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Integrated Domain Model for Operative Offshore Installation Planning

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Purpose: This article aims to identify common structural elements in the descriptions of both approaches, enabling the application of model transformations.

Methodology: Several models of both types will be compared, combining relevant concepts, i.e., entities, attributes and relationships into a generalized model. In a second step, elements crucial to either type of model are identified. For the remaining elements, interdependencies and redundancies will be identified to enable a model reduction.

Findings: While the structure and notation of both approaches are different, both describe the same fundamental concepts and relationships. The article provides a data model of these common concepts for the operational planning of offshore activities, including weather restrictions and forecasts.

Originality: In current literature, there exist no approaches to combine mathematical optimization with event-discrete simulations in the context of offshore wind farm installations. To harness the advantages of both approaches in an integrated methodology, a model of common concepts is required, which does not exist at this time.

Keywords: Offshore Wind Energy; Operative Installation Planning; Domain Model; Mathematical and Simulation-Based Models

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1 Introduction

Wind energy constitutes one of the most promising technologies to generate large amounts of sustainable energy. In 2017 new wind farms with a capacity of 52 Gigawatts were installed, raising the amount of energy produced by wind energy by approximately 11% to a total of 539 Gigawatts word-wide (REN21, 2018). In this context, offshore wind farms (OWF) are particularly capable of delivering large amounts of energy due to the higher availability of wind and higher wind speeds at sea (Breton and Moe, 2009; Sun, Huang and Wu, 2012). According to (REN21, 2018) an exponential increase in offshore wind energy could be observed over the last decade.

Despite the apparent advantages of OWFs, their installation, operation, and maintenance pose particular challenges compared to onshore wind farms. Generally, offshore wind turbines are higher powered, and their components are larger and heavier than their onshore counterparts, resulting in increased costs, e.g., for founding structures, network connection, and resources, like vessels and storage spaces. Besides, highly dynamic weather conditions at sea render consistent mid- to long-term planning of resources and operations difficult. Generally, about 15% to 20% of the costs for OWFs can be attributed to logistics during the construction process, demonstrating high potentials for optimization (Lange, Rinne and Haasis, 2012; Dewan, Asgarpour and Savenije, 2015; Muhabie, et al., 2018). Current research shows a trend towards more high-powered wind turbines with capacities over 10 or 12 Megawatts, e.g., compare the European research project (European Council, 2018). Such turbines generally require deeper water with depths of 20-50 meters for installation, which are commonly located at distances starting at 30 km to 100 km off the shoreline (Muhabie, et al., 2018), further complicating the planning and execution of operations.

To support decision making during the installation of OWFs, suitable decision support systems are required, which combine capabilities for long-term planning with short-term control. On the one hand, long-term plans can reduce the overall cost efficiently by allocating resources. On the other hand, a decision support system requires short-term control strategies to cope with ever-changing weather conditions and to handle uncertainties involved with weather forecasts. In previous work, we identified several planning tasks, which make up the overall planning problem for the installation of offshore wind farms. These cover different time horizons and activities, which range from the overall long-term capacity planning for vessels and storage, over the production and transport planning of components to the short-term operations planning (Rippel, et al., 2019a). For each of these planning tasks, there exist different approaches in the literature that can be classified in simulation-based approaches and mathematical/optimization based approaches. Each of these classes provides its particular advantages and disadvantages compared to the other, e.g., in terms of speed or solution quality.

This article focusses on the operational planning of offshore operations in the context of the OWF installation planning. To harness the advantages of both model classes, this article aims to identify shared concepts between these classes and to summarize this information into a consolidated domain model. Using this domain model, model transformations can be enabled to convert in between simulation-based and mathematical approaches to evaluate and compare their individual performance. According to (Larman, 2001) a domain model is used to decompose a targeted domain into noteworthy concepts, attributes and associations, thus describing which objects and concepts are important for a given area of focus. Domain models can take different forms and complexities, from simple schemes for databases to complex models, including inheritance and interdependencies (Fowler, 2011). Common choices for domain models are logical modelling languages (e.g. for ontologies) or the Unified Modelling Language, as chosen for this article.

The next section 2 shortly sketches the installation process. Afterward, section 3 summarizes current planning approaches and discusses the advantages and disadvantages of their corresponding classes. Sections 4.1, presents the methodology used to derive the domain model, while sections 4.2 and 4.3 describe its application to mathematical formulation and simulation-based formulations to determine parameters and the class hierarchy. Finally, section 4.4 presents the consolidated domain model for the operational installation planning of OWFs. Finally, the article closes with a description of future work.

2 Process Description

According to (Vis and Ursavas, 2016) and (Quandt, et al., 2017) the installation process comprises three stages: First, the installation of foundations and the connection to the energy grid. Second the installation of top-structures and third, the ramp up and commissioning. Commonly, one service provider is responsible for the installation of foundations and cables, and another provider takes over the installation of top-structures and the commissioning. These service providers usually conduct their own tasks sequentially, i.e., the installation of top-structures generally commences after all foundations are installed and connected. In practice, it is not uncommon, that these stages take place in different years, i.e., in the first year all foundations are installed, in the second year, the remaining stages are conducted. While the components and resources in the first and second stage are different, the overall process remains the same. This results in two, more or less, independent planning problems of the same overall type.

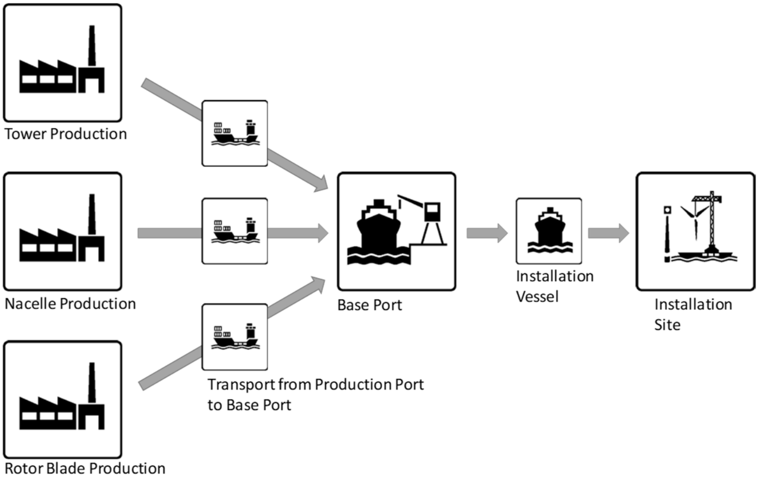

Figure 1: Conventional installation concept (Oelker, et al., 2017)

In literature, there exist two different concepts for the overall installation process. The classic concept, which is also used in this article, is given in Figure 1. This concept assumes that the components are buffered at a so-called base port before installation. So-called heavy lift vessels (HLV) perform the transport from the production sites to the base port as these vessels usually come at comparably low charter rates. During the construction process, an expensive installation vessel, usually a so-called jack-up vessel, picks up these components from the port, travels to the installation site and performs construction there. In contrast, feeder based concepts try to eliminate expensive travels of the installation vessel from the base port to the installation site by directly feeding components from the manufacturing sites to the installation site (Oelker, et al., 2018), or if necessary, from the base port (base-port feeder concept) (Ait Alla, et al., 2017) to the installation site by specialized heavy lift vessels. For this concept, these HLVs require specific technologies to enable transshipment operations, e.g. to remain steady while loading or unloading components at sea.

The installation of the top-structures is performed sequentially, generally in a single session (Rippel, et al., 2019b): Therefore, the installation vessel first positions itself close to the foundation and begins its jack-up procedure. Afterward, the components are assembled from bottom to top as tower, nacelle, blades and finally the connecting hub. Once the installation is completed, the vessel jacks-down again and moves to the next installation site or back to the base port. After the jack-up has been finished, installation vessels usually remain stationary until they finished the installation. In practice, a single position should only be used once for jacking-up to avoid damaging the foundations or even the installation vessel itself, as the seabed is punctured, sometimes for several meters, during jack-up. Each of the listed offshore operations requires specific weather conditions to be performed, which are usually given by maximum wind speed and maximum wave height. If these requirements are not met for the entire duration of an operation, the operation cannot be started or has to be aborted and restarted later on, resulting in expensive waiting times for the installation vessel. As a result, dynamic weather conditions at sea can result in high, unplanned costs. Moreover, charter contracts often set different prices for vessels being in port and for being offshore, which can differ by approximately 30% (Rippel, et al., 2019b).

3 Current Planning Approaches

Whereas the overall installation planning comprises several sub-tasks, the operative installation scheduling provides the most important of these tasks. While it is constrained, e.g., by available capacities, optimal capacities cannot be determined without an operative schedule or plan. Consequently, this article focusses on approaches for the operative plan generation.

3.1 Classification of Approaches

Within the literature, only a few articles deal with the operative installation planning explicitly (Vis and Ursavas, 2016). Nevertheless, these approaches can be classified according to their usage, either of mathematical formulations or event-discrete, usually agent-based, approaches. In general, both model classes provide their own advantages (Rippel, et al., 2019a):

Simulation-based models usually have a high level of detail, as they model and simulate the behavior of single entities and their interactions over time. This facilitates the inclusion of time-dependent data, e.g., weather information, which the simulation can sample at every time instance. The most common form of these models found in literature represents discrete-event or multi-agent simulation models. For plan generation, simulation-based approaches can record the different actors' decisions and events during the simulation run and provide these as a plan afterward. To enable the generation or optimization of plans, a distinct optimization component is required. In general, choices for such optimizers are, e.g., Genetic Algorithms, Tabu-Search or similar metaheuristics. These approaches can be found for various planning tasks in literature and are usually referred to as simulation-based optimizations. For example, (Frazzon, Kück and Freitag, 2018) apply genetic algorithms for manufacturing planning and scheduling. Nevertheless, in the context of the installation planning for offshore wind parks, the literature review shows no applications of simulation-based optimizations as shown further below. All identified simulation approaches in this domain only focus on the simulation of predefined scenarios.

While the high level of detail allows simulation-based approaches to evaluate a scenario thoroughly and enables a high degree of adaptability when it comes to different settings and conditions, the high computational requirements and high complexity in creating and maintaining the model can be considered a disadvantage. These hold especially true if combined with simulation-based optimizations, which usually have to evaluate a large number of scenarios. Moreover, when the overall planning problem becomes larger, e.g., by integrating the capacity planning, the simulation model and the corresponding amount of required experiments grow accordingly. In simulation-based approaches, it can be hard to impossible to split several, interconnected planning tasks into separate models.

Mathematical models usually come tailored to the problem they should solve, resulting in a more focused and reduced formulation. Moreover, most mathematical models found in the context of the offshore wind farm installation planning represent optimization problems. Models of this class rarely simulate the actors' decisions or events that happen over time but calculate plans or solutions on a more abstract level of detail. If set-up correctly, these models can yield optimal solutions with comparably low computational times for single tasks of the overall planning problem. In contrast to simulation-based approaches, distinct models can solve separate planning tasks, e.g., operations planning, capacity planning, etc., only requiring the corresponding constraints and results of other models. This facilitates the model creation and maintenance as several smaller models can be easier to handle than a single, complex model. Moreover, models can be developed for different tasks on different levels of abstraction, allowing for a more detailed selection of tasks to include in the current evaluation.

While the variable level of abstraction provides significant advantages, the inclusion of dynamic, time-dependent effects constitutes a major challenge. Higher levels of abstraction also require more abstract representations of such effects, which can result in unreliable results or prevent certain degrees of abstraction altogether.

3.2 Literature Review

In current literature, no work applies simulation-based optimization using discrete-event or multi-agent simulations. Nevertheless, there are several approaches, which use this class of models for an evaluation of predefined settings. (Muhabie, et al., 2018) present a discrete-event simulation to compare the effects of dynamic or static assumptions on weather conditions. (Vis and Ursavas, 2016) also apply discrete event simulations to assess the impact of different preassembly strategies on the overall installation process. (Ait Alla, et al., 2017) present a multi-agent based simulation to compare different installation concepts, i.e., the conventional and feeder based concepts. This model is further adapted in (Oelker, et al., 2018) and is also used in this article to determine required concepts and attributes in simulation-based models.

For mathematical models, most of the literature focuses directly on optimization models or on the development of cost models to evaluate different settings against each other. In terms of cost models, (Quandt, et al., 2017) presents a formulation to assess the impact of information sharing between involved companies. (Beinke, Ait Alla and Freitag, 2017) describes a formulation to determine the effects of resource sharing, focusing on sharing heavy lift vessels between different installation projects. (Kerkhove and Vanhoucke, 2017) present a precedence-based formulation of a scheduling problem, focusing on the cost-optimization in commissioning and decommissioning vessels within an installation project. Thus, this formulation presents a mixture of cost model and plan optimization. While most of the following approaches consider either total cost or the overall construction time, they usually rely on less sophisticated formulations for the costing part than the earlier described models. (Irawan, Jones and Ouelhadj, 2017) proposes a time-indexed formulation for the scheduling of offshore operations using a multi-criteria optimization to find the optimal tradeoff between short construction times and minimal overall construction cost. This model was later on extended for the decommissioning of offshore wind farms in (Irawan, Wall and Jones, 2019). (Scholz-Reiter, et al., 2010) propose a combination of a precedence-based job-shop scheduling formulation with a multi-periodic production formulation to optimize operative schedules, later proposing a heuristics-based solution algorithm in (Scholz-Reiter, et al., 2011) for solving larger problem instances. The same model was extended in (Ursavas, 2017) to include probabilistic assumptions about weather conditions. In (Ait Alla, Quandt and Lütjen, 2013) the authors propose a time-indexed job-shop scheduling formulation to determine the number of offshore operations to be conducted within a series of 12-hour timeframes. (Rippel, et al., 2019b) describes a time-indexed scheduling formulation to generate operative plans under varying durations for each operation.

4 Domain Model for the Operative Planning in the Installation of Offshore Wind Farms

This section describes the procedure and results of the domain model deduction. Therefore the next subsection presents the overall applied methodology. Afterwards, the application of selected steps of this methodology is described in more detail. Finally, this section presents the overall domain model.

4.1 Methodology

In general, there exists no standardized procedure to develop domain models. Nevertheless, (Stuckenschmidt, 2011) summarizes some best practices and proposes the following iterative steps to obtain a generalized domain model:

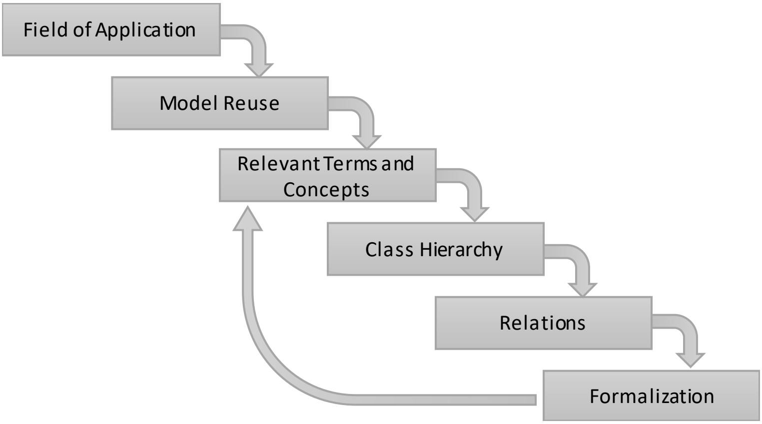

Figure 2: Procedure as proposed by (Stuckenschmidt, 2011)

The first two steps aim to focus the future domain model on the most relevant aspects and to reuse other existing models in the selected domain. Afterward, (Stuckenschmidt, 2011) proposes to follow the next steps iteratively, i.e., to define essential elements of the domain model, integrate them into a class hierarchy, define their relations to other concepts, classes or aspects of the domain model and finally to formalize those elements. During each of these steps, new ideas can arise, e.g., the introduction of more general classes, which requires to refine the overall domain model iteratively.

1. Focus the field of application: The first step in setting up an appropriate domain model, is the definition of the model's focus. The domain model presented in this article focusses on the operative installation planning of offshore wind turbines.

2. Reuse of existing models: The second step aims to identify existing models for this domain which can be used to derive essential concepts and parameters during the subsequent step of this procedure and to simplify the overall domain model design. In the case of the operative offshore installation planning, no other existing domain models could be identified. Nevertheless, several simulations and optimization models have already been described in section 3.2.

3. Identification of relevant terms: The third step of the procedure aims to identify relevant concepts, objects, parameters and relationships within the domain. For example for the operative installation planning such terms are *vessels* and *ports*, but also more abstract concepts like *plans* and *operations*.

4. Definition of a class hierarchy: In a fourth step, the first draft of a hierarchy of the identified terms is setup. Therefore, parameters are assigned to their respective classes. In particular, when working with existing models, this step is used to reorder and aggregate parameters found under different names or notations in different models. Moreover, it is quite common, that different models express the same concept in different ways or use a distinct subtype of the same basic concept.

5. Definition of relations: The next step covers the identification and definition of relationships between these classes. One Example can be the relationship that *vessels* are used in installation *projects* or that *vessels* can perform *operations*. For this purpose, different kind of relationships, e.g., associations, generalization or aggregation, can be used to express relations. Descriptions of common relationship types can be taken from *Unified Modelling Language* (UML), which is often used to describe domain models, or from the *Web Ontology Language* (OWL), which is a logic-based modeling language.

6. Formalization of classes: The final step of the procedure aims at the formalization of the designed domain model. This means that the identified classes and relationships are modeled using a modeling formalism like UML or OWL. Depending on the overall design goal, changes to the class hierarchy or the relationships can be required to satisfy the formal constraints of the selected language. For this article, UML-Class Diagrams were chosen to represent the domain model, as these diagrams are comparably easy to understand while allowing to depict even complex relationships between classes.

To create a common domain model for mathematical and simulation-based formulations for the offshore installation planning, the described procedure was applied in two stages: First, mathematical formulations were used to obtain commonly used parameters. Articles using mathematical formulations tend to describe their model thoroughly, including all relevant parameters and variables. Therefore, they provide a rich source of information on all aspects required for the domain model. During the second stage, simulation-based formulations were used to obtain a clearer picture of superimposed concepts and classes. In contrast to mathematical formulations, articles rarely present a comprehensive description of the underlying simulation model. Consequently, most information regarding simulation-based approaches and their structure can be derived from the parametrizations given. Nevertheless, for this article, we obtained the AnyLogic simulation model used in (Oelker, et al., 2018), which was used as a baseline for the second stage. Additional information was derived, e.g., from (Dewan, Asgarpour and Savenije, 2015), who describe several different settings and scenarios which can be simulated using their tool.

4.2 Definition of Relevant Terms and Concepts from Mathematical Formulations

To identify relevant parameters for the domain model, the mathematical formulations described before were analyzed. Therefore, the parameters and variables were aggregated, consolidating parameters, which have different names or notations in their models. In conclusion, 44 different parameters were identified. Table 1 summarizes these parameters and provides their relative frequency of occurrence. Thereby, a rating of three means that the parameter was present in most, if not all of the models ($\geq$ 70%), while parameters with a rating of one appeared in less than 30% of the models.

Table 1: Aggregated parameters and relative frequency

Parameter	**Rel. Freq.**	**Parameter**	**Rel. Freq.**
Number of Turbines	●●●	Day Rate Active	○○●
Component Type	●●●	Day Rate Waiting	○○●
Comp. Installation Time	●●●	Loading Capacity	○○●
Component Loading Time	●●●	Port Produces Component	○○●
Number of Vessels of Type	○●●	Operation Learning Rate	○○●
Req. Weather to Install	○●●	Number of Jobs	○○●
Seq. of Weather Classes	○●●	Distance between OWT	○○●
Num. of Planning Periods	○●●	State of Turbine in OWF	○○●
Planning Period Length	○●●	Fixed Project Cost	○○●
Traveling Time to OWF	○●●	Energy Per Turbine	○○●
Vessel Type	○●●	Process Chain	○○●
Vessel Loading Scenarios	○●●	Setup Time (Load. Scenario)	○○●
Required Weather to Load	○●●	Setup Cost (Load. Scenario)	○○●
Timeseries of Weather Data	○●●	Seafastening Time	○○●
Project Start Date	○●●	Transshipment Time	○○●
Distance to OWF	○●●	Jack-up Rate (Time)	○○●
Travel Speed	○●●	Minimum Renting Period	○○●
Port Storage Capacity	○●●	Commissioning Cost	○○●
Req. Weather Seafasten	○○●	Decommissioning Cost	○○●
Req. Weather Transship	○○●	Port Process Times (Load)	○○●
Cost for Vessel in Period	○○●	Port Weather Rest. (Load)	○○●

4.3 Class Hierarchy from Simulation-Based Models

Comparing the already acquired parameters with the simulation model from (Oelker, et al., 2018) and parametrizations given in the literature for other simulation models shows complete coverage of all used parameters by the domain model from section 4.2. Nevertheless, as simulation models usually focus on the elements they simulate, these models provide comprehensive information on the overall structure of classes and relationships. An analysis of the simulation model used in (Oelker, et al., 2018) shows, that agents mostly comprise vessels (Installation Vessels, Heavy-Lift Vessels) or locations (Base Port, Production Port, and Wind Farm). Several additional classes are used to capture additional logic and behavior but directly relate to the stated elements. Based on information about the class hierarchy derived from simulation-based models and information about parameters taken from mathematical formulations, the domain model was created.

4.4 Generalized Domain Model

Figure 3 shows all data types, i.e. enumerations, used in this domain model. These constitute lists of different types of objects in the domain. For example, the enumeration *Components* lists all Components relevant for the operative installation scheduling found in literature. Throughout all class diagrams, alternative formulations are given in brackets. For example, some models refer to *Piles* and *Cables*, while other models subsume these as *Foundations*.

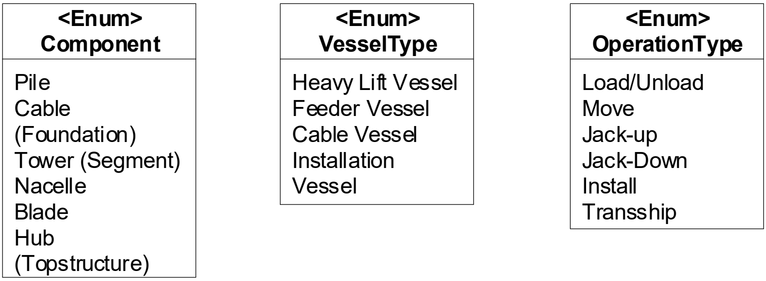

Figure 3: Relevant Datatypes, i.e. lists of operations, vessels and components

Figure 4 shows a general, conceptual overview of the domain model including all classes, subclasses, and enumerations but without parameters. All diagrams given in this section follow the notation of UML-Class Diagrams. The latter are given in subsequent, more detailed Figures later on in this section. The main components covered by this domain model are as given below:

Project: The Project constitutes the main class, linking all other information together. Therefore, it is associated with the relevant ports and the installation site, the available vessels and with the available weather (forecast) data and the schedule.

Location: Locations are used to describe physical locations relevant to the project. These are in particular installation sites, production and base ports.

Vessel and VesselType: Vessels are used to conduct offshore operations. Each vessel is assigned a loading type, which can either be capacitated or follow a fixed loading layout for specific components or tasks. The VesselType serves as a list of different kinds of vessels, e.g., Jack-up vessels or heavy lift vessels.

Component: Components themselves do not provide additional information but are only included as a list of possible components, e.g., blades or tower (segments).

Operation and OperationType: Operations subsume relevant information depending on their OperationType. They are performed by vessels or at ports.

Operative Schedule: As already described in the state of the art, schedules come in different forms depending on their formulation. Most prominent in literature are time-indexed and sequential (precedence-based) schedules. Nevertheless, more coarse, aggregated schedules can also be found.

Weather Data: Weather data is required for the overall planning. In literature, this data is usually taken from records or classified first.

Staff: Staff is required to carry out operations. In contrast, only a limited set of qualified staff is available within a project.

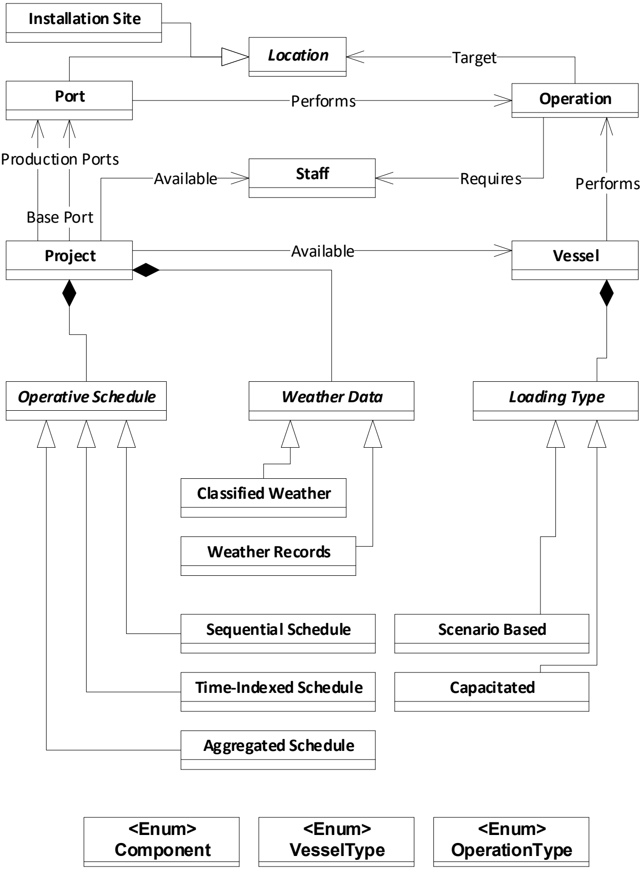

Figure 4: Conceptual overview of the domain model as UML-Class Diagram without attributes

Figure 5 provides a more detailed depiction of these main classes, leaving out further sub-classes. For the attributes, the following diagrams use a simplified notation. On the one hand, all attributes are marked *public* to avoid the need to include methods to obtain and change their values. On the other hand, these diagrams use very basic datatypes, e.g., *Number* or *DateTime*, as they are commonly used in the development of databases. This was done to keep the model more straightforward and easier to understand. Additionally, specific datatype depends on the formulation used as well as on the programming language. Therefore, the presented domain model can be adapted easily to particular requirements without losing out on its degree of detail.

As can be seen in Figure 5, the majority of attributes can be classified in either logistic/technical attributes or as attributes focusing on cost calculations. In particular, for vessels, the majority of attributes aim at capturing the cost of using or applying the vessels. This is due to the nature of the overall problem: operations scheduling. Vessels and other resources constitute the primary, variable cost factor in these projects. Components have to be bought/manufactured anyways, but an efficient use of resources, especially considering the dynamics of weather effects on operational times, is the main focus of basically all optimization/simulation models in this field. Consequently, the majority of parameters aims at processing times, cost rates, or describe parameters which can be used to calculate the previous ones, e.g., distances and speeds. The same can already be concluded from Table 1. The number of turbines to build, as well as the components' installation and loading times, can be found in every model investigated for this article.

Another important set of attributes focusses on the inclusion of weather dynamics. Whereas different models treat weather restrictions differently, e.g., by preventing operations from commencing or by prolonging their duration, the influence of wheatear conditions differentiates this scheduling problem from most other planning problems. Therefore, operations always refer to their corresponding restrictions.

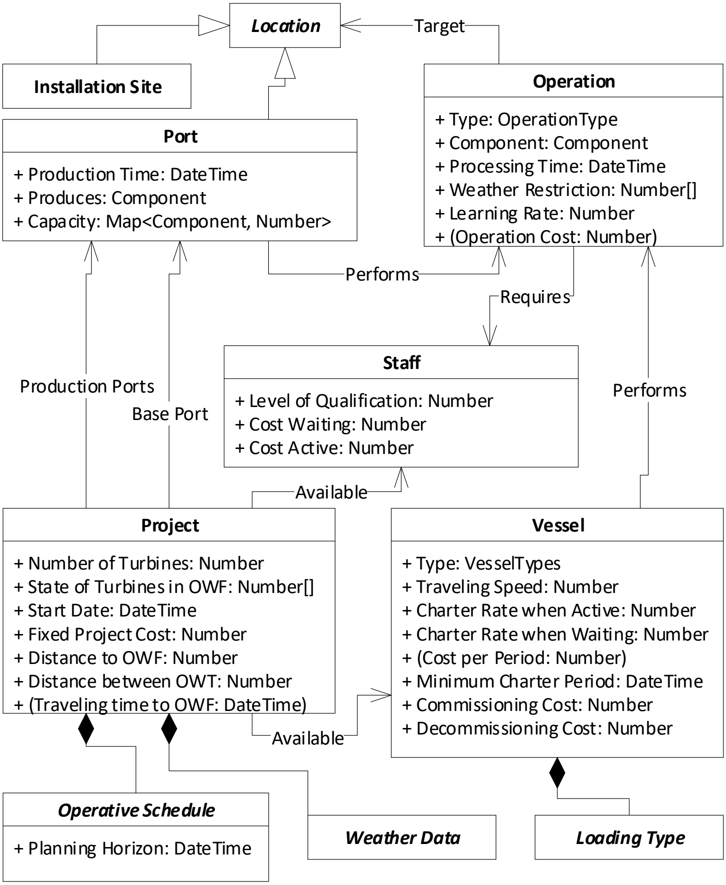

Figure 5: Detailed depiction of the models main entities as UML-Class Diagram

Another set of identified attributes focusses on the representation of capacities. Thereby, storage capacities of locations and vessels are often constrained, either directly by space/weight, by amounts of components, or by the application of loading scenarios. Loading scenarios generally describe predefined sets of components which can be stored or transported together, often including specific frames and layouts, as shown in Figure 5Figure and Figure 7. In models where loading scenarios are used, these are usually connected to set up times and costs for removing or applying these frames. An example of such a loading frame for turbine blades can be seen in Figure 6.

Figure 6: Transport frame for turbine blades on a heavy-lift vessel (Image: Senvion)

Another difference in identified models refers to the way weather data is included. Some models refer to records of weather data, working on, e.g., hourly measurements of actual values for wind speeds and wave heights directly. Other models use abstractions of these data. Therefore, literal classes of weather, e.g., good – moderate – bad, are formed, and sequences of these classes are defined, usually by providing their start dates.

The final core difference between models concerns the plan they generate by optimization or use for their simulation. The most common sub-types are time-indexed or sequential schedules. Some authors also use aggregate plans, which do not schedule operations directly but usually provide the number of operations to be performed during a period. Whereas the overall goal of all plans is the same, i.e., to provide a feasible and efficient sequence of operations, the formulation of these plans and thus, the used attributes can differ strongly, as shown in Figure 7.

5 Conclusion and Future Work

This article presents a domain model for the operative scheduling during the overall installation planning for offshore wind turbines. This domain model aims to consolidate information which is used during the scheduling from different sources. Therefore, relevant parameters were identified based on a literature review of mathematical formulations for the offshore operations scheduling. In a second step, information on existing simulation models was used to refine these attributes into a class hierarchy by identifying related objects and concepts.

The domain model covers the essential classes, e.g., locations, vessels, operations, and components. Nevertheless, future work will focus on the extension of the presented domain model, e.g., by additional resources like cranes, storage capacity and loading docks. These constitute additional cost factors, which have to be regarded but are not covered by concurrent models.

Furthermore, future work will aim to develop model transformations to generate or at least parametrize optimization or simulation models out of the presented domain model. The aim is to enable a concurrent use of both modeling techniques and establish interoperability between models of different resolutions, e.g., aggregate/sequential schedules, and scopes, e.g., capacity planning and scheduling.

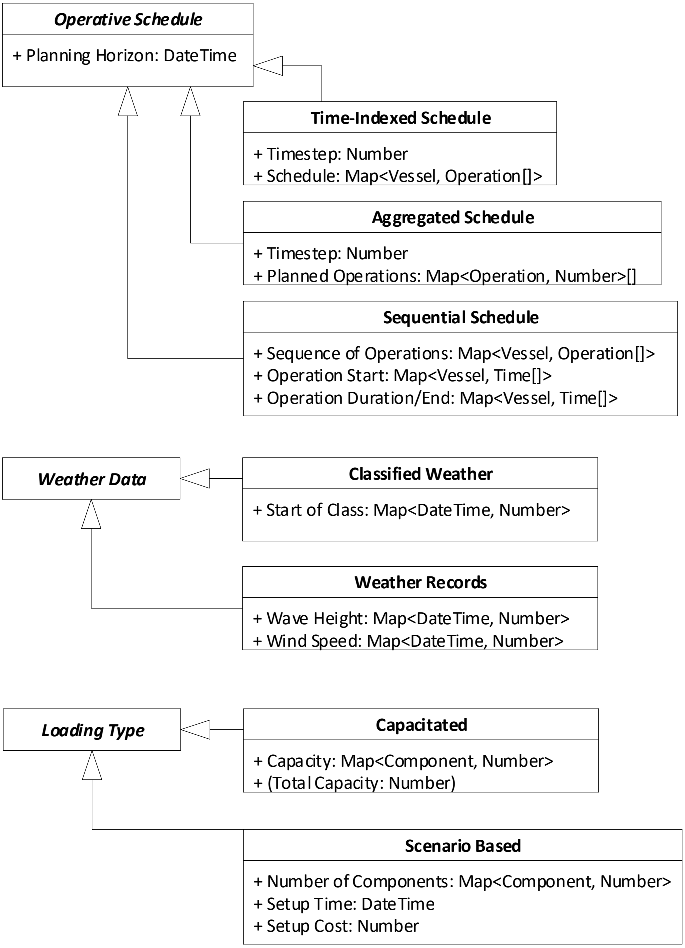

Figure 7: Detailed depiction of the models subclasses as UML-Class Diagram

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