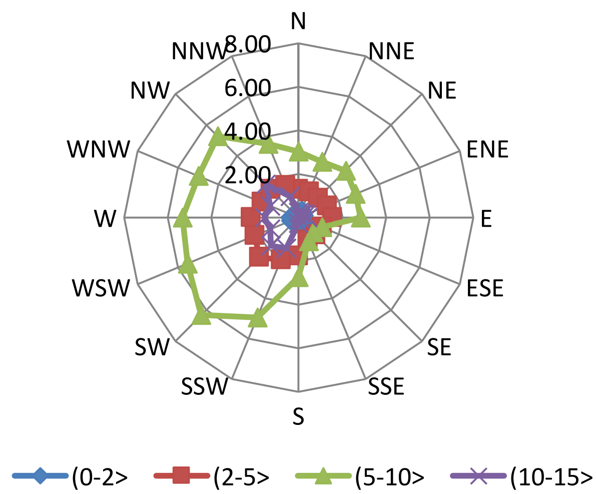


Figure 46. Wind speed and direction July based on Actimar data

The distinction between seasons based on wind speed and wind direction is clearly visible from 2 figures above. The top figure shows the relative strong winds from W to SW, while the strong winds in the bottom figure are much lower and form the NW. These graphs support the distinctions between in wind speed and directionality between two seasons.

Besides the seasonal impact of the wind the influence of the significant wave height is also present. The significant wave conditions are evaluated per quarter, from a monthly distribution *(Appendix: Hs-table*) per wave height interval. The summation of the discrete probabilities over the height intervals gives a monthly cumulative probability for a wave height per month.

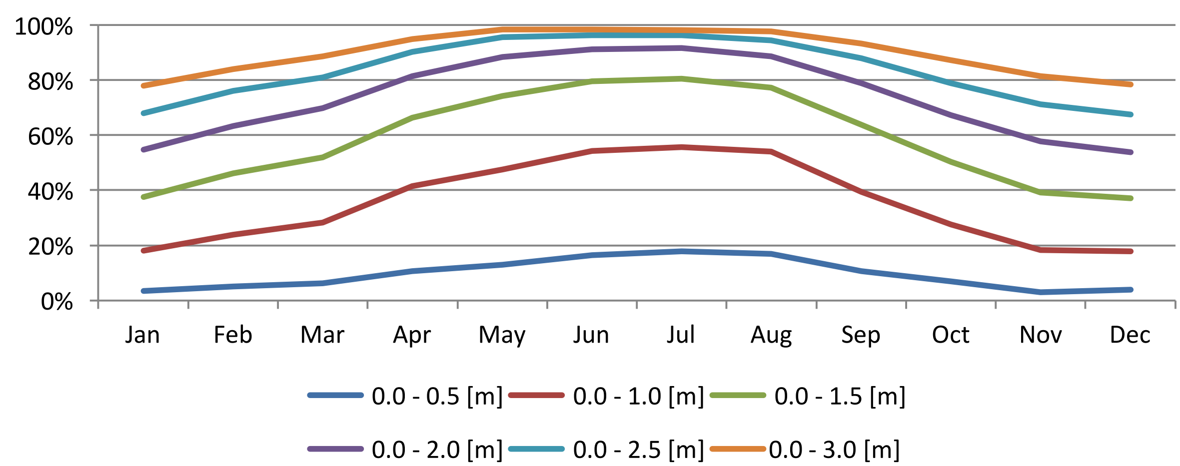


Figure 47. Monthly cumulative significant wave heights based on Actimar data.

The dissimilarity of the significant wave height between seasons is noticeable by the fluctuation of the line. The different lines represent intervals with a probability of occurrence.

Since the cost scenarios are evaluated per quarter the three-monthly averages are taken. Note to get a better approximation the monthly intervals can be evaluated separately. This simplification leads to the following:

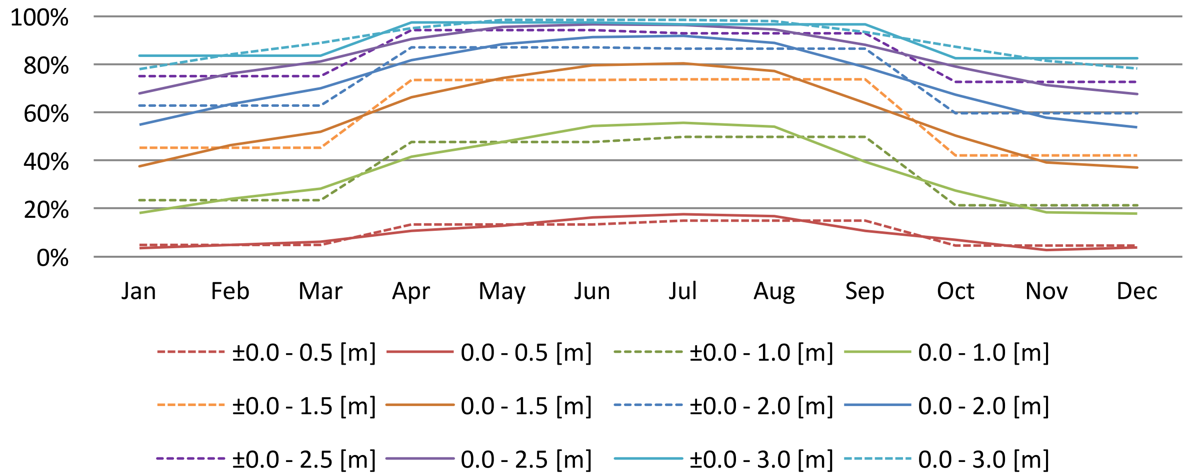


Figure 48. Significant wave height averaged over annual quarters

To illustrate the approximation of actual situation the figure shows the continuous lines for the actual level of accessibility and the dotted lines for the estimate based on three months' average.

H_s[m]	Q1	Q2	Q3	Q4
0.0 – 0.5	4.89%	13.25%	15.06%	4.50%
0.0 – 1.0	23.43%	47.77%	49.70%	21.20%
0.0 – 1.5	45.25%	73.36%	73.84%	42.16%
0.0 – 2.0	62.68%	87.08%	86.49%	59.64%
0.0 – 2.5	75.01%	94.13%	92.94%	72.62%

Table 17. Quarterly significant wave height interval probabilities

Infrastructure costs (D.6.1)

The infrastructure cost is fixed. When logistic means are used, additional costs arise to support these means: the infrastructure cost. The cost analysis of the different satellites indicates that the direct costs are insignificant compared to the indirect costs e.g. safety, hoisting is greatly contributing to the overall costs (Fig 1. D6). This will be more thoroughly explained in section 11.3 as the answer to the first sub question.

10.3 Dominant variables for cost model

The mathematical expressions from section 9.1.1 to 9.1.4 are modelled based on the key variables driving the costs of the logistic process. The influence of each factor and corresponding method is mentioned in the previous section.

10.3.1 Travel time

The travel time is especially important for the scenario involving a helicopter, since the cost of a helicopter are made up from actual flight hours. The vessel costs are expressed by a day rate so this are less impacted by the distance. The vessel however can increase cost efficiency by simultaneous servicing multiple location, this is restricted by the travel time in case of an emergency.

10.3.2 Workday

The duration of time on the platform is of the essence, because the duration needs to be multiplied by the number of team members. An additional hour, results in multiple hours since all team members must stay together. Since the rate of the vessel is expressed in days, the marginal costs only include the additional labor costs.

10.3.3 Personnel on Board (P.O.B)

Both the platform and the logistic means have a restriction based on capacity. All logistic means are expressed per defined time unit, the transportation cost of 1 person equals the cost of the full means. However, the number of people conducting work on a platform since the labor costs are relatively low in comparison to the logic costs maximizing personnel would decrease the total costs.

10.3.4 Wait on Weather (W.o.W)

The dominant environmental factor considered is the significant wave height. The cumulative probability of occurrence of a significant wave height per quarter is considered. This probability is resulting in a cost of not being able to make physical transfer or average downtime caused by weather.

10.3.5 Labor and logistic rates

The rates are purposely not considered fixed or variable since they are arbitrary depending on the view of the decision maker. The rates, or vessel prices, are dependent on the principle of supply and demand. The contract long term or short term and the season are all contributing to the costs. The logistic costs of a vessel and access system should be addressed both. The access system varies in day-rate and can include an operator or require a mob or de-mob fee. However, one of the main drivers is the installation of the access system on the vessel, if multiple days are lost the gain from a lower day rate may be lost.

The evaluation of the variables on which the mathematical expression from section 9.1 is based is explained. First the cost elements and objectives to be further explored are stated, after which the influence factors are determined by fixed of variable. By implementing different evaluation techniques, the dominant variables for modelling the total cost are obtained. The travel time is particularly important for a helicopter since cost function is a based-on flight time. The maintenance workday offshore is linked to the duration on the platform, on its term is dependent on the means used and the required work scope of the platform. The size of the maintenance team is both restricted by the platform constraints and capacity of the used transportation means. The impact of the weather specifically the wave conditions result in wait on weather time which is costly considering the rate of the required logistic means. Finally, the labor and logistic rate need are cost contributors to the operating costs. For the evaluation of the different parameters to optimize offshore operations, from a marine access perspective, a set of sub-results can be gained. These sub-results are expressed in combination with the overall results in the next chapter.

Module E: Research cost estimates & comparison

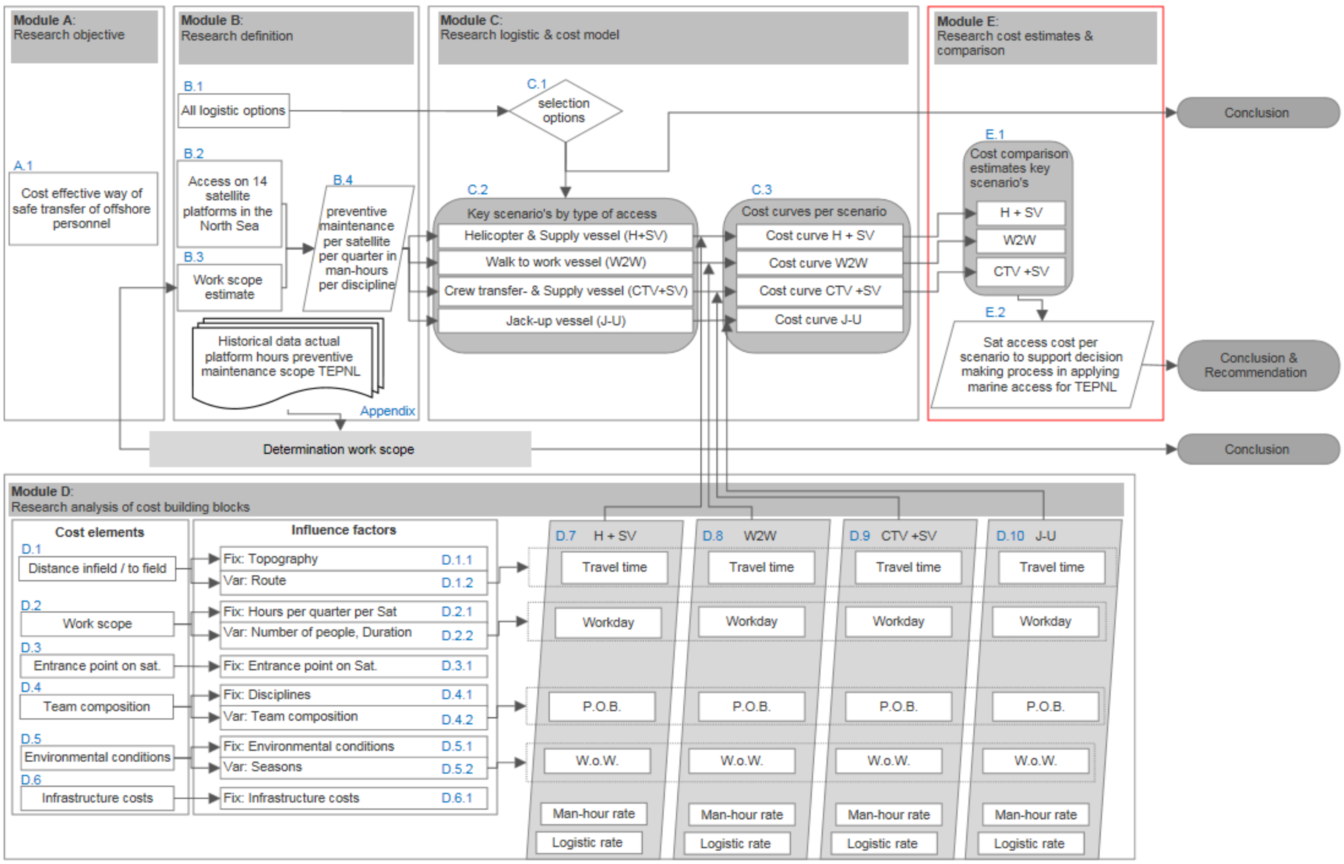


Figure 49. Process flow diagram marine access with the emphasis on research module E.

Chapter 11: Results scenario models

This chapter starts by stating the sub results obtained from the previous modules (module D). The evaluation methods applied in section 10.2 have led to some interesting results (11.1). Subsequently the main results from the cost comparison based on the key scenarios are given in section 11.2. Lastly the sub questions and main research question as defined in chapter 5 will be answered (11.3 & 11.4).

11.1 Sub-Result cost building blocks

The objectives with respect to the cost elements from table 13 in section 10.1 are evaluated using different methods, as explained in section 10.2. Some interesting results are obtained regarding operational optimization.

Sub- Result distance: shortest path

An optimization on the shortest route between the platforms is resulting in minor time saving. When this time saving is evaluated in the context of offshore operations it is not justifying a marine approach.

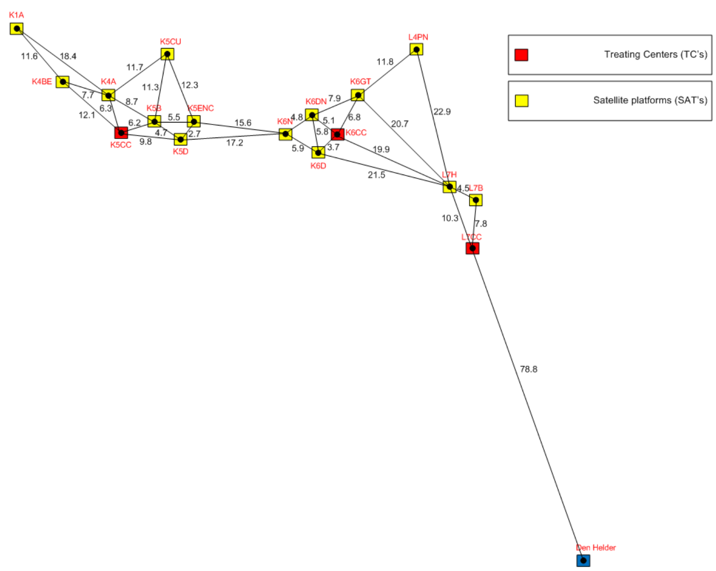


Figure 50. TEPNL field layout in network flow diagram

The considered network diagram in combination with the obtained distance matrix, and the average traveling speed results in time optimization that is insignificant with respect to offshore operations (Appendix: interfiled distance). A vessels cost is expressed in a day rate, so relevant time saving should result in a step change leading to the reduction of a day. To achieve a cost saving the scheduling should be set up in a way that non-of the platforms would require a boat visit as explained in the theory of constraints in section 8.1(bottleneck) (leanproduction , 2016).

Sub-Result distance: simultaneous servicing

The operational optimization comes from combining activities on surrounding platforms. The marginal cost of additional crew members is only the labor rate which is relatively low in comparison to the vessels rate. A vessel, in contrast to a jack up, can move between sites allowing to spread the personnel resources amongst multiple locations. The limitation in simultaneously servicing is the response time in case of emergency limits the service of distant platforms. The topography of TEPNLs assets allows this flexibility in servicing since many combinations of platforms are in the range of 11-13 km.

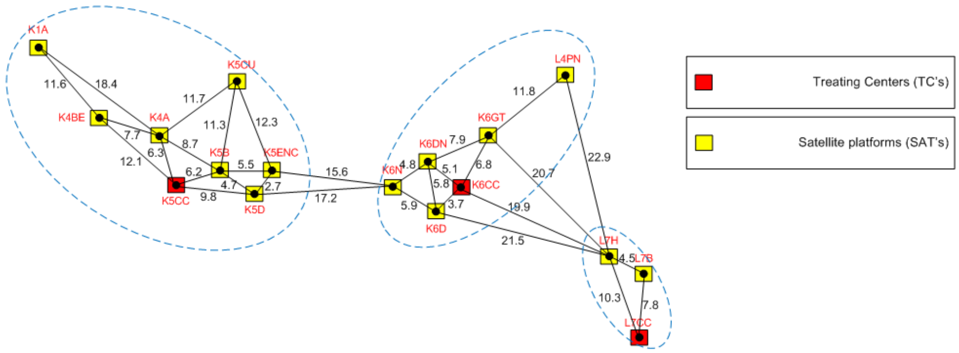


Figure 51. Network diagram subdivided for simultaneous servicing

Figure 48 illustrates the field divided in 3 area's depending on TEPNLs restrictions in the safety response time and the speed of the vessel when 2 platforms can be serviced. The recently conducted marine access risk assessment requires a response time of 20 min. (note often a large vessel is equipped with a fast rescue or daughter craft so no dangerous high speed offshore support maneuvers are necessary). Assume a vessel speed at 20 knots (1knots=1.85 km/h) results is a range of 12 km. Depending on the adopted regulation 12 km can be max distance between 2 locations or if midway is allowed 24 km is the max distance.

Sub-Result work scope: Obtaining the right hours and purpose

The investigation into hours offshore shows a lot of time is spent on what should be a unmanned installation. Besides the quantity of hours there is more information required like frequency, duration, required discipline or nature of the visit. The required work scope per satellite has been studied in many ways, the SAP analysis has been compared with a complexity index, maintenance manual inspection and minimum visitation study have led to an estimate of a 1000 hours pm at a location. A factor 10 lower than the complexity index, and a factor 100 lower than the first analysis done on available SAP data. The analysis of the work scope has resulted in; primarily, the acknowledgement that hours on the platforms are unknown and secondly the number of hours are much lower than initially assumed.

The investigation into the PM work scope has resulted in an estimate of 1000 hours per location annually. Since the work scope is currently uniformly distributed over the year, the quarterly pm work scope is 250 hours at a location *(Appendix: PM hours per location per discipline).*

Sub-Result work scope: Frequency and duration

The man-unmanned status is used to obtain insight in the durations of visits. The result from eventuating the signal is that the presence of offshore personnel and some activities can be observed. A planned activity, starting with a short visit for a container drop and ending with a short visit for a container pick up can be determined. The visits in-between these short visits are relatively long and show how maintenance visits are designed to be.

CONFIDENTIAL

Figure 52. PI manned/unmanned signal K4A Q1 2015

The figure 49 contains 3 signals, green is the binary manned on board (MOB) signal, blue is the mob-count keeping track of number of visits and yellow is the cumulative mob time. From this signal an approximation of the duration can be obtained. The evaluation of the signal per location is shows the also multiple visits after the planned Appendix manned/unmanned shows all signals of Q12015 to indicate the high visitation frequency in the current operating mode.

When the manned/unmanned data is evaluated for all 4 quarters and all 14 satellites a histogram of the frequency distribution can be obtained (table 17). An optimal distribution should show 2 peaks. The first for short visits, such as container handling or breakdown. The second for planned routine maintenance lasting a full workday. The distributions obtained from real-life date data are shown below.

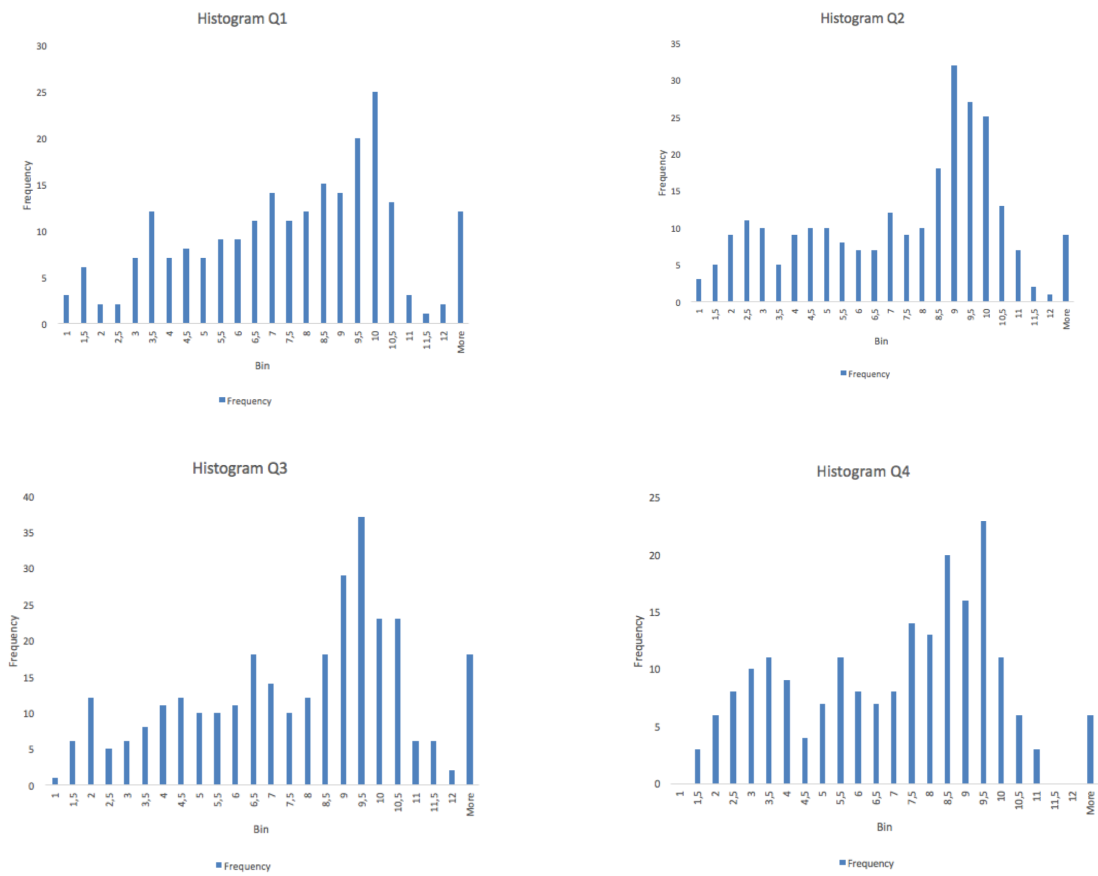


Table 18. Manned unmanned histogram of hourly distribution per quarter

The figure shows the 4 different quarters and their distribution of duration of platform visits. The frequency is expressed against the duration in hours. The ideal shape is most clearly visible Q4, 2 different peaks are noticeable. The data used are based on all platform visits, the activities include both pm, cm, boat visits, breakdown etc. All hours above 11 are either activities based on jack up access, or rotational shift which results in a constantly manned signal, and of less interest to this research. The short visits are more uniform distributed; the actual platform time of 5 hours could mean 4 hours HoTT.

The figure above illustrates the necessity to focus on the reduction of short visits. A less flexible alternative for accessing the structures requires a different ratio duration and number of visits.

CONFIDENTIAL

Figure 53. Annual satellite visits per quarter 2015

The different satellites and their corresponding number of visits per quarter are shown. To demonstrate the distribution of the visits per quarter the different colors indicate the number of visits.

Sub-Result team composition

As mentioned previously the implementation of marine access leads to a decrease in flexibility. A decrease in flexibility resulting in a limitation to moving people amongst different locations. Since all offshore personnel must be specialized and certified for their tasks, the maintenance team composition is important. This requires a detailed analysis for the preparation of work or versatile team.

Sub-Result team composition

When optimizing the maintenance team by defining the cost function, the impact of the logistic costs is shifting the optimization from selecting disciplines, to minimizing the number of days. The contribution of the vessel relative to the people is resulting in the desire to minimize the number of vessel days.

Sub-Result environment gain

The operational window increases when being able to transfer on higher wave heights. There is a rapid increase in accessible by being able to transfer in the lower wave height intervals. The gain from transfer in the highest wave height interval is much lower the when compared to the lower intervals (figure 47). The limitation of accessibility due to wave height is imposed by a company's restriction, not a technical restriction. This results in a consideration of an access system at the allowable operational boundary.

Sub-Result seasonal accessibility

The dominant condition affecting the access by vessel is the significant wave height (H_s). The (H_s) is strongly dependent on the considered month. This is directly linked to the required work.

Sub-Results infrastructure costs: market circumstance

The offshore service vessel market circumstances have led to a distorted picture *(Appendix: Vessel spot market)*. The price of a logistic means is the dominant factor in the consideration of the most cost effective solution. As expressed in section 10.3.5 the rates are sensitive to the developments in the oil and gas market. The difficult circumstances (Q3 2014 – Q4 2016) have stimulated many offshore contractors to look at other opportunities. The personnel transfer gained a lot of interest since the developments of the offshore windfarms.

11.2 Cost comparison estimates (E.1)

As discussed in chapter 8 the scenario selection has resulted in the evaluation of 4 different scenarios. The jack-up vessel is with this limited estimated work scope a means that is not justified by only preventive maintenance. The crew transfer vessel & supply vessel is very sensitive to the environment and requires a permanent access to the spider deck. Chosen is to illustrate the most suitable and likely means from this part of the report. To show how cost competitive the access means are a table with input value and results are given below.

CONFIDENTIAL

Table 19. Cost comparison Helicopter & supply vessel versus walk to work vessel

The accessibility can be varied per quarter based on the results from section 10.2. Both hourly labor rates are the same independent of the way of transportation. The logistic rates vary strongly, making a scenario analysis the ideal method to evaluate the transfer process. The number of passengers, duration and transit are dependent on the chosen logistic access means. The supply vessel is visiting all platforms once a month resulting in a boat frequency.

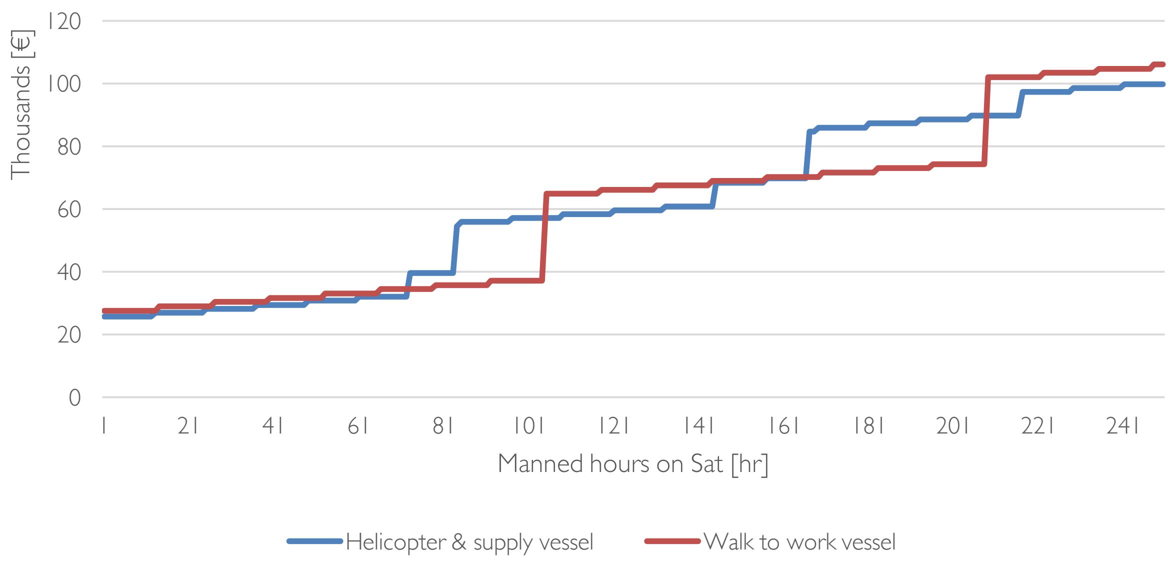


Figure 54. Cost comparison H & SV against W2W vessel based on input from table 18.

The comparison based on the cost curves of helicopter & supply vessel versus a walk to work solution on the preventive work scope for a quarter on a satellite shows no significant cost savings by interchanging one logistic means for another.

The result of the cost comparison illustrates that with the used input variables no significant cost saving is obtained. A vessel with access system under "average" market conditions in the current operating mode will be cost competitive, but not result in the desired cost saving.

To illustrate the impact of the seasons the following graph will show the seasonal cost difference due to wait on weather time. By using the following input based on the operational environmental data the distinction will be indicated.

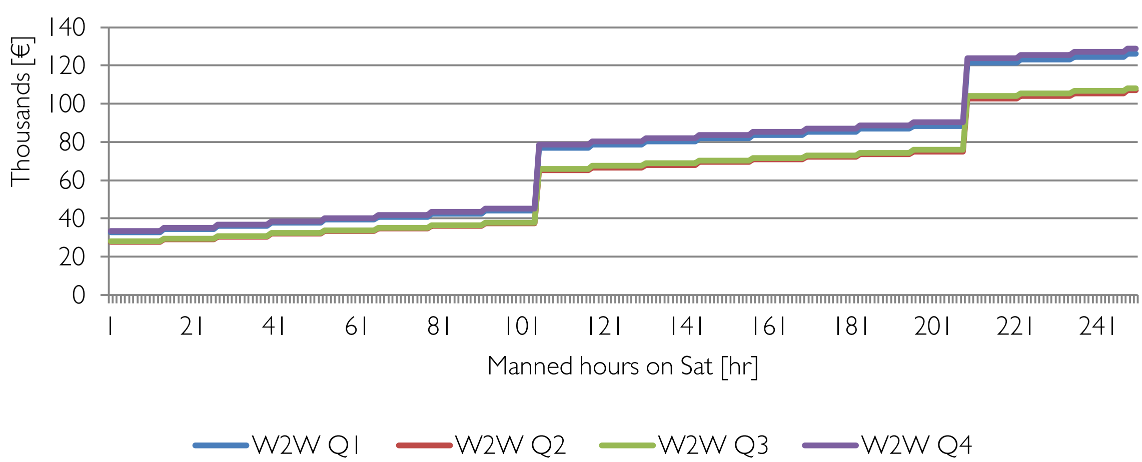


Figure 55. Seasonal impact on cost due to accessibility on one satellite per quarter

The graph indicates that for a w2w vessel the same pm work scope on an individual satellite is almost 20% more costly to be done in unfavorable season (Q1,Q4) then in a favorable season (Q2,Q3).

To indicate the relevance of looking at an optimization based on the logistic costs, the distribution related to PM activities is given below.

11.3 Answer sub question

By using the analysis path of the process flow diagram the sub questions will be answered. To indicate the relevance of the focus area the cost distribution is examined.

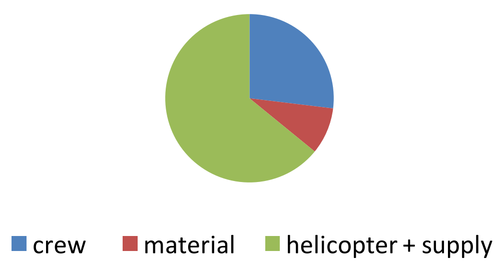


Figure 56. General distribution of costs related to preventive maintenance activities

The significance of focusing on the logistic costs with respect to preventive maintenance becomes clear. Presently the costs allocated to pm can be split into the 3-cost element as indicated in chapter 9. The crew represents the labor costs $\mathrm{c_{mh}}$, the material costs $\mathrm{c_m}$ and the helicopter & supply vessel the logistic costs $\mathrm{c_l}$.

By subsequently answering the sub questions the research question is answered.

1. Which serviceable components of existing satellite platforms are critical for the accessibility by air or by sea?

To determine the impact of the serviceable components on the entire preventive maintenance scope, the ratio access components over all components are calculated. Since the data is operational, it is chosen to take a larger time span to average out uncertainties and obtain an approximation. PM is a routine operation and should not differ much over the years. The total preventive maintenance cost for the 14 considered satellite platforms is calculated by summing the cost components over 6 years. The chosen time frame for this cost evaluation is 2010 till 2015, because the data set contains the most recent data. To ensure the repeatability of this evaluation TEPNL's maintenance and inspection manual is used as a guideline. Breaking down the total PM cost into a site-specific cost analysis the following cost allocation structure is used, $\mathbf{site\ /\ platform\ /\ system\ /\ unit\ /\ function\ id, unit\ id, equipment\ id/tag}$.

The costs are estimated by the following equation;

$$\sum_{y=0}^{y=5} \sum_{i=1}^{i=14} WPM\ cost \qquad \textit{Eq 27}$$

Where y is the year and i is the number of platforms. The following figure gives a schematic representation of the cost allocation structure.

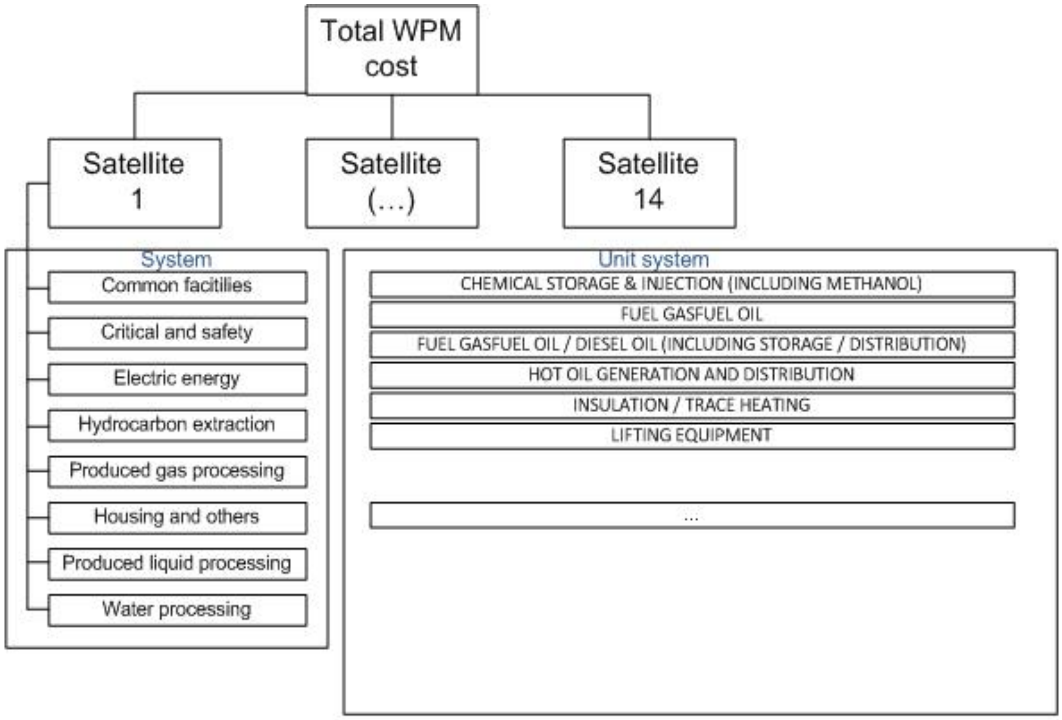


Figure 57. Cost allocation breakdown structure TEPNL

The total PM cost per site can be divided in seven system groups. These groups are sub-divided into 36 unit names, these unit names are used to gain insight in the PM cost distribution (appendix: cost breakdown confidential). The first sub question required the calculation of the pm components that are critical for access by a specific logistic means. Note no detailed analysis is done on the processing equipment.

From the investigation into the cost components the following average distribution can be obtained.

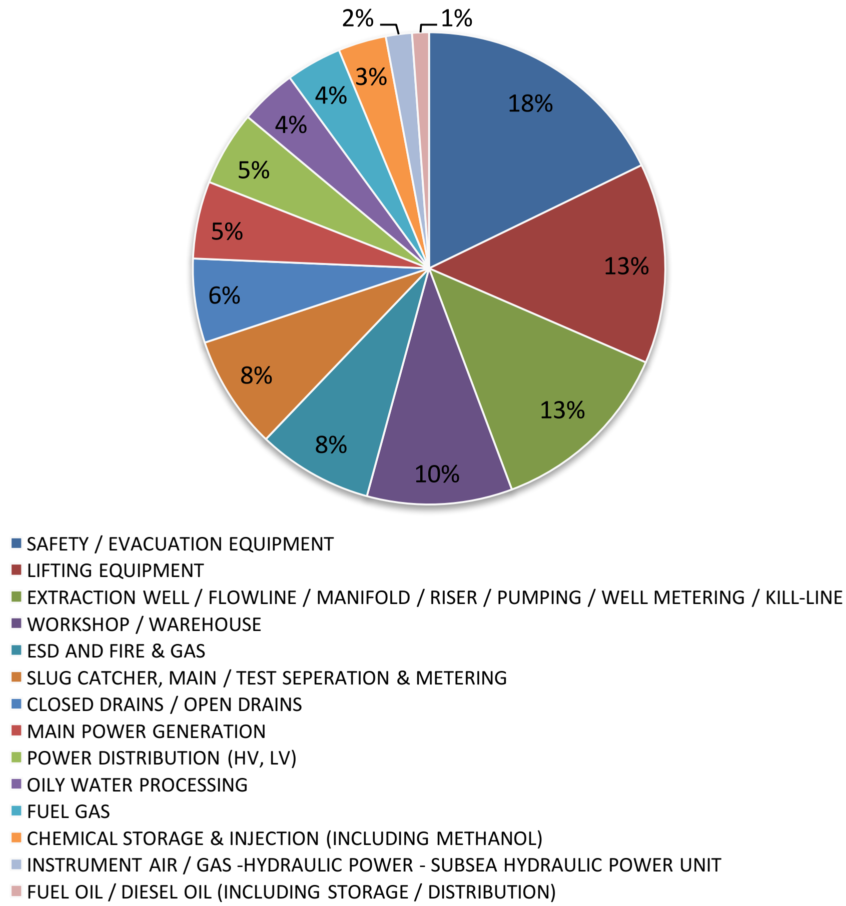


Figure 58. Cost distribution of satellite components

Figure 58 shows the top 14 of the 36 cost components accounting for 95% of the total PM costs. In addressing the costs related to the access components a distinction is made between direct and indirect access costs. The direct access component costs are the helicopter deck and lower deck costs; the indirect costs are resulting from the use of a specific way of using a logistic scenario. The PM costs directly related to the current way of access by helicopter deck are very minor, (0,7 % of total annual satellite cost). Note that the lower decks are currently only maintained for evacuation requirements resulting inadequate data.

Resulting from this analysis indicated costs related to the PM activity of satellite components are not considered dominant in the decision-making process. The 2 highest cost components, safety/evacuation and lifting equipment, represent almost 1/3 of the total PM satellite costs.

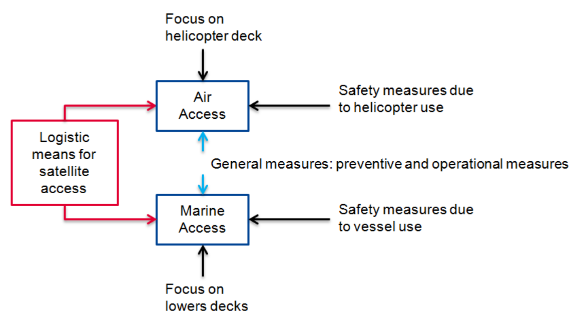


Figure 59. Air access versus marine access

The critical components for the access by helicopter besides the helicopter deck are:

- *Documentation: technical drawings, deck certification, friction certificates, instrument calibration certificates, firefighting certificates, training certification and procedure manuals*
- *Instrumentation: lighting, safety net, winds sock, firefighting, rescue equipment. (appendix: helicopter operations)*

The actual cost drivers are indirect requirements for the accessibility of the platform and give the largest gain when optimizing operations.

2. Can a generalized marine access approach be developed without large modifications to the existing satellite jacket structure?

A generalized marine access approach is considered since the logistic means should be able to enter all structures within the research scope. As illustrated by the cost curves in chapter 9, the day rates of the vessel impact the operational cost that the requirement of different vessels would involve.

A generalized marine access approach without large modifications to the structure is possible, because all satellites are equipped with multiple entrance points for vessels.

However, most optimized alternative would be to visit all satellites with the same vessel, but problematic is that all satellites' entrance points have different heights. The highest decks of any satellite platform are reachable by every large vessel. The large vessels are the most expensive ones. Therefore, Total would like to use the smaller vessels, since they are more cost competitive.

3. How can the effective working time at a satellite platform be increased, regarding optimized logistic processes?

By using the cost comparison model, the variables with respect to working time can be determined. The time on a platform is dependent on its logistic means.

Air access is quickest means, but a lot of time gets lost in the process of picking up and dropping off people. Besides the transport itself, the high safety measures lead to loss of hands-on tool time. A vessel is considered to be at the location, since the transit to the field is not done daily, the duration of time on a platform should be longer.

$$Duration_{\,air\ access} \leq Duration_{marine\ access}$$

$$T_{HoT\ air\ access} \ll T_{HoT\ marine\ access}$$

11.4 Answer main research question

The accurate information required to develop the process flow diagram (page 2), which supports the operational decision in a more cost effective servicing of the existing satellites, is the first point that needs to be addressed. The cost comparison is based on the estimated preventive maintenance work scope, since the hours at a location are uncertain. Before searching for cost saving opportunities in operations the scope needs to be accurate.

Based on the information obtained the satellite visitation frequency needs to be reduced will any form of marine access be applicable. The high costs due to the day rate of a vessel, even under these market conditions, require effective use of this logistic means.

The assumed savings that accompany a logistic infrastructure directly are relatively low. Most costs directly allocated to the use of a logistic means are sunk costs. More significant cost contributors of a satellite platform are indirectly related to the access. The safety & evacuation and lifting equipment are the real cost drivers.

"Which means of marine access can create new opportunities to be able to service the existing satellite platforms more cost effectively?"

As illustrates in the cost comparison of section 11.2 the under the same operating conditions marine access is not directly resulting in the desired cost saving. In a different operating mode, the advantages of a marine access solution can be beneficial. All different marine access means can be reduced to 4 scenarios based on costs. Based on the accessibility and the required work scope a solution of an offshore support vessel with a motion compensated access system would be the most cost effective means. The way in which the vessel is key to cost savings. The gain from marine access is implementing an operating mode that is tailored to the required workload.

The sub-results obtained from the investigation into the variables required to model a marine access approach indicate only a step change leads to a significant saving. Some of the pre-assumed cost drivers are determined less significant when making the cost comparison. The desired cost saving from operational optimization are realized by the reduction in transportation means and do not result from change in labor. The effects of the variables to the total cost curves will be expressed in the next chapter.

Chapter 12: Sensitivity cost comparison

The purpose of this chapter is to show the impact of change of the variables total cost curves. The different scenarios with corresponding parameters, are varied to check the response. Starting with an explanation shape change of step function in the general cost curve (12.1). The behavior of the scenario based on a helicopter and supply vessel will be evaluated in more detail since this represents the current state (12.2). Secondly the scenario of the walk to work solution is explored in more detail (12.3).

"A sensitivity analysis is an exploration of results from mathematical models to evaluate how depend on the values chosen for parameters" (Rardin, 2014). By investigating the logistic means by their cost characteristics, the contribution of each variable can be checked. The same analysis will be done for both scenarios; Helicopter & Supply Vessel and Walk to work vessel scenario.

12.1 General assessment of variables

The total cost functions are expressed as discrete step functions. By changing the variables, the behavior of the curves can be evaluated. The curves are evaluated by shift and shape changes.

Variable - Translating curve	Variable - Changing curve
Rate logistic means	Number of people
Rate of technicians	Duration
Required work scope	

Table 20.Cost curve translating and shaping parameter

Translating the curve represents a horizontal or vertical shift over the axes. With a shape change the width or height can be adjusted. By combining both translation and shape change the scenarios will be assessed.

The general cost step function shown in the figure below is based on a specific rate per time unit. This represents for example a satellite team or rate of a vessel. The marginal cost is the change in total cost that comes from making one additional item (Investopidia , 2016). This definition is applied in an operation and logistic context to illustrate the additional cost of a flight time, boat days or labor hour of the satellite crew.

An increase in rate per time unit shift the total cost curve upwards without modifying its shape.

Figure 60. General step function translated

The vertical shift represents a price increase or decrease while the hours are constant, this behavior is influenced by the supply and demand in the market.

The shape change, the height and width of a step, and also the number of steps can be considered.

Figure 61. General step function shape change

The width of a step is dependent on the time unit related to a rate. For example, the width of the step can is increased by duration of the work day. The costs of the vessel remain the same, while there are more workable hours on the platform. The combined behavior of the translation and shape change are a tool to evaluate the different scenarios. The total cost functions in section 9.1 indicated the mathematical expressions of the graphs in this chapter.

The variables considered for both scenarios are: number of people and duration on the platform, as explained in section 9.1 the number of people on a satellite remains the same for a visit, since no in between pick-ups are considered.

12.3 Sensitivity helicopter & supply vessel

The effect of the number of passenger on a visit and the marginal cost involved are illustrated below.

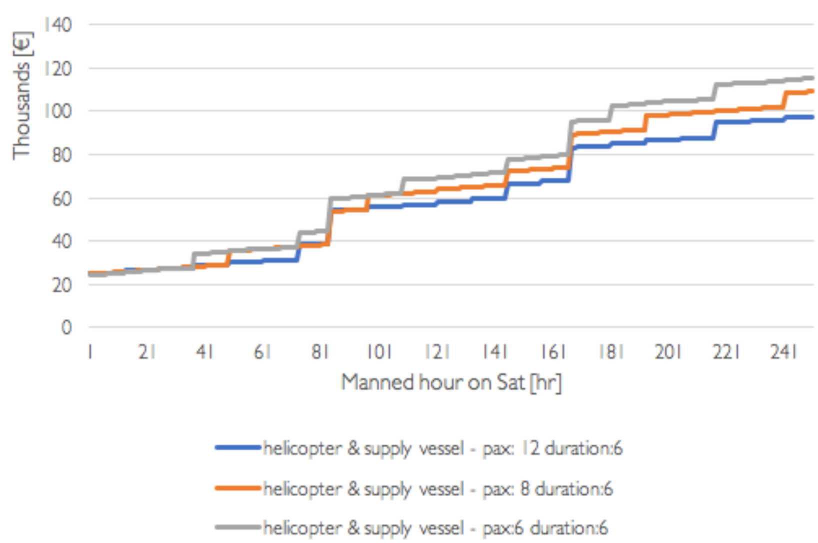


Figure 62. Helicopter & supply vessel impact of number of passengers (PAX)

By increasing the number of helicopter passengers on a visit the width of the step increases. More crew on the satellite, results in more hand on tool time, which leads to a lower visitation rate.

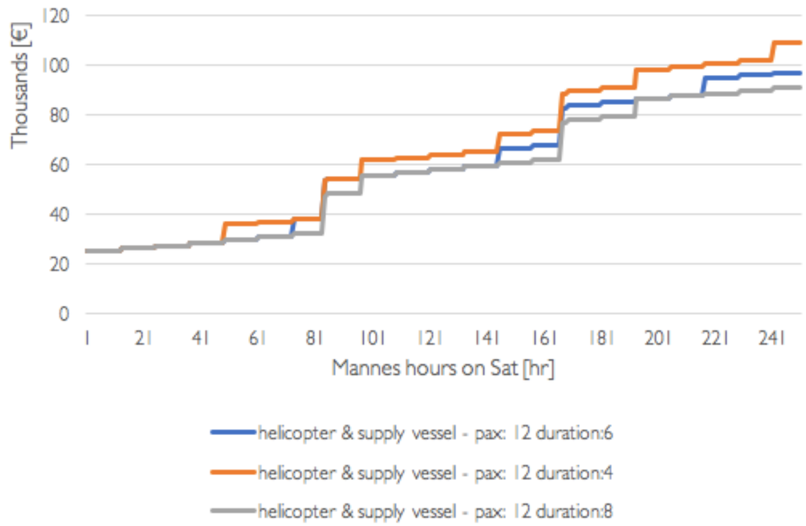


Figure 63. Helicopter & supply vessel impact of duration on platform

The increase in duration results in less visits, but the cost of flight time has a smaller impact then the costs resulting from a boat day (sensitivity of vessel duration). The hours are considered as integer values which results in a smaller step within the larger step, representing the situation described in 9.1.1. The smaller step is caused by the number of people (width of step) and the hourly rate (height of step). As expected the logistic costs, (larger step, additional shuttle) contribute significantly more to the overall cost.

12.2 Sensitivity walk to work solution

Due to the high day rate of the vessel the impact the impact of the crew size is extremely important.

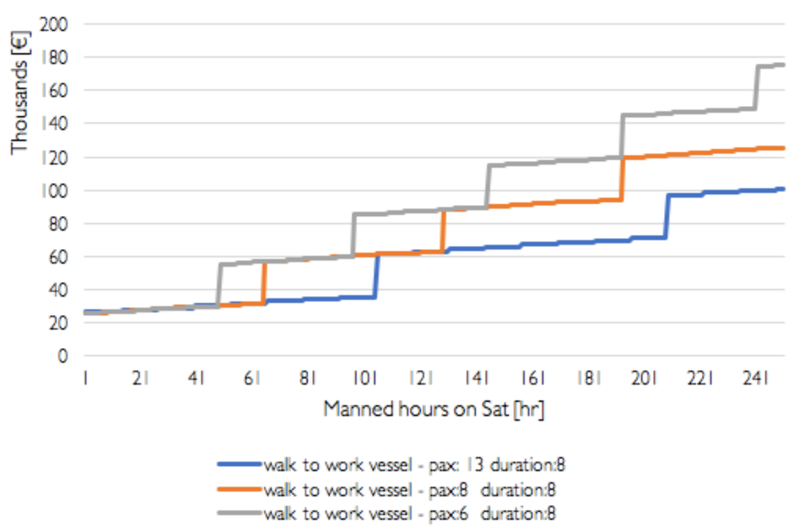


Figure 64. W2W vessel impact of number of passengers (PAX)

The smaller step within the larger step function as explained in chapter 9.1 is hardly noticeable since the cost of a small labor crew is insignificant in comparison to the vessel price. The capacity of a vessel allows a large crew. To operate as cost efficient as possible and illustrated in the previous chapter the simultaneous servicing of 2 platforms is more effective.

Besides the impact of crew size the hands-on tool time on the platform is an important factor as well. Since the vessel remains in the platform area the effective hands on tool is much higher due to the short transportation time.

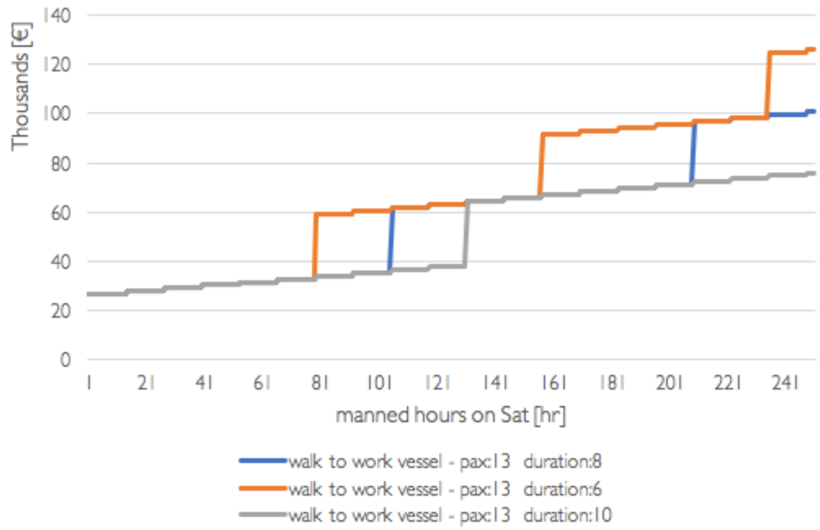


Figure 65. W2W vessel impact of duration on platform

The impact of the duration on the platform is illustrated in the figure above, the increase in hours at approximately the same cost results in a more efficient use of means. It clearly indicates that the difference in duration can result in major cost savings if a boat day can be eliminated.

Finally, to show the impact of both scenarios in one graph, the relative impact of the variables is illustrated.

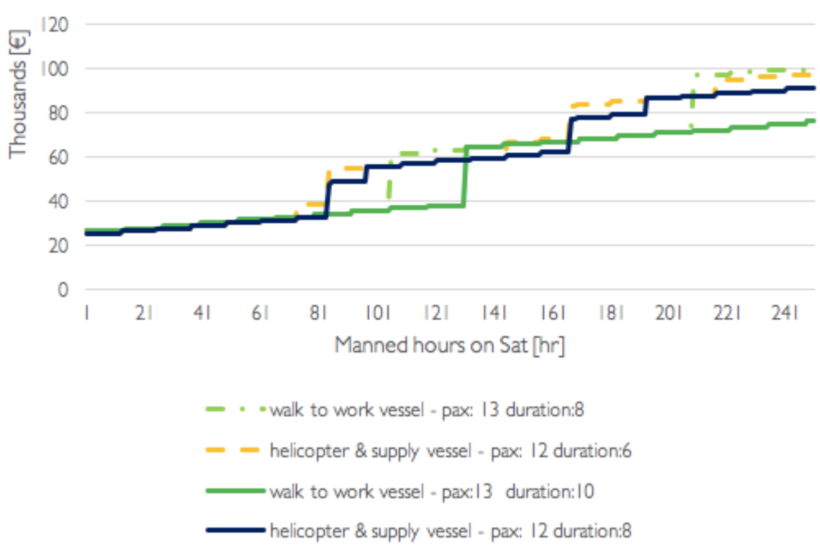


Figure 66. Difference in impact on platform duration Heli & supply vessel and W2W vessel.

This figure illustrates that increasing the duration of manned hours on the platform results in a cost saving, but the impact of the saving is much larger by reducing the vessel use then the use of a helicopter.

The previously shown discrete step function shows that by change the variables the total cost curve can be graphically evaluated. The distinction between a shift or shape change of the cost characteristics are determined. The horizontal axes show the required hours preventive maintenance on a platform and the vertical axes shows the costs. Each total cost function constrains a step function within the step function. The visitation by a team results in small steps in cost curve, till the workday requires an additional boat day, the larger cost steps.

Chapter 13: Conclusion

The key conclusions drawn from the research are elaborated upon in this chapter (process flow diagram). Firstly, the conclusions based on the logistic means will be given (13.1). Subsequently the conclusions from the exploration of the variables for the cost model will be shown (13.2 till 13.4). Parallel to the different modules, the investigation into the satellite work scope has resulted into different conclusions. Finally, a general conclusion for the TEPNL will be given based on the research questions & sub questions (13.5), which will be supported by the recommendation in the next chapter.

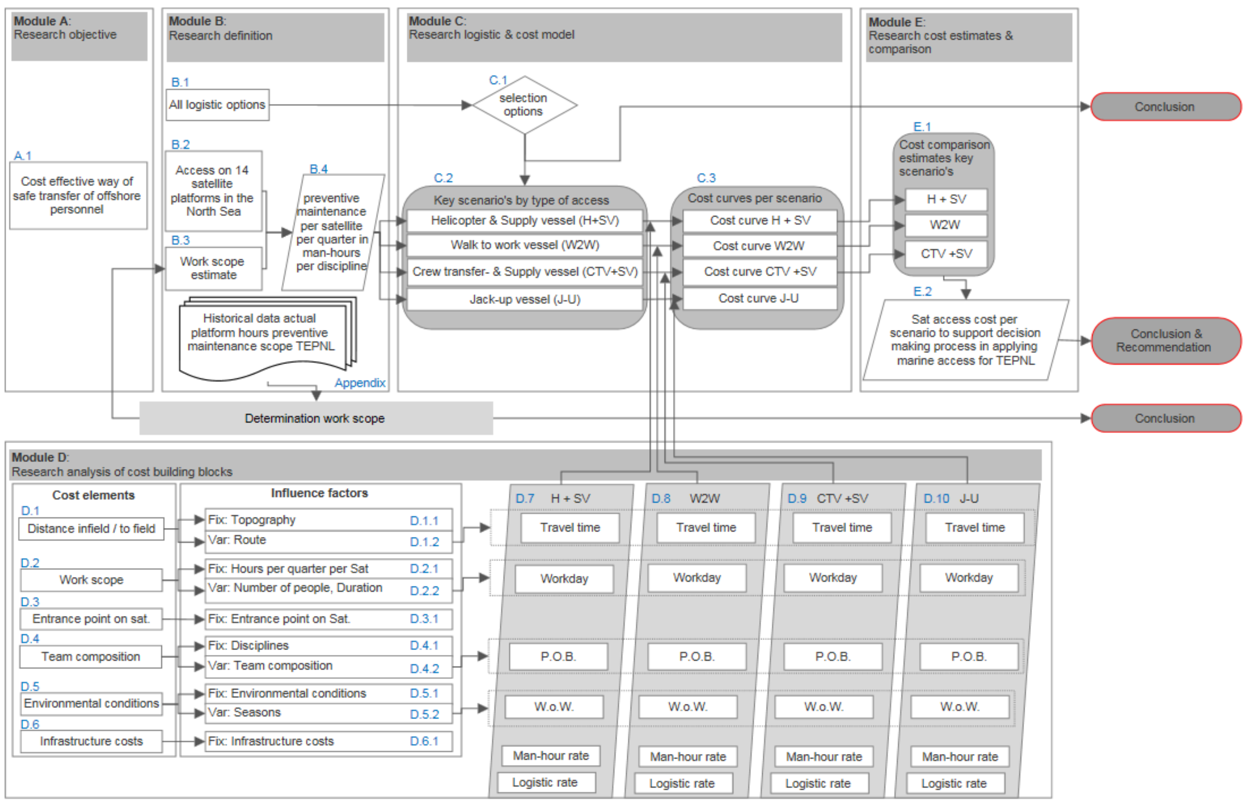


Figure 67. Process flow diagram marine access with the emphasis on research conclusions

The process of obtaining the key scenarios and influence factors, constructing the cost comparison model and creating output is finalized by interpreting the outcomes with respect to the research questions. This figure illustrates the conclusions based on the logistic options, the different scenario's and the relevance of the work scope.

The investigation into the application of marine access has originated from the interest to reduce costs. The focus on cost diminishing measures has led to the most difficult, but also rewarding and sustainable measure: activity optimization. The executing maintenance, is required to keep TEPNL's core business, the production of natural gas, ongoing. The high operational costs that come along with these visits are driven by the required logistical means to reach the remote locations under harsh North Sea conditions.

The operational costs of preventive maintenance (PM) are dominated by the cost of the logistic means.

The contribution of the logistic costs to the total costs is significant, hence the focus area is where the cost optimization has the biggest impact.

A full description of the context is required to conclude the most cost effective logistic means to service the field. The context with respect to satellite accessibility is not only based on external conditions but also internal conditions. The distance offshore, the proximity of the platforms, the yearly season, but also operational restrictions and how the selected means are used are important to operate as cost effective as possible. Since the field is in the decline phase and has a limited life time, large CAPEX prohibits structural modifications and eliminates access possibilities solutions.

The components on the satellite structure related to the way of access, and the maintenance time spent on a satellite, need to be included in the context of the visitation requirements. The satellite components related to the access means, a uniform access approach and the focus on time of a platform give the background that need to be addressed to come to an operational decision.

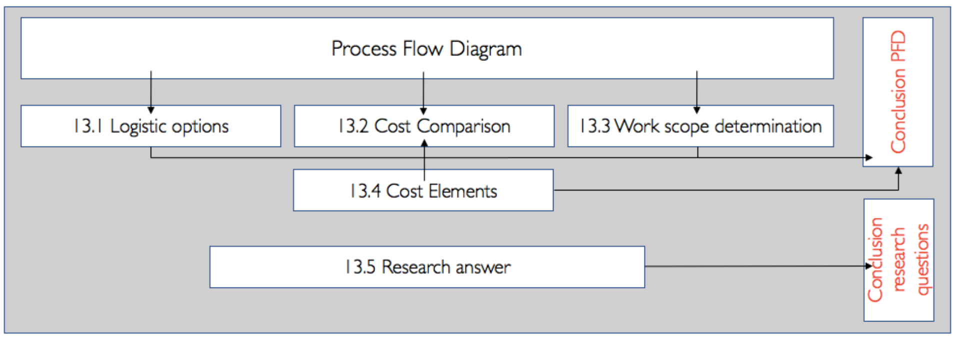


Figure 68. Conclusion structure report

From the structuring of the process flow diagram (PDF) a set of conclusions is obtained. 4 paragraphs are dedicated to each conclusion. Finally, the conclusions related to the research questions will be given.

13.1 Logistic options

For a combined transfer of personnel and equipment the number of logistic scenarios are limited due to both internal and external constraints. The internal constraints are imposed by company's restrictions and are often underlied by safety measures. The internal constraints cause limitations to the platform, transportation means and operational mode. The number of people and duration of their visit are key in selecting an access means. External constraints are factors out of control of the company, which influence the selection process as well. The dominant factors are the rate of the logistic means and the effects of the environmental circumstances.

All marine access solutions consist of 3 components: vessel, mooring method and transfer mechanism. The transfer mechanisms applicable in the North Sea and the equipment present on the platforms allow access by: the helicopter deck, a surfer-landing via spider deck or a gangway solution on to a higher deck.

The vessels are considered by type, crew transfer vessel, offshore support vessel and jack up vessel. Since the objective is to make a comparison based on costs, 4 relevant scenarios remain: helicopter & supply vessel, walk to work vessel, crew transfer vessel & supply vessel and a jack up vessel.

Any marine access solution requires a combination of vessel, mooring system and transfer mechanism which are interdependent.

The operational constraints allow transfer up to a sea state 4 which corresponds to a 2,5 m significant wave height. Generally, a larger the vessel is more expensive, but has a wider operating window.

All logistic means come at a cost, depending on the accessibility desired. The objective in cost reduction is shifting from desired to a required level of accessibility.

The accessibility must be determined by the work scope. When evaluating the different access-methods based on costs the required maintenance hours are decisive, considering the safety standards.

The logistic means used for platform visits result from a required work scope. This research uses hours on a platform as a variable. The combination of the duration of activities and number of people participating in the activity are used to determine the number of visits.

All logistic means have a level of flexibility that needs to be considered. Flexibility is defined in this report as: the ability of a system to change or react with little penalty in time, effort, cost or performance (Grigore, 2007). The flexibility required is of great importance especially for a mean producing platform. When considering the high visitation frequency of 2015 this way of operating would not be possible with any kind of marine access solution.

The use of a vessel results in a lower flexibility in platform visitation compared to the logistic deployment of a helicopter.

The lower visitation flexibility results from the relative long transit times of a vessel compared to a helicopter. To indicate the importance of the flexibility the day-rate should be compared with the loss of production.

An advantage of an offshore support vessel (walk to work vessel) is eliminating the use of a supply vessel.. The combined crew and equipment transport results in a reduction in required mobility. The downside however to multi-purpose means is always that, it also leads to inefficiency since only one is used at a time.

A trade of between multi- or fit for purpose means is dependent on the work scope on the platforms.

13.2 Cost comparison

The conclusion based on the cost comparison of the scenarios analysis generates insights in the current logistic mix. The cost comparison illustrates that TEPNL's is currently using the most costs effective means to service their assets.

Due to the high visitation frequency, the current means of operating is explained.

The self-fulfilling prophecy of the design of this operational strategy with a specific means results in the use this means. To conclude, marine access is not the solution to reduce cost. To benefit from a different access method the entire operational process needs to be evaluated.

Interchanging the current access means by a sole marine access solution, under the same operational strategy, would not lead to the desired cost savings.

An important conclusion on operational cost savings is to determine the significance with respect to the total operational cost. The operational costs are based on a combination of labor costs, logistic costs and material costs. The material costs allocated to each platform are considered independent and are not modelled in the 4 scenarios. The labor and logistic costs are dependent. In this research, all labor and logistic costs are based on a unit rate per time unit. Since the rates of the transportation means are unequal, in height and time unit, the marginal costs of an additional hour or day need to be addressed.

As expressed above the costs are modelled per time unit. The time unit for a helicopter is based on flight hours while a vessels costs are expressed in a day rate. This distinction based on unit rates is overcome by modelling the cost based on the time on a platform. The characteristic of the discrete step function representing the total costs gives insight in how the operational cost are varied.

The operational costs are described by step functions which need to be carefully evaluated to benefit a means.

The sensitivity analysis demonstrates the behavior of the total cost curve; a combination of a shift and/or shape change are graphically illustrated. Each function constrains a step function within the step function. The visitation by a team results in small steps in cost curve, till the workday requires an additional boat day. The vessel market circumstances are responsible for the height of the graph, while the operational decisions influence the shape.

The combination of translating and shifting curves show the impact of the variables; travel time, workday, personnel on board, wait on weather time and both rates of labor and logistics.

The available logistic means explain the use of the means; sunk expenditure are often used to justify its use. However, in economic decision making, these sunk costs should not be used. The argument of; "if we have it we better use is", results in higher costs. The marginal cost of labor, an additional person, with respect to the marginal cost of a logistic means are resulting in contradictory intuitive decisions. The significance of an operational saving however is obtained from reduction in the dominant cost driving means.

Sunk cost does not justify the use of logistic means.

13.3 Work scope determination

Determining the exact work scope, is of the highest priority. These are the decisive criteria in the selection of a logistic means. The PM hours on a platform must be calculated by the work scope. The hours work on a platform; the frequency and duration are of utmost importance.

To choose the most suitable logistic means the precise work scope needs to be determined.

A visitation requirement of a weekly visit or once a year allows for very different solutions. Currently there is no distinction made on activities per season. When scheduling the workload by shifting activities to favorable season for a vessel, the work scope is driving the means. The PM requirements are based on the minimum visitation necessity. A vessel is less flexible and requires an increase in effective work time to be cost competitive.

The scheduling and work preparations need to be used to increase the effectiveness to the use of a vessel.

The analysis of the work scope has resulted in the acknowledgement that hours on the platforms are not precise. The number of hours PM are much lower than initially assumed.

The conflicting data resulted in an uncertainty in PM Hours. Annual estimate of a 1000 hours is a good approximation.

The uncertainty in PM hours due to conflicting data sources have resulted in an estimate of 1000 hours annually at each satellite, this results in 250 hours per quarter.

13.4 Cost Elements

The conclusion drawn based in the evaluation of the cost building blocks show that all cost elements are considered fixed or variable. The variable elements can influence the operational process and can contribute to the overall costs of a logistic scenario. The variables used in the cost comparison are:

- Travel time
- Workday
- Personnel on board
- Wait on weather time
- Rates of labor and logistics

The shortest route calculation is done to obtain insight in the impact of the distance. Since the distance to the field is approximately the same as the longest distance infield, the impact of the route is not considered significant. A time saving should result in a step change eliminating an entire boat day since the vessel price in expressed by a day rate. The topography of the field allows for a flexibility to service 2 locations and still meet the operational safety requirements.

A significant cost reduction is achieved by simultaneous servicing of platforms.

From historical data and manned/unmanned platform status (TEPNL 2015) can be concluded that the satellites are visited too frequently, without discussing the nature of the visits. The visitation frequency and the visit duration give insight in the operating mode.

The current high visitation frequency results in a need for a flexible means of access.

Primarily, accessibility studies are focused on achieving the highest level of access. From a cost perspective, the decision based on required or desired, leads to cost efficient operations.

> *The operational limitations are the boundary of the required accessibility.*

The boundaries caused by operational restrictions are designed for a specific operating mode. The assumption is that selecting the right team in an operating mode results in a more cost effective operating mode. However:

> *The gain of optimization of the maintenance team is small compared to the gain of reducing the vessel days. A multi-skilled PM team must reduce the requirement of specialists.*

Applying any form of marine access requires a thorough understanding of the metocean conditions. The wave and wind conditions are critical in the decision process of transferring to a structure. The operational window needs to be widened to increase accessibility levels. By using motion compensated equipment an increase can be obtained.

> *The transfer by higher acceptable sea states, due to motion compensated technology leads to an increase in accessibility. The accessibility is strongly dependent on the season, lower wait-on-weather time translates directly in a more cost efficient means.*

The conclusion obtained from the evaluation of the different rates is that since the PM scope is small the effect of the labor cost in comparison to logistic cost is small. The labor cost is in each logistic scenario and are insignificant compared to the costs of the logistic means.

> *The focus must be on reducing the logistic costs since labor costs are fixed in any chosen operating mode.*

13.5 Conclusions drawn from research questions

The initial assumption that the satellite components directly related to the access are significantly contributing to the service costs of a satellite is proven to be false. From the evaluation of the PM work orders it can be concluded that the cost saving opportunities lies with the components indirectly related to the access. The two main costs components, hoisting & lifting equipment and safety & evacuation, are responsible for almost 1/3 of the annual PM costs.

> *The satellite components directly related to the way of access are of low cost, however the components indirectly related to the way of access are high cost components.*

Since the components responsible for the majority of the costs are not directly allocated to the way of access and will remain the same when implementing a different access means, this is not considered a cost saving. The assumption behind the high costs of components related to access are based on sunk costs rather than service costs. The obligations that result from a visit in the first place can be looked at from the "the chicken or the egg causality dilemma". Since an installation is visited, safety regulations and procedures are created. But on its turn the installed safety equipment requires maintenance visits etc.

The investigation into the different kinds of logistic transportation means combined with an adequate transfer mechanism with respect a to specific set of satellite platforms shows some single feasible options to service them with one mean. A preference of a generalized approach without structural modifications is given to make transfers to the platforms as easy as possible. The structural drawings combined with photos of all 14 satellites show 2 height intervals on which transfer can take place.

One possible access method by vessel would be applicable to enter all satellites.

The spider deck located in the surf zone has a lot to endure especially in the winter. This tertiary escape route must be in good condition but the condition of the grating could be uncertain. Hence an entering via the cellar deck of maintenance deck has the preference.

The time on a platform is dependent on the logistic means used. The traveling speed is not the only factor that needs to be considered, part of the non-productive time is also linked on procedures required by the use a means. The effective use of a vessel, which is a less mobile means, can result in longer duration on the platform since it can be at location by first daylight.

A vessel brings an increase of effective working time since it remains on location.

Part of the non-productive activities and preparation can already be done on the vessel resulting in a higher hands-on-tool time. Eliminating flight movements by having cargo and crane driver together can result in longer platform times for other teams since they are sharing a helicopter.

The conclusions obtained from this research result in the confirmation that TEPNL is currently using the right logistic means. The applicability of a marine access solution would benefit Total if they change their operation mode to take advantage. The marine access means best suitable for operating TEPNL's assets in the North Sea would be an offshore service vessel with a motion compensated gangway solution. The motion compensated technology increased the accessibility and therefore reduces the wait on weather time. To fully utilize the capacity of a walk to work vessel, 2 platforms need to be serviced simultaneously.

As proven in this research marine access cannot simply be considered a more cost effective solution for operations than helicopter access. Obtaining the highest level of accessibility should not be the objective of the selection of an access method. As thoroughly discussed in the previous chapters a work scope should drive the way of access. Before being able to select the most suitable solution the frequency of visits in combination with the durations is of key interest.

Chapter 14: Recommendations

As concluded in the previous chapter a marine access approach must be considered only in combination with a fundamental change in operating mode. This change in operational strategy will first be addressed to show what is required to benefit from a marine access solution. (14.1). A combination of logistical means and a tailored work load can take advantage of the external conditions (14.1.1), nature of the visits (14.1.2) with accommodation requirements (14.1.3). The reduction of work scope and a transition phase to change operating mode are explained (14.2 & 14.3). Some other key advices are to determine the cost contributors, a shift in pm/cm ratio and to include production quantities in the decision-making process. (14.4 till 14.7).

14.1 Operational strategy

As previously stated the work scope is of vital importance for an efficient use of a logistical means. The first recommendation is based on the data used to obtain the work scope to be used in the decision-making process. The hours obtained from the different data sources are not representative to determine the current or future operating mode. Rather than using historical data, I recommend to calculate the work scope based on the required maintenance frequency of the individual satellite components with accompanying time.

Currently the available means drive the visitation process but a scope driven approach results in a more cost effective maintenance approach. This requires however a close collaboration of all departments who are responsible for different activities on the platform. The weakest link or bottleneck principle needs to be determined for all activities amongst the various departments. If the frequency of specific activities can be reduced, but a few activities require still a high visitation frequency the number of visits remains unchanged. The scheduling of visits plays a key role in the optimization of the operations. I propose that the scheduling is closely involved in the operational optimization.

To align all departments a better insight in required hours' offshore needs to be established. The SAP and complexity index give a distorted view of required hours. Activities conducted in the past all have a logical argument underlying a use of means. In time these arguments of a decision are not transparent, and future decisions are based on assumptions that are not directly related to costs. Therefore, it is important to use a cost based approach resulting from a required workload.

14.1.1 Work load

The annual workload currently implemented is approximately uniform. There is somewhat more work execute during the favorable seasons, but that is mainly caused by the increase in daylight. A drastic shift in workload by lowering the average workload throughout the year and increasing it a period where the maintenance is less influenced by environmental conditions is recommended when using a marine access scenario. Note however that the maintenance crew is employed throughout the year, so this required shift should be obtained from all staff including vendors and external personnel.

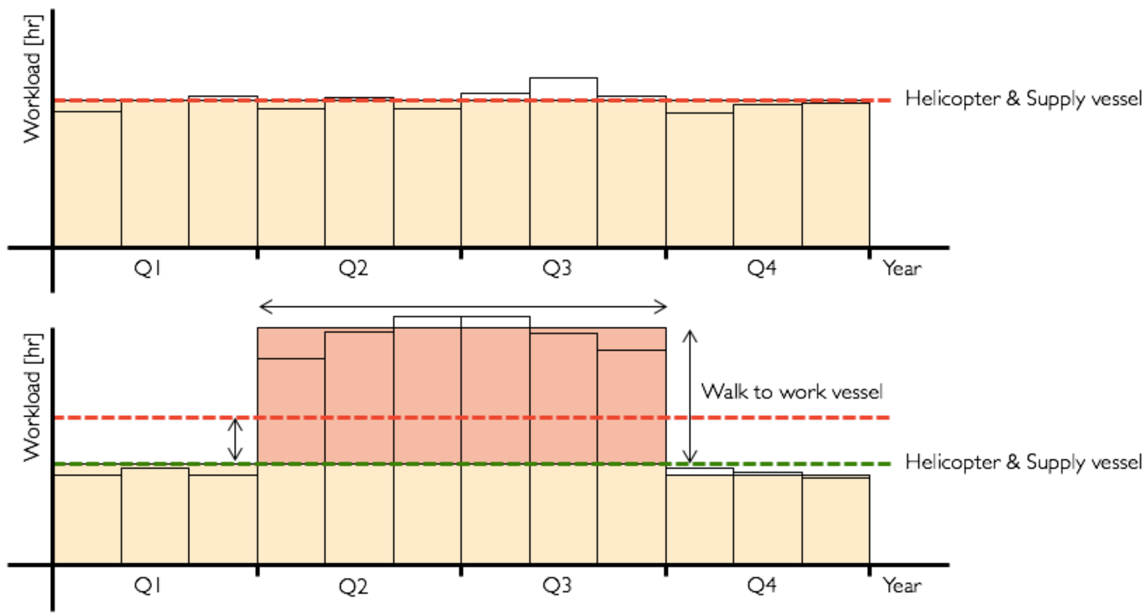


Figure 69. Recommended work-load distribution

The top figure indicates the present situation with a uniform workload throughout the year. The lower figure illustrates how a shift in workload would result in a different operating mode. The average workload should be decreased; the red dotted line needs to shift to the green dotted line. The additional work is shifted to the favorable seasons and would be carried out by a walk to work solution.

As shown in the figure above the changes in the operating mode take advantage of the beneficial seasons as recommended. Suggested is the carry to more research into the following;

- How much can the average workload being lowered and still meet the safety requirements and maintain the levels of production.
- What should be the width and height of the "marine access workload block".

14.1.2 Reduce vendors & Multi skilled teams

As suggested the shift in workload requires careful planning and the transport of some vendors on the vessels. As investigated TEPNL is currently using mainly specialized personnel to conduct the maintenance activities on the satellite. These day visits make the implementation of a marine access solution more difficult. The external services are costly since they have a high rate. A recommendation is to critically look at these service contracts and train and certify to reduce dependency of external sources.

The requirement imposed by regulations to change crew offshore personnel every 2 weeks gives the opportunity to include a vendor boat visit their scope of work is large enough. The advantage of having the specific vendor cargo on the vessel can therefore reduce also the need for a supplier. When designing a vendor, boat trip the accommodation requirement for multiple days of work is met.

14.1.3 Offshore accommodation

An important need for supporting maintenance is offshore accommodation since the satellites are designed to be unmanned. Offshore bedding is considered an expensive requirement since not only the beds are considered but also all infrastructure to accommodate a safe and comfortable stay offshore. A marine access solution is providing beds and all required infrastructure eliminating additional costs of bedding. Highly recommended is to further investigate this key requirement since this would lead to large costs savings.

14.2 Reduction of work scope

A change in operational strategy as currently proposed by the future operation mode makes a marine access a more cost efficient solution. Total has decided it will move towards a marine access operating mode since in the near future the work scope will become reduced due to the abandonment of some of its assets. Next to the shutdown of certain assets a platform simplification study is being conducted to reduce the amount of equipment leading to a lower visitation frequency.

The pre-abandonment and finally abandonment of assets still requires some inspections. A marine access approach is an appropriate means to still meet this requirement.

Doing more maintenance at once and less frequent will be less costly.

CONFIDENTIAL

Figure 70. Satellite K6N 01-01-2015 till 01-04-2015

The visitation frequency and distribution of a satellite (K6N.) The binary signal indicates the manned u manned status of a platform.

The short visits are costly since the ratio flight time vs. platform time decreases. The following figure shows the result of sort vs longer platform visits by helicopter.

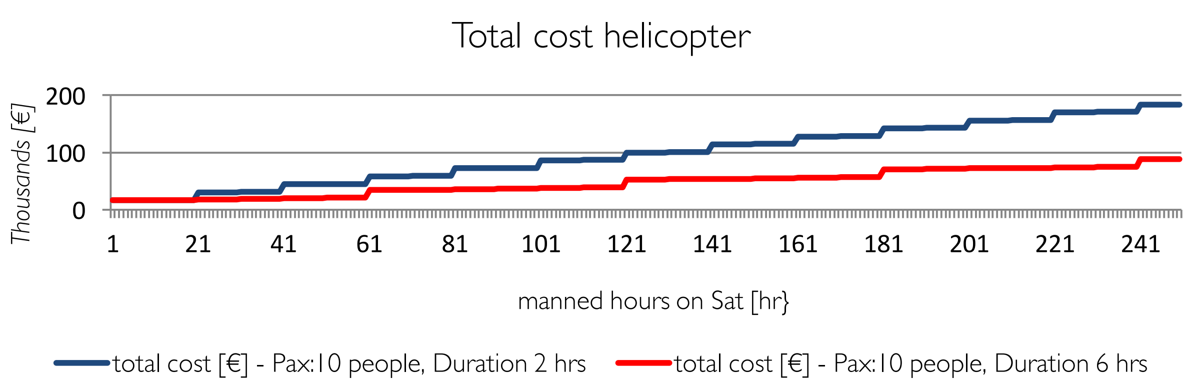


Figure 71. Impact of short duration visits by helicopter

The longer duration on a platform result in lower cost since the visitation frequency will go done. Note that the height of the cost curve is caused by the standing fee.

14.3 Transition

The transition to a marine access approach is a logistical challenge. To implement a new operational strategy requires a gentle and careful transition. By partially shifting the work scope from helicopter & supply vessel to a walk to work solution this process can be obtained. Learning from competitors who have already moved to a partially marine operating mode suggests that the crew selection is important. The operation by vessel requires a marine crew rather than a general maintenance crew.

14.4 Focus key contributors

The importance of the contribution of the costs in the logistics drives to evaluate activities from a maintenance campaign perspective. Since all costs must be seen as a rate per time unit, the difference in rates results in a cost driven mindset. The focus should be on the key contributors. To optimize in operations, a step change needs to be made. This step puts emphasis on the marginal costs of the logistic means.

The current market circumstances are unique; the shortage of work offshore has dropped the vessel prices to very low levels. On top of this the vessel prices the offshore access market, stimulated by the developments in wind industry, has many competitors. These developments allow for negotiations of long-term contracts against low rate.

The scope driven recommends a fit for purpose means to be as cost efficient as possible. The market circumstances allow for rent by purpose, rather than a multi-purpose means.

14.5 Ratio PM versus CM

With decreasing the flexibility of your operating means a shift in preventive versus corrective maintenance is required. TEPNL is currently operating with a 60/40 ratio pm vs. cm. Other operators using a marine access operational strategy have increased a much higher ratio, 80/20. Recommended is to do take preventive maintenance measures and reduce the corrective maintenance which supports the decrease of flexibility leading from the use of a vessel. Note however that there are all so visits which are production related; sampling, bleed off etc., part of these visits should be included be shifted to a marine operational strategy.

When considering alternatives less mobile than helicopters the impact of a TBO (total black out) on a platform need to be considered. By including the production quantities and the expected lifetime of the field platform distinction needs to be considered.

14.6 Production quantities

The core business of TEPNL is the production of natural gas. Keeping the production levels as high as possible is the key priority. A distinction between main and low producers plays part in the decision-making of moving to a marine access solution. To ensure delivering the required amount of natural gas and remaining the required levels of production, with an already present helicopter infrastructure, a combined use would be advised.

14.7 HSE & evacuation requirements

The application of marine access is a change in procedure which impacts on its turn on all other procedures. A close collaboration with the Health Safety and Environment (HSE) department is required when fundamentally changing the access method.

For example, when accessing the platform by vessel, the primary evacuation method could shift from helicopter to vessel. The vessel could function as a standby vessel which could lead to an increase in maintenance crew, since the lifeboats present would not be the limited factor anymore. Another advantage would be that the access by one of the decks could also increase the efficiency of executed offshore work by a change in distribution of a workday.

During the period in which this research has been conducted a lot of operational changes have happened which contribute to the outcome of this research and reverse the outcome of this research contributes to some of the decision-making process for a new operating mode.

Recommended is to fundamentally change the operating mode. It is proposed that further study based on the outcome of this research should be carried out to assess cost attractive options for changes in operating mode for TEPNL. The key recommendations are to determine the exact work scope, focus on the workload distribution and explore the required bedding for a future operating mode.

Chapter 15: Reflection

This chapter reflects on the research conducted for TEPNL. Starting by expressing the influence of the research boundary (15.1). Since the process of operational decision making is subjective, the information source supporting arguments will be contemplated (15.2). The decisions in this report are supported by costs, minimizing expenses. By including the revenues into the decision-making process, since profit = revenue – expenses, a better decision can be made. The impact of considering revenue in the decision-making process will be explained in the next section (15.3).

The scenario analysis method used in this research I would use again, since the evaluation of scenario's can best be determined by an iteration

15.1 Research boundary

The research-boundaries used in this research needs to be questioned when reflecting on this study. The decision to look at only preventive maintenance is supported by the desire to have a limited work scope. Assumed was that the pm scope was easier to obtain, since this would be periodic and approximately uniform for all platforms. The amount and conflicting data made it difficult to determine the exact work scope. All activities should be addressed when evaluated the logistic means, so I would widen the work scope by combining pm and cm.

A disadvantage from including cm is that the activities are non-routine. Often many disciplines and specialized equipment are necessary to execute this work. Hence chosen is to focus on preventive maintenance although it does not cover the entire work scope.

Secondly the focus is on satellite platforms, a logical assumption because there is no accommodation present so all people dropped of need to be picked up again. Another advantage is that there are much more satellites then treating centers. However, the accommodation on the treating centers is resulting in overnight stays. By including the treating centers were people are staying, crew change would be possible to consider.

15.2 Track record

An evaluation based on historical data, or track record, for this operational decision is not the most suitable method. The struggle of interpreting data is that the full context is often not available. For instance, the dependency between the means available and the needs, result is a discussable outcome. The impact of the international commodity prices, but even offshore activities support some operational decision.

15.3 Revenue versus expenses & Production quantities

The focus of this research is on costs, while no revenues are included. The loss of production can have a large impact, by including this in the decision model a better operational decision can be obtained.

Bibliography

4C Offshore . (2015). Wind Farm Service Vessels (WFSVs) - An Analyis of supply and demand .

Abdullah, R. (n.d.). Oil & Gas Industry - Opportunities and Challenges Ahead . Retrieved from http://www.mida.gov.my/env3/uploads/events/InvestMalaysia2012/4-Oilngas_Halliburton.pdf

Analyst sees explorers growing more cost conscious. (2016). Offshore magazine.

Anderberg. (2015). Challeges of achieving a high accessibility in remote offshore wind farms . Gothenburg : Chalmers university of technology.

Ballou, R. (2007). The ecolution and future of logistics and supply chain management .

Bard, J.; Thalemann, F. ORECCA. (2011). A report of the Off-shore Renewable Energy Conversion platform - Coordination Action. Lisbon: WaveEnergy Centre.

Beamon, B. (1998). Supply Chain Design and Analysis: Models and Methods .

Bedwell, I., Das, S., & McCall, E. (2015). Extending the Life of Mature Facilities. Retrieved from Society of Petroleum Engineers: http://www.spe.org/news/article/extending-the-life-of-mature-facilities

BP Global. (2014). BP Energy Outlook 2035 shows global energy demand growth slowing, despite increses driven by emerging economies. Retrieved from BP Global: http://www.bp.com/en/global/corporate/press/press-releases/energy-outlook-2035.html

Bresciani, G., & Brinkman, M. (2016, July). McKinsey&Company . Retrieved from Oil and Gas : http://www.mckinsey.com/industries/oil-and-gas/our-insights/five-strategies-to-transform-the-oil-and-gas-supply-chain

Buildings, D. (n.d.). www.designingbuildings.co.uk. Retrieved from the construction industry knowledge base : https://www.designingbuildings.co.uk/wiki/Scope_of_work

Businessdictionary. (2016). www. businessdictionary.com. Retrieved from scope of work: http://www.businessdictionary.com/definition/scope-of-work.html

businessdictionary.com. (2016). Retrieved from definition/cost-function: http://www.businessdictionary.com/definition/cost-function.html

Call, R. (2007). Analyzing the Relationship of Preventive Maintenance to Corretive Maintenance .

Chima, C. (2011). Supply-chain management issues in the oil and gas industry. Journal od Business & Economics Reseach .

Civil Aviation Authority. (2014). Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas.

Dalgic, Y., Lazakis, I., & Turan, O. (2014). Investigation of Optimum Crew transfer Vessel Fleet For Offshore Wind Farm Maintenance Operations . Glasgow.

Damen . (2015). Synergy Between E&P and Wind . Rotterdam .

Deloitte . (2015). Oil and Gas Reality Check . London .

Dinwoodie, I., McMillian, D., Revie, M., Lazakis, I., & Dalgic, Y. (2013). Development of a combined Operational and Strategic Decision Support Model for Offshore Wind . DeepWind 2013. Trondheim : Elsevier Ltd. .

DNV. (2011). General Marine Operations .

DNV-GL . (2015). High level review helideck and accomodation .

DNV-GL. (2015). Gangway Access To Offshore Facilities - Walk-to-Work Industry Guidance. Aberdeen: Det Norske Veritas Ltd., UK.

Dong Energy . (2012). O&M of Offshore Wind Turbine Experience and Future Challenges . Copenhagen .

Drew, J., McCallum, B., & Roggenhofer, S. (2004). Journey to Lean - Making Operational Change Stick . Springer.

EBN . (2015). EBN Workshop Low Cost Development & Maintenance . Rotterdam .

Egemen, S. (2011). Developing a Decision Support System for the Logistic Planning for Reel-lay Projects at Heerema Marine Contractors . Delft : TU Delft .

Energy Institue . (2015). Workshop report marine transfer/access systems . London.

Engh, H. (2015). Optimization of an Upstream Supply Chain. Trondheim : Norwegian University of Science and Technoloby .

Giaglis, G. (2001). A taxonomy of business process modeling and information systems modeling techniques. Brunel Universtity, Department of Information Systems and Computing . Middlesex: Brunel Universtity.

Gilbreth, F., & Gilbreth, L. (1921). Process charts, the first steps in finding the one best way to do work. The American Society of Mechanical Engineers, 16.

Grigore, S. (2007). Supply chain flexibility. Romanian Economic and Business review.

Gunasekaran, A., & Kobu, B. (2007). Performance measures and metrics in logistics and supply chain management: a review of recent literature for research and application . International Journal of Production Research .

Gursoy, M. (2010). A method for transportation mode choice . Academic Journals , 12.

Haans, R. (2015). Optimizing maintenance strategy on dynamic equipment on satellite platforms .

Hagen, B. (2013). Sensitivity Analysis of O&M Costs for Offshore Wind Farms. Norwegian University of Science and Technology , Physics . Trondheim : NTNU .

Harvard. (n.d.). Math . Retrieved from http://scholar.harvard.edu/files/harrylewis/files/notation.pdf

Hastings, N. (2015). Physical Asset Management . Springer .

Hendriks, M. (2009). Multi-step Optimization of Logistics Network: Strategic, Tactical and Operational Decisions . Eindhoven : Technical Universty Eindhoven .

Hillier, F., & Lieberman, G. (2001). Introduction to operations research . McGrawHill .

Holsapple, C. (2008). DSS Architecture and types . Springer .

IMCA. (2014). Transfer of personnel to and from offshore vessels and structures . IMCA.

investopedia . (2016). Retrieved from terms/a/activity-cost-driver : http://www.investopedia.com/terms/a/activity-cost-driver.asp#ixzz4UbQnj0qL

Investopedia. (2016). www.investopedia.com. Retrieved from Vendor: http://www.investopedia.com/terms/v/vendor.asp

Investopidia . (2016). www.investopidia.com. Retrieved from Factors that influence option prices .

Jong, F. (n.d.). Development of a model to estimate O&M costs for onshore wind farms . Eindhoven : Eindhoven University of Technology .

Kim, N. (2010). Intermodal freight transport on the right track? Delft University of Technology . Delft : TU Delft .

Lazakis, I., Turan, O., & Rosendahl, T. (2013). Modeling of vessel and equipment cost for the maintenance activities of an offshore tidal energy array. Department of Naval Architecture and Marine Engineering. Glasgow: University of Strathclyde .

leanproduction . (2016). www.leanproduction.com. Retrieved from theory of constraints : http://www.leanproduction.com/theory-of-constraints.html

Life Cycle engineering . (2007). Life Cycle engineering . Retrieved from https://www.lce.com/Analyzing-the-Relationship-of-Preventive-Maintenance-to-Corrective-Maintenance-1091.html

Lock, D. (2007). Distinction between planning and schedualing. In L. Dennis, Project management (p. 81). Hampshire.

Logistics and Supply Chain Management Technical University of Munchen. (n.d.). Network Design . Retrieved from https://www.log.wi.tum.de/index.php?id=153&L=0

Makowski, M. (n.d.). Multi-objective Decision Support Including Sensitivity Analysis. International Institute for applied system Analysis. Laxenburg: International Institute for applied system Analysis.

Maravelias, C., & Sung, C. (2008). Integration of production planning and scheduling:Overview, challenges and opportunities. University of Wisconsin-Madison .

Martins, D., Muraleedharan, G., & Guedes Soares, C. (2015). Analysis on weather window defined by significant wave height and wind speed . In T. &. Group, Renewable Energies Offshore (pp. 91-98). London .

McKinsey&Company. (2014). Meeting the challenge of increasing North Sea costs. Oil & Gas Practice. McKinsey&Company.

McKinsey&Company. (2014). Tackeling the asset production efficiency crisis in the North Sea. Oil and Gas practice, 13.

Mentzer, J., DeWitt, W., Keebler, J., Min, S., Nix, N., Smith, C., & Zacharia, Z. (2001). Defining Supply Chain Management .

Middle East Technical University. (n.d.). Operational Reseach from a Critical Viewpoint .

Min, H. (1991). International intermodal choices via change-constrained goal programming . Transportation reseach , 12.

NC State University . (20030, Oct). Success with Hub and Spoke Distribution . Retrieved from Supply Chain Resource Cooperative : https://scm.ncsu.edu/scm-articles/article/success-with-hub-and-spoke-distribution

Philips, S., Shin, I., & Armstrong, C. (2015, 1). Crew transfer vessel performance evaluation . Design & Operation of Wind Farm Support Vessel . London.

Rardin, R. (2016). Optimization in Operations Research . Pearson .

Reith, B. (2015). Low cost development & maintenance. Rotterdam.

SAP. (2016). Cost Component. Retrieved from www.SAP.com: http://help.sap.com/saphelp_erp60_sp/helpdata/en?b1/a2d

Schlumberger. (2016). Oilfield Glossary. Retrieved from http://www.glossary.oilfield.slb.com/Terms/b/brownfield.aspx

Schmidt, G., & Wilbert, E. (2000). Strategic, tactical and operational decision in multi-national logistics networks: a review and discussion of modelling issues. International Journal of Production Research.

Schmidt, G., & Wilbert, E. (2000). Strategic, tactical and operational decisions in multi-national logistics networks: a review and discussion of modelling issues. International Journal of Production Research.

Schmidt, G., & Wilhelm, W. (2000). Strategic, tactical and operational decisions in multi-national logistics networks: a review and discussion of modelling issues. International Journal of Production Research.

Simon, H. (1960). The new science of Management Decision. Sage Publications.

Simon, H. (n.d.). The new science of Management Decision . Sage Publications .

Sluimer, J. (2012). Development of a decision support system for the transport of large systems for the oil and gas industry. Delft University of Technology, Mechanical, martime and material engineering. Delft: TU Delft.

Society of Petroleum Engineers . (n.d.).

Sperstad, I., Halvorsen-Weare, E., Hofmann, M., Nonas, L. S., & Wu, M. (2014). A comparison of single-and multi-parameter wave criteria for accessing wind turbine in strategic maintenance and logistics models for offshore wind farms . EERA DeepWind 2014 (p. 10). Trondheim: Elsevier Ltd. .

Sperstad, I., Stalhane, M., Dinwoodie, I., Endrerud, O., Martin, R., & Warner, E. (n.d.). Testing the Robustness of Optimal Vessel Fleet Selection for Operation and Maintenance of Offshore Wind Farms .

Stadtler, H. (2004). Supply chain management and advanced planning - basics, overview and challenges . European Journal of Operational Research , 14.

Tennet . (2015). T.4 Access to platform .

TEPNL . (2015). Inspection and Maintenance Manual . Den Haag .

TEPNL . (2015). Maintenance Philosophy .

The graduate School for energy transportation professions. (n.d.). IFP School . Retrieved from The main steps of an oil and gas field development project : http://www.ifp-school.com/upload/docs/application/pdf/2015-02/3_main_steps_oil_gas_field_development.pdf

The Herald. (2015). Wood Group MD: the oil industry needs a work reality check. Retrieved from www.heraldscotland.co: http://www.heraldscotland.com/news/13199900.Wood_Group_MD__the_oil_industry_needs_a_work_reality_check/

thefacts. (2016). www.thefacts.org. Retrieved from what are internal constraints: https://www.thefaqs.org/what-are-internal-constraints

Total . (2014). Management of Asset Integrity in Field Operations . TEPNL .

Total . (2016). Minimum maintenance requirements . TEPNL.

Total . (n.d.). Design of offshore jacket and subsea structures . Structural .

Total . (n.d.). Escape, evacuation and rescue from fixed installations . Safety .

Total . (n.d.). Maintenance Philosophy .

Total . (n.d.). Personnel transfer between watercraft and between watercrafts and offshore structures . Logistics and Operational Support .

Total. (2015). Adverse weather working guidelines. Den Haag : Total .

Total. (2015). Design of offshore jacket and subsea structures. Structural.

Total. (2015). Design rules and construction standards for ancillary structures of offshore and onshore installations. Structural .

Total. (2015). Personnel transfer between watercraft and between watercrafts and offshore structures. Logistics and Operational Support .

Total. (n.d.). Design rules and construction standards for ancillary structures of offshore and onshore installations. Structural .

Total E&P Netherlands B.V. (2015). Maintenance and Inspection Manual. Den Haag : Total .

U.S. Energy department . (n.d.). Value management: Budgeting .

van Brussel, G., & Zaaijer, M. (n.d.). Reliability, Availability and Maintenance aspects of large-scale offshore wind farms, a concept study. Delft : Faculty Civil Engineering and Geosciences, TU Delft .

van Brussel, G., Henderson, A., Morgan, C., Smith, B., Barthelmie, R., Argyriadis, K., . . . Peltola, E. (2013). State of the Art and Technology Trends for Offshore Wind Energy: Operation and Maintenance Issues . 4.

Wall Street Journal. (2016). Total CEO Warns of Weaker Profit Amid Oil Price Collaps.

Wikipedia . (n.d.). Bathtub curve . Retrieved from https://en.wikipedia.org/wiki/Bathtub_curve

Wolfram mathworld. (2016). Wolfram Mathworld . Retrieved from Triangle Centroid : http://mathworld.wolfram.com/TriangleCentroid.html

Appendix

Appendix: Total Exploration and production Netherlands

Total contains the following three pillars: upstream, refining & chemicals, and marketing & services. Those pillars clearly cover the stages of the oil and gas supply chain. This research will be conducted on behalf of Total Exploration & Production Netherlands (Total E&P or TEPNL), one of the parts of the 'upstream' pillar. Within TEPNL the Development & Planning Department (DPD) and the Logistics Department (LD) will be providing the real-life data for this research.

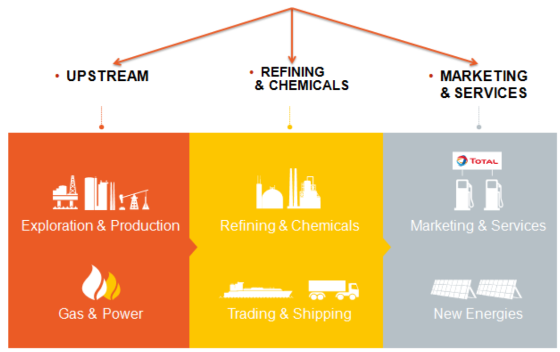


Figure 72. TEPNL pillars

Total E&P has been engaged in offshore exploration and production of gas in the Netherlands since 1964. The organization is currently working with 22 platforms and 4 subsea production facilities, which are its North-Sea assets. Most platforms are unmanned and are being operated from the control room in the head office in The Hague. Although the gas production is declining, as it reached maturity about 10 years ago, the production curve is flatted (Figure 70) thanks to the adoption of innovative processes.

Appendix: Petrochemical value chain

The value chain of a hydrocarbon field *(The graduate School for energy transportation professions)* shown below is expressed in 5 main steps. Starting at the discovery of a petroleum deposit to first gas, E&P activities are carried out over decades.

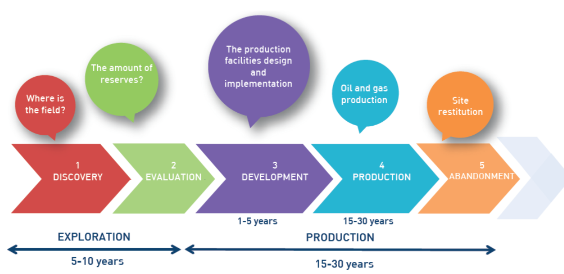


Figure 73. Hydrocarbon life cycle

(The graduate School for energy transportation professions)

The time over which gas may be extracted varies and is extended by new technologies. The life time of a reservoir is composed of different phases as is indicated *(The graduate School for energy transportation professions)*. The phases are: a period of production increase, a stabilization phase often called plateau, injection phase (water, gas or chemical injection) and finally the depletion phase when the production starts to decline. The North Sea field is considered a brown field *(Schlumberger, 2016)* the gas accumulation has matured to a stage of declining production. All operating companies seek to extend the economic producing life of the field using cost effective, low risk technologies *(Rao Abdulla, Halliburton).*

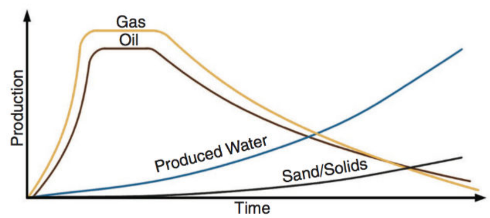


Figure 74. A typical oilfield production profile.

(Society of Petroleum Engineers)

This thesis will focus on the preventive maintenance and inspection during the production phase. As explained in the introduction the revenues are declining due to a decrease in production, the operational expenditure is increasing due to the maturing assets. As the preliminary research, optimizing maintenance strategy on dynamic equipment on satellite platforms *(Haans, 2015)*, shows the decrease in OPEX leads to the extension of profitable lifetime.

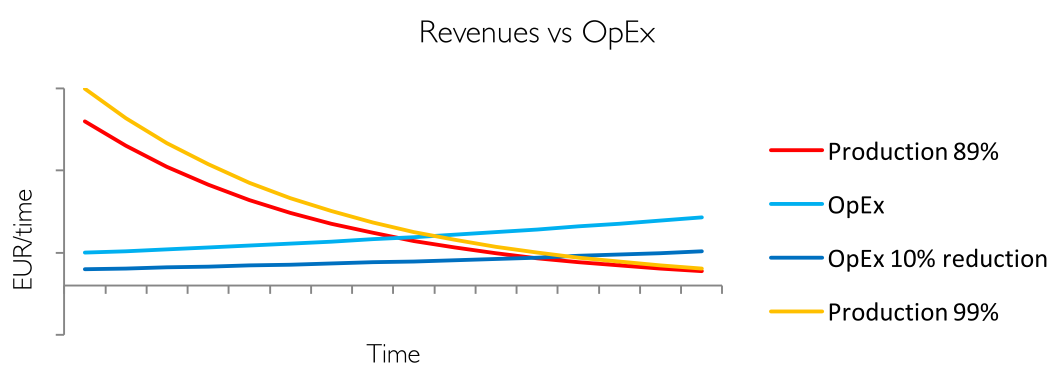


Figure 75. Revenue vs. operational expenditure

Appendix: Requirement analysis

After generally determining the industry requirements and opportunities a closer look towards the company requirements and constraints is needed. Within an organization different departments with different interest towards this topic a clear view needs to be created. *(System engineering fundamentals (Department of Defense))*

To determine which set of constraints and requirements have a priority the key stakeholders regarding marine access need to be determined. By starting to map all stakeholders within the scope of this research an overview of concerned party's remains

Stakeholder list TEPNL: a marine access solution.

- Development & planning department

- Field operations department
- Logistic department
- Inspection & corrosion department
- Health safety environment and quality department

All departments benefit from marine access in different ways. After multiple interviews amongst the different departments a need to align their expectations about this opportunity was felt. By collectively discussing this topic in a joint requirements development session a common view is obtained.

With the topic, marine access, there is a need to address this topic as a system. This combination of vessel, mooring system and transfer mechanism describes the chances and limitations. As described in System engineering fundamentals by the US department of defense a requirements analysis is the first step to analyze the process requirements for a system. To determine the functional and performance requirements the joint development session is based on a 15 task IEEE P1220 system engineering standard.

Tasks	
1. Customer Expectation	9. Life Cycle Process Concepts
2. Project and Enterprise Constraints	10. Functional Requirements
3. External Constraints	11. Performance Requirements
4. Operational Scenarios	12. Modes of Operation
5. Measures of Effectiveness and Suitability (MOE/MOS)	13. Technical Performance Measures
6. System Boundaries	14. Physical Characteristics
7. Interfaces	15. Human Factors
8. Utilization Environments	

Table 21. 15 task IEEE P1220

Totals expectation of the system and how well it functions are closely related to the cost and required availability. The trade-off between platform availability and costs are considered a management decision which evolves from this research. The general expectations are that by directly reducing the air access the cost can be minimized. The overall shift towards more marine access would be beneficial when including all secondary advantages e.g. increase in HoTT etc.

The experiences with marine access gives Total knowledge in operational procedures and a reference in costs involved. Besides marine access project constraints are company constraints which need to be considered. These constraints are not limiting the applications however they are mentioned in this research. The external constraints however such as laws and regulations and the technology available need to be considered.

The operational scenarios are dependent on the access means and visa versa. The jacket structure functionalities are determined and can be substituted in to functionalities of the vessel. The possible integration of a system, such as a crane on a vessel can substitute all platform cranes. The operational scenario needs to be a general one so that it reduces operational risk.

For maintenance and operation activities the planning and scheduling is of great importance. When accessing the satellite by vessel planning becomes even more important. The environmental conditions are the dominant factor for the safe transfer of personnel. The platforms accessibility in combination with the need to enter the platform is necessary. The optimization of the maintenance and inspection strategy due to a different access means is possible.

The access by vessel leads to direct and secondary requirements. The direct consequence of the vessels size is its range. Besides its range the transit speed gives clear requirement. A production breakdown on a platform and the way maintenance operations are done by vessel need to be addressed. Mostly, the oil and gas operators are dependent on offshore supply companies of the transportation. All different departments need to visit the satellites for specific reasons. To optimize the number of visits by combining more activities the strategy might be changed.

The research scope takes the "present "condition of 14 satellite platforms. The development, testing, training and operations of marine access scenarios will be based on this.

Potentials of marine access

- Better negotiation position: Vessel spot price has decreased and motion compensated technology has been improved.
- Pool concepts: to reduce costs sharing among operators could make concepts financially beneficial.
- Long-term commitments versus spot price rates differ a lot for both vessel and access system.
- The investments in offshore wind parks have changed the offshore access market.
- Marine access scenario's, by using the availability, planning and technical innovations and change in the maintenance strategy can lead to higher efficiency.

Situation

During the investigation into the application of marine access the various points of view among the departments within TEPNL were noticed. The alignment of their expectations is necessary to find the functional requirements and design constraints on which the scenario modeling should be based. Marine access has its benefits for every department but to increase the overall operational efficiency tradeoffs must be made by every department.

Task

The objective of the workshop was to get all key stakeholders together and discuss the requirements and constraints regarding marine access by getting input from the departments: DPD, FOD, LD, ISD and HSE. More specifically what does the system (vessel, mooring system, transfer mechanism) do and how well does it need to perform these functions under the given conditions.

Action

By organizing a joint requirement development session interaction between departments is stimulated. Through a 15 tasks requirement analysis the important topics were mentioned and additional insights from expert are obtained. The workshop started with Totals expectations, followed by internal and external constraints. After which operational scenarios, boundaries and interfaces where discussed. Finally, by looking at the systems: life cycle, functional- and performance requirements and the importance of human factors, a clear view can be gained.

Results

The output obtained from the discussions shows the common interest among the departments in marine access and the many factors that need to be considered. Agreed upon a mission statement: there is a need to have a concept to cover the operations of a platform more efficient and more cost effectively.

Access mix	A common view among all participants is that there is not one system that could fill all requirements for the operations of this field. There would always be a secondary system, helicopter access, due to environmental conditions, logistics, breakdown etc.
Research scope	The research was demarcated by focusing on fixed maintenance and inspection due to the periodic nature of this work. During the workshop the importance of including corrective maintenance was expressed.
Time frame	There is some debate on when a marine access concept can be applied. Rushing to a new approach without taking time to learn how to operate, slim down and detox from current method is criticized. Everybody agree on short term, next year.
Day visitors	Currently the satellite platforms are visited by a mixture of specialized personnel for specific purposes (vendors, audits, HSE etc). The so called 'day visits' are scheduled independently.
Operational efficiency	From the discussion on Totals expectations about marine access and operational efficiency the participants stated that by combining day visitors and bundling inspection and maintenance visits this could be obtained.
Functional compromise	A compromise should be made between the functions on a vessel and the costs. Increasing the functions of the vessel comes at a price while some functions are mutually exclusive.
Satellite location	When considering the location of the satellites, especially the distance from Den Helder to the nearest platform, the transit time is a critical element. Inter-field transfer should be discussed more extensively.
Opportunity driven	The discussion on the flexibility of marine access evolved in plan-ability. The high dependency on the weather conditions can lead to a more ad hoc maintenance approach.
Flexibility	The flexibility of staying at one platform of servicing multiple platforms depends on the choice you make in marine access means. How many visits a day, making a distinction between day visitors or week visitors is the way you operate marine access.
Crew constraints	The number of personnel that simultaneously can be present on a satellite is limited by several safety factors. Often the capacity of the escape means (lifeboats) and helicopter are the limiting factor.
Overall efficiency	The benefits of operating in months with beneficial average weather conditions (April – October) and the possibility of doing extensive preparations in less favorable months could lead to a higher overall efficiency.

24 hour coverage	The possibility of continuously working, especially in favorable weather conditions even though the efficiency at night could be much lower (30%), by eliminating all transit time could be beneficial.
Project of campaign	The possibility of staying offshore for multiple weeks and thereby eliminating all the daily transit time increased the efficiency. By transporting cargo on the same vessel as the crew (crane drivers) there will be no waiting time on either side.
Low & high production	With marine access, no distinction is made between low and high producing satellites since there is no distinction in the maintenance and inspection at this moment. The priority of solving breakdowns should be addressed by operations.
Safety	Marine access has many safety advantages; the vessel could function as a standby-vessel, but also disadvantages such as the transfer to a platform via a gangway to one of the decks or by ladder.
Physical limit	The constraint of finding and training personnel for this way of operating is a real challenge for all participants. Besides the willingness to operate from a vessel there is also the physical constraint, seasickness, with plays a significant role.

Table 22. Results requirement analysis workshop

Appendix: Access mechanisms

Transfer by boat landing or ladder (GS no boat landings North Sea)

The platforms are equipped with a ladder, which provides a way to access the spider deck. The accessibility is very poor and has high risks involved. A boat landing or a modification to the existing structure would lead to a higher accessibility. CTV exist in mono or duo hull with different designs with the focus on stability. A whole range of CTV have been developed especially for this purpose, inspired by methods used in offshore wind industry. The method of accessing by "pushing" against the structure is called 'the surfer method', which introduce, motion compensated techniques to extend the operational range.

Surfer method

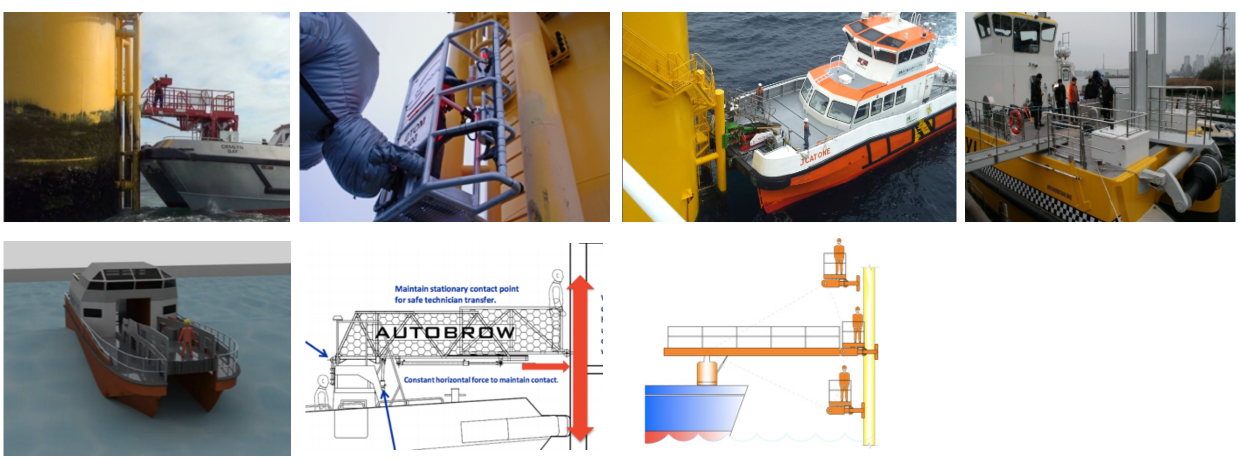


Figure 76. Motion compensated techniques to increase the accessibility by the surfer method

Type	Hs limit [m]	Description
TAS Turbine Access System • Mark II	3	The TAS has been developed by Houlder & BMT Nigel Gee. Specially designed to be fitted on a small CTV. • No DP required • Less dependent on friction by trust • Active motion compensated
MOTS (Momac Offshore Transfer system • MOTS 500 • MOTS G/1000	 3.2 4	Momac has developed an innovative robot arm which compensates for the ship-motions and provides a stable platform for accessing
MaXccess • T-series	2.5	Osbitpower's T-series is access system which clamps the CTV to the structure. • No stick-slip effect • Step off point remains stationary • Passive motion compensation • Saves on vessel running costs
Rolling Jack	2.5	Baltec offshore has developed a stabilizing platform on a ocean runner with a sten landing. • The rolling-system eliminates stick-slip • Light weight vessels low energy consumption
Pivoting deck vessel	?	North Sea logistics has developed the pivoting deck vessel concept which reduces the motion significantly during transfer.
Autobrow	?	Autobrow is a partnership between Ad Hoc Marine Designs and South Boats,Uk. The autobrow is a simple modular transfer system that can be retrofitted to existing vessels.
Wind bridge	?	Knud E. Hansen, Denmark

Table 23. Data by motion compensated techniques to increase the accessibility by the surfer method.

Personnel transfer carrier (GS only evacuation purpose in North Sea)

'A personnel transfer carrier method' is based on transfer of personnel by crane. The aim of this research is based on how to get on the unmanned platform without helicopter access. This eliminates most solutions of personnel transfer. The remaining options would be to use the vessel's crane or to use a remote-controlled crane with is positioned on the platform. Total only uses personnel transfer carriers in case of emergencies.

Figure 77. Personnel transfer carrier

Type	Hs limit [m]	Description
PTS personal transfer system	3	Personnel transfer system Gmbd consists of a remote-controlled crane which lifts the crew from the OSV • Remotely controlled crane
FROG	3	FROG is a crane devices from RelflexMarine which provides a safe access solution.
SEA SPIDER	3	Reflex Marine offers personnel transfer solution • Winch based access system

Table 24. Data personnel transfer carrier

A crane driver is required to transfer the crew to and from the platform by crane, but first the crane drive needs to get on the platform Total only uses this concept in case of emergency. The North Sea is not very suitable for this solution (*FROG type personnel basket, Bily Pugh personnel basket*).

Bridge and gangway transfer

The most common way of marine access is by a bridge of gangway. The layout of the platform is of importance to determine the safest access point. The environmental conditions need to be considered and an optimal access points can be determined. The combination of vessel height and gangway solution give optimal height with a minimal inclination. The behavior of the vessel in the waves translates in a motion of the gangway on the fixed structure.

- Active motion compensated
- Active/passive motion compensated
- Passive motion compensated

Figure 78. Motion compensated gangways

Type	Hs limit [m]	Description
OAS (Offshore Access System)	2.5	OAS was developed by Offshore Solutions, which operates as subsidiary of Ampelmann Operations B.V. since Nov 2013. • Telescopic gangway 21m • Heave compensated • Operates dynamically until clamped - passively
Ampelmann • L-type (CTV) • A-type • E-type	2 - 2.5 m 3.1 – 3.5 m	Ampelmann's inverted Stewart Platform, real time motion compensated • Telescopic gangway 25m • Fixed to long- vessel (70m) • No connection to structure
Safeway	3.5	Safeway iis a company within the Van Aalst Group • Bridge length 28,5 m • Motion compensated • 75 m Platform supply vessel
Maxccess • P-Series • AM-Series		MaXccess systems developed by Osbitpower delivers passive, active w2w solutions • Telescopic gangway 25 m • mid-sized DP vessel 80-140 m • Active motion compensated
BM gangway • BM-gangway 3.0 • BM-gangway 4.5	3.0 4.5	BM gangway fit of purpose • Telescopic gangway 23m • Possibility to intergrade motion compensated crane
UPTIME	3.5	Uptime AS was founded by ICD Industries AS and Marine Aluminium AS. • Gangways range 15-40 m • OSV has to be large than 30 m
ZBridge	3.1	Z-bridge one of the concepts designed by Ztechnology

Table 25. Data motion compensated gangways

Appendix: SNS-Pool

The SNS-pool is an initiative of multiple logistic service companies who are combining their forces to supply 9 various North Sea operators.

Figure 79. Southern North Sea Pool participants

Appendix: CHC Helicopters

The helicopter used for personnel transfer is the Agusta Westland AW139, with a capacity of 12 pax. The helicopter is used for both maintenance and inspection visits but also crew change. The advantage is a very quick and flexible means to transfer people, but the down side is the strict requirements and the high costs.

The occupancy rate

The most cost effective way of shuttling crew to offshore locations is to strive to maximize the PAX on flights; this is expressed in the occupancy rate.

$$occupancy\ rate = \frac{used\ space}{available\ space} \qquad \text{Eq 28}$$

Two different processes impact this rate; crew change and platform day visits. To clarify how the occupancy rate is influenced an illustration is given, assuming that the full capacity of the helicopter is used. The people drop off (blue) and the pickup (red) show how the occupancy rate by day visits will never be higher than 0,5.

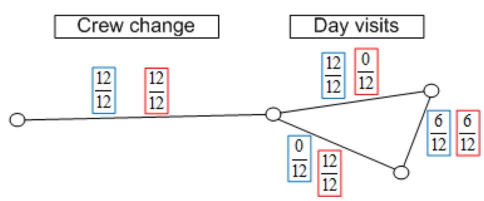


Figure 80. Occupancy helicopter crew change and day visits

The aircraft commander is responsible to suspend or abort flights if the current or forecast of the weather is affecting the safety of the crew. The helicopter landing officer (HLO) has the same responsibility for the landing on the helicopter deck. Likewise, the distinction in aviation's operations in adverse weather are considered for flying and helicopter deck operations (Total, 2015). The restrictions for flying:

- Wind - flying limit is 60 kts mean wind speed at 100 meters.
- Sea state - 7m significant wave height.
- Visibility - < 250 m within 5 nautical miles.

Since an incident in the North Sea, (CAP1145) the regulations by British CAA (Civil Aviation Authority) provide restriction in the maximum sea state in which helicopters may be used. The sea state considers the significant wave height in which the aircraft remains floating upright. The restriction uses 2.5 m - 4 m significant wave height. *(Civil Aviation Authority, 2014)*.The helicopter deck operations are also largely influenced by the same factors. For wind, the gust speed and the direction are requirements to consider. If the direction of the wind is such that the exhausts are blown towards the helicopter deck, the deck needs to be closed. Another factor for which caution is required is based on snow and ice accumulation.

Appendix: Vessels

Marine access is described by the access via any watercraft to an offshore structure. There are many types of vessels with different designs and specialties. This research limits itself to the means of access by type not the selection of a specific vessel design. The types of vessels can be divided into two groups:

Vessel	Type
Construction and installation vessels	Jack-up barge
	Jack-up vessel
	Crane ships
	Semi-submersible platforms
Operation and Maintenance (O&M) vessels	Crew transfer vessel (CTV) (mono-hull)
	Fast Crew transfer vessel (FCTV) (mono-hull)
	Small Water-plane Area Twin Hull (SWATH)
	Platform supply vessel (PSV)
	Walk to Work Vessel (W2W Vessel)

Table 26. Offshore vessel types

Construction and installation vessels

This research focuses on preventive maintenance and corresponding logistic means. The larger and more heavy-duty vessels mainly used for the installation and construction activities are an overkill for the activities considered.

Operation and Maintenance vessels

The effective use of O&M vessels are considered. A more extensive market analysis has been done and can be found in (Appendix: Marine transfer solutions 2016). By selection of two access systems, which have past precertification, the operational performance is given.

Vessels	Hs limit (significant wave height)	Wind limit	Travel speed	POB	Material Capacity
CTV & Boat landing	0.5 - 1.5 m	>10 m/s	20-30 knots	12	15 ton
PSV & W2W • Access system	2.5 - 3.0 m	10-15m/s	10-15 knots	20-45	1000 ton
Helicopter	2.5 - 4 m	21 m/s	250 km/h	12	

Table 27. Indicative market numbers

(DNV-GL , 2015)

Figure 81. Walk to Work vessels

Appendix: Supply chain

A supply chain can be defined as: a set of three or more entities (organizations or individuals) directly involved in the upstream or downstream flows of products, services finances and/or information from a source to a customer (Mentzer, et al., 2001).

Accordingly, there are various ways of defining logistics, depending on the literature considered. The Council of Logistics Management (Ballou, 2007) states that logistics can be defined as "the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of conforming to customer requirements". Harvard Business Review states: "that purchased products and services account for more than 50 percent of the average oil and gas company's total cost". The interest of operators to improve the supply chain by focusing on supply chain market intelligence, supplier relationship management and new supply chain technologies according to SDC (supply and demand chain) is therefore evident (Beamon, 1998).

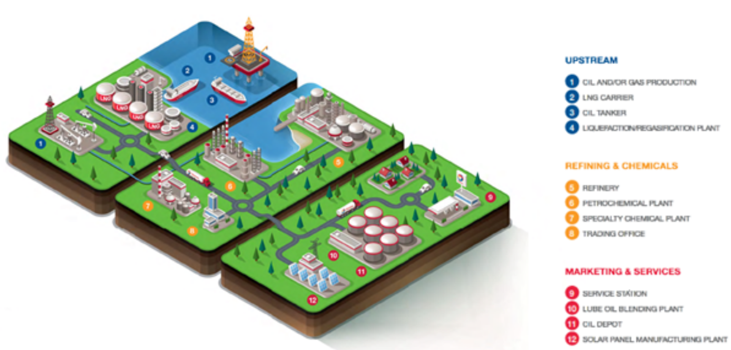


Figure 82. Total Upstream to Downstream overview

Appendix: Spoke hub

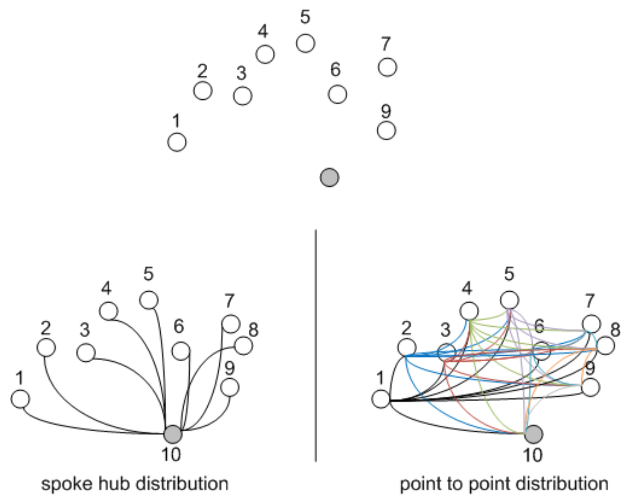


Figure 83. Spoke hub distribution paradigm

A point to point distribution requires $\frac{n(n-1)}{2} = 45$ connections while the spoke hub distribution requires only 9 to connect all nodes. Especially when complicated tasks or special conditions, in this case offshore accommodation are concerned, the spoke and distribution network saves in costs of specialized equipment.

Appendix: Logistic network

A logistical network is a schematic presentation of nodes and arcs based on a real-life problem. The network designed *(Logistics and Supply Chain Management Technical University of Munchen, n.d.)* shows the physical configuration and infrastructure of the supply chain. The modification of the supply chain of a brown field (Schlumberger, 2016) gives certain limitations. By evaluation the system as a network and applying different levels of decision making, the optimization of logistics for an existing field can be obtained.

Title	Report/article	Published by:
Marine Operations, General DNV-OS-H101	Service Specifications, Standards, Recommended practice	DNV
Helideck and accommodation facilities on offshore platforms for wind farms	Report	DNV GL Energy, TenneT
T.4 Access to platform	Position Paper	Tennet
Transfer of Personnel to and from Offshore vessels and Structures	Guidance	International Marine Contractors Association (IMCA)
O&M of Offshore Wind turbines Experiences and Future Challenges	Conference	DONG energy
Minimizing Crew Transfer Risk	Conference UK Health and Safety	Xodus Group

Table 28. Literature logistic networks

Appendix: Maintenance

This thesis will focus on fixed maintenance and inspection; the process is continuous over the lifetime of the assets. Preventive maintenance can be divided in: Safety critical (SC) and Business critical (BC) components. Safety critical component are considered to be of the highest priority for HSE reasons. Business critical components are directly linked to the company's profit. The ratio preventive maintenance to corrective maintenance has been studied to a great extend (Call, 2007). One proven theory is that PM to CM works ration should be 6 to 1.

The "6 to 1 Rule", proven by John Day, Jr., Manager of Engineering and Maintenance at Alumax of South Carolina, during the period when Alumax of South Carolina was certified as the first "World-Class" maintenance organization. *(Life Cycle engineering , 2007)*

Many maintenance activities however have external circumstances that influence the ratio. To determine the real ratio between PM and CM many variables need to be considered;

- Assets life time. Failure newly installed or aging equipment.

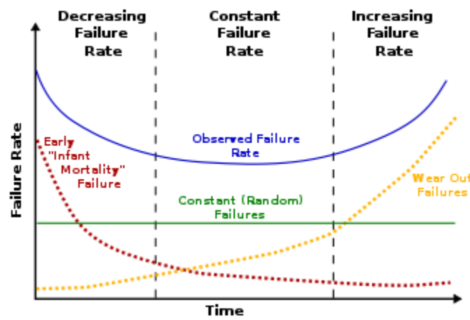


Figure 84. Bathtub curve

(Wikipedia , n.d.).

The first part is a decreasing failure rate, known as early failures. Then the second part is a constant failure rate, known as random failures. The final part is an increasing failure rate, known as wear-out failures.

- Asset Criticality. Safety or Business critical. (TEPNL , 2015)
- Asset History – The failure history of an asset. (Hastings, 2015)
- Asset Technology – Vary advanced control center with life feed. (Reith, 2015)
- Distribution of maintenance activities, ratios PM, CM, breakdown work.
- Affiliate guidelines and Total general requirements. (TEPNL , 2015)

Total's oil and gas supply chain is shown in figure 18. This research is conducted for the exploration and production department so it focuses on the upstream supply chain. Much research has been done into the field of maritime supply chain, since the international transport greatly benefits from this means of transportation. Unfortunately, there is no overlap between shipping and the upstream supply chains. The objective of managing a supply chain is to maximize profit and minimize cost along the chain (Engh, 2015). According to experts some industries benefit more from optimizing their supply chain then others. (Chima, 2011)

Appendix: Criticality work orders

CONFIDENTIAL

Table 29. Maintenance and inspection manual

Appendix: SCE & BCE

CONFIDENTIAL

Table 30. Safety or Business critical elements

Appendix : Distance-matrix

Distance	K1A	K4A	K4BE	K5B	K5CU	K5D	K5EN/C	K6D	K6DN	K6GT	K6N	L4PN	L7B	L7H	Den Helder	L7CC	K6CC	K5CC
K1A	0.0																	
K4A	18.4	0.0																
K4BE	11.6	7.7	0.0															
K5B	27.0	8.7	16.3	0.0														
K5CU	24.5	11.7	17.6	11.3	0.0													
K5D	31.7	13.4	20.9	4.7	14.0	0.0												
K5EN/C	32.0	14.0	21.6	5.5	12.3	2.7	0.0											
K6D	52.7	35.1	42.8	26.7	29.3	22.5	21.2	0.0										
K6DN	49.4	32.6	40.3	24.8	25.3	21.2	19.4	5.8	0.0									
K6GT	55.8	39.8	47.3	32.4	31.3	29.0	27.0	10.4	7.9	0.0								
K6N	46.8	29.4	37.1	21.2	23.5	17.2	15.6	5.9	4.8	12.5	0.0							
L4PN	63.7	49.3	56.5	42.7	39.4	39.8	37.5	22.0	19.4	11.8	24.2	0.0						
L7B	78.6	61.0	68.7	52.6	54.8	48.2	47.1	25.9	29.4	25.0	31.8	26.0	0.0					
L7H	74.1	56.6	64.3	48.2	50.3	43.8	42.7	21.5	25.0	20.7	27.3	22.9	4.5	0.0				
Den Helder	152.1	133.9	140.6	125.5	132.6	120.9	121.4	104.8	110.3	108.8	110.1	111.4	85.4	88.9	0.0			
L7CC	81.2	63.2	70.8	54.6	58.2	50.0	49.3	28.9	33.4	30.4	34.7	33.2	7.8	10.3	78.7	0.0		
K6CC	54.3	37.1	44.8	29.0	30.4	25.1	23.5	3.7	5.1	6.8	7.9	18.3	24.4	19.9	105.4	28.3	0.0	
K5CC	23.6	6.3	12.1	6.2	15.1	9.8	11.5	32.4	30.9	38.5	27.0	48.9	58.0	53.6	128.4	59.5	34.9	0.0

Table 31. Distance matrix locations TEPNL field

Appendix: Hs – significant wave height

Hs (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0.00 - 0.50	3.43	4.97	6.26	10.56	12.83	16.35	17.73	16.80	10.66	6.86	2.84	3.80	9.42
0.50 - 1.00	14.70	18.95	21.97	30.85	34.77	37.95	37.93	37.20	28.78	20.67	15.47	13.95	26.07
1.00 - 1.50	19.52	22.29	23.66	24.86	26.67	25.24	24.81	23.24	24.38	22.73	20.83	19.34	23.12
1.50 - 2.00	17.07	17.17	18.06	15.31	14.15	11.71	11.34	11.52	15.08	17.14	18.66	16.64	15.32
2.00 - 2.50	13.21	12.66	11.11	8.77	7.16	5.21	4.49	5.75	9.10	11.55	13.46	13.93	9.70
2.50 - 3.00	10.01	8.01	7.74	4.58	2.94	2.04	2.02	3.28	5.45	8.38	10.22	10.71	6.30
3.00 - 3.50	7.92	5.94	4.57	2.88	1.04	0.74	0.90	1.44	3.23	5.30	7.01	8.10	4.10
3.50 - 4.00	5.56	4.08	3.23	1.07	0.33	0.42	0.45	0.54	1.66	3.29	5.01	5.64	2.61
4.00 - 4.50	3.93	2.60	2.07	0.59	0.07	0.21	0.26	0.20	0.84	1.80	3.13	3.66	1.62
4.50 - 5.00	2.19	1.33	0.79	0.27	0.05	0.09	0.06	0.03	0.53	1.13	1.78	2.10	0.87
5.00 - 5.50	1.09	0.81	0.30	0.11		0.05		0.01	0.22	0.69	0.91	1.19	0.45
5.50 - 6.00	0.65	0.51	0.11	0.07					0.06	0.21	0.40	0.47	0.21
6.00 - 6.50	0.35	0.32	0.08	0.04					0.01	0.19	0.14	0.22	0.11
6.50 - 7.00	0.18	0.20	0.05	0.02						0.04	0.10	0.16	0.06
7.00 - 7.50	0.11	0.12								0.02	0.02	0.06	0.03
7.50 - 8.00	0.04	0.03									0.01		0.01
8.00 - 8.50	0.03	0.02										0.01	0.00
8.50 - 9.00											0.01		0.00
9.00 - 9.50												0.01	0.00

Table 32. Annual Hs overview

Appendix: interfiled distance

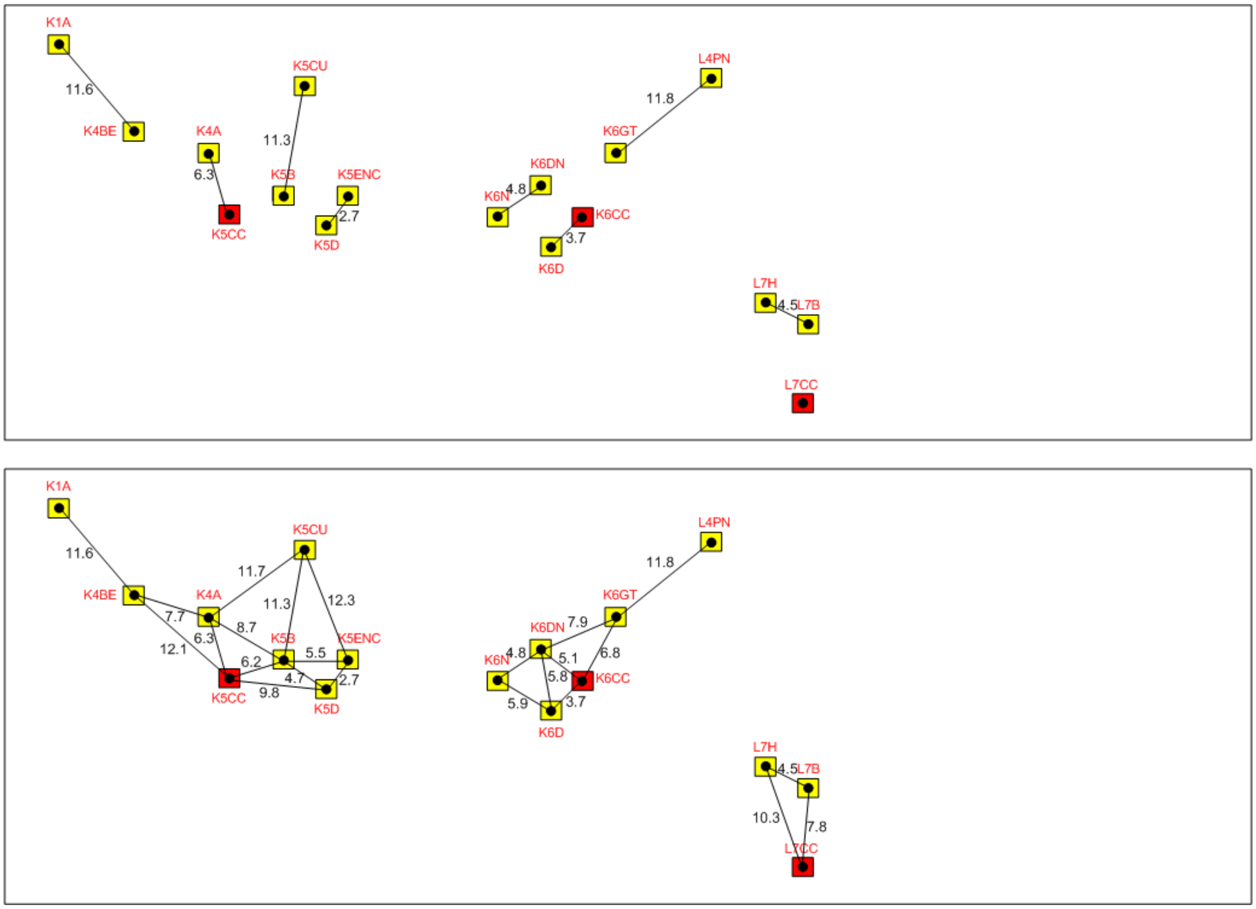


Figure 85. Inter-field distance North Sea field

Appendix: Manned / Unmanned PI data

CONFIDENTIAL

Figure 86. PI manned unmanned data Q1 2015

Appendix: Complexity Index

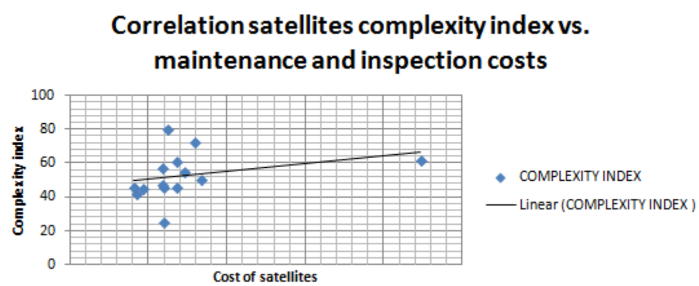
Due to the diversity in layout and equipment of the satellite platforms a factor is into introduced which quantifies the relative cost components; a complexity index. As introduced by W.L. Nelson in 1960 the Nelson index or complexity index is a pure cost index. The index has originated from the refinery industry and has been applied to Totals satellites platforms. The index indicated the complexity of the installations equipment and is therefore directly linked to maintenance. For the maintenance on site, it gives the typical manning by trade: mechanical, electrical and instrumentals with an accuracy of 15%. Since the focus is on equipment, time consuming activities such as structural and scaffolding but also painting, major overhaul and inspection activities are not included in the complexity index. The results from the maintenance complexity index give an indication in hours spent on routine maintenance. *(W.L. Nelson oil & gas journal)*

The complexity index does not include:

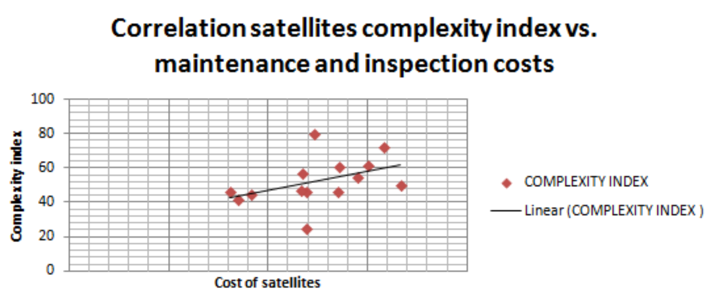
- Inspection activities.
- Structural and scaffolding activities.

- Workshop activities ((workshop for routine activities is included).
- Heavy Planned Maintenance (e.q. Turn Around, Major Overhaul, etc).
- Heavy painting jobs.
- Modification.
- Civil works.

Data complexity index L7B outlier because of extremely high cost on the structural since the platform has been hit by a freak wave.



Linearize based on extrapolating outlier



Explanation complexity index Literature

Objective: evaluate the complexity of installations in terms of fixed maintenance.

- The basis for the calculation is the count of the equipment installed. (process and instrumentation drawings (PID's) or process flow diagrams (PFD's))
- The activity per equipment is deducted from statistics on several sites (data from Paris)
- No breakdown maintenance (corrective maintenance) into account

Manpower on platforms

- For each equipment a routine maintenance yearly requirement (in hours for M,I & E) is used
- The site personnel time schedule is taken in account
- Not including the management levels

Appendix: Offshore O&M models

Although the gas production in the North Sea has been ongoing for many years now, only the last decade special attention is paid to allocating costs. The declining gas production of the maturing offshore assets in combination with a drop-in gas price has led to a strong focus on costs.

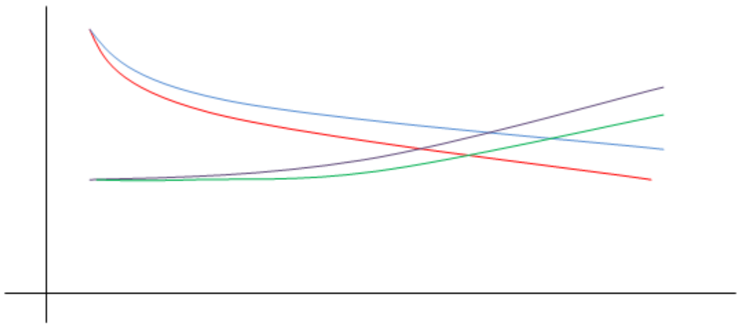


Figure 87. Maturing assets and declining production

The blue line represents the decreasing profit combined with the purple line that represents the increasing costs for the North Sea assets. A drop-in gas price (red line) gives an intersection of both curves sooner. The green line represents a change in maintenance strategy which reduces operational expenditure and extends the profitable lifetime of the field. *(McKinsey&Company, 2014)*

No O&M models for offshore O&G: 4 reasons:

- The Oil and Gas industry has had high margins on their products. Although the capital expenditure of an offshore gas field is extremely large the operational expenditure is relatively low in comparison to the turnover of an offshore development.
- Every offshore development is totally different. The location, environmental conditions and field layout are restricted to a specific field.
- Oil and gas majors have been operating in a very profitable and independent market. The companies have not shared their data and have not been able to learn from each other.
- The general idea of every growing demand for energy has put the focus on exploration and production, rather than the most cost effective servicing of the field.

The developments in the O&G industry have resulted in innovative ideas to challenge the current way of operating. Trends such as standardizing and minimizing offshore satellites platforms are getting more attention. An example is a presentation by Damen shipyard on "the synergy between E&P and wind". Although the offshore wind is an extremely young industry, their knowledge of O&M costs has been developed extensively. The O&M accounts for approximately 30% of the life cycle cost of a wind farm.

The many differences between the O&G industry and the offshore renewables make it difficult to draw a parallel between both industries. However, considering the scope of this research; remote location, unmanned, multiple platforms that are relatively close near each other and of course the access from the ocean a close show resemblance.

Offshore wind models

Many O&M models take the operational costs and the preventive maintenance costs as straightforward deterministic value while the corrective maintenance cost is a probabilistic value. In a wind farm the individual turbines produce "the same" amount of power while this is not the case with offshore satellite platforms. This research is especially focused on reducing the operational and preventive maintenance. By constructing a new O&M model it is designed for the O&G industry rather than the wind industry. By creating the model TEPNL's specific requirements and constraints can be met. By using the software that Total E&P is working with the model can be used in the future.

Appendix: North Sea Offshore – spot market

A spot market is a commodities market in which goods are sold for cash and delivered immediately. Due a drop-in oil price, E&P activities around the world have declined. Due to the high costs in the offshore support vessel market, some contracts are postponed, changed or even cancelled. An effect caused by the lower price is that OSV companies are also experiencing difficult times, because of the lack of OSV utilization. Because of these developments day rates have decreased substantially.

PSV market in North Sea

Offshore service companies, specialized in transportation of equipment, are playing with supply-demand of their vessels. Shipbroker Sea brokers argues that more than 30 PSVs are stacked in northwest Europe to modify the supply site.

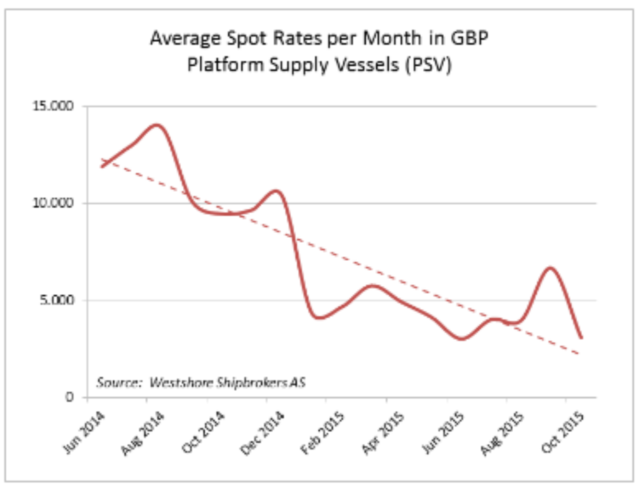


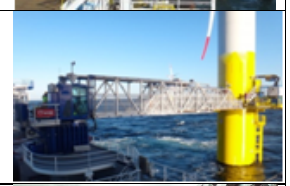
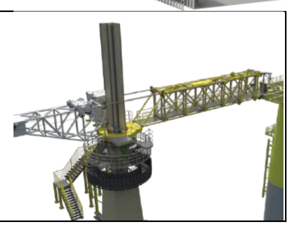
Figure 88. Average spot price platform supply vessel

Appendix: Boat landings

CONFIDENTIAL

Appendix: Marine transfer solutions 2016

Company	Hs limit [m]	Available on market	Safety record	Track record	Description	

SMST TRL: 7	3	Yes	No	Yes	- Modular - Both active + passive - No operators - DNVGL-ST-0358	
Z-bridge TRL:6	3.5	prototyp e	No	No	- High workability - High transfer height	
Ampelmann TRL:9	3.5	Yes	Yes	Yes	- Real time motion compensated - Extensive experience - Certified	
OAS TRL:7	2.5	Yes	Yes	Yes	OAS was developed by Offshore Solutions, which operates as subsidiary of Ampelmann Operations B.V.	
Uptime TRL: 9	3.5	Yes	Yes	yes	- Extensive experience - Approved after NORSOK and other HSEQ schemes	
Osbit TRL:8	3	Yes	Yes	Yes		
Barge Master TRL:6	3	prototyp e	no	Yes	- Experience with motion compensated technology - Possibility to integrate motion compensated crane	
Kenz TRL: 5	3	Prototyp e	no	no	- Offshore cranes background	
Safeway TRL: 6	3.5		no	No	- Test case jan.	

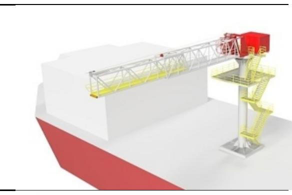
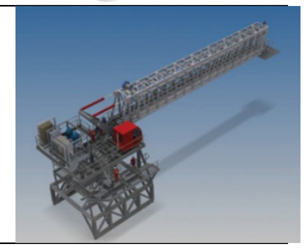
Osbit & seatools TRL: 4	3	Prototype	No	No		
Houlder TRL: 6	3	Prototype	no	no	- Both active and passive compensated -Large range of heights	
Motus TRL: 6	3				- Offshore cranes background	
MME TRL: 6	3	yes	no			

Table 33. Marine transfer solutions 2016

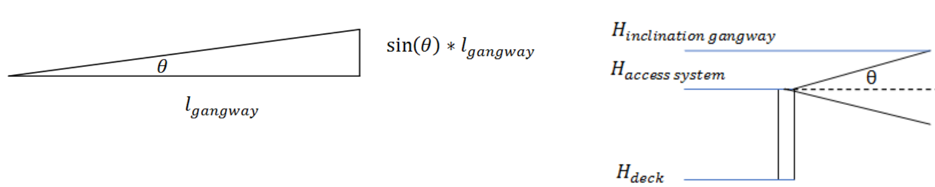
As shown by the number of access systems the offshore access market is rapidly developing. Resulting from this development, access systems prices will be more competitive. The selection criteria of any system should be based on: safety, price and operational range.

The combination of height of the vessel with access system and the length and inclination of the gangway define the interval of possible entrance heights. (For simplicity the impact of the height and its deflections, dynamic behavior, are not considered).

$$H_{\max transfer} = H_{deck} + H_{access\ system} + H_{inclination\ gangway}$$

$$H_{\min transfer} = H_{deck} + H_{access\ system} - H_{inclination\ gangway}$$

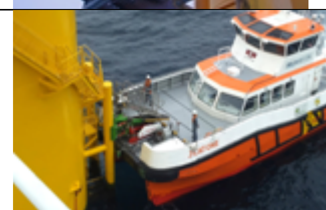
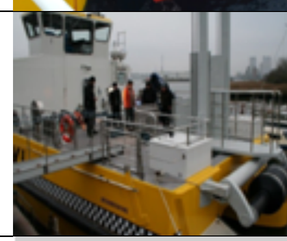
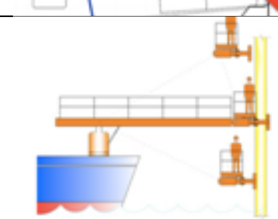
$$H_{inclination\ gangway} = \sin(\theta) * l_{gangway}$$



Inclination (degree)

Length gangway [m]	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
15.0	1.3	1.6	1.8	2.1	2.3	2.6	2.9	3.1	3.4	3.6	3.9
16.0	1.4	1.7	1.9	2.2	2.5	2.8	3.1	3.3	3.6	3.9	4.1
17.0	1.5	1.8	2.1	2.4	2.7	3.0	3.2	3.5	3.8	4.1	4.4
18.0	1.6	1.9	2.2	2.5	2.8	3.1	3.4	3.7	4.0	4.4	4.7
19.0	1.7	2.0	2.3	2.6	3.0	3.3	3.6	4.0	4.3	4.6	4.9
20.0	1.7	2.1	2.4	2.8	3.1	3.5	3.8	4.2	4.5	4.8	5.2

The second transfer mechanism considered is based on a smaller vessel (crew transfer vessel), the operational window will be much smaller and the greater dependency on the season needs to be considered.

Type	Hs limit [m]	Available on market	Safety record	Description	
TAS Turbine Access System • Mark II	3	Yes	Yes	- designed to be fitted on a small CTV. - no DP required - less dependent on friction by trust - active motion compensated	
MOTS (Momac Offshore Transfer system	3.2	Prototype	No	- a robot arm which compensates for the shipmotions and provides a stable platform for accessing	
MaXccess	2.5	Yes	Yes	- no stick-slip effect - step off point remains stationary - passive motion compensation - saves on vessel running costs	
Rolling Jack	2.5	yes	No	- a stabilizing platform on a ocean runner with a stern landing. - the rolling-system eliminates stick-slip - light weight vessels low energy consumption	
Pivoting deck vessel		no	No	- pivoting deck vessel concept which reduces the motion significantly during transfer.	
Autobrow		No	no	Autobrow is a partnership between Ad Hoc Marine Designs and South Boats,UK. The autobrow is a simple modular transfer system that can be retrofitted to existing vessels.	
Wind bridge		no	No		

Conclusion

Depending on the purpose (required number of transfers, season) a motion compensated gangway system is the best solution in North Sea conditions. Depending on the time span and economics, the most preferable systems are:

Short current (ad hoc)

- Ampelmann
- Uptime

Long term (near future 2018)

- SMST
- Z-bridge

The objective is to find one solution to service all platforms without large modifications to the structure. All platforms have one or multiple points for transfer, the height difference can be adjusted for by the level of inclination of the access system. The disadvantage of a larger gangway leads to a stronger and bigger system due to the enforced moment and larger displacements that need to be compensated. The relation between length and inclination should be given by the access system supplier.

Appendix: Access points

- Spider deck (range 6m – 8m)
- Horizontal part stairs (10m – 15m)
- Cellar/ Maintenance deck (16m – 22m)

The different access points require 2 different access solutions.

Smaller vessel + access system Range (6m – 12m)	15 K per/day.
Larger vessel + access system Range (16m – 22m)	30 K per/day.

The height required to access the structure depends on, the height of the access system on the vessel and the inclination of the gangway. To increase the access locations without modifications, the tip of the gangway could be equipped with a rounded solution. The load required to keep the gangway in to position ranges from 300 to 1000 kg (Fmax 1000N).

General Specification GS EP STR 901. Design rules and construction standards for ancillary structures of offshore and onshore installations

Appendix: PM hours per location per discipline

CONFIDENTIAL

$$\overline{w}_{year} = \frac{\sum_{n=1}^{14} hr}{n} \qquad \text{Eq 29.}$$

The Equation 29 averages all hours on the 14 satellites based on the table above. The annual average is 926 hours at each location, so approximately 1000 hours on each site.

Appendix: Literature

Optimization of maintenance and inspection

Title	Report/article	Published by:
"A model for optimization of maintenance support organization for offshore wind farms"	Paper	F.Besnard, K.Fischer, L Bertling IEEE Transaction on sustainable Energy
"on maintenance optimization for offshore wind farms"	Thesis for doctor of philosophy	Francois Bernard Gothenburg
Challenges of achieving a high accessibility in remote offshore wind farms	Master thesis	Christopher Anderberg Gothenburg
Operation & Maintenance	Presentation offshore wind farm design	Gerard van Brussels TU Delft
Development of a model to estimate O&M cost for onshore wind farms	Report	TU Eindhoven, MECAL, TU Delft
Lightning Damage of OWECS, parameter relevant for cost modeling	Report	ECN Wind Energy
Optimization of maintenance strategies for offshore wind farms, OMCE-calculator	Paper	R.P. van de Pieterman, H. Braan T.S. Obdam, L.W.M.M. Rademaker, T.J.J. van der Zee
Quantifying O&M savings and availability improvements form wind turbine design for maintenance techniques	Paper	J.Carroll, Ian Dinwoodie,Alasdair McDonanld, David McMillian
Advanced maintenance strategies for power plant operators – introducing inter-plant life cycle management	Paper	U.Graber
State of the Art and Technology trends for Offshore Wind Energy: Operation and Maintenance Issues	Paper	G.J.W. Van Bussel, A.R. Henderson, C.A. Morgan, B.Smith, R.Barthelmie, K.Argyriadis, A.Arena, G.Niklasson, E.Peltola
An integrated and Generic Approach for Effective Offshore wind farm Operation & Maintenance	Thesis	H. Koopsta, TU Delft

Transportation and supply chain optimization

Title	Report/article	Published by:
Routing helicopters for crew exchanges on off-shore locations	Article	G. Sierksma, G Tijssen, RUG
Logistic network planning for offshore air transport of oil rig crew	Article	N. Hermeto, V.Filho, L.Bahiense Petrobras & University of Rio de Janeiro
Testing the Robustness of Optimal Vessel Fleet Selection for Operation and Maintenance of Offshore Wind farms	Article	I. Sperstad, M.Stalhane, I.Dinwoodie, O.Endrerud, R.Martin, E. Warner
Vessel charter rate estimation for offshore wind O&M activities	Paper	Y.Dalgic, I.Lazakis, O.Turan
Robust Ship Scheduling with Multiple Time Windows	Paper	M.Christiansen, K.Fagerholt MARINTEK Trondheim
Discrete Time and continuous time formulations for a short sea inventory routing problem	Paper	A.Arga, M.Christiansen , A.Delgado
The vehicle routing problem: An Overview of exact and approximate algorithms	Paper	G. Laporte
Inventory routing problems	Paper	L. Bertazzi, M.Speranza

The exact solution of several classes of inventory-routing problems	Paper	L.Coelho, G. Laporte
The inventory-routing problem with transshipment	Paper	L.Coelho, J.Cordeau, G.Laporte
Industrial aspects and literature survey: fleet composition and routing	Paper	A.Hoff, H.Andersson, M.Christiansen, G.Hasle, A.Lokketangen

Appendix: Metocean conditions

The numerical data of K4A, L4A and L7B is available, based on the future developments, main producing platforms, and similarity in values of the blocks the L4A data, will be used for the specific case study. For this research only the operational conditions will be considered. The operational conditions can be simulated with a JONSWAP spectrum associated with a peak enhancement factor equal to 1.4 and spreading index equal to 6 for the cos2s distribution.

Conditions	Component 1	Component 2
Operational Total Sea	$y = 1.4 \,\&\, s = 6$	
Operational Wind Sea	$y = 1.5 \,\&\, s = 7$	
Operational Sea & Swell	$wind\ sea\ y = 1.6 \,\&\, s = 8$	$Swell\ y = 2.2 \,\&\, S = 12$

See excel file (metocean conditions) containing: Operational wind conditions, Operational wave conditions, Operational swell, Operational wave spectra, Operational current, Operational temperature seawater, Operational temperature air

When interpreting the metocean data from the North Sea the average and standard deviation are given below. The wave height is critical for loading and unloading, but also the speed at which a vessel can sail. Wait on weather (WOW)

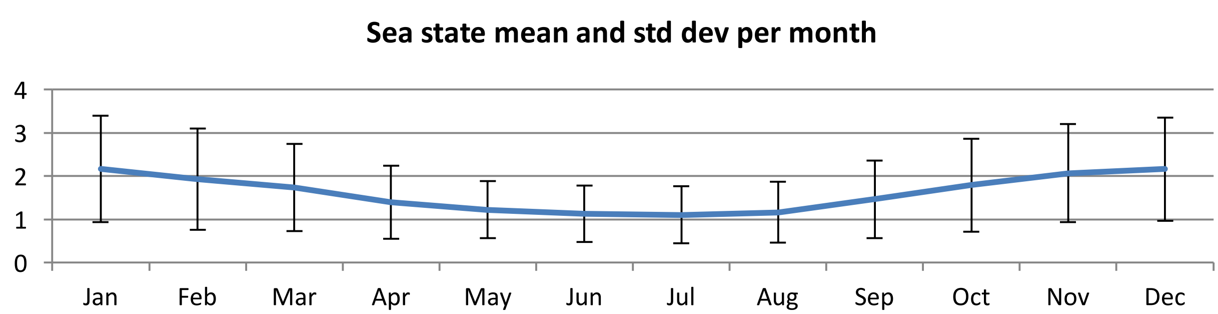


Figure 89. Mean and standard deviation of Sea state per month

All offshore operations are limited by wind, sea and weather conditions. Besides the many safety regulations and restrictions for operations in severe weather, the operators are limited by their corporate specifications.