Quantitative Evaluation of Draught Survey Through Correlation Test of Quarter Mean: A Case Study on a Coal Bulk Carrier

Denny Murdany Muchsin[1], Rahmad Setya Darmawan[2]
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***Abstract*— Complicated draught survey activities both at the data collection stage and the calculation stage, especially at sea, make it difficult for surveyors to accurately inform coal cargo volumes. However, in practice, most coal bulk-carrier surveyors can provide precise information on coal cargo volumes between ports up to a difference of less than 0.5%. This difference is not enough to be used as the only parameter in supervising draught survey activities. More effective monitoring needs to be done so that data reliability can be validated. This study aims to propose a new method of off-site surveillance of draught survey activities through correlation tests with a case study on a bulk-carrier ship less than 10 years old in all coal shipments at one of coal-fired power plant during year 2021. The results of the study show that based on the correlation test of Pearson (2-tailed), Spearman (2-tailed), and Kendall (2-tailed), during coal shipments in 2021 both at loading ports and at unloading ports, the interpretation of the quarter-mean as independent variable is at least strongly correlated with both displacement and displacement corrected for density, while the correlation of quarter mean with both net displacement and constant is not significant (negligible).**

Keywords—bulk carrier, coal, draught survey

I. INTRODUCTION

Based on the primary energy mix used as an energy source for power plants, coal fuel has a significant contribution of ±60% of all electrical energy generated. For information, in 2021 coal expenses contributed 16.3% to PT PLN (Persero)'s operating expenses. The government instructed PLN to make savings from various sides. In coal purchasing, the author obtains an indirect saving opportunity through quantitative evaluation on draught survey activities. Draught survey is a method for determining the cargo quantity based on the measurement of the immersion weight or the reading of the ship/barge draught either before or after loading/unloading, considering changes in weight other than cargo, which may occur during cargo handling, such as changes in the weight of ballasts, bunkers, stores [1].

Most coal shipping to coal-fired power plants use either bulk carriers or barges, instead of trucks. The parameter used commonly to assess the surveyor's performance in carrying out the draft survey is the difference in the value of coal cargo between the loading port and the unloading port of 0.5% which has been regulated by the SOP for Coal Receiving by referring to standard ECE/ENERGY/19 [2].

Inaccuracy in determining the quantity of coal through draught surveys is influenced by many things, especially draught readings on ship hulls which experience many limitations in readings on offshore draught, unfavorable natural conditions (sea waves, rain, etc.), and surveyors' experience/competence [3]–[5]. The draught mark installed on the hull of the ship should be in good paint condition and easy to read [6]. Due to the limited facilities and time given to surveyors reading the offshore draught, some surveyors read the draught at a very non-ideal position on the offshore deck. Draught reading has been improved a lot so that surveyors are more precise in getting draught values [7], [8]. In addition, determining the deductible weight requires greater effort both energy and time. The limited time for conducting a draft survey is a challenging thing, especially if the determination of the deductible weight is carried out all measurements.

During this time the precision value has been achieved in almost all coal shipping at all power plants in Indonesia even below 0.1%. Therefore, the surveyor's performance is assessed to be properly confirmed according to standard procedure, both at the loading ports and the unloading ports. The precision requirement of maximum 0.5% refers to the standards of the Economic Commission for Europe [6]. In addition, according to research conducted by Denny et al. (2023) constant evaluation needs to be carried out because effectively showed "anomalies" in the activities of the draught survey of each shipment. However, the author realizes that there needs to be another breakthrough so that there is another type of quantitative evaluation that can see in more detail the trend of the quality of draught survey activities, especially on each ship throughout the shipment using correlation tests with the criteria for the formulation of draught survey calculations according to standards.

Therefore, this study aims to prove that quantitative evaluation of draught survey activities can be done through the correlation test of Pearson, Spearman, and Kendall on a coal transport bulker.

Denny Murdany Muchsin, PT PLN (Persero), Learning and Training Unit, Indonesia, E-mail: d3nny354@gmail.com

Rahmat Setya Darmawan, PT PLN (Persero), Power Plant Unit, Indonesia, E-mail: rahmaddonat@gmail.com

II. METHOD

A. Description

The international standard used as a reference for the draught survey procedure is ECE/ENERGY/19 published by the Economic Commission for Europe on February 3, 1992. The draught survey formula contained in the standard can be concluded mathematically that the parameters displacement, displacement corrected for density, net displacement, and constant are functions of the draft in the form of quarter mean or in other words quarter mean at least has a strong correlation with these parameters. Therefore, in this quantitative analysis the quarter mean parameter is set to be the dependent variable and the other parameters (displacement, displacement corrected for density, net displacement, and constant) to be the independent variable.

B. Data Collection

This study collected secondary data in the form of the calculation of an independent surveyor's draught survey when the ship was empty on each coal shipment both at the loading port and at the unloading port during 2021 contained in the provisional report draught survey document. The coal transport ship used as the object of research is a Panamax type of bulker ship of the youngest age (under 10 years old in 2021) from several ships available to serve PT PLN (Persero) coal-fired power plants located in Central Java. The technical age of the ship is 30 years, so the ship selected as the object of this study has not yet reached one-third of its technical age, and constant change remains minor [9]. For information, the rate of constant value addition of ships due to undetermined weight such as ballast residual mud is generally 0.2% of light displacement per year [10].

The secondary data originates from the provisional report draught survey documents of ships both at loading ports (coal suppliers) and unloading ports (coal power plants) during 2021 with 12 coal shipments. The documents were issued after the surveyor carried out draught survey so that there are a total of 12 provisional report documents at each port (loading and unloading). Surveyors at the loading port originated from the survey service company PT ABC (not the real name), while at the unloading port originated from PT DEF (not the real name). The data taken from the documents are on the condition of the empty ship without cargo (the initial survey at the loading port and the final survey at the unloading port). The data includes quarter mean (unit: meters), displacement (unit: MT), displacement corrected for density (unit: MT), net displacement (unit: MT), and lightship weight (unit: MT).

C. Analysis

The stages of quantitative analysis are as follows:

1) Constant calculation both at the loading port and unloading port with the formula as follows:

$$\text{Constant} = \text{Net Displacement} - \text{Lightship Weight} \quad (1)$$

where all variables in units of MT.

2) Comparative constant evaluation between two ports and between two shipments.

- Aims to measure the ratio of constant difference at the loading port with the loading port to constant at the loading port and measure the ratio of constant difference (Δ) among shipments at the loading / unloading port.
- The formula used in this evaluation is as follows:

$$\text{Ratio of } \Delta \text{ constant between two ports} = (\text{constant}_{\text{unloading port}} - \text{constant}_{\text{loading port}})/\text{constant}_{\text{loading port}} \times 100 \quad (2)$$

where the ratio is in percentage (%) and constant in Metric Tons (MT).

- The formula used in the evaluation of constant comparison between two shipments respectively is as follows:

$$\text{Ratio of } \Delta \text{ constant between two shipments} = (\text{constant}_{n+1} - \text{constant}_{n})/\text{constant}_{n} \times 100 \quad (3)$$

where the ratio is in percentage (%) and constant in Metric Tons (MT) on shipment number of n and n+1.

A constant difference is declared normal when the ratio is less than 10% [6], [11].

3) Normality Test

- Aims to determine the distribution of data from the dependent variables and the independent variable so that the best type of correlation test can be determined at each port.
- Before statistical analysis such as correlation tests, it is necessary to conduct normality tests to prove the assumption that data distribution is normal [12].
- This test uses STATCAL software with the Kolmogorov-Smirnov (Asymptotic) method resulting in P-value of KS.
- The distribution of data is declared normal when the P-value of KS > 0.05, and vice versa is declared non-normal.

4) Correlation Test

- Aims to determine the existence of correlation between the dependent variables and the independent variable and the magnitude of the correlation coefficient at each port.
- Correlation is a measure of monotonic associations between two variables [13].
- Normal distributed data must have a linear correlation. The Pearson method is most widely used in these conditions to determine the degree of correlation linearly [13]–[15]. Data that are non-normally distributed and have a monotonic but non-linear relationship use the Spearman and Kendall method to determine the degree of correlation [13], [15], [16].

  This test uses STATCAL software with the Pearson (2-tailed) method for normally distributed dependent variables resulting in

P-value, while the Spearman (2-tailed) and Kendall (2-tailed) methods for non-normally distributed dependent variables resulting in P-value also.
- In all three methods, it is stated that there is a correlation between the independent variable and the dependent variable when the P-value < 0.10. The interpretation of the magnitude of the correlation coefficient follows accordingly Table 1.

Contradictory to the port of unloading, the constant value always changes by a significant difference (range: 373 – 670 MT). Until this stage, no final conclusions can be drawn even though there are contradictory things.

B. Evaluation of Constant Comparison Between Two Ports and Between Two Shipments Respectively

The calculation result of both the ratio of constant difference between two ports and between two shipments each port is shown by Table 3. The ratio of Δ (difference) constant between two shipments respectively at the loading port is completely below 10% even exactly 0% which means perfect. However, number of the ratio of Δ constant between two shipments at the loading port with value more than 10% (exceed standard) are 8 data (72,7% from total 11 data). Also, number of

TABLE 1.
ABSOLUTE INTERPRETATION OF THE CORRELATION COEFFICIENT [15]

Absolute Correlation Coefficient	Strength of Correlation
0.00 – 0.10	Correlation ignored
0.10 – 0.39	Weak correlation
0.40 – 0.69	Moderate correlation
0.70 – 0.89	Strong Correlation
0.90 – 1.00	The correlation is very strong

III. Results and Discussion

A. Constant Calculation

The results of constant calculations both at the loading and unloading ports are shown Table 2. The constant value at the loading port does not change (remains 360 MT) for entire coal loading activities during year 2021.

TABLE 2.
CONSTANT CALCULATION RESULTS

Shipment No.	Lightship Weight [MT]	Loading Port		Unloading Port	
		Net Displacement Initial [MT]	Constant [MT]	Net Displacement Final [MT]	Constant [MT]
1	13,537	13,897	360.00	14,207	670.00
2	13,537	13,897	360.00	13,910	373.00
3	13,537	13,897	360.00	13,959	422.00
4	13,537	13,897	360.00	14,064	527.00
5	13,537	13,897	360.00	13,930	393.00
6	13,537	13,897	360.00	14,070	533.00
7	13,537	13,897	360.00	13,945	408.00
8	13,537	13,897	360.00	13,910	373.00
9	13,537	13,897	360.00	13,929	392.00
10	13,537	13,897	360.00	14,122	585.00
11	13,537	13,897	360.00	13,924	387.00
12	13,537	13,897	360.00	13,946	409.00

and the ratio of Δ constant between two ports are 7 data (58,3% from total 12 data). The comparison of constant evaluation between two shipments respectively at the loading port is considered very good so that the draught survey activity at the loading port is considered very good, while the other two constant comparison evaluations (between two shipments at the unloading port and between two ports) are considered not good so that the draught survey activity is considered not good, in other words it should be re-drafted even though it is actually practically inefficient in time. This type of evaluation has been discussed in research that has been conducted by Denny et al. (2023) which involved more coal ships in his research. The study used evaluation that required only one shipment and could directly validate the quality of the draught survey activities [11].

C. Normality Test

The results of the normality test are shown by Table 4. Quarter mean data is the only independent variable which has normal distribution both at the loading port and at the unloading port. The others are dependent variables which have normal distribution at two ports, unless both net displacement and constant data have non-normal distribution at loading ports.

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TABLE 3.
CONSTANT CALCULATION RESULTS

Shipment No.	Loading Port		Unloading Port		Ratio of Δ Constant Between Two Ports [%]
	Constant [MT]	Ratio of Δ Constant Between Two Shipments [%]	Constant [MT]	Ratio of Δ Constant Between Two Shipments [%]	
1	360.00	-	670.00	-	86
2	360.00	0.00	373.00	-44	4
3	360.00	0.00	422.00	13	17
4	360.00	0.00	527.00	25	46
5	360.00	0.00	393.00	-25	9
6	360.00	0.00	533.00	36	48
7	360.00	0.00	408.00	-23	13
8	360.00	0.00	373.00	-9	4
9	360.00	0.00	392.00	5	9
10	360.00	0.00	585.00	49	62
11	360.00	0.00	387.00	-34	8
12	13,897	0.00	409.00	6	14

TABLE 4.
NORMALITY TEST RESULTS

No.	Variables	Loading Port			Unloading Port		
		P-Value of KS (Asymptotic Approach)	N	Distribution	P-Value of KS (Asymptotic Approach)	N	Distribution
1	Quarter Mean	0.749	12	Normal	0.283	12	Normal
2	Displacement	0.670	12	Normal	0.358	12	Normal
3	Displacement Corrected for Density	0.684	12	Normal	0.267	12	Normal
4	Net Displacement	0	12	Non-Normal	0.219	12	Normal
5	Constant	0	12	Non-Normal	0.219	12	Normal

D. Correlation Test

The results of the correlation test of between quarter mean (as independent variable) and dependent variables both at the loading port and at the unloading port with the Pearson (2-tailed) method are shown by Table 5. The Pearson method is applied to independent variable (quarter mean) paired with dependent data which has normal distribution at their own ports based on the results of the normality test.

Both at the loading port and at the unloading port the independent variable (quarter mean) can be validated to correlate very strongly with displacement and displacement corrected for density. This is consistent with the formulation of the ECE/ENERGY/19 international standard which is used as a reference for the draft survey procedure that displacement and displacement corrected for density are functions of the quarter mean. Until the calculation stage of displacement corrected for density, it can be stated that the results of the calculation of the coal bulker ship draft survey both at loading and unloading ports are still consistent with the direction of mathematical logic formulated from UN ECE standards.

However, the results of the Pearson correlation test between quarter mean and both net displacement and constant at the port of unloading could not be validated as significantly correlated with the independent variable quarter mean. This is not consistent with the formulation of the ECE/ENERGY/19 international standard which is used as a reference for the draught survey procedure that both net displacement and constant are functions of the quarter mean. After the displacement corrected for density calculation stage, it can be stated that the results of the calculation of the draught survey of coal bulker ships at the unloading port are not consistent with the direction of mathematical logic formulated from the UN ECE standard.

The results of the correlation test of between quarter mean (as independent variable) and dependent variables at the loading port both by the Spearman (2-tailed) and Kendall (2-tailed) methods are shown respectively by Table 6 and Table 7. Spearman and Kendall's method was applied to quarter mean paired with dependent data that have non-normal distribution at their own port based on normality test results.

In the results of the Spearman and Kendall correlation test between quarter mean and both net displacement and constant at the loading port could not be validated significantly correlated with the independent variable quarter mean. This is not consistent with the formulation of the ECE/ENERGY/19 international standard which is used as a reference for the draught survey procedure that both net displacement and constant are functions of the quarter mean. After the calculation stage of displacement corrected for density, it can be stated that the results of the calculation of the coal bulker ship draught survey at the loading port are not consistent with the direction of mathematical logic formulated from the UN ECE standard.

Based on the evaluation method with the Pearson, Spearman, and Kendall correlation tests that had been carried out, the calculation of draught surveys both at loading ports and at unloading ports on all shipments during 2021 had problems in calculating net

TABLE 5.
PEARSON CORRELATION TEST RESULTS (2-TAILED)

No.	Variables Paired with Quarter Mean	Loading Port				Unloading Port			
		Pearson Correlation Coefficient	P-Value	Significance of Correlation	Strength of Correlation	Pearson Correlation Coefficient	P-Value	Significance of Correlation	Strength of Correlation
1	Displacement	0.998	0	Significant	Very Strong Correlation	0.998	0	Significant	Very Strong Correlation
2	Displacement Corrected for Density	0.995	0	Significant	Very Strong Correlation	0.989	0	Significant	Very Strong Correlation
3	Net Displacement	N/A	N/A	N/A	N/A	-0.181	0.573	Insignificant	Correlation Ignored
4	Constant	N/A	N/A	N/A	N/A	-0.181	0.573	Insignificant	Correlation Ignored

TABLE 6.
SPEARMAN AND KENDALL CORRELATION TEST RESULTS (2-TAILED) AT LOADING PORT

No.	Variables Paired with Quarter Mean	Spearman Correlation				Kendall Correlation			
		Correlation Coefficient	P-Value	Significance of Correlation	Strength of Correlation	Correlation Coefficient	P-Value	Significance of Correlation	Strength of Correlation
1	Net Displacement	-	-	-	-	-	-	-	-
2	Constant	-	-	-	-	-	-	-	-

displacement and constant, while the calculation of both displacement and displacement corrected for density is declared normal. However, if we use the research evaluation method that had been carried out by Denny et al. (2023), not all shipments have problems in the calculation of the draught survey.

In the ECE / ENERGY / 19 international standard, displacement data is obtained directly from the results of interpolation on the ship's hydrostatic table with the input of quarter mean data which is the result of processing primary data on draught readings. One of the inputs in the calculation of displacement corrected for density is primary data, namely the results of measuring seawater density with a hydrometer. In addition, input in the calculation of net displacement is also in the form of primary data, namely the results of deductible measurements consisting of ballast water, fresh water, fuel oil (MFO and HSD), lubricating oil, swimming pool water, stores & provisions, crew, slops, and anchor/chain. Primary data retrieval for net displacement calculation has much more to measure and in principle takes more time and effort if done according to ECE/ENERGY/19 international standards. For example, the deductible of a Supramax type coal bulker ship which is very dominated by ballast water by volume can consist of more than 20 ballast water tanks. Ballast water data collection consists of depth measurement by sounding and density measurement of each tank. Generally, in every measurement there is an error both the influence of the accuracy of the measuring instrument and the human error. Several errors accumulated in the measurement of various deductibles have the potential to affect the calculation of net displacement and then the calculation of constant so that in the end the calculation of the quantity of coal received by the buyer of the power plant will be affected as well.

IV. CONCLUSION

The conclusions of this study are as follows:

1) The evaluation results are based on the correlation test of Pearson (2-tailed), Spearman (2-tailed), and Kendall (2-tailed), during the delivery of coal in 2021 to one of PT PLN (Persero)'s coal-fired power plants both at the loading port and at the unloading port, the quarter-mean (as independent variable) is at least strongly correlated with both displacement and displacement corrected for density, while the correlation of the quarter mean (as independent variable) with both net displacement and constant is not significant (negligible).
2) Correlation test between quarter mean and dependent variables (displacement, displacement corrected for density net, displacement, and constant) can be applied to evaluate draught survey which has carried out by surveyor for both each port and each ship.

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