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SHIPBUILDING PRODUCTION PROCESS DESIGN METHODOLOGY USING COMPUTER SIMULATION

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Summary

In this research a shipbuilding production process design methodology, using computer simulation, is suggested. It is expected from suggested methodology to give better and more efficient tool for complex shipbuilding production processes design procedure. Within the first part of this research existing practice for production process design in shipbuilding was discussed, its shortcomings and problem were emphasized. In continuing, discrete event simulation modelling method, as basis of suggested methodology, is investigated and described regarding its special characteristics, advantages and reasons for application, especially in shipbuilding production process. Furthermore, simulation modeling basics were described as well as suggested methodology for production process procedure. Case study of suggested methodology application for designing a robotized profile fabrication production process line is demonstrated. Selected design solution, acquired with suggested methodology was evaluated through comparison with robotized profile cutting production line installation in a specific shipyard production process. Based on obtained data from real production the simulation model was further enhanced. Finally, on grounds of this research, results and droved conclusions, directions for further research are suggested.

Key words: *shipbuilding; production process design; decision making; computer simulation*

1. Introduction

On today's market, shipyard continuously has to invest in improvement in their production process and technology so to increase productivity and profit. Therefore, shipyard management is often conducting significant actions in their production process, especially in terms of implementing new technologies into the existing production process, which is a complex task. Design of the new production process is a task that is often based on various assumption within known existing limitations, furthermore, solution is necessary the result of interaction between dependent decision making variables [1]. Regarding these issues, the author has analyzed existing design methods, techniques and tools for designing production processes, and the shipbuilding process in particular [2]. Following perceived shortcoming of existing method, the need for a new scientifically founded methodology for shipbuilding process design is identified. Such method should provide a better support within implementation of shipyards new technologies, within managing and improving of existing ones, and within decision making process overall. Therefore, in this paper a methodology for shipbuilding production processes design based on simulation modeling method and chosen operation research methods will be presented. Suggested methodology and designed computer simulation model was tested through case study of particular shipyards production process design and was confirmed after the production line installation. Model was further enhanced with real process data and confirmed against several different production scenarios and as such it has potential to be used in real production process for scheduling, conducting what – if scenarios, optimization, planning, control, etc.

2. Problem discussion

Shipyard production process, regarding its characteristics, is one of the most complex business and production systems. This complexity is the result of the complexity of its final products - ship, individual product of high capital value, which are mainly of different types and sizes. Such a complex product requires equally complex shipbuilding process with following fundamental characteristics [3]: large number of intermediate products; significant interaction and interdependence of processes; mostly it is about non-repeating processes with different durations; process input contains a large number of components, but with small number of different output final products; processes are conducted in many parallel sub processes, with greater or lesser time overlaps; processes are technologically different, using different means of work; production process has both, a "movement of products through the process," as well as "the process moving through the product". On figure 1, a simplified scheme of a shipbuilding production process is given. Within conducted research, various existing methods, techniques and tools for production process design were investigated and shortcomings of such methods are identified, especially in terms of above mentioned complexity of the shipyard production process [2, 4]. In general, with a conventional approach a design solution is commonly defined based on comparison with other shipyards which already have similar technology. Such solution in particular cases can be satisfactory, however not necessarily optimally adapted to the observed shipyard [5, 6]. For that matter, the application of the scientific methods for process design and improvement is more widely accepted, i.e. relevant methods of mathematical modeling [7, 8]. However authors identifies shortcomings of conventional mathematical modeling and analytical approaches for designing complex production processes, such as shipbuilding, which makes the application of conventional mathematical methods with certain limiting factors, such as [9]: real production process, elements and their relations are often insufficiently known and can’t be mathematically defined; real problems are often very complex, which makes its analytical definitions very difficult; with conventional mathematical modeling it is difficult to render dynamics of observed process. Following identified issues, within this research, a new methodology for shipbuilding production processes design, based on simulation modeling method, and chosen operation research methods and tools is presented.

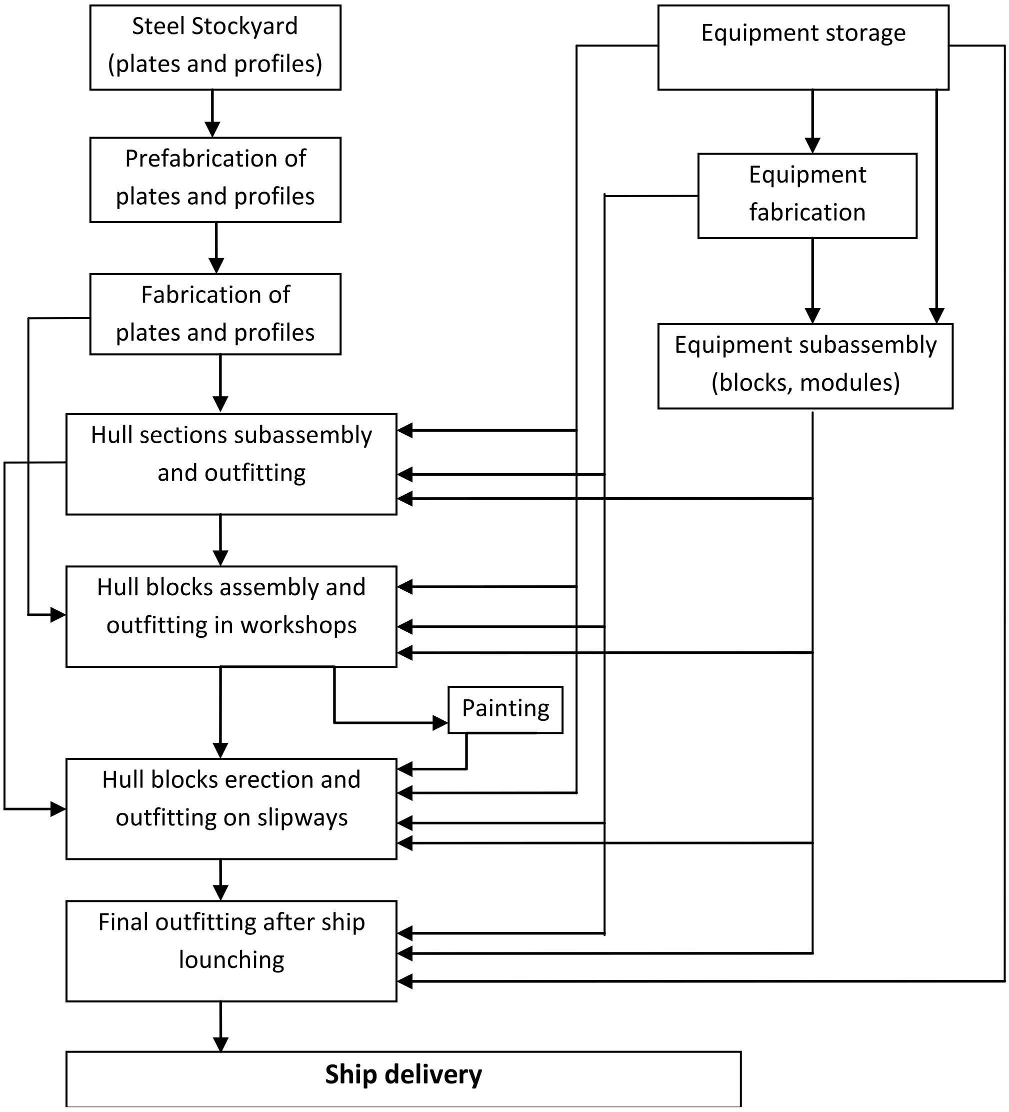


Fig. 1 Shipbuilding production process scheme

3. Problem solving methodology

Based on conducted analysis and identified shortcomings a new methodology for shipbuilding production process design is developed and suggested, with discrete event simulation modeling as its basic method.

3.1 Discrete event simulation modeling

The term simulation modeling expresses a complex activity that involves three elements: the actual system, model and the computer. Simulation can be defined as the process of establishing a dynamic model of the actual dynamic system, within the defined requirements and limits, for the purpose of understanding the behavior of the real system and evaluation of different design and/or production alternatives for the design of new system or to improve of the existing one [10]. Within proposed methodology, an object oriented *SimTalk* language, within discrete event simulation modelling software *eM-Plant*, is used. Discrete event simulation is used because the system of the production process researched in this work is mainly recognized as discrete event system. In such system each event occurs at a particular instant in time and marks a change of state in the system, between consecutive events, no change in the system is assumed to occur [11]. A computer simulation model, compared to traditional analytic model, is more descriptive, more manageable and it allows designers to verify various decisions alternatives on computer, fast and in early design stages, [12]. Furthermore, such approach makes the final decision more reliable and better adapted to the observed shipyard because it provides a lot of relevant and timely information enabling more reliable and lower risk decisions with solution better adapted to the particular shipyard prior to the line installation. In general, some of the most significant reasons why simulation modeling method is suggested as basic method for production process design are, [13]: computer simulation model can be used for evaluating different design alternatives (what-if scenarios) prior to the final investment; computer simulation model can be used for experimenting with certain critical equipment parameters without influencing the real process; using computer simulation model, it is possible to spot process bottleneck on its computer model before they occur in the real process; using process simulation computer model could improve process productivity; using process simulation computer model could improve scheduling policy; using process simulation computer model could reduce production costs and improve quality, etc. On the other hand, one should be aware that simulation modeling process could be time consuming and costly so it should not be used if for example: problem can be solved faster and easier analytically; problem can be solved using classic experiment; developing simulation model costs more than potential benefits; there is no time which developing simulation model requires; simulation model results can not be confirmed; behavior and characteristics of modeled system is too complex and unknown.

3.2 Proposed methodology description

In this work, of particular interest will be the case of shipbuilding production process and its computer simulation model. Methodology itself is structured through seven phases as follows:

Phase 1; Problem and project goal definition; Within this phase existing process should be analyzed and problems, goals and deadlines should be defined using methods and tools such as graphic process flow, cause effect diagram, pareto chart, benchmarking (SWOT, comparison tables, expert survey, potential analysis) etc. Main tasks of this phase are as follows: define problems and its causes, and what has to be improved; project goals should be clearly defined; responsibilities and deadlines should be defined.

Phase 2: Definition of input data and conceptualization of simulation model; The main goal of this phase is to gather required input data, establish preliminary new design solution and it simulation model using methods and tools such as cause effect diagram, CAD tools, process flow chart, simulation object programming language, etc. Main tasks of the phase 2 are: definition of input data and preliminary new design solution (defining equipment CAD drawings, process flowchart, cause effect chart. etc.); conceptualization simulation model (simulation model of new production process should be conceptually defined).

Phase 3: Computer simulation model development; The main goal of this phase is to develop functional computer simulation model of new production process design using primarily discrete event simulation model method and tools such as regression analysis, statistic analysis, simulation, etc. Main tasks of this phase are: organization and systematization of gathered data (understands overview of available data and identification of missing ones); definition of input production data (input production data as basis for simulation model should be defined); developing of computer simulation model (computer simulation model of new design is developed within discrete simulation software).

Phase 4: Verification of simulation model; The main goal of this phase is verifications of developed simulation model and confirm it for further analysis, to establish confidence in functionality and logic of developed simulation model. Methods used are mainly benchmarking (comparison tables) and expert survey. For that matter verification of model understands removing logical mistakes from model and insuring full functionality of the model.

Phase 5: Production scenarios analysis and improvement of simulation model; The main goal of this phase is to evaluate simulation model of design solution and its potential improvement. This phase should result with definition of line parameters as to satisfy project goals. Main task of this phase are: analysis and validation of simulated design solution (design solution should be analyzed against project goals as to find if the goals of the project are satisfied. If not, solution should be further analyzed and improved); analysis and improvement of simulated design solution. Hereby suggested methods and tools used are: for validation of design solution, material flow analysis and production line load analysis simulation method is used; with sensitivity analysis result is tested against changes of line parameters and most influence one are identified.

Phase 6: Results documenting; Main task of this phase is to document project procedures and results on clear and understandable manner.

Phase 7: Implementation of design solutions; the main goal of this phase is implementation of suggested design solution into the real shipyard production process. Main task of this phase are: implementation of the final design solution into the real shipyard process; improvement of simulation model (simulation model is further improved based on gathered data from real production process). Such improved model can be used for continuous production improvement and production planning.

In Table 1, a condense presentation of methodology phases and associated main tasks is shown.

Table 1 Condense presentation of methodology phases and associated main tasks

Phase No.	Main tasks
1.	- Problem definition - Project goal and deadline definition
2.	- Input data definition - Simulation model conceptualization
3.	- Definition of input product mix - Computer simulation model development
4.	- Simulation model verification
5.	- Analysis of simulated design - Improvement of simulated design
6.	- Documenting procedures and results
7.	- Implementation of final design solution

4. Methodology application case study

Developed methodology was applied and tested through case study of designing shipyards robotized profile fabrication production line. Methodology was conducted following the defined procedure explained in this section.

4.1 Identifying the goal of the new robotized profile fabrication line design

Existing profile fabrication line, in observed shipyard is obsolete and have inadequate throughput rate, occupies too large production area and workers. Therefore, the shipyards major goal to design a new, robotized profile fabrication line, which will require less space, be more efficient and have larger throughput rate. Method used in this phase, for defining initial design, was mainly benchmarking through comparison with similar shipyard already having such production line, where shipyard and chosen equipment manufacturer had suggested an initial production process design. Line throughput was initially estimated using average profile production time which was provided by equipment manufacturer. However, such solution, based on average profile, was not fully satisfactory. It than was required to test suggested solution with a production data from typical ship sections of several ship types in order to minimize the decision making risk and to be more certain that suggested production line will comply the required throughput. Therefore, it was decided to develop a simulation model of initially suggested production line solution. Such model will be tested with selected production mix of chosen ship types as to evaluated if suggested solution fulfills required throughput. If not, the line will be further analyzed and improved in order to achieve required throughput. Such conclusion could be than communicated to the equipment manufacturer with requirement to improve initially suggested solutions to the particular demands. In this way, decision making involves much less risk with the final solution more adapted to the particular shipyard and expectably with reduced overall cost. To summarize, the major goal for application of developed methodology is: based on developed computer simulation model, it have to be tested if manufacturer suggested design solution of new robotized line match the minimum throughput requirement, T_{min}; if not, it should be suggested how to improve line characteristics and its parameters.

4.2 Computer simulation model conceptualization and development

Based on initially suggested design solution of the new robotized profile cutting line, conceptual cause effect chart (Figure 2) and production process flow chart (Figure 3) are created. Furthermore, preliminary technical characteristics of the line, operation and material flow characteristics and input production data are defined. This data are partially accepted from equipment supplier and partially from shipyards experts survey method. Most important input parameters from observed production line, as input data for conceptual simulation model, are presented in table 2. Based on conducted analysis, gathered data and defined production process, computer simulation model is conceptually defined regarding its structure, logic, functionality and organization.

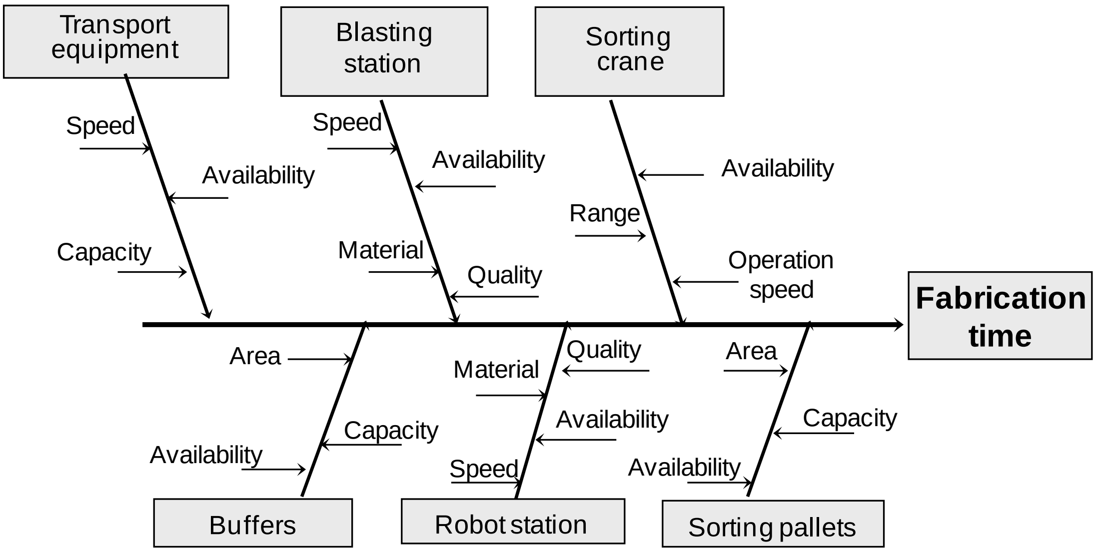


Fig. 2 Robotized profile fabrication line cause effect chart

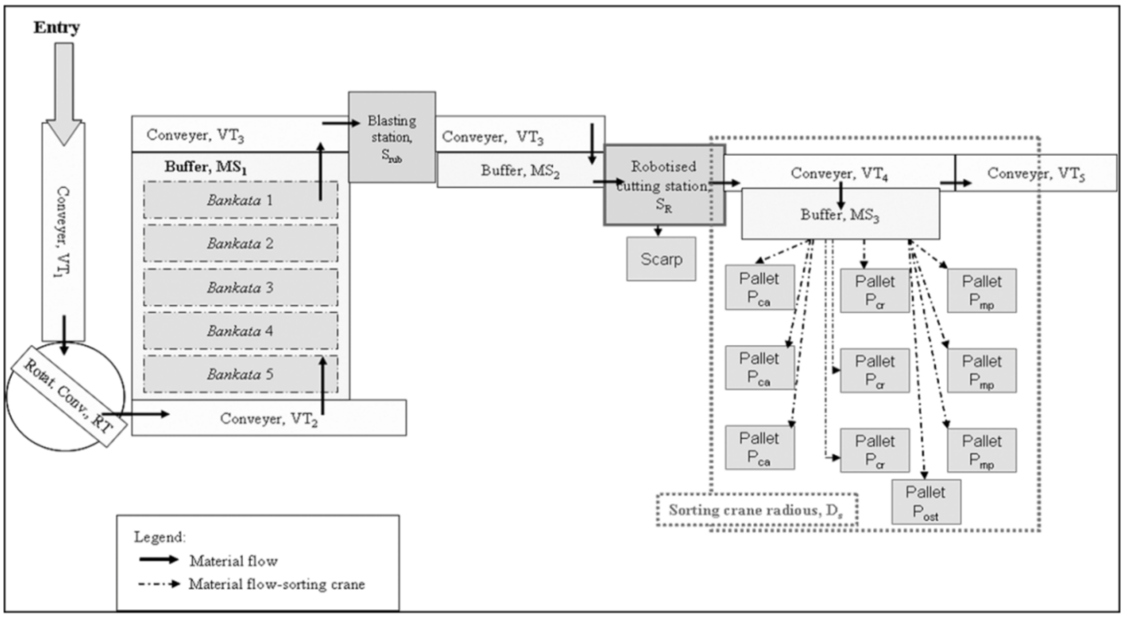


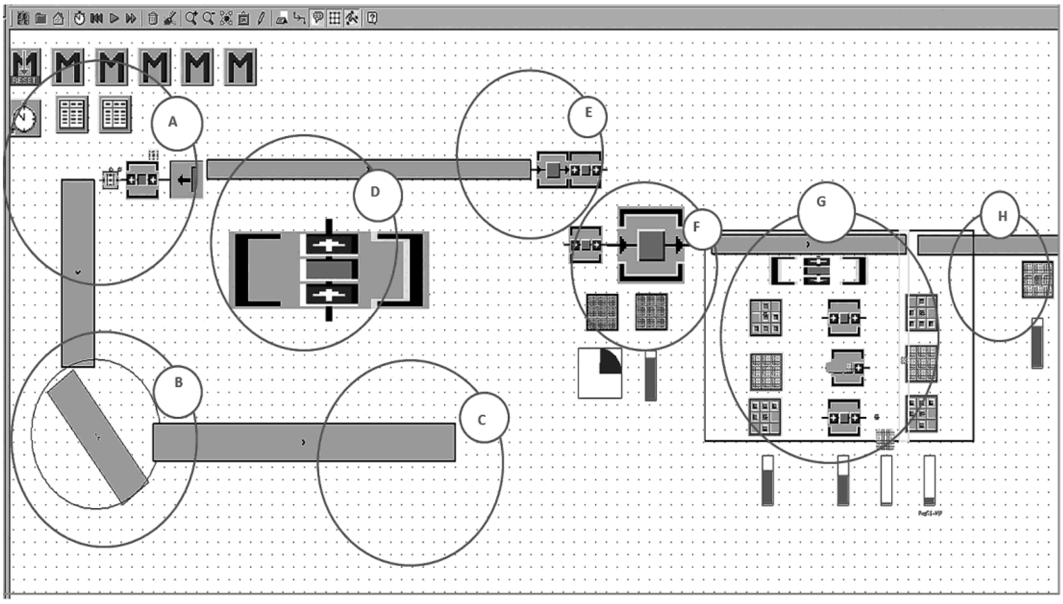
Fig. 3 Robotized profile fabrication line conceptual production process flow chart

Table 2 Production line elements input parameters for simulation

Production line element	Description	Defined parameters
Conveyer VT_1	Conveyer profile transport from prefabrication to profile fabrication production line	Length/width Speed range Capacity
Rotating conv. RT	Rotation conveyer	Length/width Speed range Rotation speed Capacity
Conveyer VT_2	Conveyer profile side transport to buffer storage	Length/width Speed range Capacity
Bankata 1-5	Standard package of profiles	Capacity

Buffer MS_1	Buffer storage	Dimensions Capacity
Conveyer VT_3	Conveyer profile transport from buffer to blasting station	Length/width Speed range Capacity
Conveyer VT_4	Conveyer profile side transport to buffer storage and robot cutting station	Length/width Speed range Capacity
Buffer MS_2	Buffer storage before robot cutting station	Dimensions Capacity
Robotized cutting station	Profile cutting station	Cutting speed
Conveyer VT_5	Conveyer profile transport from cutting station	Length/width Speed range Capacity
Buffer MS_3	Buffer storage before profile sorting	Dimensions Capacity
Pallet Pca	Pallet with profiles for automatic subassembly line	Capacity
Pallet Pcr	Pallet with profiles for robotized subassembly line	Capacity
Pallet Pmp	Pallet with profiles for subassembly line	Capacity
Conveyer VT_6	Conveyer profile transport to panel line buffer storage	Length/width Speed range Capacity
Profiles	Each profile from profile stockyard is defined and imported from external database.	Type Dimensions Number of cuts Type of cuts Cutting length Scrap

Based on defined production process cause effect chart, process flow chart, technical characteristics of the line, the simulation model of the new robotized profile fabrication cutting line has been developed in specialized discrete simulation software, (Figure 4). Hereby, it is important to distinguishing between relevant and irrelevant facts and making the right assumptions is of essential importance for the development of a quality model as the basis for simulation modeling process. Therefore, it is important to: determine what should be included in the model and the level of details in the model; distinguish basic resources in the process and operations that are performed; identify and define any limitations on the system in terms of spatial or temporal constraints; agree and define the conditions and methods for verification and confirmation of the model; determine what is expected as the final result as well as deadlines.



Legend: Area A – conveyer with profiles and flat bars; Area B – rotating conveyer diverging material to the workshop; Area C - Main input conveyer; Area D – Buffer space; Area E – Blasting station; Area F – Robot cutting station; Area G – Sorting crane and sorting pallets; Area H – Conveyer for profiles for panel line.

Fig. 4 Simulation model of new robotized profile cutting production line

Further, input material specification as production mix for a simulation model was defined (Table 3), where product mix specific configuration was defined through shipyard expert surveying method. Sample contains profiles and flat bars from double bottom of ship for chemical products and profiles and flat bars from bottom of ship for asphalt.

Table 3 Input material specification

Sample mix of profiles (HP) and flat bars (FB)			
Label	Height, [mm]	Thickness, [mm]	Number of pieces
HP 220x 11,5	220	11,5	30
HP 240 x 10	240	10	22
HP 280 x 11	280	11	2
HP 340 x 12	340	12	20
HP 340 x 14	340	14	60
HP 370 x 13	370	13	54
HP 370 x 15	370	15	4
HP 400 x 14	400	14	2
FB 80 x 15	80	15	12
FB 120 x 13	120	13	2
FB 130 x 12	130	12	108
FB 150 x 12	150	12	96
FB 150 x 13	150	13	521
FB 150 x 15	150	15	1205
FB 200 x 10	200	10	5
FB 200 x 15	200	15	6
FB 200 x 20	200	20	14
TOTAL			**2136**

4.3 Simulation model verification, analysis and improvement

Initial model verification is conducted in cooperation with shipyards experts. Such verification is primarily involving testing process model logic, functionality, behavior and results mainly based on shipyard expert experience and known data. If required, model is fine tuned in several iterations, until final confirmations. Such confirmed model can be used to evaluate if suggested design is fulfilling the project goal which is: simulated fabrication time, F_{tsim}, of initially suggested design solution for defined characteristic input production mix of profiles and flat bars, should be less than minimum fabricated time, F_{tmin}, based on defined goal throughput rate of profiles – T_{min}, achieved in one month and two shifts. Therefore:

$$F_{tsim} < F_{t\,\min} \tag{1}$$

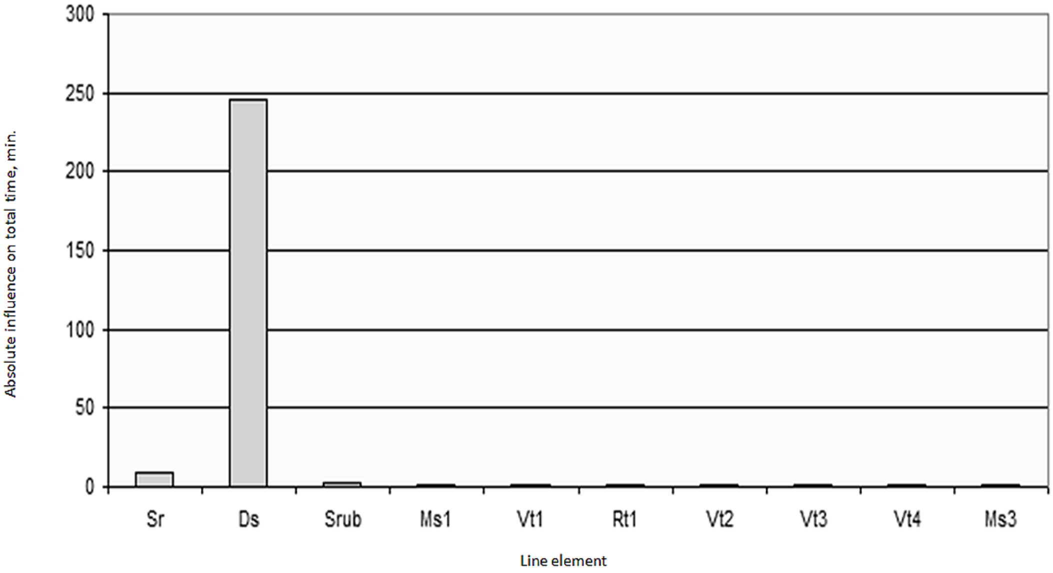
and

$$F_{t\,\min} = \frac{N_p}{T_{\min}} \cdot N_{wd} \cdot N_s \cdot N_{whs}, \quad [h] \tag{2}$$

Where F_{tsim} is simulated fabrication time for chosen input production data of initially suggested design solution; F_{tmin} is minimum required fabrication time for chosen input production data; N_p is number of profiles and flat bars in chosen product mix; T_{min} is number of profiles and flat bars in targeted shipyard month production; N_{wd} is number of working days in month; N_s is number of working shifts in day; N_{whs} is number of working hours in shift. With simulation modeling, it is determined that simulated fabrication time, F_{tsim}, of initially suggested design solution for selected characteristic input data, takes approximately 20 % longer time than minimally required fabrication time, F_{tmin}:

$$F_{tsim} = 1.2 \cdot F_{t\,\min} \tag{3}$$

Above does not comply with project goal. Therefore, suggested design solution has to be further analyzed to determine the cause. Major topics of further analysis are as follows: material flow analysis; production line loads analysis and identification of potential line bottlenecks; identification of the most influence line parameters on the goal function with the sensitivity analysis method. Within sensitivity analysis method, line characteristics where changed within range of 10% over the initial input values, and all scenario combinations were simulated. In particular, parameters changed were a robot cutting head speed; crane movement and lifting speed; blasting station speed; the size of buffers and speed of conveyers. Range of parameters variations were defined according to shipyard expert’s survey method. It has been identified that primary bottleneck and most influence line element on the cutting time, of the suggested design solution is the performance of sorting crane (Area G on figure 4) which is sorting out cut profiles at the exit of the profile cutting robot station, (figure 5.).



Legend: S_r–Robot cutting station; D_s – Sorting crane; S_{rub} – Blasting station; M_{S1} – Buffer 1; M_{S3} – Buffer 3; V_{t1} – Conveyer 1; R_{t1} – Rotating conveyer; V_{t2} – conveyer 2; V_{t3} – conveyer 3; V_{t4} – conveyer 4

Fig. 5 Results of sensitivity analysis on the total process duration time depending on the changing values of line elements

Since the operation performance of that crane is insufficient, robot cutting station is blocked more that 35% of the time, which is unacceptable, and has to be improved. Therefore, more simulations of various production scenarios have been conducted, simultaneously varying crane and robot cutting stations parameters. Results are shown in table 4, where improved simulated fabrication time, F_{tsimp}, time is presented in comparison with targeted minimum fabrication and simulated fabrication time of initially suggested solution. Also, improvement over each is presented.

Table 4 Fabrication time results and improvement against initially suggested solution

Targeted min. fabrication time for required throughput, T_{tmin}	Simulated time of a initially suggested design solution, F_{tsim}	Improved simulated model fabrication time, T_{simp}	Improvement over the initially suggested design solution
69 h	77 h	67 h	13 %

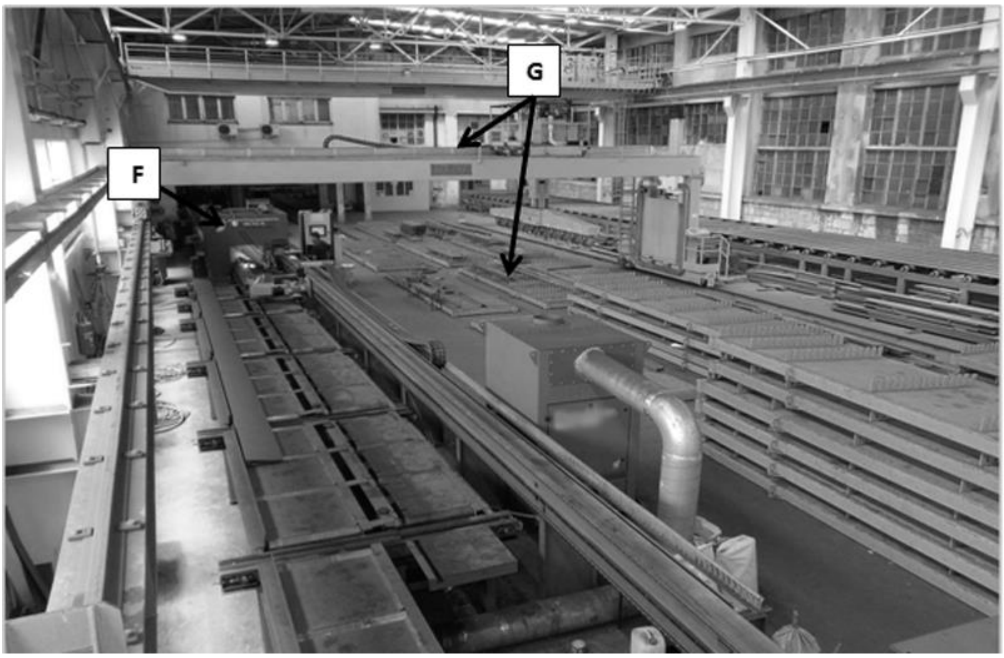
Where T_{min} is calculated according to (2), based on following particular shipyards production data: N_p – 2136 profile and flat bar parts; T_{min} – 11000 profile and flat bars per month; N_{wd} – 24 working days in a month; N_s – 2 working shifts in a day; N_{whs} – 7.5 working hours in a shift. From table 4, it is evident that improved simulation model solution, over the initially suggested design solution by the manufacturer, achieved improvement of 13%. Also, such improved solution met the objectives regarding the required monthly throughput, which the initial proposed solution was not achieving. Furthermore, suggested methodology provides the possibility to make comments and communicate to the manufacturer, regarded perceived issues, which would result in a decision that better meets the requirements of the particular shipyard. Otherwise, problems (regarding inadequate throughput performance) would have been noticed only after the installation of the line, when the changes would be extremely expensive, if at all feasible. Such improvement requirements would most probably increase the overall cost of investment, but this cost will be much lower than a cost potentially emerging from repairing production line after installation or from using inadequate production line during the exploitation. In the following section, further enhancement of developed simulation model will be explained, based on comparisons with the actual process.

4.4 Simulation model confirmation, enhancement and further research

Simulation model based methodology and computer model itself, was tested against real production process data after project realization and implementation in the shipyard production process, (Figure 6). Based on comparison data with a real production process, computer simulation model was evaluated in terms of its representation of real production process. Certain differences, with real production process were perceived. For the several scenarios, using the four production mix samples of different ships and ship sections the real production process time was different, in average, for approximately 7,25%, (Table 5). In general product mix are consisted of sections from three different ships as follows: Product mix 1 is composed primarily from flat bars and profiles from product carrier double bottom section from ship mid section; Product mix 2 is composed from flat bars and profiles, also from product carrier ship type, but from consequent double bottom section from ship mid section; Product mix 3 is composed from flat bars and profiles, from product carrier ship type, mainly from double hull section from ship mid section. Product mix 4 is composed from flat bars and profiles, from asphalt carrier ship type, primarily from bottom section of ship mid section. Differences in measured times between product mixes are mainly because of different structure characteristics between those ships and used section within ship structure, as average profile thickness, profile dimensions, profile ending preparation, profile treatment type and characteristics, etc. Also, the size and type of product mixes was similar to initial one used for simulation modeling and are related to the particular shipyard sorting and assembly strategies.

Table 5 Computer simulated process time compared to measured real production time

	Computer simulated time, min	Measured time in real production process, min	Difference
Product mix 1	4130	4460	8%
Product mix 2	3850	4081	6%
Product mix 3	4528	4845	7%
Product mix 4	4601	4969	8%
		Average:	7,25%



Legend: F- Area of robot cutting station; G-Area of sorting crane and sorting pallets

Fig. 6 New robotized profile cutting line

Differences, presented in table 5, should be assessed taking into account the following facts: actual measured processing time includes failures, maintenance, human factors; it was determine that the specific parameters of the robot cutting head regarding positioning of the robot cutting head, marking and cutting, are different from what they were used initially in the simulation model. Therefore, the computer simulation model was enhanced including the following: failures were included based on gathered real process statistical data within several months; robot characteristic values were updated (based on real production data); maintenance intervals were included based on manufactured requirements. After such model enhancement, the model was again tested based on previously used several different production mix scenarios. Difference between computer model simulation and real production time were now between 3-5%, depending on ship type, production sample mix used, etc, (Table 6)

Table 6 Difference between simulated and measured time for several newbuildings after improvement

Product mix	Product mix 1	Product mix 2	Product mix 3	Product mix 4
Sim. time diff.	+5%	-2%	+3%	-3%

Still persisting difference can be discussed because certain human factor issues, unexpected failures or jams are not included in simulation model and which can be included in the model as statistical and probability variables, based on gathered data from production process over the longer period of time. Furthermore, there is still some fine tuning that can be done regarding robot specifications, sorting crane specifications and sorting pallet specifications. Still, this version of model was accepted as sufficiently accurate, because, as stated before, it is not purpose of computer simulated model to be exact perfect copy of the real system but to be adequate, logic, technologically accurate and sufficiently precise presentation of a real system. Furthermore such model also could be used for: planning and evaluation of required working hours for certain production mix; spotting and predicting problems and bottlenecks in production before they occur; continuous measurement and analysis of the production process depending on various conditions so that he could continually be adapted and improved, etc. Regarding model future application potentials, the author’s research is primarily continuing as to implement this computer model into shipyards CAD/CAM system, to integrate it with relevant software and production data to potentially enable real time functionality.

5. CONCLUSION

In this research, analysis of the existing methods and techniques for production process design has been conducted with emphasis on shipbuilding production process. Based on this analysis, the shortcomings of conventional approach and traditional mathematical modeling with analytic solution for complex production processes design have been perceived. Furthermore, regarding identified problems, suitability of discrete event simulation modeling method application for designing shipyard processes in particular, has been determined. Therefore, a methodology for designing shipbuilding production processes, based on discrete event simulation modeling method and selected operations research methods and tools, has been developed and presented. Developed methodology was applied and presented over the case study of designing the shipbuilding production process of robotized profile fabrication line. Design solution accomplished with suggested methodology, had fabrication time improved over the initially suggested design using conventional approach. Also, such solution fulfilled the objectives of the shipyard regarding the required monthly throughput, what the initial proposed solution was not. Furthermore, it is possible, during the early design stage, to make quality comments to the manufacturer, regarding production line setup and parameters, which will provide solution more adapted to the particular shipyard, which is much feasible and less expensive than making changes after line installation. Simulation model was tested against real production process data, after production line installation, and model was further enhanced and updated. Finally, the primarily contribution of developed methodology is improvement in shipbuilding production processes design practice. Such methodology provides shipyard management with efficient tool for validating design alternatives in early design stage, efficient tool for production process planning and control and also enables management to make decisions with lower risk level.

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NOMENCLATURE

VT_1 – conveyer number 1
RT – rotating conveyer
VT_2 – conveyer number 2
MS_1 – buffer storage number 1
VT_3 – conveyer number 3
VT_4 – conveyer number 4
MS_2 – buffer storage number 2
VT_5 – conveyer number 5
MS_3 – buffer storage number 3
Pca – pallet for automatic subassembly line
Pcr – pallet for robotic subassembly line
Pmp – pallet for subassembly line
VT_6 – conveyer number 6
F_{tsim}- simulated fabrication time of initially suggested design solution
F_{tmin} - minimum required fabrication time for chosen input production data
N_p – number of profiles and flat bars in chosen product mix;
T_{min} – number of profiles and flat bars in targeted shipyard month production;
N_{wd} – number of working days in month;
N_s – number of working shifts in day;
N_{whs} – number of working hours in shift.
T_{simp} - improved fabrication time

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