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Ship Repairing Time and Labour

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Introduction

- Ship repairing time, duration of stay of a ship in a shipyard (also a slipway or a floating dock), is a part of the routine maintenance schedule of a ship, mainly required by the classification societies and the flag states.
- Ship owners and shipyards always try to reduce the repairing time to lessen the loss of income (for an owner) and maximise the annual turnover through handling more ships (for a shipyard).
- Labour cost is an important and sensitive issue in labour intensive industry. In regular ship repairing or routine maintenance of a ship, labour cost contributes the highest amount in the final invoice. This figure may go up to 70% of the total cost. This cost is directly provided by labour (man-days) utilised for the ship repairing works. Lesser man-days can directly be translated into the lower final invoice (for the ship owner) and higher productivity (for a shipyard), which can help the shipyard to stay in a competitive market.

Introduction$_2$

- Ship repairing time (days) related information for **600 cargo ships** and ship repairing labour (man-days) related information for **50 cargo ships** of various ages, sizes and types were collected from a single shipyard.
- A multiple linear regression model was developed and analysed using these primary data of time and labour each. Ship repairing time was then expressed as a function of a ship's age, deadweight, repairing works of mainly hull coating, piping, structural steel and tank coating.
- Similarly, ship repairing labour was then expressed as a function of a ship's age, deadweight, type and repairing works of mainly hull coating, piping, structural steel and tank coating. "Method of least squares" was applied to estimate the regression coefficients.
- In this paper, the authors have made an attempt to identify the number of those independent variables that influence ship repairing time and labour (the dependent variables) and their inter-relationship.

Review

- Though sufficient literature is available on ship operating expenditures, ship maintenance expenses and related issues, very few research on ship repairing related subjects were found. Not much research was found particularly on ship repairing time and labour.
- The probable reason for the nonexistence of investigation on ship repairing labour seems to be the non-availability of such commercial data and information that are strictly considered as the trade secret of the concerned shipyard, ship owner and ship manager.
- This lack of ship repairing research area motivated the authors, who have more than three decades of direct experiences in marine and offshore industries particularly in repairing and new building of various types and sizes of ships, to take the task of investigating ship repairing time (days) and labour (man-days).

Problem Formulation

- The question is "Is there any scope and avenue to reduce the ship repairing time and labour utilised?" The answer is not straightforward and easy. Past data of ship repairing time and labour can provide the valuable information to get an appropriate answer to this question.
- Given the above difficulty, this paper focuses on the inter-relationship between ship repairing time and labour and various variables like age, deadweight, type and routine maintenance/repairing works.
- Using this above relationship, the necessary ship repairing time (days) and labour (man-days) could be estimated, which may then be used to solve the above problem, if not entirely, at least partly by the ship owner and the shipyard.

Assumptions

- Ships’ Age
- Ships’ Deadweight
- Ships’ Type
- Scope of Repairing Works
  - Hull coating
  - Piping
  - Structural steel
  - Tank coating

Assumptions$_2$

- It has been highlighted theoretically that ships' age, deadweight, type and scope/quantity of ship repairing works (hull coating, structural steel, piping and tank coating) are directly, positively and linearly, associated with the corresponding ship repairing time (days) and labour (man-days).
- In other words, ship repairing time and labour (dependent variable) is a linear function of ships' age, deadweight, type, the scope of repairing works (independent variables). Mathematically, the above assumptions can be expressed in the form of **equations 1-6** for ship repairing time and **equations 7-13** for ship repairing labour respectively as shown in the next slides.

Assumptions$_3$

- $SR_{\mathrm{TIME}} = \mathrm{f}(S_{\mathrm{A}}) = a + b * S_{\mathrm{A}}$ (1)
- $SR_{\mathrm{TIME}} = \mathrm{f}(S_{\mathrm{D}}) = a + b * S_{\mathrm{D}}$ (2)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{hc}}) = a + b * R_{\mathrm{hc}}$ (3)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{tc}}) = a + b * R_{\mathrm{tc}}$ (4)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{s}}) = a + b * R_{\mathrm{s}}$ (5)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{p}}) = a + b * R_{\mathrm{p}}$ (6)

- *a*, *b* : Regression coefficients

Assumptions[4]

- $SR_{\mathrm{TIME}} = \mathrm{f}(S_{\mathrm{A}}) = a + b * S_{\mathrm{A}}$ (1)
- $SR_{\mathrm{TIME}} = \mathrm{f}(S_{\mathrm{D}}) = a + b * S_{\mathrm{D}}$ (2)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{hc}}) = a + b * R_{\mathrm{hc}}$ (3)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{tc}}) = a + b * R_{\mathrm{tc}}$ (4)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{s}}) = a + b * R_{\mathrm{s}}$ (5)
- $SR_{\mathrm{TIME}} = \mathrm{f}(R_{\mathrm{p}}) = a + b * R_{\mathrm{p}}$ (6)

- a, b : Regression coefficients

Assumptions$_4$

- $SR_{\mathrm{LABOUR}} = \mathrm{f}(S_{\mathrm{A}}) = a + b * S_{\mathrm{A}}$ (7)
- $SR_{\mathrm{LABOUR}} = \mathrm{f}(S_{\mathrm{D}}) = a + b * S_{\mathrm{D}}$ (8)
- $SR_{\mathrm{LABOUR}} = \mathrm{f}(S_{\mathrm{T}}) = a + b * S_{\mathrm{T}}$ (9)
- $SR_{\mathrm{LABOUR}} = \mathrm{f}(R_{\mathrm{hb}}) = a + b * R_{\mathrm{hb}}$ (10)
- $SR_{\mathrm{LABOUR}} = \mathrm{f}(R_{\mathrm{hp}}) = a + b * R_{\mathrm{hp}}$ (11)
- $SR_{\mathrm{LABOUR}} = \mathrm{f}(R_{\mathrm{s}}) = a + b * R_{\mathrm{s}}$ (12)
- $SR_{\mathrm{LABOUR}} = \mathrm{f}(R_{\mathrm{p}}) = a + b * R_{\mathrm{p}}$ (13)

- *a*, *b* : Regression coefficients

Sample Data

- Data Collection
  - 600 cargo ships for ship repairing time

Table 1 Sample ships for repairing time at a glance

Types of ships	No. of ships	Average age	Average deadweight	Average repairing time
General cargo	19	8.53	12,394	11.79
Container carrier	180	10.48	37,150	12.31
Car carrier	15	13.80	15,502	12.47
Chemical/Product Tanker	91	7.44	38,766	13.73
Bulk carrier	91	8.95	75,653	13.73
Dredger	6	15.33	8,274	16.17
Crude oil tanker	154	9.79	171,535	19.42
L.P.G. carrier	40	12.93	47,196	21.1
L.N.G. carrier	4	6.50	72,776	23.25
Total	600	9.82	77,020	15.25

Sample Data$_2$

- Data Collection
  - 50 ships for ship repairing labour

Table 2 Sample ships for repairing labour at a glance

Types of	No. of	Average						
Ships	Ships	S_A	S_D	R_{hb}	R_{hp}	R_s	R_p	SR_{LABOUR}
Crude oil tanker	13	7	188,005	2,845	42,367	2,795	41	1,925
Container carrier	12	11	34,620	3,821	29,838	11,603	6	3,065
Chemical tanker	9	7	46,136	2,073	23,766	1,694	23	2,481
L.P.G. carrier	8	14	41,866	2,402	27,101	14,916	37	4,773
Bulk carrier	5	9	85,409	1,681	26,848	5,560	27	1,489
L.N.G. carrier	1	5	75,248	3,172	54,309	597	0	3,681
General cargo	1	20	9,594	316	5,214	2,255	5	2,857
Car carrier	1	2	15,154	300	10,287	7,064	0	1,216
Total	50	10	82,733	2,658	30,872	6,957	25	2,750

Methodology

- To establish the relationship between the ship repairing time (days) and labour (man-days) and its independent variables, the following function of the linear equations 14 and 15 are chosen because individually the independent variables are linearly associated with the dependent variable as per initial assumptions.

- $$SR_{\mathrm{TIME}} = \mathrm{f}\left(S_{\mathrm{A}}, S_{\mathrm{D}}, R_{\mathrm{hc}}, R_{\mathrm{p}}, R_{\mathrm{s}}, R_{\mathrm{tc}}\right) \qquad (14)$$

- $$SR_{\mathrm{LABOUR}} = \mathrm{f}\left(S_{\mathrm{A}}, S_{\mathrm{D}}, S_{\mathrm{T}}, R_{\mathrm{hb}}, R_{\mathrm{hp}}, R_{\mathrm{s}}, R_{\mathrm{p}}\right) \qquad (15)$$

Ship Repairing Time

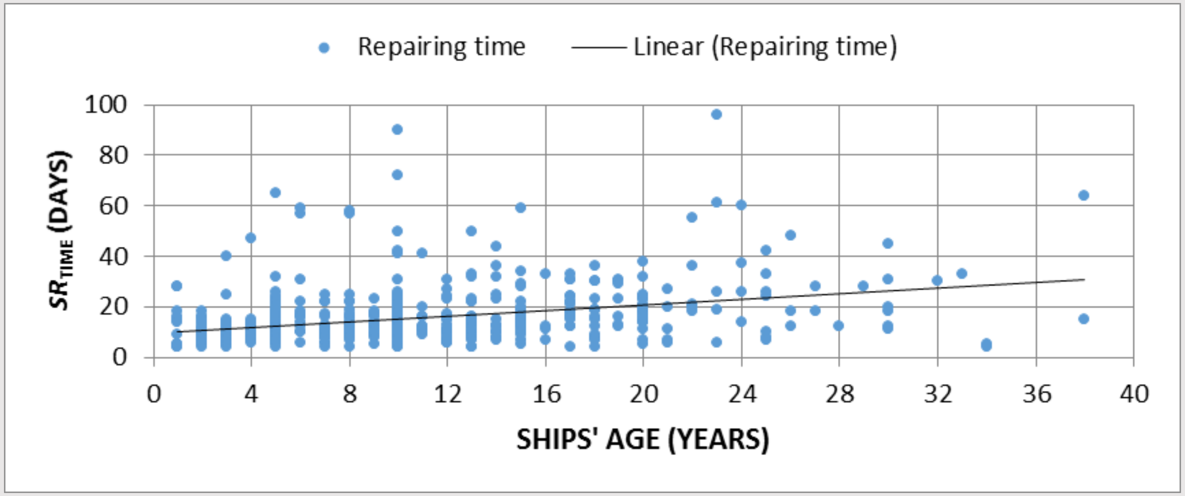

Figure 11 Ship repairing time versus age of sample ships

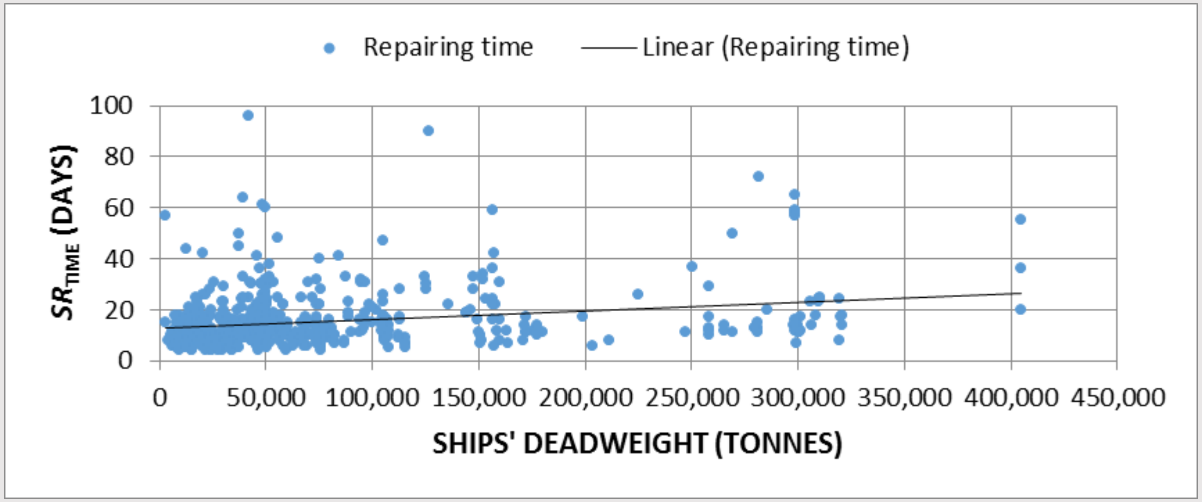

Figure 12 Ship repairing time versus deadweight of sample ships

Ship Repairing Time$_2$

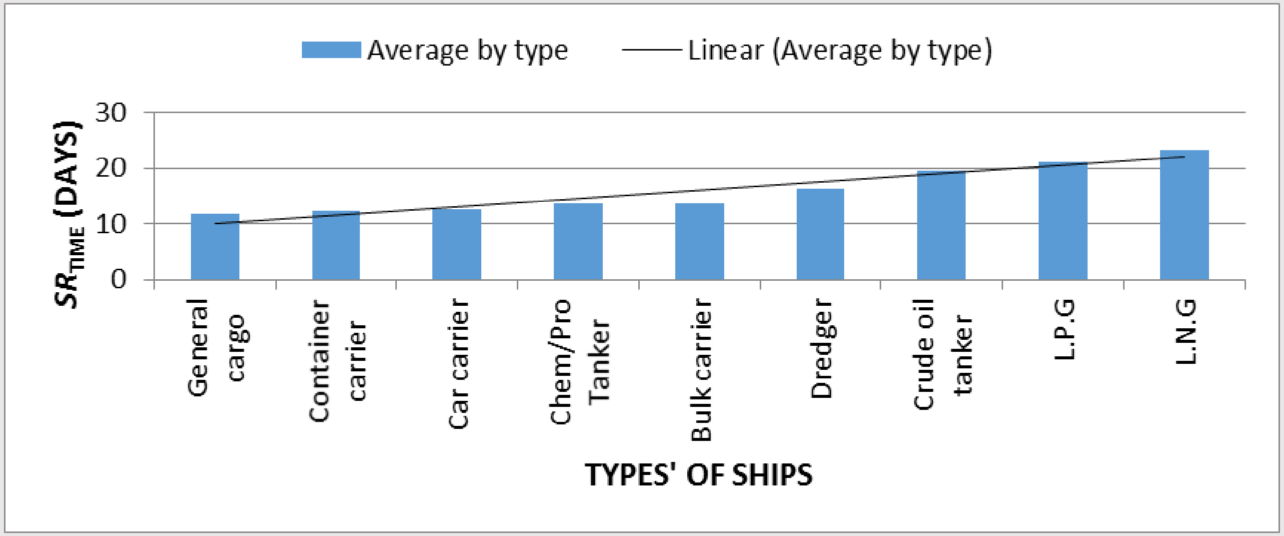

Figure 13 Average **s**hip repairing time versus type of sample ships

Multiple Linear Regression Analysis

- The multiple linear regression analysis is a mathematical procedure to determine the mathematical relationship involving more than one independent variable, unlike a single independent variable in simple linear regression analysis. This method uses the past data of both dependent and independent variables to establish the relationship to predict the dependent variable against a set of independent variables.
- A general idea of the multiple linear regression analysis can be explained as follows. Let us consider an equation of the form: $y_i = b_0 + b_1 * x_{1i} + b_2 * x_{2i} + b_3 * x_{3i} \ldots\ldots\ldots\ldots + b_k * x_{ki}$, where $b_0, b_1, b_2, b_3, \ldots\ldots b_k$ are the regression coefficients, k is the size of the independent variables and each set of data point $\{(x_{1i}, x_{2i}, x_{3i}, \ldots\ldots\ldots\ldots x_{ki}, y_i); i = 1, 2, 3, 4, \ldots\ldots\ldots n$, where n is the sample size and $n > 2\}$ satisfy the equation. Applying the method of least squares (Walpole, R.E. and Myers, R.H. 1978), the following normal equations can be obtained.

Multiple Linear Regression Analysis$_2$

- For this research, the following multiple linear regression model is chosen to represent the relationship expressed in equations 14 and 15.

$$SR_{\mathrm{TIME}_i} = b_0 + b_1 * S_{\mathrm{A}_i} + b_2 * S_{\mathrm{D}_i} + b_3 * R_{\mathrm{hc}_i} + b_4 * R_{\mathrm{p}_i} + b_5 * R_{\mathrm{s}_i} + b_6 * R_{\mathrm{tc}_i} \quad (20)$$

$$SR_{\mathrm{LABOUR}_i} = b_0 + b_1 * S_{\mathrm{A}_i} + b_2 * S_{\mathrm{D}_i} + b_3 * S_{\mathrm{T}_i} + b_4 * R_{\mathrm{hb}_i} + b_5 * R_{\mathrm{hp}_i} + b_6 * R_{\mathrm{s}_i} + b_7 * R_{\mathrm{p}_i} \quad (21)$$

Where

SR_{TIME} : Ship repairing time (days)

SR_{LABOUR} : Ship repairing labour (man-days)

$b_0, b_1, b_2, b_3, b_4, b_5, b_6$ *and* b_7 : Regression coefficients

i : 1,2,3,4.............*n*

n : Sample size

Discussion

- Ship Repairing Time
- Using the mathematical model under the estimation method of least squares and collected data, the final regression equation for the ship repairing time for crude oil tankers is as follows:

$$SR_{TIME} = 8.4557 + 0.57 * S_A + 1.65x10^{-5} * S_D - 1.37x10^{-4} * R_{hc} + 2.035x10^{-2} * R_p + 1.86x10^{-4} * R_s + 5.09x10^{-4} * R_{tc} \quad (22)$$

- The findings are in line with the assumptions made earlier. In the regression equation, all the variables, except the hull coating works (R_{hc}), have the similar sign as assumed. Age, deadweight, piping work, structural steel work and tank coating work have the positive and significant impact on the repairing time.

Discussion$_2$

- Ship Repairing Labour

- Using a mathematical model under the estimation method of least squares and collected data, the final regression equation for the ship repairing labour (man-days) is as follows:

$$SR_{LABOUR} = 178*S_A + 0.0021*S_D + 534*S_T - 0.0091*R_{hb} - 0.0026*R_{hp} + 0.078*R_S - 3.78*R_p - 417 \quad (23)$$

- In the regression equation, all the variables, except the hull blasting (R_{hb}), hull painting (R_{hp}) and piping (R_p), have the similar sign as assumed. Age, deadweight, type and structural steel have the positive and significant impact on the ship repairing labour (man-days).

Concluding Remarks

- This paper explores and identifies the possible independent variables responsible for ship repairing time (day) and labour (man-days). This paper also suggests a possible relationship between various variables in the form of a mathematical equation using multiple linear regressions and verified with statistical testing parameters to demonstrate the adequacy of the model for the system.
- This paper explores and identifies the possible independent variables responsible for ship repairing time (day) and labour (man-days). This paper also suggests a possible relationship between various variables in the form of a mathematical equation using multiple linear regressions and verified with statistical testing parameters to demonstrate the adequacy of the model for the system.

Concluding Remarks$_2$

- This research may be considered as a first step in uncovering the relationships that exist among the possible variables in ship repairing activities and entire ship repairing time (days) and labour (man-days).
- This research can further be fine-tuned with larger sample data size with all types of repairing/maintenance scopes. Also, it can be considered to use partly of sample data (say 80%) for the model formulation and the remaining for the validation of the developed model.
- Furthermore, Artificial Neural Network may be considered as an alternative method to develop the mathematical model for the estimation of ship repairing time and labour.

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Thank you!

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