The Effect of Ship Coefficients on the Efficiency Gain f Propeller-Vane System

Setyo Leksono[1], IKAP Utama [1], MA Djoni [2], and WD Aryawan[1]

Abstract— **This paper discusses a correlation between non dimensional parameter of the ship (L/B,B/T, wake fraction, ratio between induced and advance velocity, thrust loading coefficient) and energy gain by applying vane-turbine in the propeller slipstream. The data based on the basis of statistical data (numerical) and model testing. The correlation data can be calculated by quantifying the contribution of causal variables to a targeted effect variable directly and indirectly through other variables and this would be examined by Path analysis. By using this coefficient, it is possible to demonstrate which variable has the main contribution on the efficiency gain. The Data analysis of Microsoft Office Excel software is used to approach the calculation. It is found that L/B and CT affected indirectly the efficiency gain of vane-turbine.**

Keywords— **Path analysis, path coefficient, causal factors, effect variables, efficiency gain**

I. INTRODUCTION

Reference [1,2] show the calculation of applying vane turbine in the propeller slipstream, based on numerical approach by using ship powering software (DESP code 10), ship model test and some empirical formulas. The application of vane-turbin in the propeller slipstream for single- and twin- screw ship, is adequately good. For moderate propeller thrust loading, the efficiency gained is about 8% and for high thrust loading is about 3 %. Most of twin screw ship which are equipped with vane-turbine, the efficiency gained is tendentiously negative. All these information are presented in Tables 1 and 2.

In Table 1, it shows that the efficiency gain of single screw ship is scatter. To find the factor that influencing the magnitude of the efficiency gain for single screw ship, the Path Analysis methods was applied, but not for the twin screw ship (Table 2) because of applying vane turbine behind propeller is not recommend.

The path coefficient method was pioneered by l Wright (1921) [3]. The work was only related to population genetics at first. Now it is being applied in all works of life such as social, ecological [4, 5]. Path analysis extends multiple regression analysis, but while regression gives the best or closest prediction of the response variable based on the given causal factors by the method of least squares.

Path analysis goes further by providing probable interpretation of the relationships between and within the contributing causal factors to the observed effects [6, 7, 8].

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + U \qquad (1)$$

The case of multiple regression in the equation above (eq.1) looks at a single response variable as a function of several causal / explanatory variables with the assumptions that values of variables are random, normally distributed and that the causal variables are independently contributing to the response variable.

$$p_{01}X_1 + p_{02}X_2 + p_{03}X_3 + U = Y \qquad (2)$$

Path analysis (eq. 2) on the other hand, examines several explanatory variables as a function of the response variable of interest. It assumes that causal factors are correlating to contribute to the response variable. In other words causal factors do not act independently.

Certainly the most three important sets of decisions leading to a path analysis are:

1. Which causal variables to include in the model.
2. How to order the causal chain of those variables.
3. Which paths are not "important" to the model – the only part that is statistically tested.

Usually a path analysis involves the analysis and comparison of two models – a "full model" with all of the possible paths included (see Figure 1a) and a "reduced model" which has some of the paths deleted, because they are hypothesized do not contribute to the model (see Figure 1b).

The path coefficients for the full model (with all the arrows) are derived from a series of "layered" multiple regression analyses. For each multiple regression, the criterion is the variable in the box (all boxes after the leftmost layer) and the predictors are all the variables that have arrows leading to that box.

---

[1]Setyo Leksono, IKAP Utama, WD Aryawan are with Department of Naval Architecture and Shipbuilding Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia, E-mail : leksono2004@yahoo.com

[2]MA Djoni is with Department of Mechanical Engineering, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia.

II. METHODOLOGY

The data for analyzing are taken from (Leksono et all, 2013) and presented in Table 3. This data is standardized before a regression analysis is carried out using Excel [8,9]. Regression on a standardized variable/s gives partial regression coefficients unlike regression on non-standardized variables that gives concrete regression coefficients. This contains one dependent variable Y and four independent variables $X_1…X_4$ (6 cases), applying the eq. 3   to the raw data on the left results in the standardized set on the right.

$$x^* = (x - m)/sd \tag{3}$$

A. Direct Path Coefficient

Regression analysis on a set of standardized variables results in partial regression coefficients. Partial regression coefficients are in fact another name for direct path coefficients.

Assuming a set of five variables are Y, X_1, X_2, X_3 and X_4. The indirect contributions of X_1 to Y will include X_1 to Y through X_2, X_3 and X_4. The same applies to X_2, X_3 and X_4 correlation coefficients into its component parts. It could be defined as the ratio of the standard deviation of the effect due to a given cause to the total standard deviation of the effect (direct path coefficient).

If Y is the effect and X_1 is the cause, the path coefficient for the path from cause X_1 to the effect As earlier mentioned under direct path coefficients calculation the path coefficient from X_1 to Y.

The indirect contributions of X_1 to Y will include X_1 through X_2, X_3 and X_4. The same applies to X_2, X_3 and X_4.

The equation below illustrates the splitting process for a 3 factor causal variables with one effect variable Y

$$r = (X_1,Y) = a + r(X_1,X_2)b + r(X_1,X_3)c$$
$$r = (X_2,Y) = r(X_2,X_1)a + b + r(X_2,X_3)c$$
$$r = (X_3,Y) = r(X_3,X_1)a + r(X_3,X_2)b + c \tag{4}$$

The above equations shows that the partition each of the correlation from X_1 to Y, X_2 to Y, X_3 to Y into their component paths, i.e in the case of X_1 to Y, from the sample data.
1. Due to direct effect of X_1 on Y
2. Due to indirect effect of X_1 on Y via X_2
3. Due to indirect effect of X_1 on Y via X_3
4. Due to indirect effect of X_1 on Y via X_4

For evaluating the correlation each variable, according to AN Akintunde [9] stated as followed :
(1) If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship.
(2) If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the cause of correlation. In such cases, the indirect causal factors are to be considered.
(3) The correlation coefficient may be negative but the direct effect is positive and high. In these circumstances, away to selectively drop the

undesirable indirect effects will have to be introduced. (Singh; Chaudhary, 1977).
(4) The residual effect determines how best the causal factors account for variability of the dependent variable. If the residual accounts for a large portion of the variability in the dependent variable, it then means that other causal variables have to be brought into the study as those being considered are not the causal factors directly responsible for the effect.
(5) A way to cross check / validate the result is to add the direct path coefficient of a particular causal factor to its indirect effects; the result should be equal to the correlation coefficient between that causal factor and the response variable. There may be some rounding errors and these should be apparent. If the correlation coefficient is not equal to the total indirect + direct path coefficient, double checking on the datas and multiple regression coefficients.

III. CALCULATION

These basic statistics (Average, Count and sum) will form the base for calculating the standard deviation and standardization process of the data. This can be done easily in Excell. The data and the first process for calculating basic statistics are presented in Table 4. Also the correlation matrix is presented in Table 5.

The next step towards obtaining an indirect path coefficients is to bring forth the direct path coefficients generated earlier (Table 6). With these two tables (Table 5 and Table 6), the indirect contributions for all variables in the equation could be generated, presented in Table 7.

IV. DISCUSSION

The research diagram for analyzing all variables is shown in Fig.2 corresponding with the data in Table 3. After processing the calculation, there is some rounding error (statement no 5 of Akintunde). So, a part of the data should be omitted. In this case the variable Ui/Va could be deleted, the data will be five variables (Eff.Gain= Y, w=X_1, CT=X_2, L/B=X_3, B/T=X_4) as presented in Table 4.

Calculating the path coefficient for five variables as mentioned above (Table 7), the indirect effects seem to be the cause of correlation. In such cases, the indirect causal factors are to be considered according point (2) of the Akintunde's statement as shown in Fig.3a The biggest value of path coefficient is L/B to Efficiency Gain via Coefficient Thrust Loading. Both path coefficient (L/B to Eff. Gain via w and L/B to Eff. Gain via B/T) could be omitted, because of the value of them are small. So, the main dimension ratio (L/B) will affected the efficiency gain via CT (Coefficient Thrust Loading). It means that the efficiency gain of the vane turbine depends on L/B indirectly. The correlation diagram of such case is shown in Figure 3b.

Comparing the regression analysis of CT as a function of L/B (Fig.4a) and Efficiency gain as a function of

Coefficient Thrust loading (Fig.4b) with this result is quite reasonable.

V. CONCLUSSION

Successful prediction of consequences / effects ships coefficient on the efficiency gain of vane-turbine system is presented. The factor of non dimensional ratio L/B of the ship contributes the magnitude of the efficiency gain of the vane turbine, but still depends on the value of Coefficient Thrust loading of the propeller (CT).

REFERENCES

[1]   S Leksono, IKAP Utama, MA Djoni, and W D Aryawan, "A Vane Turbine as an Energy Conversion in the Propeller Slipstream of Single Screw Ship," *Advanced Materials Research*, vol. 789, pp. 417-422, September 2013.

[2]   S Leksono, I K A P Utama, M A Djoni, and W D Aryawan, "A Vane Turbine in the Propeller Slipstream as an Alternative Energy Saving Devices," in *5th International Conference on Tech. and Operational OSV*, Singapore, 2013.

[3]   Sewal Wright, "The Method of Path Coefficients," *The Annals of Mathematics Statistics*, vol. 5, no. 3, pp. 161-215, September 1934.

[4]   D Brown and P Rothery , *Models in Biology: Mathematics,Statistics and Computing*. Chichester, England: John Wiley & Sons Ltd, 1993.

[5]   R F Gunst and L R Mason, *Regression Analysis and Its Application*. New York, USA: Marcel Dekker, Inc, 1980.

[6]   Samuel M Scheiner and J Gurevitch, *Design and Analysis of Ecological Experiments*. New York, USA: Chapman & Hall, 1993.

[7]   Sugiyono, *Statistika untuk Penelitian*. Bandung, Indonesia: Alfabeta, 2011.

[8]   A N Akintunde, "Path Analysis Step by Step using Excel," *Journal of Technical Science and Technologies*, vol. 1, no. 1, pp. 9-15, 2012.
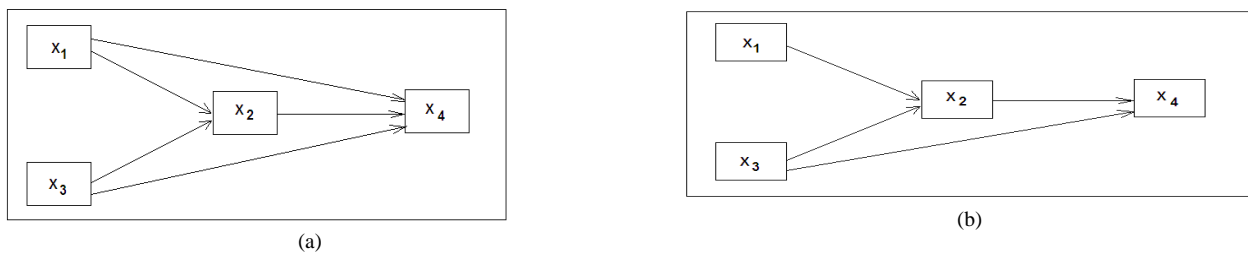

Figure 1. (a) Path diagram with five path coefficient, (b) Path diagram with four path coefficient
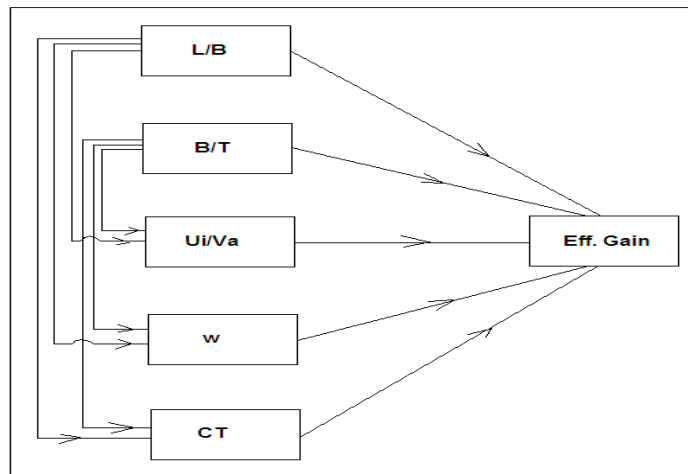

Figure 2. Research diagram: the effects of main dimension ratio of the ship and coefficient on propulsion to the efficiency gain of vane turbine.
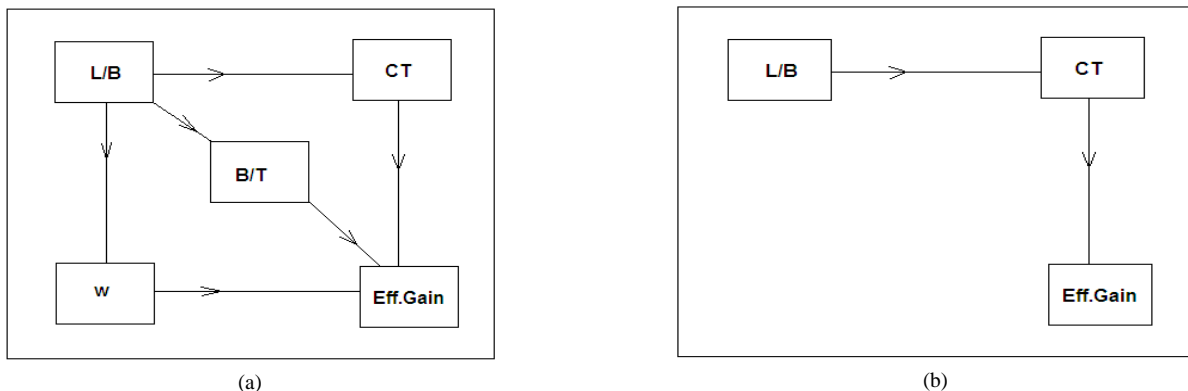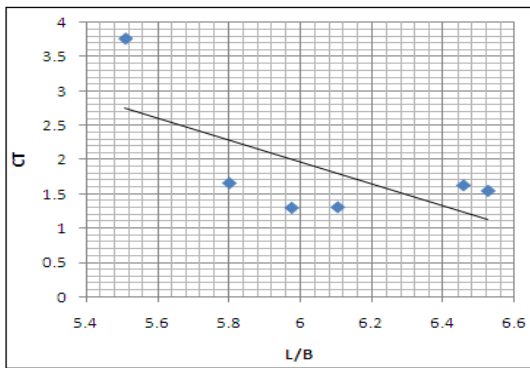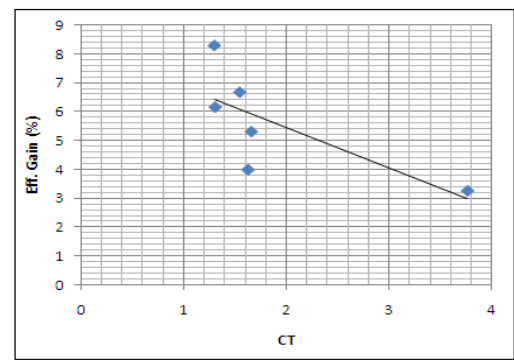

Figure 3. (a) Path Diagram of the effect of ship coefficient on the Eff. Gain of Vane turbine (b) Path Diagram of the effect of ship coefficient on the Eff. Gain of Vane turbine

(a)   (b)

Figure 4. (a) Coefficient Thrust Loading as function of L/B, (b) Efficiency gain as function of Coefficient Thrust Loading

TABLE.1
ADVANTAGE OF PROPELLER – TURBIN SYSTEM AT VARIOUS TYPE OF SHIP

No		Tanker	Bulk Carrier	Container	G. Cargo	Container	Ropax	Rescue Vessel
1	Vs (knots)	13	14.5	16.5	13	19	16	22
2	T_{PT} (kN)	366.145	699.6533	1307.291	223.4825	1017.062	224.1707	387.849
3	Act. Speed (knots)	12.3965	14.0205	15.7705	12.63035	19.03967	15.49918	21.3066
4	Speed Loss (knots)	0.603501	0.479501	0.7295	0.369649	0.460328	0.500824	0.693397
5	Act. Eng. Power (kW)	2737.826	6111.585	14879.63	1861.86	11811.06	2503.542	8075.97
6	Total Power (kW)	3296.158	7394.058	17550.17	2205.225	13993.52	3002.891	10287.67
7	Power Gained (kW)	104.1577	567.0548	674.1689	111.225	812.5229	181.8915	784.6738
8	Eff. (%)	3.26308	8.30000	3.9948	5.31162	6.164349	6.447765	8.257

TABLE.2
DISADVANTAGE OF PROPELLER – TURBIN SYSTEM AT VARIOUS TYPE OF SHIP

No		Pax 200	Cruise Linear	Pax 1000	Cement Barge	KPC	KCRS	LST
1	Vs (knots)	1	18	18	9	26	28	16
2	T_{PT} (kN)	78.39144	493.5972	230.8169	206.7416	332.9969	256.3061	384.3643
3	Act. Speed (knots)	11.67983	16.83196	17.46659	8.866687	24.84141	26.58576	15.46346
4	Speed Loss (knots)	0.320168	1.168038	0.522415	0.133313	1.158591	1.41424	0.536543
5	Act. Eng. Power (kW)	640.0287	4473.323	2847.296	1468.016	17053.65	6023.791	4684.64
6	Total Power (kW)	726.9001	5125.701	3266.056	1553.918	17638.99	6657.833	5283.944
7	Power Gained (kW)	-11.0999	-680.299	-15.9437	-18.0824	-542.009	-19.1667	-158.056
8	Eff. (%)	-1.50405	-13.1129	-0.48579	-1.15028	-2.98118	-0.28706	2.90437

TABLE 3.
VARIABLES FOR PATH ANALYSIS

Eff. Gain	w	CT	Vi/Va	L/B	B/T
Y	X_1	X_2	X_3	X_4	X_5
3.263	0.455	3.7639	0.5913	5.509	3.957
8.3	0.255	1.2989	0.2581	5.975	2.773
3.995	0.216	1.6271	0.3104	6.457	4.163
5.312	0.249	1.6585	0.3152	5.8	2.667
6.164	0.277	1.3079	0.2596	6.104	2.835
6.68	0.143	1.546	0.29781	6.526	4.16908

TABLE 4.
BASICS STATISTIC CALCULATION

	Eff. Gain	w	CT	L/B	B/T
	Y	X1	X2	X3	X4
	3.2630	0.4550	3.7639	5.5090	3.9570
	8.3000	0.2550	1.2989	5.9750	2.7730
	3.9950	0.2160	1.6271	6.4570	4.1630
	5.3120	0.2490	1.6585	5.8000	2.6670
	6.1640	0.2770	1.3079	6.1040	2.8350
	6.6800	0.1430	1.5460	6.5260	4.1691
Mean	5.6109	0.2658	1.8671	6.0618	3.4273
StD	1.8380	0.1038	0.9421	0.3886	0.7388

TABLE 5.
CORRELATIONS MATRIX

	Y	X_1	X_2	X_3	X_4
Y	1	0.53757	-0.71422	0.286646	-0.51537
X_1	-0.53757	1	0.845913	-0.86991	-0.0373
X_2	-0.71422	0.845913	1	-0.66217	0.417115
X_3	0.286646	-0.86991	-0.66217	1	0.399234
X_4	-0.51537	-0.0373	0.417115	0.399234	1

TABLE 6.
PARTIAL REGRESSION COEFFICIENT

Intercept	0
X_1	-0.30399
X_2	-0.90173
X_3	-0.61237
X_4	0.093891

TABLE 7
DIRECTED AND UNDIRECTED PATH COEFFICIENT

Direct Path Coeff. of X_1 on Y	=	-0.30399
Indirect effect of X_1 via X_1 on Y	=	-0.30399
Indirect effect of X_1 via X_2 on Y	=	-0.76278
Indirect effect of X_1 via X_3 on Y	=	0.532708
Indirect effect of X_1 via X_4 on Y	=	-0.0035
Total indirect effects	= -0.23358	
Direct Path Coeff. of X_2 on Y	=	-0.90173
Indirect effect of X_2 via X_1 on Y	=	-0.25715
Indirect effect of X_2 via X_2 on Y	=	-0.90173
Indirect effect of X_2 via X_3 on Y	=	0.405493
Indirect effect of X_2 via X_4 on Y	=	0.039164
Total indirect effects	= 0.187508	
Direct Path Coeff. of X_3 on Y	=	-0.61237
Indirect effect of X_3 via X_1 on Y	=	0.264443
Indirect effect of X_3 via X_2 on Y	=	0.597092
Indirect effect of X_3 via X_3 on Y	=	-0.61237
Indirect effect of X_3 via X_4 on Y	=	0.037485
Total indirect effects	= 0.899019	
Direct Path Coeff. of X_4 on Y	=	0.093891
Indirect effect of X_4 via X_1 on Y	=	0.011339
Indirect effect of X_4 via X_2 on Y	=	-0.37612
Indirect effect of X_4 via X_3 on Y	=	-0.24448
Indirect effect of X_4 via X_4 on Y	=	0.093891
Total indirect effects	= -0.60926	