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SIMULATION-BASED EVALUATION OF UPSTREAM LOGISTICS SYSTEM CONCEPTS FOR OFFSHORE OPERATIONS IN REMOTE AREAS

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ABSTRACT

Increased competition and low oil prices coupled with promising prospects for new oil and gas (O&G) reserves in the Arctic region has led to expansion of activities into the offshore Arctic. This brings along new challenges for the offshore logistics that need to be addressed. These challenges impose more stringent requirements for the logistics system setup, especially on the design and operation of vessels. Copying the logistics system and vessels designed for the North Sea operations is not a sustainable way forward. The few existing studies related to Arctic logistics mainly focus on ship technology solutions for cold and ice infested areas or solutions to the area-specific operational challenges for shipping companies. However, there is a need to understand how these solutions are connected and impact each other in a larger offshore supply logistics system, and thus address the challenges of Arctic logistics as a whole. A methodology for quick evaluation of the feasibility and costs of the logistics system in the early stages of offshore supply planning was developed and presented in previous research [1]. It allows for testing the effects of using alternative ship designs and the overall supply fleet composition on system's cost and performance while satisfying prospective campaign requirements. Safety standards and requirements for emergency preparedness and environmental performance are taken into account while cost effectiveness of the logistics system as a whole is the main quantifiable measure. Building on the new methodology a simulation tool for remote offshore operations has been developed and is presented in current work. Simulation models allow us to consider the dynamic and uncertain nature of variables, such as variation in weekly transport demand, weather impact on sailing times and fuel consumption, and schedule deviations. The evaluation of the performance of a logistic system is done by simulating the logistic operation over a large number of scenarios. Input parameters are weather data generated from historical observations and probability distributions for transport demand. Output from the tool are key performance indicators for: system costs, logistic robustness and emergency preparedness. The tool consists of three main components: simulation of a regular supply logistics operation, simulation of emergency situations, and visualization of the simulated operations. The proposed methodology and tool are tested on real-life cases for offshore supply planning of drilling campaigns in remote areas for one of the major international O&G operators.

INTRODUCTION

Increasing scope of oil and gas (O&G) activities in remote areas impose new challenges for the offshore logistics. For the Arctic region these, first and foremost, are the harsh weather conditions with few daylight hours, low temperatures, fog, wind and the marine icing phenomena. Vessels and personnel need to be well-prepared to operate in these conditions and manage ice-infested waters. The remoteness of land and necessary facilities and infrastructure adds to the complexity of operations and requires new operational thinking, advanced technology and innovative ship design. Remote operations, especially with regard to safety and emergency preparedness become increasingly dependent on the presence of other maritime and O&G activity in the area. Lastly, government regulations and industrial policy requirements need to be complied with.

These challenges impose more stringent requirements for the logistics system setup, especially on the design and operation of vessels. Copying the logistics system and vessels designed for the North Sea operations is not a sustainable way forward. A more structured and innovative approach is needed. The up-to-date research does not suggest any new comprehensive decision support framework or tools that are based on current industry practices that can be readily applied in the planning and evaluation stages for new developments. This, however, is the main goal behind this work on upstream offshore logistics evaluation and the corresponding tools developed for assessment and analysis of possible logistics system alternatives presented here and in the previous research [1].

The few existing studies related to Arctic logistics mainly focus on ship technology solutions for cold and ice-infested areas, like Erceg et al. [2], Ehlers et al [3] and Ehlers & Østby [4]; or solutions to the area-specific operational challenges for shipping companies, like for example Kisialiou et al. [5] and Schartmüller et al. [6]. One study by Hasle et al. [7] provides an insight into industry practices for considering environmental risks in the decision process for new exploration, and the oil company's tools and criteria in decision making, in this case with a particular application to the Norwegian Barents Sea.

Fleet size and routing and scheduling problems for the supply vessels servicing O&G activities in the North Sea have been studied extensively in the last decade. Some important contributions just to name a few are Maisiuk & Gribkovskaia [8], Shyshou et al [9] and Halvorsen-Weare et al. [10] where the two former studies incorporate stochasticity due to rough weather conditions at sea and their effects on supply operations. Studies related to the offshore logistics in the Arctic are few but very recent. Molyneux&Boyd [11] study the performance of an existing offshore supply vessel (OSV) fleet serving the Grand Banks region off the coast of Newfoundland and the necessary improvement to supply fleet composition and operations for developments in more remote areas. Milakovic et al [12] describe a typical offshore logistics system and point out Arctic-specific challenges as well as the interdependencies of the multiple stakeholders in the Arctic offshore development. Bergström et al. [13] describe a maritime transport system for an LNG (liquefied natural gas) project incorporating effects of uncertain sea ice conditions and the choice of vessel's ice class. Ulstein [14] developed a simulation model to quantify the environmental effects on the duration of supply vessels operations, and tested the model's capability to find an optimal fleet composition from a range of supply vessels of different deadweight while in operation in Arctic conditions.

Due to increased interest of O&G operators in activities in remote areas and the Arctic, in particular, and a limited number of cross-disciplinary studies to provide proper insight there is a need to understand how the vessel design and logistics solutions are connected, and impact each other in a larger offshore supply logistics system, and thus address the challenges of the Arctic and potentially other remote logistics as a whole.

SCOPE

Improvement of cost effectiveness in logistical solutions for the supply of offshore O&G activities is the main guidance for the study, without however compromising on safety, emergency preparedness and environmental performance. It should be noted that new solutions could enable a more reliable emergency preparedness setup with a better time-response, even and especially given the remoteness characteristics.

Two dimensions are used to scope out the solution spectrum: logistics system concepts & practice of operations, and vessel design & technology. This is a change from the current practice that is more or less based on current technology and logistics practices from near-offshore operations. Utilising the proposed methodology future developments within offshore vessel design that satisfy new requirements can be mapped, the drivers for the design development can be identified along with alternative lines of design, and the regional distribution of the use of different types of design.

For the logistics concepts the overarching goal is to reduce the total number of vessels involved through a multifunctional analysis of offshore operations. Extra vessels are often added in remote operations in order to cover specific functions required (such as oil spill response (OSR) and surveillance) rather than increase transport capacity. These functions can instead be covered by multifunctional vessels or standard vessels with additional equipment and/or advanced technological solutions (e.g. drones). A smaller fleet is easier to control, hence safer and more reliable. It is more cost efficient and produces less emissions. Any further vessel design improvements will only contribute to the overall effectiveness.

For the operational practices, the focus is to reduce the number of movements to and from the offshore operation area, including improvements in the balance of logistics load between to and from the offshore installations. The latter will also be impacted for instance by the choice of the drilling technology.

EVALUATION METHODOLOGY

In a feasibility study phase of any type of development it is important to be able to make comparative assessments of alternative concepts and options thereof. Logistics system feasibility studies shall enable rapid investigation and benchmarking of a number of alternative concepts and options in an early phase of the decision process. As such, they represent an approach that can be used to assess new supply chain management practices in a range of industries.

Several logistics feasibility studies were performed for the offshore upstream supply chains of oil operators. One of these by Fagerholt & Lindstad [15] was addressing the supply vessel requirement for supply from an onshore supply base on the west coast of Norway. This study enhanced the structured understanding of the supply demand, and the capacities of the supply vessels, and used this to optimize the routing of the supply vessels to suggest cost-minimal supply vessel use that covered the cargo supply demand to the offshore installations. One other example of a comparative supply chain study of the offshore upstream supply chain covering both the supply vessel design and the complete supply chain infrastructure including offshore warehouses for remote developments was performed by Nordbø [16].

In this research the ambition is to find new logistics solutions that represent an improvement step-change, not only an incremental improvement of existing solutions. In order to achieve this, the functional concept assessment (FCA) method has been developed and applied, Lindstad et al [17]. The method is divided into three phases focusing on functional requirements, concept alternatives and assessment as shown in Figure 1.
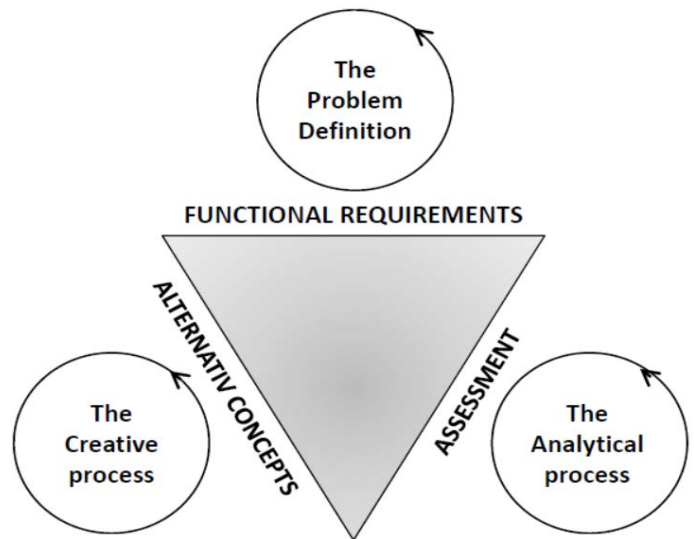

Figure 1. Functional concept assessment.

The problem definition phase

The FCA method starts with establishing the functional requirements for the logistics solution. This is done by defining the problem in terms of decision variables, constraints and assumptions, and finding an appropriate set of KPI's. Target value limits for the KPI's represent functional requirements for the solution. For an offshore logistics concept, the requirements are typically related to transport capacities, delivery frequency, lead-times, robustness and emergency preparedness.

The creative process

The main goal here is suggest alternative concepts, think outside the box suggesting drastic changes compared to the current technology or operations. Concepts with smaller changes that have low implementation time/cost should also be considered, as these could be "low-hanging fruits". The creative process depends strongly on the knowledge, experience and confidence of the involved parties. Changing the base location, introducing new vessel designs and configuring the fleet differently are examples of alternative offshore logistics concepts.

The analytical process

When alternative concepts have been suggested, these need to be analysed quantitatively and qualitatively against the functional requirements and KPI's. To do this in full detail could be time-consuming, and hence limit the number of alternatives one is able to consider. It is therefore important to develop high-level analytical tools that enable rapid screening of alternatives. The promising alternatives should then be looked further into with detailed tools, see Figure 2. For the offshore logistics problem, a model in MS Excel for rapid static calculations has been developed, presented in [1]. The next step providing a more detailed assessment of supply alternatives is based on a simulation tool presented in next chapters.

The FCA method results in a shortlist of logistic concepts satisfying the functional requirements, with the accompanying quantitative and qualitative assessments. When performed correctly, the highest ranked concepts will be closer to the global optimum, instead of just incremental improvements achieved with the traditional approach for logistic studies.
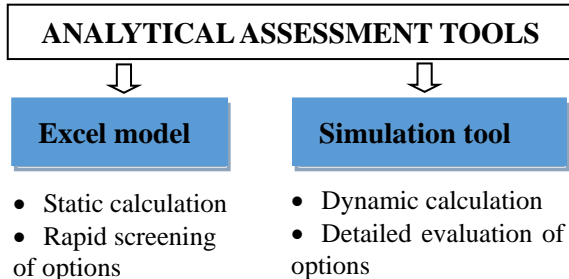

ANALYTICAL ASSESSMENT TOOLS

Excel model
- Static calculation
- Rapid screening of options

Simulation tool
- Dynamic calculation
- Detailed evaluation of options

Figure 2. Analytical tools for the assessment of logistics system alternatives.

SIMULATION MODEL

While the Excel based feasibility study model presented in [1] is based on a set of simplifications, assumptions and static input data, a simulation model is suitable for investigating the more dynamic behavior of a logistics system. The calculations in the static model are based on fixed values. For instance, it is assumed that a vessel's sailing time between the base and a rig is a fixed number of hours. In real life, however, this figure may vary a lot from day to day, depending on weather, time of the day or the cargo on board. In the simulation model, all such variations are taken into account.

Simulation means that we imitate the behavior of a given logistics system over time in a pre-defined scenario. By doing this repeatedly over a large number of scenarios, a more realistic evaluation of a logistics system can be achieved. Figure 3 shows an overall structure of the simulation model.
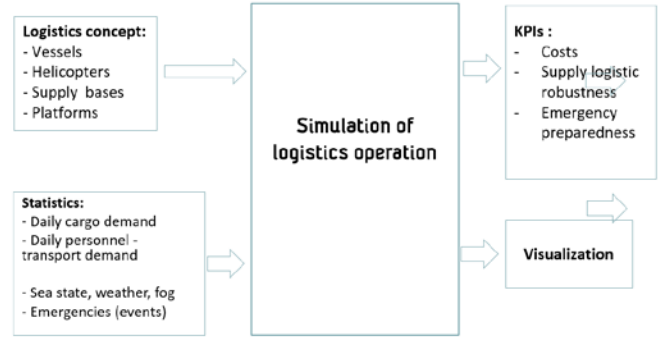

Figure 3. Simulation model.

Input data

The input to our simulation tool is quite similar to that of the static feasibility model. Every logistics system concept is described by a set of vessels and helicopters, with capacities, speed, fuel consumption, charter costs etc. Locations of supply base and rigs are used for calculating distances. Length of the campaign period and average turnaround times at base and rig are also necessary inputs. In opposition to the static model where capacity requirements are important input parameters, average weekly demand for cargo and personnel transport is used in the simulation model. All the input data can be edited and stored in an Excel work book, which can be read by the simulation application.

Scenario generation

The scenario generator module generates a large number of realistic scenarios based on a set of input parameters. A scenario consists of generated weather data (wave height, wind speed and fog) for the entire rig operation period. The weather data is based on several years of historic data from the area in question. If detailed weather data is not available, the module can instead generate a set of daily sea margins.

Furthermore, a scenario consists of bulk cargo, deck cargo and personnel transport demand for each day. Cargo demand is based on input parameters for the average weekly demand of bulk and deck cargo. A probability distribution formula derived from historical data is then used to stochastically generate the daily amount of cargo to be shipped from the base to the rig. This leads to a realistic variation in the cargo demand, both from day to day, week to week, and from scenario to scenario.

When comparing several different logistics systems, the same set of scenarios will be used for all of them, reducing the risk of unfair assessment.

Simulation

The simulator application is implemented in Java. The simulation starts with day one. As soon as a vessel is ready at the base, and there are available cargo to load, it loads as much at its capacity allows. Then, based on the current weather, the sailing time to the base is calculated. When it arrives at the rig, the turnaround time is calculated based on weather, amount to discharge and the average turnaround time at the rig. In the same way, all the movements of the vessel are simulated until the end of the campaign period. The behaviors of all the agents of the system, i.e. supply bases, rigs, ships and helicopters, are simulated in parallel. A discrete event simulation framework makes sure that all the interaction between the agents are synchronized. Since the logistic systems evaluated in this study are relatively simple, the scheduling of the vessels in the fleet is done by a greedy heuristics that, by simple rules, decides when and where the vessels should sail.

In remote areas, PSVs in the supply logistic system are possible valuable resources in case of an oil spill incident. The number of vessels in the fleet, their speed, their OSR capability and the sailing pattern of the fleet will affect the systems total response time. The simulation model continuously calculates the response time for the vessels, given their simulated positions.

The computational time is acceptable. For example, performing 1000 simulations of a 100 days campaign with a fleet of three PSVs and a helicopter takes approximately twenty seconds.

Model output: Key performance indicators

The output of the model is a set of key performance indicators of the evaluated logistics system. There are economic indicators, like *total cost*, *CAPEX, OPEX, VOYEX*. Then there are capacity and service indicators, like *visiting frequencies*, amount of *bulk and deck cargo transported*, *cargo delays*, *waiting time for helicopter passengers and idle times*. Finally, there are performance indicators for the systems oil spill preparedness. The model calculates *average response time for the first OSR ready supply vessel*, *worst-case response time*, and *percentage of the simulation runs that has a response time that violates the given time limit*s. For easy comparison of different logistics system concepts, the simulation tool displays average KPIs for each concept. It is also possible to study the underlying KPIs of each single simulation run. Figure 4 shows a screen shot from the tool, displaying some simulation results.

Figure 4. Example of simulation results.

Visualization of a single simulation

During the simulation runs, every state change of the agents (rigs, bases, helicopters, vessels) is logged in an action log. The tool also includes a visualization module which can display a single simulation run as movements in a map.

Graphs showing the level of cargo demand, and oil spill response time as function of date and time are simultaneously displayed, see example in Figure 5. By studying the fleet movements and the graphs, the decision maker using the tool can gain further insight in how a given logistics system will behave under certain conditions.
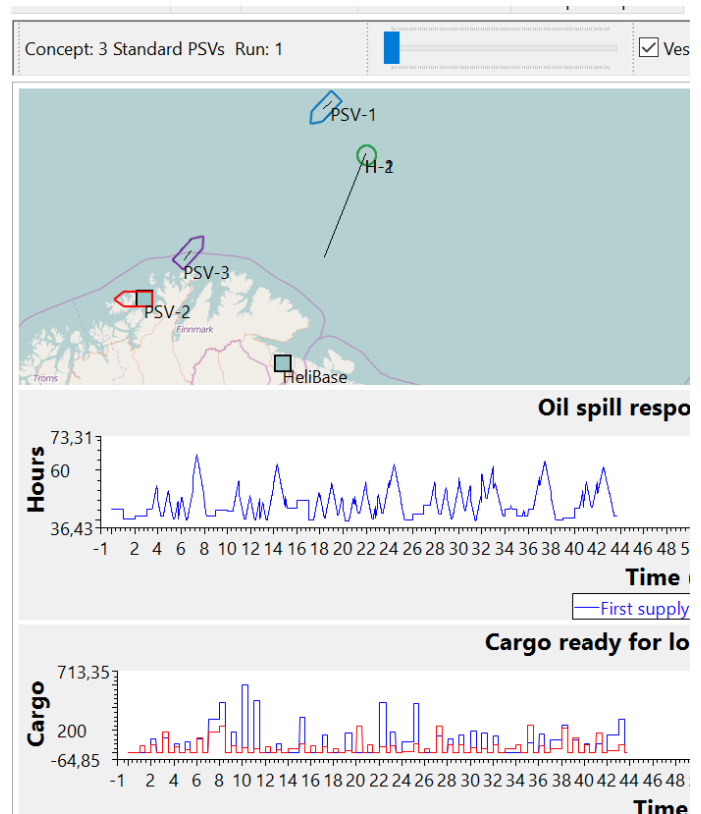

Figure 5. Visualization of a simulated rig supply operation.

CONCLUSIONS

Our studies have shown that using simulation for evaluating a logistics system concept can give valuable documentation of its capacities and robustness. When comparing the results of simulation with the ones from the static feasibility model, we see some differences. In some cases, two logistics concepts that seem to perform almost identically when evaluated by the static model, turn out to be rather different when they are evaluated by simulation over several different scenarios.

Finally, using the simulation tool and the visualization module can, in some cases, reveal certain patterns or show critical bottlenecks in the logistic systems. If we consider the FCA model, this information can in turn be used as input to the creative phase, in order to suggest new concepts.

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