A new model to manage vessels flow in a Port Terminal

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Abstract: - The goal of this paper is to model, through a system dynamics approach, vessel operations to provide a support for its management. The choice of utilizing the SD paradigm derives from the fact that for complex systems, such as the port one, it is very difficult to collect real data regarding its functioning.

Key-Words: - Petri Nets, Berths Allocation, Shipping, Flow management vessels, Scheduling, Simulation, System Dynamics.

1 Introduction

A port terminal is a node in the freight network both container and dry bulk. The terminal can be divided into a set of components, each with its own problems:

- the access channel: channel outside the port, which must be followed in order to access the dock;
- the roadstead area inside the port where ships can get at anchor, sheltered from the winds and waves, while waiting for it to clear a dock where dock;
- the basin evolution: area inside the repaired area of the port, within which the vessels are maneuvering, in order to dock in an optimal manner to the quay;
- facilities that protect the port from waves;
- the docks: the perimeter dedicated berthing of ships, which carry out loading and unloading;
- the storage system: area divided into yards, that is, storage yards, where the goods are awaiting transshipment or continue their journey by land;
- the gate: represents the point of access to the port side of the earth;
- the cargo handling system, consisting of a set of means for the handling of goods within the terminal.

In order to understand what issues are technical and managerial face off in a port terminal, it is necessary to first describe the flows that take place within it.

There are three types of logistics flows through which goods move in a terminal:

- import flow: the flow of goods which is dock-yard-gate;
- export flow: the flow of goods which is gate-square-shore;
- transhipment flow: the flow of goods which is platform-square-shore, so far the goods have been unloaded from a ship, temporarily stored in yards and then continue their journey by sea always, in this case, then, we speak of operation transhipment.

Based on the type of goods traffic inside the terminal, there are two major types of port terminals for the handling of goods: the import-export terminal and the terminal of transhipment.

Table 1: Input flow

Table 2: Export flow

The term LNG tankers Bulk identify specialized in the transport of liquefied natural gas.

The category identifies the liquid bulk tankers specialized in the transport of liquid cargo. Within this segment, we can see the ships:
• oil tanker specialized in the transport of crude oil;
• product tankers for the transportation of refined petroleum products (gasoline, naphtha, refined oils, etc..)
• chemical tanker for the transport of chemicals.

2 Problem Formulation
A port terminal is a complex system to manage, in fact inside, often encounter criticality difficult to decipher and to overcome. In a port terminal, daily, are handled a multitude of containers of different species and sizes, especially when it comes to a terminal of transhipment. Therefore, the container must remain inside the terminal, temporarily, in storage areas (or yards), then for each different type of container will a different yard.

The storage phase, however, is not just about the parking of container yards within dedicated, but depends mainly on the various means of handling of containers used in the terminal, so you have to analyze the different handling equipment that are present in the terminal, the possibility of each equipment, the amount of TEUs/h which can move, how high can stack containers.

Another unknown factor to consider is the arrival of their real container terminal and the service methods.

With regard to the transit by land of containers, must be made to the transport systems to be able to access the terminal, the problem arises especially for trains, because the trucks have a greater flexibility compared to trains, as the latter can transit only on binary, which then represents a constraint.

As for the transit of containers by sea, the critical points are different: first of all is the access channel to the port, or the Bay, is the basin evolution, and the whole area of mooring of ships, must have a deep bottom sufficient to accommodate the ship with a draft greater, this means that in the course of time in the port and in the access channel must perform repeated operations of dredging, in order to maintain their suitability to accommodate vessels with high draft, the problem is more accentuated in transhipment terminal, the terminal because they are hosting large container vessels, mother ships, and ships that have a great draft.

The bay must have the ability to accommodate different ships, so that they are protected from wave motion, waiting for a berth to become available.

The basin of evolution, since it has the function of allowing the vessels to perform maneuvers with the end of mooring efficiently to the quay, inside of it must be taken to ensure that the maneuvering of each ship are not disturbed by the operation of other ships.

The dock to accommodate a certain type of ships and the order to play in a more efficient and faster, the loading and unloading, must have the appropriate size and have the right equipment for vertical movement of containers.

3 Problem Study
The access channel to the terminal leads of the critical issues to be reckoned with during his meet and critical analysis of structural type of logistics. The size of the access channel, they are definitely structural problems, but in turn resulting complexity throughout the terminal in logistics. The access channel is not the same for each port terminal, otherwise, each channel has its own length, but above all one of its width, dependent mainly on the morphology of the place.

Obviously an access channel to the terminal with smaller width, will present the major complications compared to a channel with a width greater.
From the width of the channel depends on the possibility of passage of two or more ships alongside, then the channel is as large as more fluid will transition both in input and output of the boats, in certain cases it is even possible that, the channel, thanks to the its width and then to the large number of vessels that may intersect during transit, presents a congestion almost equal to zero. Not always access channels of the terminal, however, have a capacity such as to pass through a considerable number of ships alongside, indeed, very often, their widths allows the passage of only two vessels and there are cases in which the passage is bound to only one vessel at a time, for both directions of travel.

The case in which the transit of the channel is constrained to a single ship involves, first of all, problems of congestion is the entrance of the terminal, specifically those related to an access channel, either inside the port if this problem is not handled optimally. So a critical structural we moved to a critical logistics, as a ship, not to create congestion inside the port and disturb the operation of other vessels that are inside, along the channel only if it has the possibility to moor at a berth, and a ship out, it can leave the port and then go through the canal in the sense of output, if the channel is not already occupied by an incoming ship. Another critical, that exhibits high complexity, is that relating to the safety distance, that vessels must maintain between them as they run across the channel.

The safety distance is a critical issue that comes out when the ships have to travel the access channel to the port. For security vessels above should avoid disturbing the other ships with the waves generated. It is thought, therefore, to a minimum safety distance, that vessels must maintain between them during the passage of the channel.

This safe distance is also useful when you arrive at the port, because in that moment before the ship is making maneuvering and mooring, which are among the most dangerous stages, then, following the ship must maintain a safe distance from the ship above, such as not to obstruct or transit through the channel, nor the subsequent operation, ie for maneuver and mooring.

Critical issues related to the access channel to the terminal, specifically those related to an access channel can be practiced by one ship at a time, are at the heart of the case study of this work. This problem has been addressed by building a model both theoretical and application, with the use of a simulation software, the Powersim.

In the case of absence of a channel switched limited, one must face the problem of "berth allocation planning". A first approach to the problem relating to the access channel was to insert gates, not physical but temporal at the end of the channel, which divide the inside of the circulation channel in two sessions, session and incoming session output.

The gates of course have a time interval in which are open, of course, is open when the gate time of entry is closed to output and vice versa, so they can not be opened both at the same time, the ships can traverse the channel time interval only in which the gate corresponding to the direction in which ships have to cross the channel is open.

The different sessions storms have the same length of time and alternate continuously. In order to maintain a constancy in the temporal duration of the session, each session is activated in the event that are not present in the channel of the vessels in the direction opposite the gate time that must be open, to better understand we use an example: opens the first gate temporal incoming of a duration of 4 hours, the vessels can enter for the entire duration of the session of entry, in the case where the last ship exits the channel at the exact moment in which expire 4 hours, then immediately triggered the gate temporal in session output, while if the last entry ends of ship through the canal that have expired after 4 hours of entry of the session, then the session will be output following skid, ie part after a certain amount of time equal to the time in more in which the ends of last ship through the canal, finished the 4 hour session of entry.

After the construction of the gate time it is inserted, always at the two ends of the channel, a traffic light control, which is used to ensure that all vessels, in session incoming and outgoing session, within the channel, maintain a minimum safety distance, so that the ship follows enters the channel only after the ship that precedes has exceeded the minimum safety distance.

A ship, however, to access the channel must not only take into account the traffic lights and control the gate time, but can only do so if, in combination with the constraints outlined above, within the marina is a dock available to receive it, the which, consequently, is booked, then made unavailable, from the ship when it enters the access channel.

By hypothesis all vessels run across the channel with the same law of speed, then employ the same time to follow it.

After crossing the canal and entered the dock, ships must turn off the means of propulsion to be towed by tugs, for reasons of internal security at the port.
The vessels undertake the operations of maneuver in the basin of evolution when the latter is available, in such a way to moor with its bow facing the outside and to facilitate the operations of unloading. After finishing maneuvering and finishing operations of unloading the vessel is ready to leave the port terminal, but the operations do not lead immediately setting sail ships in the output channel. The ships, when they leave the docks, moving in a defined area of the dock parking area which does not behave as a parking lot itself, in the sense that it is not always as a staging area for ships out in case in which the vessels that have finished the operations of unloading and preparing to disormaggiare, find the combination in which the output channel is available, then the combination for which the temporal gate is open and the outgoing traffic lights which monitors the distance Safety is green, the ship transits only to the parking area without stopping in it, then the parking, in this case, acts as a transit zone for ships. The basin of evolution, used to allow ships to perform the maneuvers for then moor at berth, is also feasible by a single vessel at a time, this means that the basin directly affects the possible congestion that can be created within the channel, as vessels after covering the entire channel, arrive at the end of the channel with zero velocity and then be towed by tugs in the basin of evolution, when the latter is busy, the boat remains parked at the end of the channel, generating a queue vessels behind it and not allowing other vessels exit, consequently also slide the session temporal output of the channel. The occupation of the quay by vessels occurs for times far, as the time of unloading of ships, both dry bulk containers both, is high, this does not require a congestion of vessels in the channel, but involves an accumulation of all vessels' outside of the channel, because the vessels enter the channel only if they have a quay free and therefore can reserve it, otherwise prolong their time waiting outside the channel, this implies that in a certain time horizon, not all vessels generated to 'outside of the channel can be served, so it's like if you lose ships. Have in a dock parking area helps make the entire fluid circulation model, thanks to the function that performs. But it must be said that the car park has very small, often has a capacity that varies between 1 and 2 ships, this model has a capacity of 2, so this size limit leads to a saturation of easy parking, which to be released will have to wait until the channel is viable in output, so it's back to the challenges connected to the docks. So the objectives are those going to build a model of the traffic for a port terminal, which present an access channel that allows movement within the channel, only one ship at a time, taking into account different critical that such a configuration of the access channel involves, taking into account, also, of certain factors, including, primarily, the safety distance that the boat must maintain between them within the channel and the capacity of the dock to accommodate boats.  

3 Problem Solution

We followed a phased approach to the construction and implementation of the model. In the first phase of the simulation implements the physical flow of the circulation pattern for individual vessel. Through the physical flow trying to identify which are within the same physical flow, the critical points, ie those points or areas of the port, that once were saturated, do not allow the flow of vessels progress in their internal circulation to the port, creating congestion, then the queues in the various critical points, which result in inefficiency in the use of port infrastructure and loss of time. The critical points are identified in the simulation from the level variables.

![Fig. 3: Physical flow that models ship movement in the port.](image)

The chain of events is the core of the simulation, as through the construction of this chain are unable to trigger events that allow the progress of the ships in the circulation model.

![Fig. 4: Event Chain](image)

The innovation in this model is the chain of events is that it has been constructed by exploiting the logic of Petri nets. The chain of events is built from the logic of movement identified.

Although the chain of events as in the physical flow levels are present, here have a different meaning. In the physical flow levels represent areas with limited capacity of the port, where ships go by and take until you have finished the activities at that level or the port area, and in the chain of events
represent the different levels operations that make the ships in the harbor, from where a vessel enters the channel until it comes out by the same channel.

The flows of the chain of events represent the different events that must be activated to switch from an operation to the next, and are the same events that are then inserted in the physical flow and allow the advance of this flow once come true, by what is shows the very important role that the events taking place within the whole simulation.

To activate the events, and then switch between operation to the next in the chain of events, we must satisfy the constraints, which are identified graphically for each event by an arrow linking each event to the constraints that must be satisfied by avversarsi.

The logic used to trigger the events is a type of logic if … then, that is, if the constraints satisfy some requirements then the event is active, otherwise the event remains inactive for a longer time until the combination of all the constraints are not allows you to activate it.

The main constraints related to events, are dimensional constraints and temporal, ie the dimensional constraints are related to the ability of a certain area of the port, such as the quay, to be able to accommodate only a limited number of vessels at the same time because of the limited size of that area, while the timing constraints are represented by the time required to make and finish the operation that precedes before switching operation which follows.

The dimensional constraints are represented in the simulation as a resource to exploit to saturate its capacity.

The timing constraints instead are represented by means of “hourglasses”, used in such a way as to exhaust the remaining time of a certain task.

From what we can see from the chain of events, a ship to enter the port or to get out through the channel, must also take account of two types of constraints and temporal dimensions different from the others seen so far, the first constraint is defined temporal gate inbound or released (tasso_in or tasso_out in the simulation) which tells us that the temporal gates are opened one at a time at intervals of time constants, thus there will be in the simulation sessions input to the channel and sessions of output, the second constraint instead, concerns the minimum safety distance that the different vessels which cross the channel must maintain between them, so a ship can not occupy the channel if the ship that precedes it has not first removed the safety distance.

Resources represent the constraints that must be met to ensure that the event is released.

These constraints are the size limitations that are encountered inside the port, which being subject to saturation, may, once exhausted its capacity lead to congestion and delays for the movement of vessels within the port.

In this simulation, we identified four resources:
1. resource platform;
2. resource basin evolution;
3. resource comes to parking;
4. parking resource.

For each resource was used the same construct.

Each event is updated when they were experiencing some constraints implemented in "hourglasses time" only when an hourglass (a level empties) runs out you can move on to the next step, then this means the time that must pass in order to complete the previous step and then start the next one.

We have used in the model a simple vectorization. For vectorization is meant that no longer working with single ship, but with different types of vessels, in this work, for the specific, have been taken into consideration five different types of
vessels, which are all ocean-going vessels, then high capacity for their species.

The different types of ships are:
1. cereals;
2. iron ore;
3. clinker;
4. cement;
5. TEU's.

4 Simulation and Results analysis

The results of a comparison of the different scenarios are as in the following table.

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<th>SCENARIO 2</th>
<th>SCENARIO 3</th>
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Table 3: Scenario Results

The maximum number of vessels in the channel incoming and outgoing is almost the same for all 4 models, this is due to the fact that this parameter is most influenced by the spacing of safety, which is always the same.

Comparing the model starting with scenario 2, that is, where the parking is varied from 2 to ship 1 ship, we see that the total number of ships entering and leaving the port terminal is reduced, which means that only one parking place is sufficient, you can also see by looking at the graphic related to parking, which show how widely exploited are the 2 places.

If the total number of vessels entering and outgoing is considered in scenarios 1 and 3, it is seen that increases in number, this is due to the fact that in both scenarios has been decreased the time of opening of the gates temporal, from 4 to 3 hours, even in scenario 3 will work with one parking space.

With regard to other parameters taken into consideration are not noticed major differences between the four scenarios.

Even varying scenarios the number of ships waiting outside the channel is greater than 100, this means that the model is always valid because it can serve more than 1700 vessels even in different scenarios, however, it must be remembered that are lost more 100 ships, even with a parking place with a ship and a gate time of 4 hours if they lose 200.

Table 4: Ship waiting outside of channel

It can be concluded that the greater the difference will be between scenario 2 and scenario 3, with about 100 ships served difference, but also graphical analysis should, however, work with 2 parking spaces, as they are both fully exploited is with gate time of 4 hours is 3 now, with this type of car there is no substantial difference between the two scenarios, then you have to take into account dell'ingente number of ships lost.

5 Conclusions

In this paper, after a general analysis on the logistics of port terminals, both dry bulk and container, you went to build a theoretical model of the traffic for a port, which has its greater complexity in the access channel, as it can be crossed by one ship at a time.

Assumed in the theoretical model does not take into account the port system in its entirety, that does not extend outside of the channel to the gate linking the port with the means of transport by road and rail, but this model is only interested in circulation of vessels during unloading, and does not account for what happens in the inner harbor.

To evaluate the theoretical model has exploited a simulation software. The results achieved through the software validate the goodness of the model, as in the channel of 12 Mn do not create a queue never more than seven ships, both incoming and outgoing are served a number of vessels greater than 1700 ships, a period of 6 months.

The downside of this model concerns the high number of vessels that are waiting outside the channel, in fact, in the scenario that fully reflects the theoretical model hypothesized, is formed a queue of 173 vessels outside the channel, but also in different scenarios, changing from a queue of about 100 vessels up to overcome the 200 ships. In reality, a value of this type means going to lose most of these ships, as it is not plausible leave pending such a large number of boats, the port system will be forced to refuse access to the port of different commercial companies.

By analyzing the different scenarios considered, the first future development to do is to pass through a gate time of 4 hours to one of 3 hours, starting to increase the number of ships served, which went from 1717 to 1736 ships. A second consideration, always observing the results, would be to pass not only to a gate time of 3 hours, but also to decrease the parking places from 2 to 1 place, doing so increases the number of vessels still served from 1736 to 1782 vessels, then there is an increase of 46 vessels, which value allows to thin out the tail outside the channel of about 70 ships, compared to that which is formed as a result of the theoretical model suggested, this is justified by the fact that the number docks is sufficient for the number of ships
which are welcome, in fact, have never occupied all together at the same time.
A further future development concerns an extension of this model, by supplementing with a further model, in which one tries to optimize the use of the means handling of goods and consequently optimize the use of the docks, so as to exploit them completely, so to try to cut down on the number of ships in the queue outside the channel, especially trying to make the docks type TEU's, which are those that are more saturated than the other, are increased number of integrating into the docks dry type bulk, then move to a better allocation of resources, both human and machine, to try to serve a greater number of vessels.

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