Improving Drilling Operations Management Using Combined Simulation

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Abstract: This paper presents an integrated logistic study to estimate the fitness for purpose of a Supply Base during the development and exploitation of the XY gas field. The logistic study includes a dynamic modelling of the overall system (incoming logistic flow, base occupation and outgoing logistic flow) in order to properly evaluate possible necessary actions to be implemented in order to ensure the reliability and availability of the base services and to define the costs related to the activities to be carried out along the project schedule.

Keywords: Simulation, System Dynamics, Logistics facilities

1. Introduction

When dealing with the modeling and simulation of transportation and logistics problems, the Discrete Event Simulation (DES) is one of the most used techniques, especially when dealing with the operational context [8]. Other authors have addressed the logistics context by using the System Dynamics (SD) simulation that works in the continuous time [5]. In logistics unpredictable events can affect the system, forcing to change in real time the standard flow of activities and events that had been previously scheduled. In this case SD is more suitable for modeling purposes, considering that interruptions in the chain of events are not possible in the DES, because it considers the starting event and the final one but not what is going one between the two [9]. Moreover, SD tool is more appropriate when dealing with activities such as storage, filling and emptying, which are all continuous processes [1]. On the other side, the “pure” SD is not an effective methodology when the level of detail of the system must be very high or when the number of variables is noteworthy, so that the model becomes very complex and onerous in terms of computational effort and speed. In these cases the DES is the most appropriate simulation approach.

In order to overcome these issues, the authors propose an innovative methodological approach able to effectively address particular kind of logistics and transportation problems by utilizing a hybrid System Dynamics simulation[2][3]. More specifically the simulation framework here proposed is composed of two main parts:

• the “discrete event simulation” part, which provides the chain of events that characterize the system;

• the “pure System Dynamics” part, that accomplishes two main goals: continuous processes (such us filling or emptying processes, exploitation of a resource, waiting, delays, etc.) that are part of the normal operations flow and unpredictable events to be properly managed.

The advantages of adopting this kind of approach are numerous: from one side, the capability, typical of the DES, of providing detailed analysis of a particular system (the system has to change at specific points in time); on the other side, this new
methodology can address the modeling of continuous processes, can deal with systems where behavior changes in a non-linear fashion and/or where extensive feedback occurs within the system, or can take into consideration “fuzzy” qualitative aspects of behavior that, while difficult to quantify, might significantly affect the performance of a system - these last features are typical of the SD [4][6]. The paper presents one real life application were such innovative approach has been extensively tested and used in order to evaluate the fitness-for-purpose of a base logistic facilities.

2. Project Background
In order to evaluate the fitness-for-purpose of the logistic facilities of an offshore supply base a preliminary study has been carried out, focusing on the base “downstream” asset (i.e. transportation from the base to the sites) and providing indications about the base buffer capability. The addressed logistic items are listed here below:

- **Quayside**: consisting of the base area where the supply vessels are loaded and off-loaded and the material in transit in the base is temporarily stocked
- **Warehouse**: consisting of a sheltered storage area for the material which cannot be exposed to the open air
- **Stocking Area**: consisting of the unsheltered area for the storage of tubular material such as casings, tubing, drill pipes, etc.
- **Bulk Silos**: consisting of the tanks for the containment of barite, bentonite, cement, water and fuel.
- **Supply vessels**: for material transportation. The current fleet consists of two units.
- **Crew Boat**: for personnel transportation from the base to the sites. The current fleet consists of one unit.
- **Helicopter**: for personnel transportation from the base to the sites. Currently there is one helicopter available.

The Figure 1 shows the project schedule. As far as the Engineering, Procurement, Construction (EPC) scope of work is concerned, only the tie-in operations have been included in the logistic study (at the end of paper).

The study considers the interaction between the base and the rigs operating in the various hubs as far as the Company’s responsibilities are concerned. Figure 2 shows an image of the Base.

3. Model Specification
In figure 3 the schematic model is presented. In such schema is possible to notice three logical layers: material transportation. State of the Vessel (yellow), material loading from the base (red) and material off-loading to offshore hub (green). In particular, the Vessels can be in State A (In loading at the base) or in state B (In unloading at the offshore hub). Transition from State A to State B is regulated by the consumption of time allocated from loading material from the base. Only when the vessel is charged the event “transitionAB” occurs and the Vessel changes its state in B. Similarly the transition from State B to State A is regulated by the consumption of time allocated from offloading material from the hub.

The study considers the interaction between the base and the rigs operating in the various hubs as far as the Company’s responsibilities are concerned.
According to the diagram illustrating, the logical and functional characteristics of the model are described hereafter with reference to the following operations:

- Incoming material modeling
- Material transportation from the base to the field and vice versa
- Loading, off-loading, travel timing for the supply vessels
- Personnel transportation from the base to the hubs and vice versa

### 3.1 Incoming material modelling

The software accounts for the supply flow as a function of the point of origin (material group), quantity of material (material lot size) and lead time (material time). In addition the port of arrival (either port 1 or port 2 for the material arriving from abroad) is statistically considered with the same level of probability (50% each port). The Monte Carlo methodology is applied.

In order to properly model the incoming material flow, the different items have been categorized in accordance to three main characteristics:

**Group:** the material belonging to the same group is likely to be provided by the same supplier, thus when the material is planned to arrive in the port of reference it will be modelled as belonging to the same ship. As a consequence, all the statistical uncertainties applicable will be accounted for the entire batch of material.

**Lot size:** in accordance to the material characteristics (i.e. massive production material, regular material, material available locally, etc.) the dimension of the typical lot have been differentiated. The rationale used is the “operation”. In other words it is assumed that the base manager plans the material arrival in accordance to the foreseen scheduled operations. As a consequence the material lot size will be defined accordingly, for instance casing for two wells, subsea manifold for three subsea hubs, etc.

**Type:** depending on the material characteristics (i.e. long lead items, regular material, material available locally, etc.) the schedule for the material arrivals is differentiated. In other words the availability of the material is accounted for by means of a longer or shorter advance (and as a consequence a bigger or smaller buffer in the base) in the material arrival request.

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Nine groups have been identified according to the likely origin of the material:

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drilling tubular material manufacturer</td>
</tr>
<tr>
<td>2</td>
<td>Wellhead manufacturer</td>
</tr>
<tr>
<td>3</td>
<td>Bulk Fuel supplier</td>
</tr>
<tr>
<td>4</td>
<td>Catering supplier</td>
</tr>
<tr>
<td>5</td>
<td>Spare parts supplier</td>
</tr>
<tr>
<td>6</td>
<td>X-mas Tree manufacturer</td>
</tr>
<tr>
<td>7</td>
<td>Subsea control system manufacturer</td>
</tr>
<tr>
<td>8</td>
<td>Line pipes manufacturer</td>
</tr>
<tr>
<td>9</td>
<td>Chemicals supplier</td>
</tr>
</tbody>
</table>

![Figure 4. Material Groups](image)

**Lot size**

The lot size have been defined in accordance with the material type (described in the following paragraph) and with the relevant availability.

**Material Type**

As previously described the material types are the following:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>REG</td>
<td>Regular material</td>
</tr>
<tr>
<td>LLI</td>
<td>Long lead items</td>
</tr>
<tr>
<td>LOC</td>
<td>Local material</td>
</tr>
</tbody>
</table>

![Figure 5. Material Type](image)

### 3.2 Material Transportation from the base to the field

The model generates the material in the base on a daily basis. In particular the material, subdivided according to the four main areas of the base (Quayside, Warehouse, Stocking Area and Bulk Silos) is created by impulses.

### 3.3 Loading, off-loading, travel time for the supply vessels

The supply vessels operations at the base are limited by the following conditions:

- Access to the base and loading: the supply vessels can access the quayside only from 7:00 a.m. to 8:00 p.m. The loading operations can be carried out from 7:00 a.m. to 6:00 p.m. As an example, if the vessel returns to the base at 6:00 p.m. can access the quayside but cannot be loaded. She will be loaded the following morning. The time frames above listed are indicative and, though they could be disputable, they are assumed according to the experience and mainly aim at accounting for the time losses due to the base operations.

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• Supply vessel departure from the base: the loaded supply vessel can depart for the hubs from 7:00 a.m. to 1:00 p.m.

3.4 Personnel transportation from the base to the hubs and vice versa

Similarly to what modelled for the material, the software generates the personnel to be transported on a daily basis. The simulation is focused to determine the number of trips to be carried out by the current fleet of helicopter and crew boat in order to satisfy the transportation demand and evaluate possible requirements for future fleet increase.

4. Model Validation.

In order to verify the consistency of the model with the real system the walk-through methodology has been adopted. The scope is to avoid that possible errors in the software code might be hidden by the stochastic behaviour of the simulation, thus the validation has been carried out in a deterministic regimen. The validation procedure involves the loading of the supply vessels at base. The material input to ship from the base to the offshore hub is assumed like a impulse. The magnitude of this impulse is shown in Figure 6.

![Figure 6. Material Input to ship to the offshore hub](image)

The characteristics of the fleet are assumed as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quayside</th>
<th>Warehouse</th>
<th>Stocking Area</th>
<th>Bulk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight [tons]</td>
<td>80.5</td>
<td>10</td>
<td>1051</td>
<td>1830</td>
</tr>
<tr>
<td>Space occupation [m²]</td>
<td>265</td>
<td>0</td>
<td>1210</td>
<td>0</td>
</tr>
<tr>
<td>Space occupation [m³]</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>1850</td>
</tr>
</tbody>
</table>

Figure 7. Vessel Characteristics

4.1 Loading of the biggest supply Vessel

The material in the base generates a transportation demand. The vessel, once arrived at the quayside, starts the loading phase. The tool accounts simultaneously for the weight, space and volume limitations of the supply vessels. The supply vessels carry out various trips in order to satisfy the transportation demand, as shown in the graphs below:

![Figure 8. Validation of Loading operation (largest vessel)](image)

You can see that the vessel's maximum capacity is never exceeded. The analysis of the material within the base versus the material transported by the vessel confirms the consistency of the model:

![Figure 9. Validation of Loading operation (largest vessel)](image)

4.2 Loading of the smallest supply Vessel

By changing the supply vessel the model accounts for the new restraints.

![Figure 10. Validation of Loading operation (smallest vessel)](image)

In this case 4 trips in 5 days are necessary to fulfil the transportation demand.
4.3 Loading of both supply Vessel

The supply vessels are correctly loaded once at a time. In this configuration only 2 days are necessary to satisfy the transportation demand. You can see that the max weight in the Vessel depend of the Vessel picked.

4.4 Stochastic property

The above stochastic characteristics are reported hereafter.

<table>
<thead>
<tr>
<th>Item</th>
<th>Stochastic property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigation (for single journey)</td>
<td>From 6 to 7 hours (uniform distribution)</td>
</tr>
<tr>
<td>Loading/Off-loading time in the hubs (per operating unit)</td>
<td>From 4 to 6 hours (uniform distribution)</td>
</tr>
<tr>
<td>Transported material</td>
<td>Probabilistic (normal distribution with 20% shift from average)</td>
</tr>
<tr>
<td>Supply Vessel 1 availability</td>
<td>6 days a week (different day-off than Supply Vessel 1)</td>
</tr>
<tr>
<td>Supply Vessel 2 availability</td>
<td>6 days a week (different day-off than Supply Vessel 1)</td>
</tr>
</tbody>
</table>

5. Result Analysis

At the light of the analyses the current logistic asset can be evaluated to ensure its fitness for purpose for the planned operations.

The different logistic facilities and the fleet configuration are compared to the requirements arising from the system modelling and possible recommendations are then listed and described.

5.1 Quayside

It is important to underline that the current study do not account for the internal transportation within the base, nevertheless some issues might arise in case of heavy transportation due to the soil and roads characteristics. These aspects shall be accounted for and investigated at a later stage of the project, in order to avoid bottle necks in the internal logistic. All the base material will eventually pass through the quayside to be loaded onto the supply vessels. The quayside availability has been modelled in the simulation accounting for tides and operator shifts.

The graph above shows the quayside space demand trend on a monthly basis against the limit due to the agreement in force with Supply Base. At the end of third year the limit is exceeded, but the marshalling area of the base should be able to cover the needs for such a limited period.

5.2 Warehouse

The warehouse aims at sheltering the material which cannot be exposed to the open air. The current warehouse characteristics in terms of available surface are sufficient to cover the needs of the project even considering a space subdivision of 600 m² of usable space with 400 m² spare.
5.3 Stocking Area

The pipe stocking area consists of an open air area made of concrete flooring on top of which the tubular material is laid and piled up. In order to define the space demand for this area the typical tubular material to be stored has been characterized by different piling capabilities.

The graph below shows the stocking area space demand trend against the limit due to the actual space availability.

It is important to underline that the current tubular material stocking capabilities are sufficient to cover the space demand for almost the entire period of the project. The peak is very limited to the arrival of the line pipes for the pipeline construction.

Contingency solutions can then be chosen for this event, including the temporary rent of an additional area within the base.

5.4 Bulk Silos

Figure PP shows the bulk material volume demand vs availability.

The material for the bulk silos area consists of the following:

- Water
- Powders (cement, barite, bentonite) and drilling mud
- Fuel

Most of the required volume is for the fuel, thus the limit of 1000 m³ for the Oil-based mud is complied with. The remaining volume is to be rented according to the Base price list.

5.5 Supply Vessels

The fleet is composed of two supply vessels. The simulation accounts for the ordinary maintenance of the supply vessels limiting their availability to 6 days a week. Limitations are also given for the access to the port and for the loading operations at the quayside in order to account for the operational constraints of the base. The timing of off-loading at the sites accounts not only for the operational constraints but also for possible downtimes due to bad weather. The maximum monthly demand of trips is 19 for a limited period of time around March 2014, thus the fleet is sized properly.

Given the material transportation demand it came out that there is no need for an additional Fast Support Intervention Vessel (FSIV).

The figure 18 shows a monthly number of trips for Supply Vessel.

5.6 Crew Boat

The characteristics of the available crew boat are suitable for the personnel transportation demand arisen from the analysis. The maximum number of trips per month is in the fourth year.

The figure 19 shows a monthly number of trips for Crew Boat.

5.7 Helicopters

The characteristics of the available helicopter are suitable for the personnel transportation demand arisen from the analysis. The maximum number of trips per month is in the fourth year.
6. Conclusions

The practical application of the proposed methodology, as described in the previous section, and its application to several real life examples[10] led to the identification the fitness-for-purpose of a base logistic facilities.

The successful results obtained on the example application not only validate the robustness of the methodology but also demonstrate its potential for solving a wide range of transportation logistics and supply chain management problems.

References


Figure 1. Project Schedule

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling &amp; Completion</td>
<td>DRIL</td>
</tr>
<tr>
<td>Subsea Production System</td>
<td>EPC2</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Risers &amp; Flowlines</td>
<td>EPC3</td>
</tr>
<tr>
<td>Onshore Treatment Plan</td>
<td>EPC4</td>
</tr>
<tr>
<td>Production</td>
<td>EPC1</td>
</tr>
</tbody>
</table>