Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 88 (2020) 122–126

www.elsevier.com/locate/procedia

13th CIRP Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME '19

Method for integrated logistics planning in shipbuilding

Jan Sender[a,*], Steffen Klink[b], Wilko Flügge[b]

[a]*Fraunhofer Research Institution for Large Structures in Production Engineering IGP, Albert-Einstein-Str. 30, 18059 Rostock, Germany*
[b]*University of Rostock, Chair of Manufacturing Technology, Albert-Einstein-Str. 2, 18059 Rostock*

* Corresponding author. Tel.: +49-381-49682-55; fax: +49-381-49682-12. *E-mail address:* jan.sender@igp.fraunhofer.de

Abstract

In shipbuilding the transport processes are of major concern during the planning of production facilities and processes. Due to the heavy weights of the shipbuilding interim products the transport resources and procedures are essential planning topics for shipyards. This paper describes an approach for an integrated production and logistics planning focusing the particular circumstances of the shipbuilding transport processes. Therefore a logistics simulation module is introduced which enables the integration of issues from the planning of logistics processes into the production planning of shipyards. The functionality of the approach is proven on a planning example for a shipyard.

Keywords: Shipyard planning; Digital shipbuilding; Logistics simulation

1. Introduction

The shipbuilding industry has to cope with high complexity within the shipbuilding process. This complexity results from a high complex structure of a ship with a large number of different parts and interim products. A ship assembly takes place in a large number of production stages starting with steel parts and outfitting components and ending with the final ship. Between the production stages are a lot interdependencies as well as a high degree of parallelization to keep the execution time as short as possible. Shipyard deploy specialized resources to built ships. Beside shipbuilding specific production facilities (e.g. panel assembly lines, drydocks) transport systems as large goliath cranes characterize todays shipbuilding process. Especially in the higher production stages shipyards have to handle large and heavy interim products (e.g. units, blocks, modules). [1] Figure 1 shows a typical arrangements of cranes in a final assembly hall of a shipyard.

To ensure an efficient and competitive shipbuilding process it is necessary to synchronize all shipyard resources according to the production program. By an insufficient synchronization of the resources the shipyard loses efficiencies in the processes. This results in unnecessary production costs caused by waiting times, low resource utilization or missed delivery dates what reduces the competitiveness of the shipyard.

The maritime market is highly volatile. Fluctuating demand of different ship types influence the strategic planning of shipyard facilities [2]. This forces shipyards to adapt their production system continuously to new circumstances. Changes in one production stage have a high impact on the up- and downstream processes due to the high interdependencies between the production stages. Thus, an isolated consideration of adjustments on a resource is inappropriate.

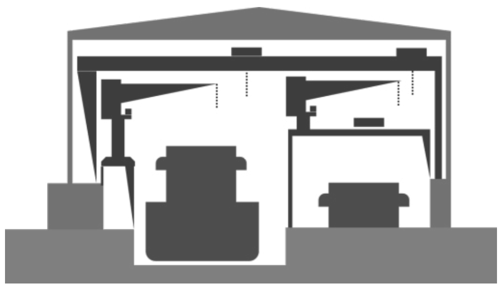

Fig. 1. Crane arrangement in shipyard final assembly.

10.1016/j.procir.2020.05.022

To deal with these dynamic interdependencies within production processes it is common to apply simulation-based planning tools. These tools often implement the discrete event simulation approach. It is well-suited for this kind of planning issues as it is able to consider the dynamic behavior of a complex systems with many interdependencies and parallel processes. [3]

This paper introduces an approach for the integrated logistics planning within the shipyard planning process. A simulation tool is presented, which enables to regard shipyard specific logistic process in a factory design environment.

2. Integrated logistics in production planning

To design production facilities production planner use modern simulation tools to support the decision-making process for different planning tasks. Typical planning tasks in the maritime industry are:

- Layout planning and evaluation of investments
- Reorganization of production structure and/or processes
- Performance and productivity analysis
- Make-or-buy analysis
- Evaluation of producibility of new orders

By performing simulation studies for the planning tasks the simulation tools generate key figure that characterize the performance of the production system for a certain simulation run. The most important key figures of simulation studies for the planner are:

- Utilization of production resources (machines, personnel, transport systems, area) for identification of bottlenecks and productivity potentials
- Throughput times of parts
- Delivery dates of ships in comparison to the proposed delivery date of a ship
- Generated production costs for different orders

Fig. 2 shows an exemplarily result for key figures of shipbuilding network evaluation [4]. As the variation of the planning tasks is very high, the focus of scientific work in the simulation-based planning in shipbuilding also shows a wide range in the application. Most application show a focus on the consideration of production facilities as they in general represent the highest investment within a planning project. In these cases, the transport processes are often regarded as sequential processes (e.g. [5, 6, 7, 8]). So the transport processes are modelled in a simplified way. In these approaches often only certain workshops or processes of a shipyard a considered in the planning application [9, 10, 11, 12, 13]. The problem is, that this kind of modelling is only sufficient for throughput time analysis. But when it comes to bottlenecks within the transport resources the simplified modelling could lead to wrong key figures. As a result, the planner could make wrong decisions based on these key figures.

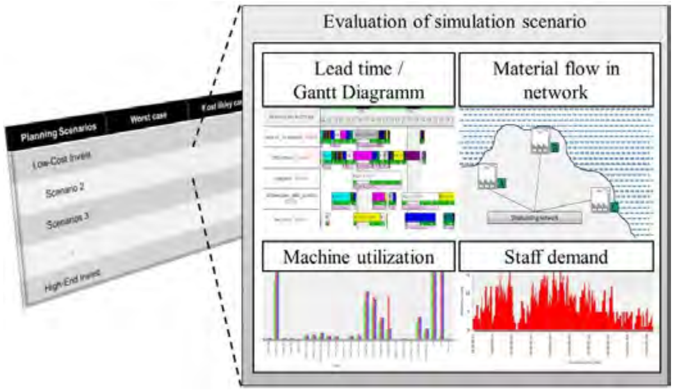

Fig. 2. Results of a simulation study [4].

In shipbuilding another planning approach is a separated consideration of production and logistics. In the first step the production simulation model calculates delivery dates as well as sources and sinks for transport processes for each production stage. The information of the production simulation model used as input data for the second step, the transport simulation. The transport simulation only considers the transport process and resources. The aim of this simulation is to find a configuration of transport resources to meet the transport demand of the production simulation model. An integrated planning is not part of this approach. [14]

The research approaches performing an integrated consideration consider especially the crane resources. The implementation of crane models in the simulation systems enable to simulate certain crane activities. Exemplarily activities are:

- Turning parts with the crane during transport process [15]
- Coupling of different cranes to increase transport capacity [16]

Other simulation approaches only consider the transport itself but in a very detailed way. The tool calculates forces in wire ropes as well as the dynamic behavior of the structures. The collision detection between transport part and transport resource is another aim of these tools. They are used for the detailed planning of complex transport maneuvers. [17, 18, 19, 20]

In other industries integrated logistics approaches are also gaining an importance. Some approaches show the advantage of an integrated planning approach taking the example of an integrated scheduling [21, 22, 23, 24]. Further examples focus on integrated logistics approach for supply chain applications [25, 26, 27].

The analysis of current work on integration of logistics into production planning shows the benefits of an integrated approach for production facilities and logistics as well as first good approaches for shipbuilding applications.

Nevertheless, a planning approach is missing to implement the integrated logistics planning in the shipyard planning process by considering shipyard specific transport processes.

Here it is required to incorporate the logistics process into the production-planning tool. Therefore, the next chapter explains the shipbuilding specific transport processes and shows the process models as a basis for implementation into a production simulation model.

3. Modelling logistics in shipbuilding

Transport processes connect the resources of the production stages and fulfill the shipyards material flow. The large dimensions and weight of shipbuilding interim products make special transport systems necessary. Thus, the transport systems of a shipyard are accompanied with a high investment. Consequently, the shipyard planner should consider the transport processes within the shipyard planning with major concern. *Andritos & Perez-Prat* give an overview on typical shipbuilding transport resources and their transport capacity range. [28]

Beside the high investment the transport resources are often a bottleneck during the shipbuilding process. They are relevant to the shipbuilding lead time and embody a strategic resource for a shipyard. These transport resources should be integrated into the production planning process in an adequate manner. To integrate the transport systems into the planning process it is essential to understand the logistic processes on a shipyard. In the following two shipbuilding specific process, which need to be regarded, are explained exemplarily.

3.1. Overlapping usage of transport and production resources

The use of crane resources during assembly is very common in shipbuilding. In the block assembly blocks are assembled from units. And in the final assembly the ship is assembled from blocks. Both assembly is done by crane usage. The following explanation focusses on the block assembly process but it is the same procedure in the final assembly. The crane transports the unit to the block assembly area. Then the unit is positioned by crane. After exact positioning the unit is tack-welded to the already assembled unit of the block. During this tack welding the crane has to hold the weight of unit. The crane is occupied for the holding process until the welding seam is proper to hold the weight of the unit and there is no risk for a drop down of the unit. After the holding time the crane is available for the next transport process. Figure 3 shows the process in a swim-lane diagram.

3.2. Combined transport with overlapping transport resources

When a shipyard operates in different production halls a combined transport is necessary to realize a transport from one production hall to another. For large scale part as units or blocks each production hall possesses a transfer station. According to paragraph 3.1 the following explanation focuses on a unit transport to the block assembly. A crane transports the assembled unit from the assembly area to the transfer station. At the transfer station the crane positions the unit onto a heavy load transporter.

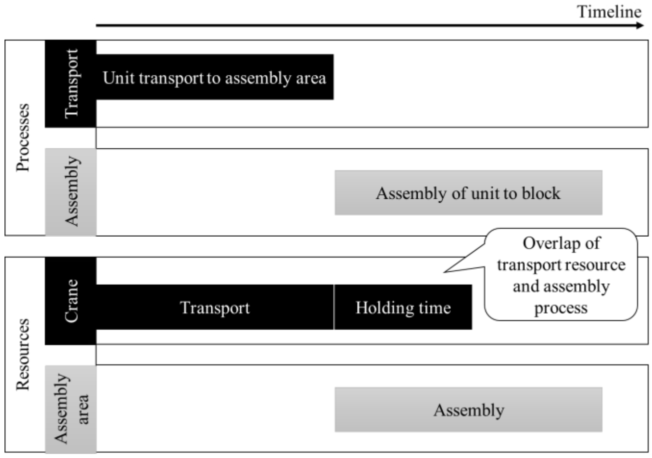

Fig. 3. Process of overlapping production and logistics resources.

This process is quite difficult as an exact position is required for safe transport of the unit. In the next step the heavy load transporter fulfills the transfer of the unit to the next production hall, the block assembly. In the block assembly the heavy load transporter moves to the transfer station. Then the crane in this production hall fastens the unit. When the unit is fastened the crane unloads the unit from the heavy load transporter. The crane positions the unit on the desired area in the assembly. Figure 4 shows the combined transport with the parallel occupation of transport resources. Some shipyards deploy special racks on the transfer station to decouple the crane from the heavy load transporter. In practice a combination of this two transport types take place to fulfill the overall transport process of unit to the block assembly. The described processes are transferable to other transports of a shipyard. For example:

- Outfitting modules from outfitting to block assembly
- Main Engine from delivery to final assembly
- Unit from unit assembly to blasting and painting

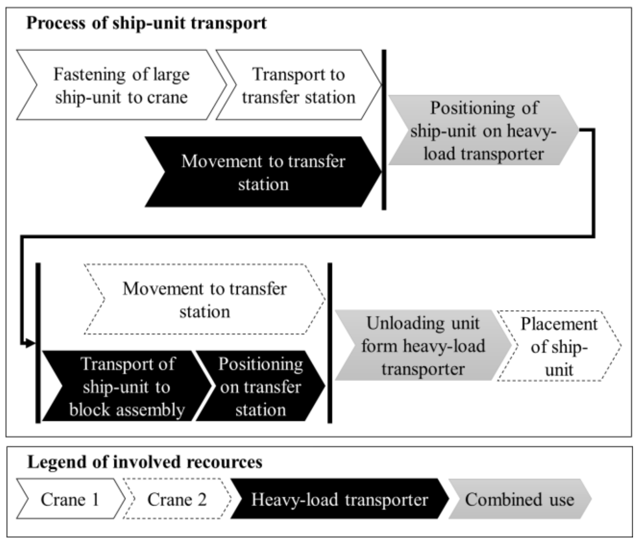

Fig. 4. Process of overlapping logistics resources.

The process models are a good basis to implement them to a shipyard production simulation model. The implementation enables to accomplish an integrated production and logistics planning system.

4. Implementation in shipyard simulation tool

For an existing shipyard production simulation model [4] a new transport planning module is introduced. The transport planning module is integrated to the resource structure of the shipyard resource model. Each transport resource has specific characteristics as for example:

- Capacity
- Speed
- Possibility to combine with other transport resources
- Range of motion

With this data it is possible to verify if the transport resource is able to fulfill a transport request from a part with a specific weight, a source station and a sink station. In case that there is no transport resource able to reach source and sink a combination of resources takes place. An Algorithm is implemented to perform this combination. The algorithm check routes of possible transport resources from source to sink by checking the capacity for each transport resource on the route as well as the possibility to combine the resources. In case that the algorithm finds out more than one combination of transport resource, the combination with the shortest and fastest track is defined to fulfill the transport. The next step is the extension of the work plan of the units and blocks with the information for required holding times. With this information the unit is able to request a transport resource not only for a transport but for holding procedures during the assembly process. This integration of the logistics module enables the shipyard planner to perform most of the planning task in one simulation tool. All relevant resources and processes are modeled and implemented to perform a simulation run for the entire shipyard.

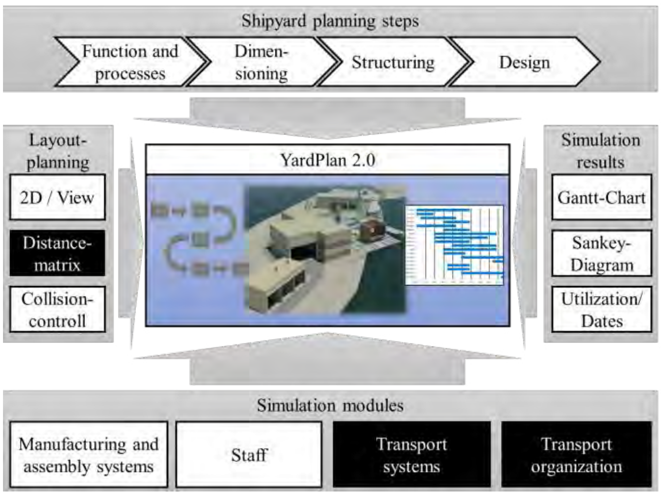

Fig. 5. YardPlan 2.0 planning tool.

The simulation run points whether there is a bottleneck in a production or a logistics facility. The presented simulation tool is called YardPlan 2.0 and is used in shipyard planning projects around the globe. Figure 5 shows the structure of YardPlan 2.0. The figure highlights the transport module in black.

5. Use case

To verify the simulation to this chapter describes a shipyard planning use case. The goal of the planning task to find a resource configuration for an existing shipyard to realize a production program of four containerships per year. The lead time per ship should not exceed 9 month. Therefore the shipyard planner has to define an investment program suitable for this task.

The first step is to model the shipyard with the resources within the simulation tool. The resources include the production as well as transport systems with their characteristics. Then the planner defines the product model for the container ships with the product structure as well as the work plans for the parts.

In the next step the first simulation run takes place and points out the bottleneck of the shipyard. Then the planner eliminates the bottleneck by simulation an investment and increasing the capacity. For the first simulation run it is the panel line of the shipyard. After implementing a new panel line, the next simulation run is performed. Now the bottleneck changes to the painting process. In the following simulation run the planner increase painting capacity by investing in new painting facilities. In the third simulation run the block assembly is the bottleneck. The analysis of the simulation data enables the planner to check which resource has the highest utilization. Here the crane has the highest utilization. Thus not a new block assembly area is required but an additional crane.

Figure 6 shows the results of this iterative simulation procedure. The upper array points out the investment needed to reach the planning goals.

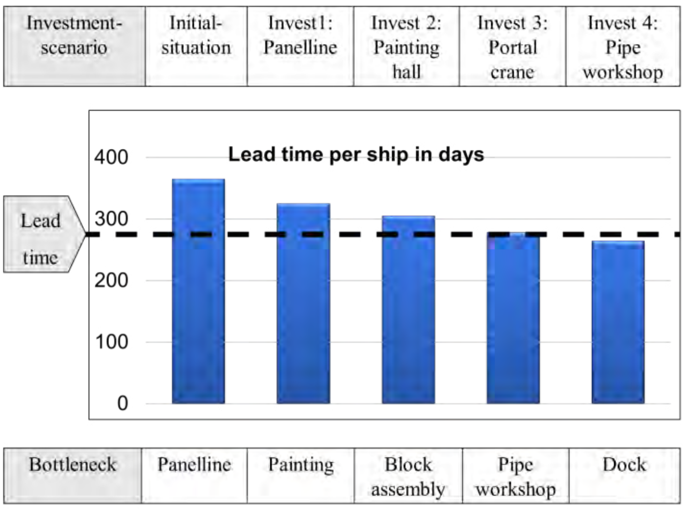

Fig. 6. Results from iterative planning procedure for the use case.

4. Conclusion

For shipyard planning the integrated consideration of production and logistics resources is necessary to ensure a sophisticated planning procedure. Therefore the authors introduce an approach to model the shipyard specific transport processes and integrate these processes into a shipyard simulation tool called YardPlan 2.0.

The YardPlan 2.0 was developed during and applied in different shipyard planning projects. The use case in this article as well as the experiences of the authors with shipyard planning projects confirm the advantages of an integrated consideration of production and logistics in one planning tool.

Future development in shipyard simulation will concentrate warehouse resources and processes within a shipyard to evaluate supplier integration as well as purchasing strategies and their influences on production and logistics resources.

References

[1] Storch RL, Hammon CP, Bunch HM, Moore RC. Ship Production. 2nd ed. New Jersey: THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS; 1995.

[2] Sender J, Wanner MC, Meißner J. Design of Production Systems for Large Maritime Structures. Proceedings of the 5th International Conference on Changeable, Agile, Reconfigurable and Virtual Production. CARV 2013;437-442.

[3] Schenk M, With S, Müller E. Factory Planning Manual: Situation-Driven Production Facility Planning. Berlin Heidelber: Springer-Verlag Berlin Heidelberg; 2010.

[4] Sender J, Illgen B, Flügge W. Digital design of shipbuilding networks. 12th CIRP Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME ´18. 2019;79:540-545.

[5] Caprace JD, Trevisani Da Silva CT, Rigo P, Martins Pires FC. Discrete Event Production Simulation and Optimisation of Ship Block Erection Process. In: Bertram V, editor. Proceeding of the 10th International Conference on Computer Applications and Information Technology in the Maritime Industries; 2011. p. 271-282.

[6] Lee K, Shin JG, Ryu C. Development of simulation-based production execution system in a shipyard: a case study for a panel block assembly shop. Production Planning & Control 2009;20-8:750-768.

[7] Caprace JD, Freire RM, Assis LF, Pries CM, Rigo P. Discrete Event Production Simulation in Shipyard Workshops. In: NN, editors. Proceeding of the 21th COPINAVAL. Bunos Aires: COPINAVAL; 2011. p. 20 (Pages).

[8] Bair F, Langer Y, Caprace JD, Rigo P. Modelling, Simulation and Optimization of a Shipbuilding Workshop. Entrepeneurship and innovation CAHIER DE RECHERCHE 2007;7:283-293

[9] Song YJ, Woo JH. New shipyard layout design for the preliminary phase & case study for the green field project. Int. J. Naval Archit. Ocean Eng. 2013;5:132-146.

[10] Song YJ, Woo JH, Shin JG. Research on a simulation-based ship production support system for middle-sized shipbuilding companies. Inter J Nav Archit Oc Engng 2009;1:70-7.

[11] Wang C, Mao P, Mao Y, Shin JG. Research on scheduling and optimization under uncertain conditions in panel block production line in shipbuilding. International Journal of Naval Architecture and Ocean Engineering 2016;8:398-408.

[12] Jeong YK, Lee P, Woo JH. Shipyard Block Logistics Simulation Using Process-centric Discrete Event Simulation Method. Journal of Ship Production and Design 2018; 34-2:168-179.

[13] Kwon B, Lee GM. Spatial scheduling for large assembly blocks in shipbuilding. Computers & Industrial Engineering 2015;89:203-212.

[14] Wang C, Mao YS, Xiang ZQ, Zhou YQ. Ship Block Logistics Simulation Based on Discrete Event Simulation. International Journal of Online and Biomedical Engineering 2015;11-6:16-21.

[15] Steinhauer D. The Simulation Toolkit Shipbuilding (STS) – 10 Years of Cooperative Development and Interbranch Applications. In: Bertram V, editor. 10th Ero-Conference on Computer and IT Applications in the Maritime Industries (COMPIT). Berlin: TUHH Technologie GmbH; 2011. p. 453-465.

[16] König M, Beißert U, Steinhauer D, Bargstädt HJ. Constraint-based Simulation of outfitting processes in shipbuilding and civil engineering. In: Zupačič B, Karba R, Blažič S, editors. Proceedings of the 6th EUROSIM Congress on Modeling and Simulation. Ljubljana: ARGSIM; 2007. p. 359-369.

[17] Park KP, Ham SH, Lee CY. Application and validation of production planning simulation in shipbuilding. Ocean Engineering 2016;114:154-167.

[18] Lee H, Roh MI, Ham SH. Block turnover simulation considering the interferences between the block and wire ropes in shipbuilding. Automation in Construction 2016;67:60-75.

[19] Cha JH, Roh MI. Combined discrete event and discrete time simulation framework and its application to the block erection process in shipbuilding. Advances in Engineering Software 2010;41:656-665.

[20] Cha JH, Park KP, Lee KY. Development of a simulation framework and applications to new production processes in shipyards. Computer-Aided Design 2012;44:241-252.

[21] Ehm J, Freitag M. The benefit of integrating production and transport scheduling. In: Teti R, editor. Research and Innovation in Manufacturing: Key Enabling Technologies for the Factories of the Future - Proceedings of the 48th CIRP Conference on Manufacturing Systems. Ischia (Naples): Elsevier Procedia; 2015. p. 585-590.

[22] Frazzon EM, Albrecht A, Hurtado PA. Simulation-based optimization for the integrated scheduling of production and logistic systems. IFAC-PapersOnLine 2016;49-12:1050-5.

[23] Ehm J, Scholz-Ritter B, Makuschewitz T, Frazzon EM. Graph-based integrated production and intermodal transport scheduling with capacity restrictions. CIRP Journal of Manufacturing Science and Technology 2015;9:23-30.

[24] Frazzon EM, Albrecht A, Hurtado PA, de Souza Silva L, Pannek J. Hybrid modelling approach for scheduling and control of integrated production and logistic process along export supply chains. IFAC-PapersOnLine 2015;48-3:1521-6.

[25] Díaz-Madroñero M, Peidro D, Mula J. A review of tactical optimization models for integrated production and transport routing planning decisions. Computers & Industrial Engineering 2015;88:518-535.

[26] Ullrich CA. Integrated machine scheduling and vehicle routing with time windows. European Journal of Operational Resarch 2013;227:152-165.

[27] Scholz-Reiter B, Frazzon EM, Makuschewitz T. Integrating manufacturing and logistic systems along global supply chains. CIRP Journal of Manufacturing Science and Technology 2010;2:216-223.

[28] Andritos F, Perez-Prat J. State-of-the-Art report on, The Automation and Integration of production Processes in Shipbuilding. Joint Research Centre, European Commission. 2000.