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Considerations regarding the variables of the ship repair process in the shipyards

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Abstract. The ship repair process in shipyards is a complex one and its components are usually influenced by a significant number of factors with random variability. The retention period of a ship in the shipyard for repair works present a particular interest, both for the shipyard and for the beneficiary of the repair works. In the most general way, the variables that could be the basis for the prognosis of the total period of repair works are selected from the content of the technical specification of works prepared by the owner / technical manager of the ship.. The paper highlights some independent variables that can be taken into account when estimating the period of repair work. The case studies presented in the paper refer to a portfolio of 400 tank type ships for which repair works were carried out in the Constanta Shipyard.

1. Introduction

A shipyard is interested in estimating the docking time of ships for repair work, in order to plan the loading of the gravy/floating docks. The authors of this paper appreciate this estimate depends on the content of the Technical Specification of works received from the beneficiary / owner of the ship not by the human and technical capacities of the shipyard. The construction of the database from the works portfolio of the Constanța Shipyard, respectively the simulation presented in the content of the work, were performed based on the hypothesis that the site has at its disposal the optimal number (considered constant) of workers and equipment for repairs.The content of the Repair Works Technical Specification received by the shipyard (expressed in square meters, cubic meters, linear meters, tons, etc.) is the variable that the shipyard takes into account in the analyzes performed to assess the possibilities of repair works.

Resumming: knowing its human resources and technical equipment and considering them constant from one project to another, the shipyard is interested in estimating the docking and berthing time of a ship for the execution of repair works depending on the content of the Repair Works Technical Specification (this content being the variable of interest for the shipyard).

This is the question to which the authors have tried to provide an answer in the content of the paper.

Without claiming a complete knowledge of the contributions made, over time, by various authors, on the subject of interest [1], [3], [4], [5], [7] it was found during the documentation that the studies analyzed refer, in particular, to the minimization of ship operating costs and ship maintenance costs (depending on the evolution of the maritime transport market and the evolution of fuel prices). From the documentation made, it was found that there is insufficient information regarding the analysis, modeling and forecasting of the total period of ship maintenance and the docking period in a shipyard, although there are also authors [2] concerned with this subject, including the authors of this paper[12],

[13], [14], [15], [20].

The conclusion is that modeling must necessarily be preceded by:

a) knowledge of the operational structure of a shipyard for ship repairs, because it directly influences the construction of the mathematical model, allowing the particular identification of the variables to be taken into account in the modeling process;
b) knowledge of the works to be performed on the docked ship and, if applicable, of the works performed with the ship at the quay (the difficulty of mathematical modeling is generated by the fact that, during the course of the works, additional work may occur that requires execution and is very difficult to anticipate, in many cases);
c) identifying the number of variables with significant influence and their inter-relationship.

2. Identification of variables with significant influence on the ship repair process

In the most general way, the variables that could be the basis for the mathematical modeling of the total period of development of ship maintenance works and the period of docking in a shipyard, could be selected from the volume of works included in the technical specification and which, in principle, comprises [21], [22], [23], [24], [25]:

- works executed with the ship in the dock: external coating treatment (high pressure water washing; washing with water at low pressure; sandblasting to different quality standards; air blowing; dye house); overhaul valves and siding flaps; anodic protection (anode replacement); anchoring installation works; hull cover sheet replacement; governance system works; propulsion plant works etc.
- works performed with the ship at the quay: replacement of body structure sheets in different locations; treatment works in locations other than the outer body such as ballast tanks and cargo warehouses, exterior decks, superstructure; pipe replacement works of different diameters; mechanical and electrical works on equipment and installations by types of equipment; works necessary for the preparation of the ship for the execution of maintenance works consisting of scaffolding works on different locations for sheet metal replacement and treatment as well as cleaning works for ballast and / or fuel tanks.

The experience of the shipyards concludes that the retention period of a ship in the dock and / or at the quay for the execution of repair works depinde de un număr considerabil de factori cu o variație, de multe ori aleatoare, which negatively affects the possibilities of forecasting the duration of the works.

It is therefore considered necessary to highlight the intensity with which one or another of these variables affects the duration of the detention period of a ship in the dock and / or at the quay for the execution of repair works, to be able to determine, finally, what is the number of variables that can be taken into account in an anticipatory forecasting process considered to be reasonable. Based on studies and research [2], [10], [18], the validity and appropriateness of using the following function were analyzed:

$$PELM_S = f(V_S,\quad TDW_S,\quad LTCEX_S,\quad LITub_N,\quad LITab_S,\quad LTInt_S) \tag{1}$$

The meaning of the terms involved in relation (1) is specified below:

$PELM_S$ - the period of carrying out the maintenance works of the ship at the dock and at the quay in the shipyard; is expressed in number of days from the date of entry of the ship to the shipyard until the completion of the maintenance works and the date of departure of the ship from the shipyard;

V_S - the age of the ship at the time of indocked and/or berthed ship maintenance works performing in the shipyard; it is expressed in years and is calculated from the date of delivery of the ship in operation to the shipowner;

TDW_S - the deadweight of the ship; is expressed in tons;

$LTCEX_S$ - the ship external hull treatment works volume; is expressed in square meters;

$LITub_S$ - the ship piping replacement works volume; is expressed in linear meters;

$LITab_S$ - the ship steel plates replacemet works volume; is expressed in kilograms;

$LTInt_S$ - the ship internal hull treatment works volume; is expressed in square meters;
$LSAL_S$ - the ship scaffolding works volume for access; is expressed in cubic meters;
$LTkCV_S$ - the ship cargo/ballast tanks volume cleaning works; is expressed in cubic meters;
$LTkCS_S$ - the ship cargo/ballast tanks surface cleaning works volume; is expressed in square meters.

The database was built in an EXCEL software file and, in order to avoid oversizing the work, only the limits (minimum and maximum) of variation of the values of the independent variables are indicated in table 1.

The case study was carried out for a number of 400 tank type ships (see figure 1.) included in the works portfolio of the Constanța Shipyard.

Table 1. Variation limits of independent variables

V_S	minimum – 1year; maximum - 44 years
TDW_S	minimum - 3 390 tons; maximum - 170 022 tons
$LTCEX_S$	minimum - 0 square meters; maximum - 209 999 square meters
$LITub_S$	minimum - 0 linear meters; maximum - 2 903 linear meters
$LITable_S$	minimum - 20 kilograms; maximum - 523 876 kilograms
$LTInt_S$	minimum - 0 square meters; maximum - 98 346 square meters
$LSAL_S$	minimum - 0 cubic meters; maximum - 19 234 cubic meters
$LTkCV_S$	minimum - 0 cubic meters; maximum - 1 340 cubic meters
$LTkCS_S$	minimum - 0 square meters; maximum - 4 289 square meters

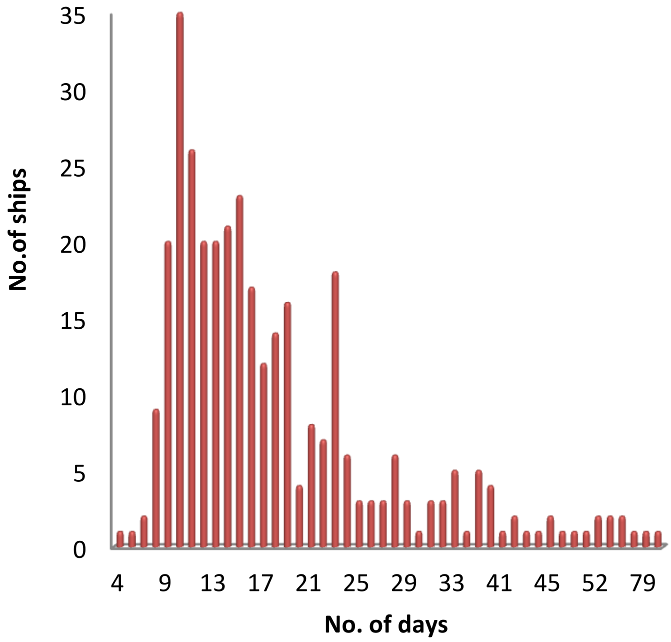


Fig. 1. Number of ships included in the database correlated with the number of days of detention of the ship in the repair shipyard

3. Case sudy

The paper aims to express individually the evolution of independent variables depending on the dependent variable (see figure 2), aiming to highlight the degree of scattering (dispersion). For a more suggestive illustration, the graphical representations were made with both EXCEL and MATLAB Software and show the data dispersion and the interpolation line.

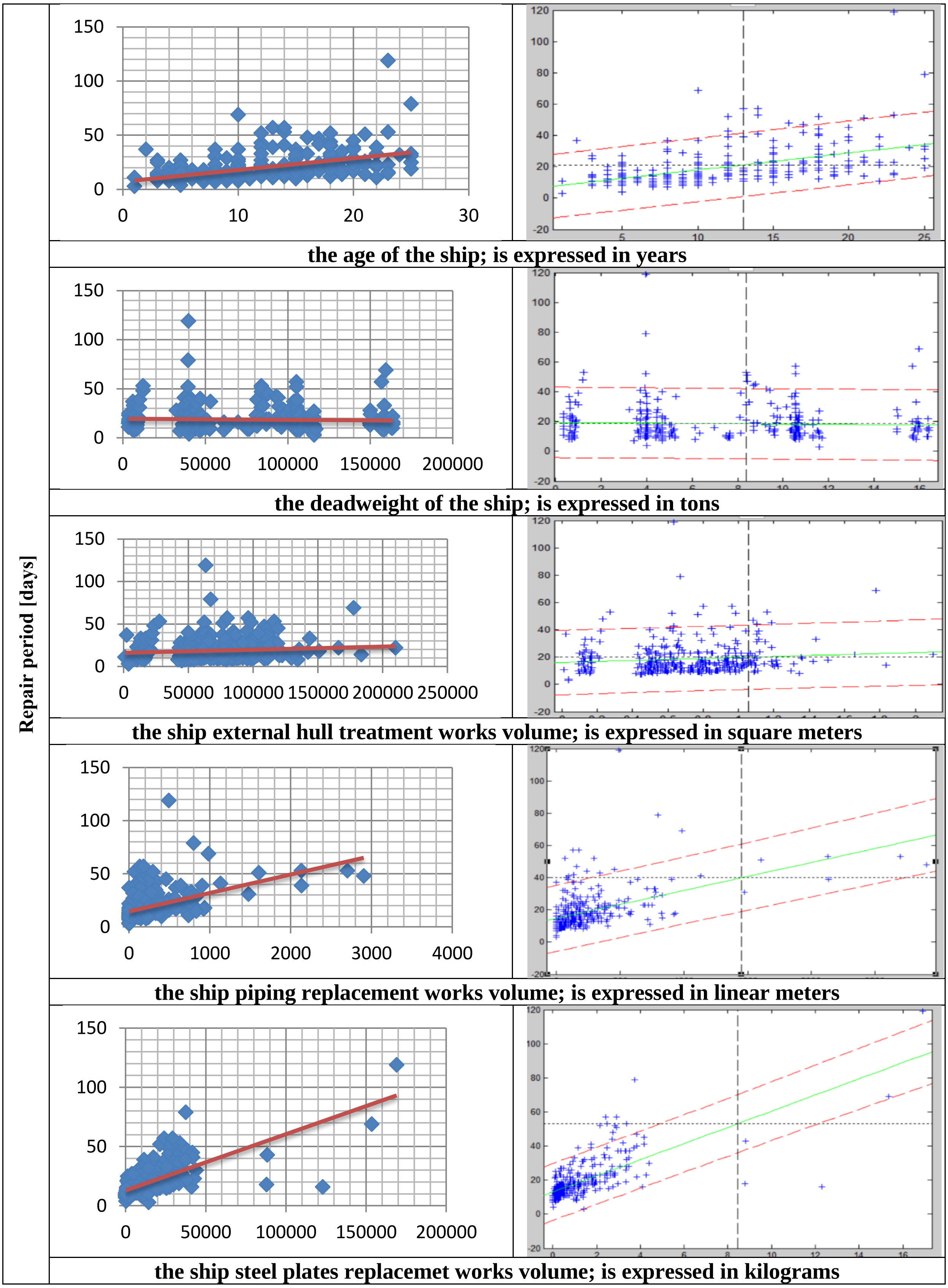
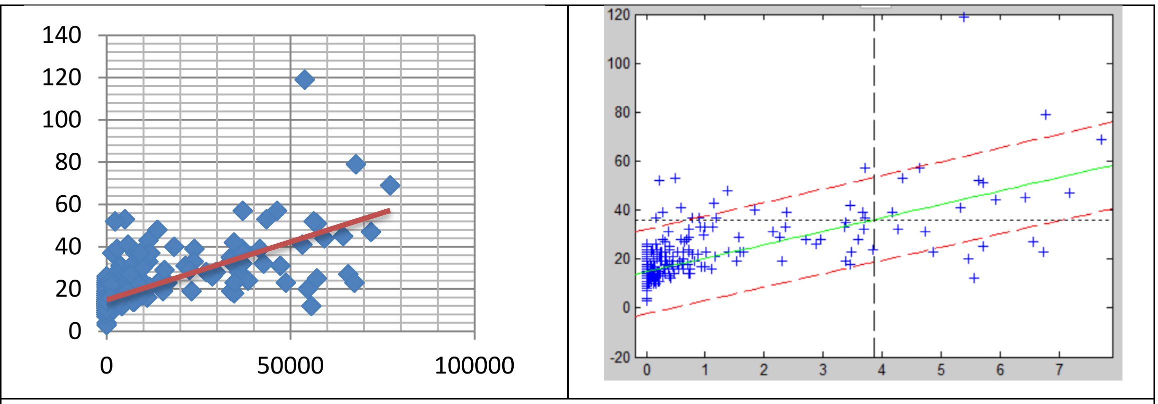
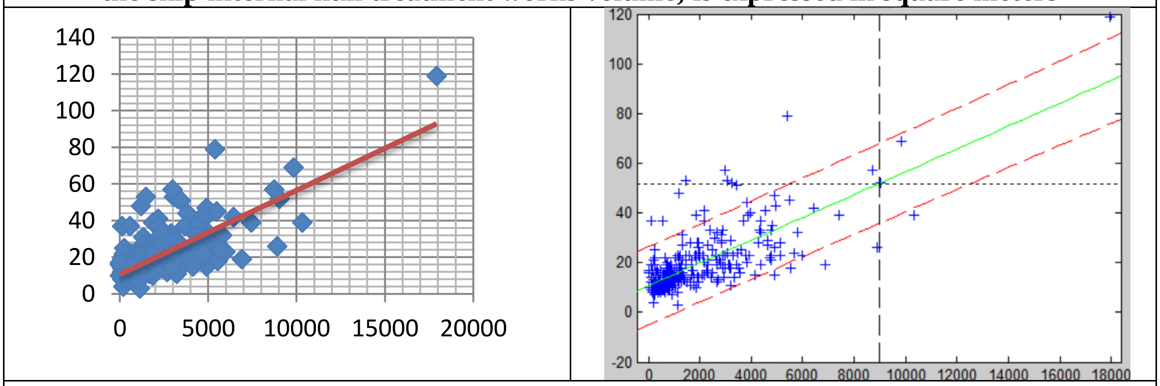


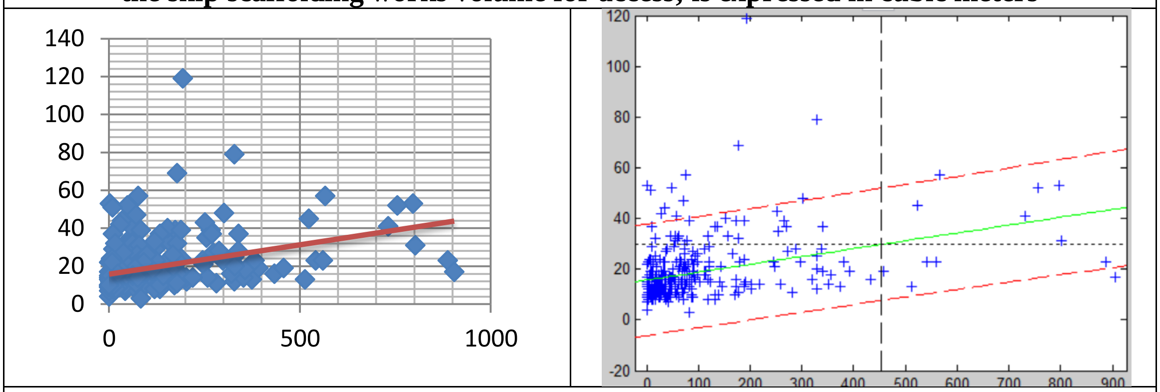
Fig.2. Data scatter and interpolation line [left in EXCEL; right in MATLAB]



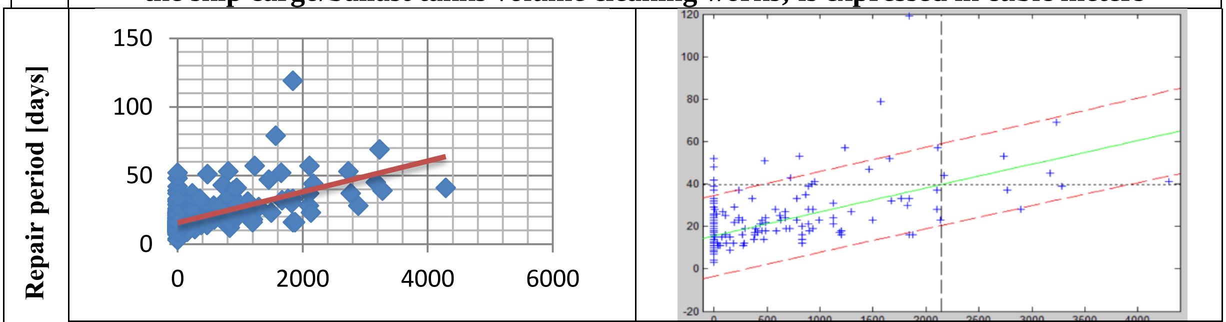
the ship internal hull treatment works volume; is expressed in square meters



the ship scaffolding works volume for access; is expressed in cubic meters



the ship cargo/ballast tanks volume cleaning works; is expressed in cubic meters



the ship cargo/ballast tanks surface cleaning works volume; is expressed in square meters

Fig.2. Continuation

Table 2 presents the results obtained, with reference to the analytical expression of the regression function, the limits of the confidence interval and the predicted value for the time necessary to perform the respective work.

Table 2. Results

analytical expression of the regression function	the limits of the confidence interval (95%) (marked on the graph with dotted red lines)	predicted value
$PELM_S = 7.1577 + 1.0821 \cdot V_S$	+/- 20.28 days	21.22 days
$PELM_S = 19.438 + 1 \cdot 10^{-5} \cdot TDW_S$	+/- 23.57 days	18.53 days
$PELM_S = 16.075 + 4 \cdot 10^{-5} \cdot LTCEX_S$	+/- 23.5 days	19.88 days
$PELM_S = 14.673 + 17.4 \cdot 10^{-3} \cdot LITub_S$	+/- 20.95 days	39.87 days
$PELM_S = 13.035 + 5 \cdot 10^{-4} \cdot LITable_S$	+/- 17.07 days	53.11 days
$PELM_S = 14.848 + 5 \cdot 10^{-4} \cdot LTInt_S$	+/- 17.34 days	36.03 days
$PELM_S = 10.681 + 4.6 \cdot 10^{-3} \cdot LSAL_S$	+/- 16.03 days	51.81 days
$PELM_S = 15.766 + 3.09 \cdot 10^{-2} \cdot LTkCV_S$	+/- 22.13 days	29.74 days
$PELM_S = 15.609 + 1.12 \cdot 10^{-2} \cdot LTkCS_S$	+/- 19.23 days	39.70 days

4. Conclusions

Multiple correlation coefficient [5], [16], R, has values between 0 (if there is no connection between the dependent variable and the independent variables) and 1 (if there is a perfect functional connection).

Multiple coefficient of determination [5], [16], R^2, which is the square of the multiple correlation coefficient, shows the proportion of the total variation of the dependent variable, which is explained by the independent variables. In practice, a multiple correlation is considered to be strong enough if the value of the coefficient of determination is greater than 0.7 (or 70%, in percentage expression).

For the case study, the results are presented in table 3.

The interpretation of the obtained results leads to the conclusion that the analysis based on a single independent variable cannot be considered satisfactory, the values of the simple coefficient of determination, R^2, being small (between 0.001 and 0.555) which shows that the period of carrying out the maintenance works of the ship in the dock and at the quay in the shipyard, depends on many factors, each, in part, contributing to a certain proportion, quite little.

Table 3 Multiple coefficient of determination, R^2 and multiple correlation coefficient, R

Equation	$\boldsymbol{R^2}$	$\boldsymbol{R}$
$PELM_S = f(V_S)$	0.2592	0.5091
$PELM_S = f(TDW_S)$	0.0018	0.0429
$PELM_S = f(LTCEX_S)$	0.0090	0.0952
$PELM_S = f(LITub_S)$	0.2393	0.4891
$PELM_S = f(LITable_S)$	0.5003	0.7073
$PELM_S = f(LTInt_{NS})$	0.4670	0.6833
$PELM_S = f(LSAL_S)$	0.5555	0.7453
$PELM_S = f(LTkCVl_S)$	0.1349	0.3673
$PELM_S = f(LTkCS_S)$	0.3522	0.5935

Given the previous findings and starting from the premise that each shipyard has unique organizational and functional structures, to improve organizational performance by forecasting the duration of maintenance work on ships in shipyards, the following recommendations can be made:

- request from the owner / technical manager of the ship a technical specification of works as correct and complete as possible;

- the use of distinct databases, built on functional and constructive types of ships;
- the use of the own portfolio of ships for which maintenance works were performed in the dock and / or at the quay;
- implementation of an IT system for managing the databases in its own portfolio, for updating, in real time, the forecasting equations of the duration of maintenance works of seagoing ships in repair yards.

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References

[1] Apostolidis, A., Kokarakis, J., Merikas, .A, Modeling the Dry-Docking Cost - The Case of Tankers , Journal of Ship Production & Design;Aug2012, Vol. 28 Issue 3, p134.
[2] Arun, K.D., Makaraksha, S., Modeling and analysis of ship repairing time, Journal of Ship production and Design, Vol.31, No.1, february 2015, pp.1-8
[3] Castrillon Dussan, R., Shiprepair competition: drivers and opportunities, World Maritime University Dissertations, 2007
[4] Dussan, R.C., Shiprepair competition: drivers and opportunities, World Maritime University Dissertations, 2007.
[5] Gulati, R., Smith, R., Maintenance and reliability best practices, Industrial Press, Inc., New York, USA, 2009.
[6] Hilber, P., Maintenance optimization for power distribution systems, Doctoral thesis, Royal Institute of Technology, Sweden, 2008.
[7] House, D.J., Dry-docking and Shipboard Maintenance: A Guide to Industry, Witherby Seamenship International Ltd., 2003
[8] Jamali, A.M., Ait-Kadi, D., Artiba, A., Maintenance: Concepts et stratégie de mise en oeuvre, Université Laval, Canada, 2001.
[9] Kaabi-Harrath, J., Contribution a l'ordonnancement des activites de maintenance dans les systemes de production, These de Doctorat de l'Université de Franche-Comté, France, 2004.
[10] Kumar, S., Reliability analysis and cost - Modeling of degrading systems, Doctoral Thesis, Lulea University of Technology, Sweden, 2008
[11] Lyonnet, P., La Maintenance: Mathematiques et Methodes, Tec et Doc, Paris, France, 2007
[12] Manea E., Chiţu M.G., Ships new buildings, repairs & conversions outlook 2009-2012. Trends, Analele Universităţii Maritime din Constanţa, an XIV, Vol.19, 2013
[13] Manea E, Militaru C., Chiţu M.G., Zăgan R., Black Sea area shiprepairs outlook, ModTech International Conference, Modern Technologies in Industrial Engineering, 13-16 iulie 2014, Gliwice, Polonia
[14] Manea E., Militaru C., Zăgan R., Chiţu M.G., Improving organizational performance through the application of integrated management systems in maintenance activities in the shipyards, Analele Universităţii Maritime din Constanţa, 2016.
[15] Manea E., *Manea M.G., The Influence of the Deadweight in the Projection of the Duration of the Maritime Ships Mentenancy Works*, International Conference Advances in Engineering and Management, ADEM, 2018, Drobeta-Turnu Severin, http://www.imst.ro/adem/, https://www.scientific.net/AEF.34/5, Trans Tech Publications Ltd., https://doi.org/10.4028/www.scientific.net/AEF.34
[16] Mohora, C, Coteţ, C. E., Pătraşcu, G., Simularea sistemelor de producţie - Simularea proceselor, fluxurilor materiale şi informaţionale, Editura Academiei Române, Editura Agir, Bucureşti, 2001.
[17] Monchy, F., Maintenance – Methodes et organisation, Edition Dunod, Paris,France 2003
[18] Sauerhoff, C., Competitive Differentiation within the Shipbuilding Industry-The Importance of Competence in the Field of Services, Springler Gabler 2013 ISBN : 978-3658058036.

[19] Simeu-Abazi, Z., Sassine, C., Maintenance integration in manufacturing systems: from the modeling tool to evaluation, The International Journal of Flexible Manufacturing Systems, 13: 267–285, Kluwer Academic Publishers, The Netherlands, 2001.
[20] Zăgan R., Manea E., Militaru C., Chiţu M.G., Planning production for ship repair, ModTech International Conference, Modern Technologies in Industrial Engineering, 15-18 iunie **2016**, Iaşi, România, I.S.S.N 2286-4369
[21] Yousef, A., Development of Ship Maintenance Performance Measurement Framework to Assess the Decision Making Process to Optimise in Ship Maintenance Planning, The University of Manchester, Phd Thesis, 2011
[22] *** IACS, No.47 Shipbuilding and Repair Quality Standard ,1996, Rev.7, June 2013Another reference
[23] ***NaveSea Instruction 4790.8C, Ship's Maintenance and Material Management (3-M) Manual, 2013
[24] ***Ship Structure Commitee, Ship Maintenance Project – Repairs and Maintenance, 1995
[25] ***Organisation for Economic Co-operation and Development, The Interaction between the Ship Repair, Ship Conversion and Shipbuilding Industries, Council working party on shipbuilding, 2008