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An INNOVATIVE HYBRID SIMULATION APPROACH FOR SUPPORTING MARITIME LOGISTICS

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Abstract

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. Other authors have addressed the logistics context by using the System Dynamics (SD) simulation that works in the continuous time. 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.

1. Critical aspects in logistic modeling

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 empting, 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]. 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 empting 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. An Application Example

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 main airport to the operating sites. Currently there are two helicopters available.

3. Using System Dynamics as base for Hybrid Modeling

One of the critical aspect of the modeling of a complex logistic system is related to the particular nature of the process that could be summarized in two main categories:

1. First category is a class of process that if interrupted they resume at the same point where they were stopped. In this category belong loading and unloading operations, deliveries, pick-ing and similar activities.

2. Second category is a class of operation that if interrupted the resume to the beginning despite the point they were interrupted. Examples of such operations are clearance procedures, safety procedures and similar.

In order to explain this point is possible to consider a more complex example that was already de-scribed in a previous work (Briano et al. 2010): a LNG tanker has to dock inside of a LNG terminal in or-der to deplete loading and unloading operations.

The layers are described through the dynamics-system and involve the ports, the ships at sea, and the ships into the port. The first layer involves all the ports mainly to check parking availability, so a system which dimension is the number of the ports, is managed. The second layer involves the ships and its cy-cle's phases are the check availability of ship, the possible navigation to homeport, the loading phase, the navigation to destination port, docking at the port, downloading phase, the re-placement and finally the ship could be avail to start an other cycle. Each ship can start and stop its cycle as need. This layer han-dles a system which dimension is equal to ship number. Finally, the last level is focused on the dynamics of the ship into the port. The steps involved are the entry maneuvers, the landing operations, tanks attack.

Since weather and sea conditions could severely affect the loading and unloading operation the tanker should be ready to prompt undock if sea condition became too worst to guarantee the safety level of the operations. Of course if this occurs when part of the loading/unloading has been done the tanker has later to resume from the same point (first category process) while all the docking, security checks and clear-ance operations has to be repeated completely (second category process). In this approach any operation could be interrupted if certain conditions occurs and, according to the category of the operation, a resume condition should be investigated. Based on such assumption the discrete event paradigm should not be considered suitable moving towards a time stepped approach where unexpected events may take place in every moment. In figure 1 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.

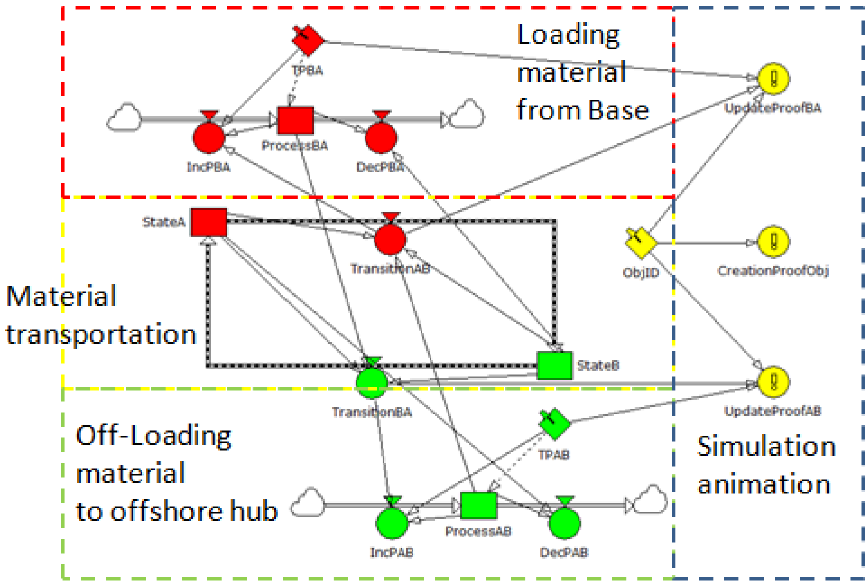

Figure 1. The schematic simulation model

In the schema the system is bouncing cyclically from State A to State B as the two process time elapsing [7].

According to the diagram illustrating, the logical and functional characteristics of the model are described hereafter with reference to the following operations:

- Material transportation from the base to the hubs and vice versa (Vessel state)
- Loading, off-loading, for the supply vessels
- Personnel transportation from the base to the hubs and vice versa (Helicopter and crew boat state)

3.1. Material Transportation

It was developed a chain that allows highlighting the logical state of the vessel. In other words, in every moment the tool is able to determine whether the vessel status is “Sailing” or “ Anchorage”, etc. The logical chain is a vector of size equal to the number of fleet vessels. The transition from one state to another is bound to a set of parameters which are constantly monitored. For example, the transition from "Sailing" to "Anchorage" is determined by the consumption of time allocated (in this case modeled by a normal distribution). Only when the entire lapse of time is consumed, the supply vessel status can switch to “Anchorage” (figure 15).

3.2. Loading, off-loading, travel timing for the supply vessels

The upload operation is bound by the availability of a supply Vessel and in accordance with its characteristics. In particular, during the upload the remaining capacity of the vessel in terms of weight, surface area and volume is constantly monitored. To achieve a maximum capacity of one of these values (or the end of the material to be loaded from the base), the supply vessel can leave the quayside (Figure 16).

3.3. Personnel transportation from the base to the hubs and vice versa

Same logic of the Material Trasportation.

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 behavior of the simulation, thus the validation has been carried out in a deterministic regimen and after it was used in stochastic regimen in order to provide risk assessment of the proposed logistics. 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 analysis of the material within the base versus the material transported by the vessel confirms the consistency of the model:

5. Use of the model in the practical application

In order to define the criticalities of the project, the results reported above have been analyzed with the following methodology:

1. Subdivision of the system into logistic units (quayside, warehouse, stocking area, bulk silos, supply vessels, crew boat, helicopters)
2. Definition of the demand peaks in terms of area or volume (depending on the kind of logistic unit under consideration
3. Definition of the demand peaks in terms of schedule

According to the above the result analysis is able to provide significant indications in order to draw the conclusions of the study.

5.1. Quayside

The Company Quayside is physically separated from the rest of the Company base. 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. In the proposed figure 2 is possible to notice that the occupancy is well below the limit of the available space.

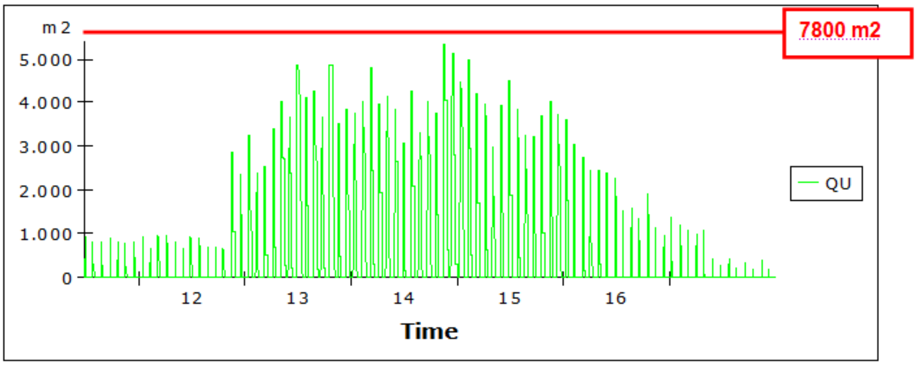

Figure 2. Quayside occupation

5.2. Warehouse

The current Company Warehouse has been built in 2008/2009 when the foreseen material demand was lower than the one arising from the present integrated analysis. The warehouse aims at sheltering the material which cannot be exposed to the open air. It is important to underline the fact that the present warehouse is fitted with an overhead crane which constrains the space exploitation, reducing the overall efficiency (in terms of shelved area). Nevertheless a warehouse re-arrangement is to be seriously considered in order to increase the shelved area availability and consequently increase the warehouse efficiency.

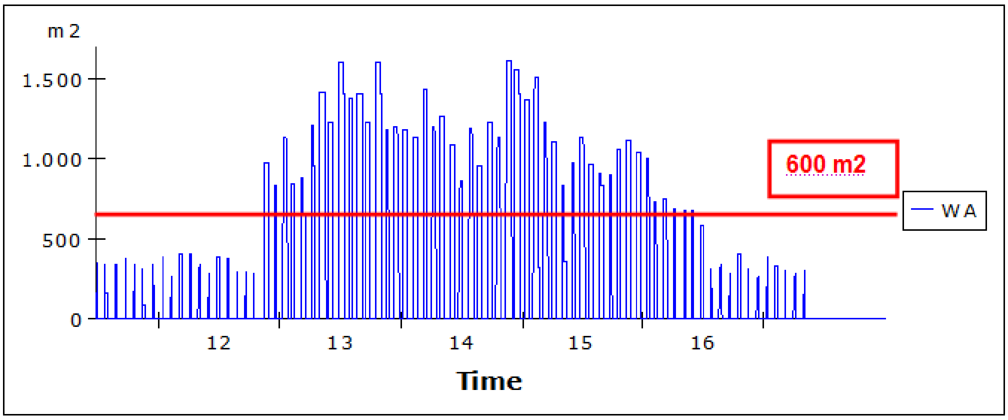

Figure 3. Warehouse occupation

As it can be seen the peak period are mainly concentrated at mid 2014 and end 2014, but anyway the space demand is well beyond the current availability for a much longer period (figure 3). The main countermeasures consist of:

- Increasing the space exploitation efficiency
- Double the current warehouse gross surface

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, again from the simulation is was possible to identify that the maximum occupancy was well below the maximum available space.

5.4. 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. Considering all the limitations listed above it has been pointed out that the maximum number of trips that both supply vessels would be able to do is 9 per week (i.e. 4/5 trips for each supply vessel). The maximum monthly demand of trips is 22-24 thus the fleet is sized properly. Nevertheless in the peak period (second half of 2013) considerations shall be made to include one additional unit for contingency.

5.5. Crew Boat

The current fleet is made of one crew boat. The crew boat transports the personnel from base to the sites. The Figure 4 shows the required number of trips for the crew boat to satisfy the personnel transportation demanded.

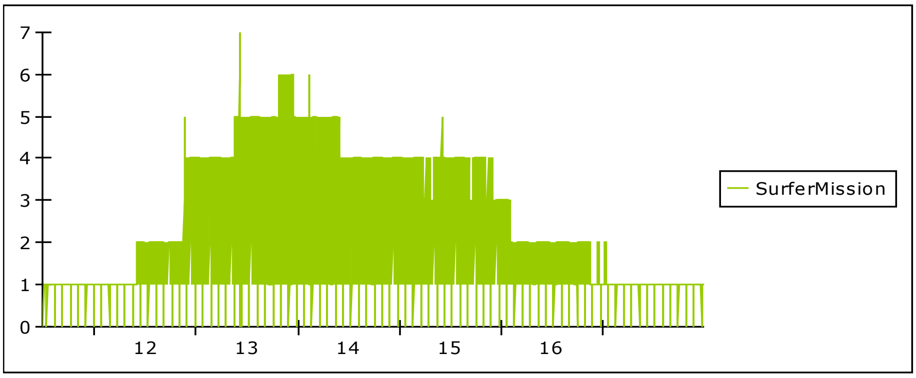

Figure 4. Number of Surfer Mission

As it can be seen, the maximum number of trips is manageable. The possible challenges might come from the hook-up/start-up phases of the FPSOs, but for this configurations a synergy with the supply vessel can be foreseen.

5.6. Helicopters

The current helicopter fleet is made of two units: one Superpuma and one Dolphin. It has been considered that the personnel flow will be concentrated into two days per week in order to get the connection with the international flights. This hypothesis limits the available flight time and a s a consequence the helicopter are obliged to flight within this time frame only. The total number of helicopter flights in order to satisfy the personnel transportation demand has been recorded.

6. Conclusions

The practical application of the proposed methodology, as described in the previous section, and its application to several real life examples 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.

7. References

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