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Stochastic Sequence Simulation of Shipyard Block Erection Process

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Abstract:
In the context of shipbuilding, the block erection process is one of the most critical point of planning. It is known that the production cycle in the preassembly area determines the production capacity. Therefore, optimization of the shipbuilding activities is crucial to improve productivity and competitiveness. However, the tools commonly used in the design phase do not cover all stages of shipbuilding, allowing only an incomplete planning. Thus, the purpose of this work is to simulate the pre erection and erection processes of large ships to compare the effectiveness of different building strategies. In order to achieve this objective, a discrete-event simulation model have been developed which has the advantage to include all parameters of building processes providing results closer to reality. The analysis found that the production time using different sequences of building: ring, pyramid or layer can be significantly affected. The methodology provided is effective to identify the performance of different erection sequences. Therefore, this tool might be applied to identify the best assembly alternatives that improve shipyard productivity.

1 - Introduction

Recently, there have been significant advances in the use of simulation tools for improving the shipbuilding industry. As a solution to the matters of planning, management and optimization of production, virtual reality technologies and use of simulation has been increasingly applied by many large shipyards.

According with Shannon (1992), the simulation permits to study the risks and influence of changes by emulating the real scenario, or part of it. The main objectives of the simulation are to study the efficiency of new production technologies, to find optimal combinations of processes and to analyze production bottlenecks. Any planning of change or analysis supported by virtual modeling results provides greater reliability and security while taking strategical decisions.

Another advantage is to be able to test different layouts, process settings and different strategies of construction without requiring capital investment and any physical or organizational change (Krause, 2004). The simulation models can be quickly adapted to study different scenarios. Finally, the processing time of the simulation is depreciable in regards to the real time which allow to study complex processes during a long period, e.g. a year.

As published by Caprace et al (2011-a), it is of grand interest to combine simulation tools to optimization algorithm. Silva and Pires (2010) relates that is also common that some industries combine simulation with a planning tool to improve the decision's process.

The pre-erection and erection processes are considered as a bottleneck for the shipbuilding industry. According to Souza (2009), block erection activities involves the ultimate stages of the ship production, but it is the first step related to the production planning and scheduling. These activities will directly influence the building time. Knowing that, this work aims to develop a discrete-event simulation model (DES) to analyze the pre-erection and erection processes of a large ship, as well as viewing a shipyard in a 3D environment. The simulation model considers the following decision variables that affect the production lead-time: the number of ships, the erection strategy and the position where the ship erection starts.

2 - Methodology

2.1 - The Model

The work consists in simulate the pre erection and erection process of large ships in a hypothetical shipyard.

For this, Quest, a 3D DES software developed by Dassault Systems has been used. It operates with a discrete sequence of events in time. At a particular instant in time, only one event occurs and marks its changes in the simulation. Between two consecutive events, nothing happens in the system, in other words, there is no continuity. Time cans jump directly hours from one event to the next (Banks et al, 2009). The opposite would be a continuous simulation, where there is a small time variation between every time steps.

In addition, this kind of simulation uses random-numbers generators. It means that the stochastic events will use these random variables and will always have a different result than the precedent simulation.

The model is parametric and changes can be easily made by modifying the input database (DB).

The DB provides the necessary information to build and to execute the simulation model. Three different databases were developed to support the simulation model.

- The ship work breakdown structure (SWBS), which holds the information of different ships used within the tool such as steel block characteristics and welded connections.

- The simulation process DB that store the required information to carry out the simulation. This database content information concerning building strategy and ship position in the dry-dock. This DB also stores all the results of the simulation.

- The shipyard DB that provides information related to the shipyard layout, workshops and resources (transportation systems, cranes and workforce).

The visualization of the 3D shipyard model is presented in Figure 1. This view shows the ship block erection process including the steel stockyard, block assembly workshops, painting shop, pre-erection area and erection area (dry-dock).

In this study, the simulation starts in the exit of the steel stockyard. Processed steel is supplied for the assembly shop. Then, blocks build in the assembly shops are transported by a hydraulic vehicle to the painting and blasting zone. The number of vehicles responsible for the transport of the parts between different zones in the shipyard can be more than one depending on the parameters given before the simulation starts. The user might also alter the speed, the initial position and the strategy to pick parts. It could pick one part at time and place it in the destination.

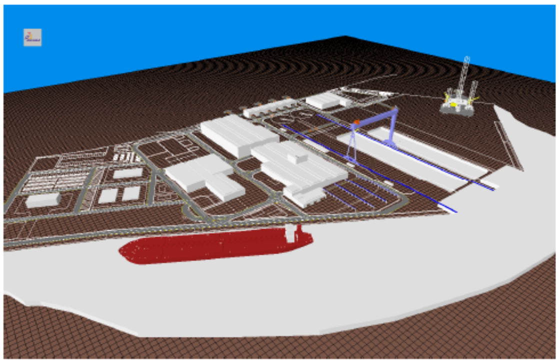

Figure 1 – Picture of the shipyard 3D model

In the blasting and painting zones there are 6 machines. Two of them are receiving the parts for blasting and the other four for painting. The vehicles leave the steel place with a part and let it in the blasting machine. After blasting time, the same vehicles are request to move the part in the direction of the painting machine. The vehicle request is always the nearest free vehicle.

The two machines work with processes. Each process is designed for a different part and can be applied only in the parts that they were designed. It has a normal distribution with a mean time and a variation. In each simulation, this distribution gives a different result. However, after a certain number of iterations a convergence of the results might be observed. A process might also have some pre-process required. For example, the painting process could not be done before that the blasting of the part is finished.

Workers are required to making those processes happen in the machine and therefore their availability is affecting the total processing time.

After passing by this process, the part is taken by the same vehicles and it is delivered in the pre-erection zone. The number of vehicles has influence in how much time the part will wait until to go to the next zone. If the part is ready for going to another zone, but all vehicles are busy, the part will wait for the availability of vehicle.

Once in the pre-erection zone, a crane is placing the parts in the reserved area of the pre-erection area. Each part is then waiting for the others parts of the same assembly before to be processed. The software identifies the parts of the same assembly by their names. In this paper, each sub-assembly has been affected to a predefined position in this area.

The gantry crane works just like the vehicles mentioned before, however there is a limited area where it can work. It will works as the parts call it and it can only take one part at time.

Once all the parts from a same group are together, three processes are executed in those groups, i.e. the assembling, welding and reworking processes.

After assembling, welding and reworking all parts of a same group, they constitute a new large block that will be used in the erection zone.

The large blocks will pass by the same three processes, assembling, welding and verification for the ship erection at the dry-dock (Figure 2).

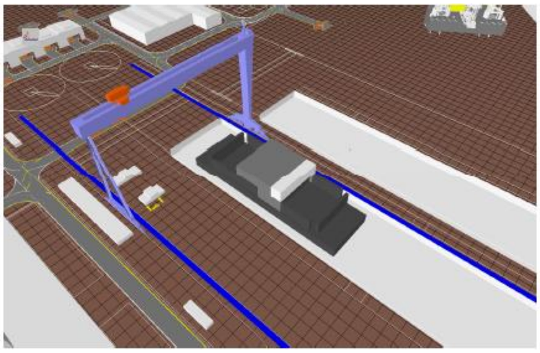
Figure 2 – Ship erection process.

The simulation model has the purpose of support discussions relative to resources requirements and layout of greenfield shipyard as well as to support the production planning of existing shipyard.

In the present work, the model was used to analyze the shipyard block erection process sequence. The ship construction time and dry-dock utilization caused by different types of building strategies have been evaluated by the simulation model.

Then, after the model calibration, several building strategies have been tested by the model.

For the model verification, it was used tools provided by the software. Also, the software has an animation that represents the simulation and that allows a visual checking of integrity.

In the absence of any information about the real output of the shipyard, experts opinions were used to calibrate the model (Shin et al, 2002). In the view of the evaluation made by the experts, the model did not show discrepancies considering the assumptions taken to build it.

2.1 - The Scenarios

In the shipyard the building methods and the building sequence are set up to optimize the work.

However, it is well known that the manufacturing cycle of the dry-dock has a strong effect in the shipyard production capacity (Souza, 2009).

Thus, different ship erection strategies have been tested in order to achieve the shortness ship production time.

The most common strategies for block erection are (Storch et al, 1995):

1. Ring-type. Taking from a longitudinal position, or a range of longitudinal positions, the block in that area is constructed starting in the bottom, and going to the top of the ship. Once it is finished, another range is taken and it starts the construction of another block. Only one block is constructed at time or two if the construction started in the middle section of the ship (one in each side, stern and bow).
2. Pyramid-type. Same concept of longitudinal position, or a range of it. However, in this type, the blocks start being constructed even before the last is finished. The antecedent is always the first one to finish. In this way there are more than two blocks being constructed at the same time.
3. Floor-type. In this case, the blocks are not going to be constructed at once. First, all the parts that goes in the bottom of the ship will be placed, forming a first layer. Then, a second layer is constructed in the middle of the ship. In the end, a third layer that contains the top of the ship. So, in this case, all the blocks are constructed in parallel.

Figure 3 shows the three different types of ship block erection.

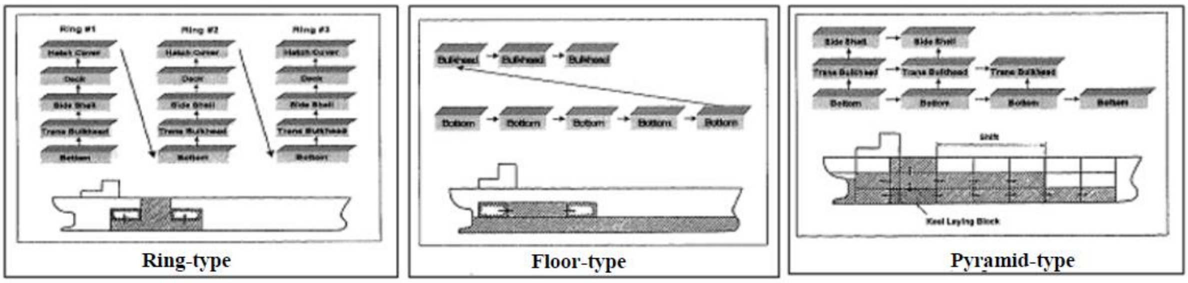

Figure 3 – Ship block erection types.

Besides those 3 types of pre-erection, the ship can also be constructed starting from the middle section of the ship and going to the stern and bow. Alternatively, the ship can starts in the stern and go until the bow (Figure 4). With a mixture of those types, there are 6 different kinds of construction in the model. It is possible to construct by:

1. Ring starting in middle.
2. Ring starting in stern.
3. Pyramid starting in middle.
4. Pyramid starting in stern.
5. Floor starting in middle.
6. Floor starting in stern.

The scenarios are coded by color in the charts presented in the next part of the paper. Each scenario name is composed by 4 digits and starts with a letter followed by a number. This letter and this number represent the ship that will be considered in the simulation. If these two digits are flowed by the character "A", it means that 3 similar ships has been simulated at the same time, otherwise it means that only one ship has been used for the simulation. Then, the next digit represents the erection strategy that has been applied: Ring-type (G), Pyramid-type (P) or Floor-type (C). Finally, the last digit of the name give the information on where the construction starts, at the stern (1) or alternatively at the middle (2).

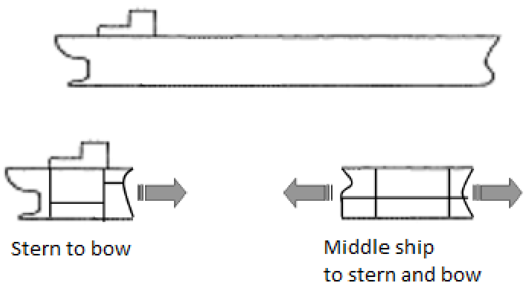

Figure 4 – Difference between types of stating construction point.

Since the same ship has been used for simulations, the first two digits are identical and equal to M9. The names of scenarios are:

For the ring-type of construction: M9G1, M9AG1, M9G2 and M9AG2;

For the pyramid-type of construction: M9P1, M9AP1, M9P2 and M9AP2;

For the floor-type of construction: M9C1, M9AC1, M9C2 and M9AC2;

Once chosen the kind of erection, the order of delivered parts in the steel yard changes. The parts that will be assembled first in the erection zone will be also produced first and they will pass by the process blasting and painting before the other parts.

Those differences between the different kinds of erection will imply variations in the total time of construction denoted lead-time. By repeating a same scenario several times (around ~200 iterations) it is possible to obtain the average lead-time of the overall construction process.

Repeating this procedure for all scenarios will allow to compare the strategies and find the best option for a specific ship.

It has been chosen to analyze the 6 kinds of erection for a scenario with a single ship. Another scenario with 3 ships simulated simultaneously has been considered. First and last ships are used to warm up the simulation. Indeed, it is not common to start to work with an empty shipyard. Therefore, the second ship to be produced is considered the reference to measure the output indicators.

In addition, in the pre-erection zone, there is a potential issue of limitation of the area available to work. This problem is studied testing all scenarios with and without this restriction. This will increase the lead-time of construction of ships since some parts will have to wait an available space in the pre-erection zone.

Once all the results were simulated, the lead-times were gathered to make a comparison between them.

3 - Results

The DES model was executed for all above-mentioned scenarios. The computation time for one single simulation was about 15 minutes in the scenarios with one ship. In the scenarios with 3 ships, the computation time was about an hour.

Considering that simulations are stochastic, bigger the number of simulations realized, better the results are. However, there are a certain number of iterations for each scenario where the results start to converge. After analyzing the convergence in each case, it was recommended to use between 150 and 200 iterations for each scenario. The number was enough to achieve the convergence and limit the computation time.

There are two types of simulation scenarios. In the first one, consider a limitation of the availability of the area of the edification zone whereas in the second one this constraint is not considered.

In total, 12 different scenarios were analyzed both without and with area limitation. So, in total 24 simulations were made. They are divided in scenarios with 1 ship and with 3 ships.

The results of the simulations without area limitation are present in Figure 5 and Figure 6. It represents the accumulated average lead-time of the ship construction. The results related to area restriction are presented in Figure 7 and Figure 8.

The average construction lead-time (in days) for each scenario, without and with restriction, was calculated for the second ship and their results are shown in Table 1 and Table 2, respectively.

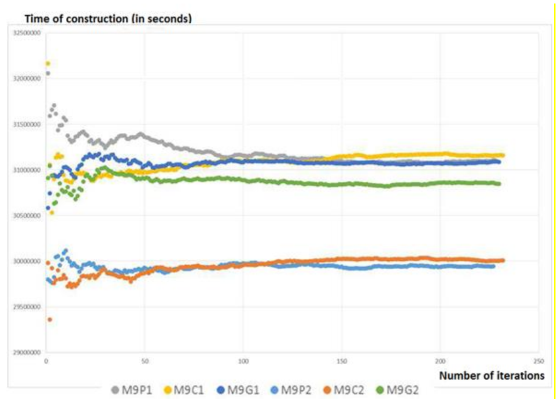

Figure 5 – Convergence of the overall lead-time of the process considering a DES with 1 ship and no constraint on the availability of the edification zone

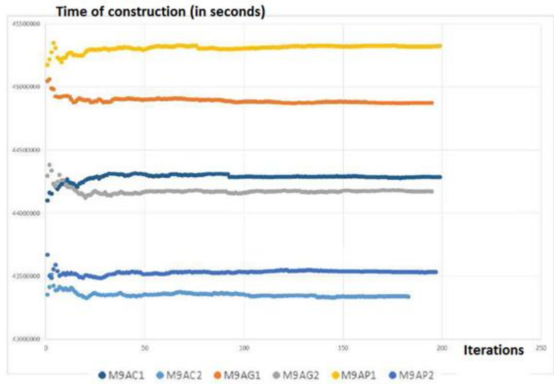

Figure 6 – Convergence of the overall lead-time of the process considering a DES with 3 ships and no constraint on the availability of the edification zone

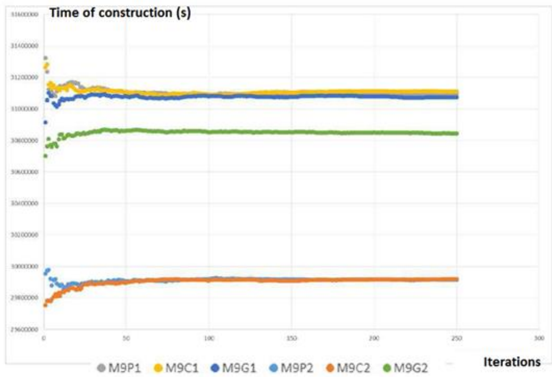

Figure 7 – Convergence of the overall lead-time of the process considering a DES with 1 ship and the constraint on the availability of the edification zone

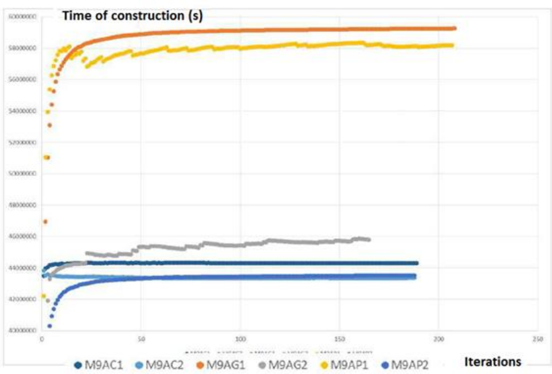

Figure 8 – Convergence of the overall lead-time of the process considering a DES with 3 ships and the constraint on the availability of the edification zone

Table 1: average construction – no area restriction

		1 ship		3 ships	
	Type of contruction	Scenario's name	Time	Scenario's name	Time
Stern to Bow	Floor	M9C1	360,60	M9AC1	512,60
	Pyramid	M9P1	360,00	M9AP1	524,60
	Ring	M9G1	359,80	M9AG1	519,40
Middle section	Floor	M9C2	347,30	M9AC2	501,60
	Pyramid	M9P2	346,50	M9AP2	503,80
	Ring	M9G2	357,00	M9AG2	511,20

Table 2: average construction – with area restriction

		1 ship		3 ships	
	Type of contruction	Scenario's name	Time	Scenario's name	Time
Stern to Bow	Floor	M9C1	360,10	M9AC1	512,60
	Pyramid	M9P1	359,90	M9AP1	673,40
	Ring	M9G1	359,60	M9AG1	685,70
Middle section	Floor	M9C2	346,30	M9AC2	501,60
	Pyramid	M9P2	346,20	M9AP2	503,50
	Ring	M9G2	357,00	M9AG2	529,90

As it can be seen from the data presented, the time of the ship construction is influenced by the chosen erection strategy. The difference of time with the change of the edification strategy, considering or not considering the area restriction, is especially noticeable for the scenarios of 3 vessels.

Moreover, the construction lead-time of one ship, in scenarios of 3 ships, is larger than the lead-time when only one ship is considered. It was expected and can be denoted as the effect of the warming-up of the simulation.

Edifications starting from the midship presented, on average, less time than from the stern and perform better in the case of layer or pyramid construction type.

In relation to the area restriction, it will not make a significant difference between the simulated scenarios. However, the restriction has a major impact on the average lea-time that is consequently higher especially in the scenarios with 3 ships and erections of ring-type and pyramid-type, starting from the stern.

As it can be observed in the histograms presented in Figures 9 to 12, the model captured the stochastic variation of the production processes. It allows to assess the risks associated with times construction. This analysis might help the shipyard to better plan their occupation and dimensions of the production slots for a certain period.

4 - Conclusion

The study showed that it is possible to create a virtual shipyard, respecting all procedures and logical sequences of building a vessel and its possible stochastic variability.

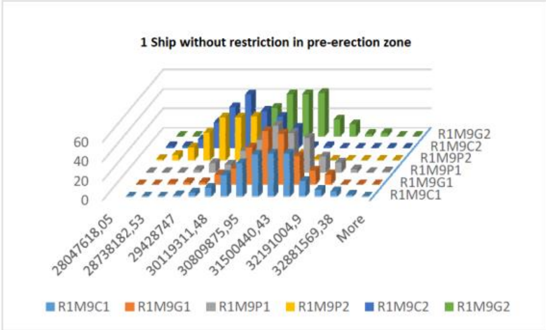

Figure 9 – Histograms of the lead-time – 1 ship and no area restriction

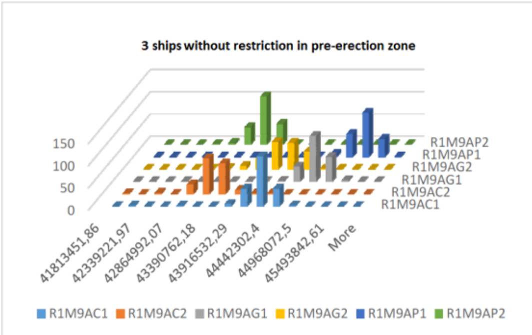

Figure 10 – Histograms of the lead-time – 3 ships and no area restriction

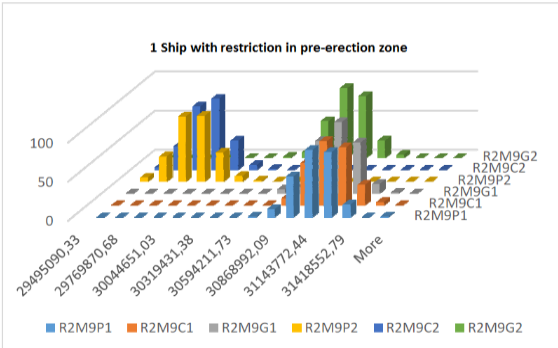

Figure 11 - Histograms of the lead-time – 1 ship with area restriction

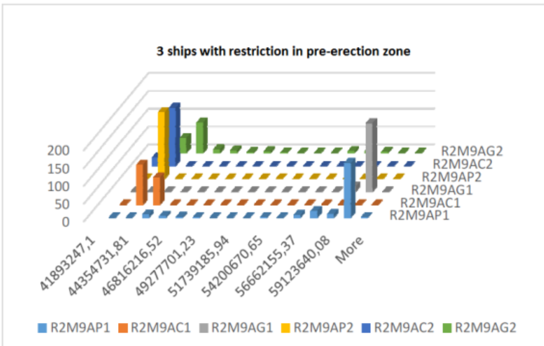

Figure 12 – Histograms of the lead-time – 3 ships with area restriction

The discrete-event simulation has proved to be an efficient tool to identify bottlenecks in production and more favorable strategies to build ships. It is noticed that as the model covers all processes of a shipyard, the discrete-event simulation might be used in the future to study other stages of production as well as to evaluate the use of resources and work force.

All the simulation scenarios presented in this paper has been generated parametrically trough a database containing the required information. It shown high flexibility and will future allow generating simulation models for optimization. The individual characteristics of each scenario were provided by the database consisting of external files to the software. Therefore, to make the change of scenario, it was necessary to modify only a field of the database spreadsheets, an easy reusability of the model is guaranteed.

The simulation is a useful tool to identify the different impacts of each variable of the process on the overall time required for the construction of a ship. In addition, decisions involving goals and deadlines can be taken with greater awareness, from the information returned by the model. In general, the discrete-event simulation has a great potential to be applied in favor of the Brazilian shipbuilding industry.

5 - Acknowledgments

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6 - References

BANKS, J.; CARSON, J. S.; NELSON, B. L.; NICOL, D. M. Discrete-Event System Simulation. Prentice Hall; 5th edition, 2009. 640 pages.

CAPRACE, J. D. J. E. M.; DA SILVA, C. T.; RIGO, P.; PIRES, F. C. M. *Discrete event production simulation and optimization of ship block erection process*. In: 10th International Conference on Computer Applications and Information Technology in the Maritime Industries, 2011, Berlin. Proceeding, May 2011, pages 271-282.

SHANNON, E. R. Introduction to simulation. Proceedings of the 24th Conference on Winter Simulation, 1992.Pages 65-73.

SHIN J.G.; WON, S. I.; RYU, C. H.; YIM, H.; LEE, J. H. *Object-Oriented Development of an Integrated System for Manufacturing Information of Roll Bending Process*. Journal of Ship Production, Volume 18, Number 23, pages 86-91, 2002

SILVA, C. T. ;PIRES, F C M. *Potencial de aplicação de simulação de processos industriais à construção naval*. In: 23 Congresso Nacional de Transporte Aquaviário, Construção Naval e Offshore, 2010, Rio de Janeiro. 23 Congresso Nacional de Transporte Aquaviário, Construção Naval e Offshore. Rio de Janeiro: Sociedade Brasileira de Engenharia Naval, 2010. v. 1. p. 1-15.

SOUZA, C M. Técnicas avançadas em planejamento e controle da construção naval. Tese de Doutorado, Universidade federal do Rio de Janeiro/ COPPE, Rio de janeiro, 2009.

STORCH, R.L.; HAMMON, C.P.; BUNCH, H.M.; MOORE, R.C. Ship Production. Cornell Maritime Press, 2nd edition, 1995. 420 pages.