AN ESTIMATION OF THE FINAL PRICE OF CONTAINER SHIPS BASED ON MAIN SHIP PARAMETERS WITH THE USE OF NDCURVEMASTER CURVE FITTING SOFTWARE

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Abstract. The paper presents regression formulas that allow us to estimate the final price of new container ships, based on TEU and deadweight capacity, service speed, length between perpendiculars and gross tonnage of container ships built from 2005 to 2015. The formulas were developed using the author's own method based on curve fitting techniques and regression methods. The study shows that utilising the author's method to predict the final price could offer greater accuracy solutions than any standard methods presented in literature. This method was implemented properly with ndCurveMaster curve fitting software which was developed by the author and was applied to develop regression equations presented in the article. The formulas presented in the article have practical application for estimation of container ship final price needed in transport studies or preliminary parametric container ship design. These equations refer to the most up to date vessels and offer the chance to advance ship design theory.

Keywords: container ship, price, ndCurveMaster, deadweight, regression

INTRODUCTION

Ship design is a multistage process which consists of preliminary design, contract design and detailed design stage. Papanikolaou (2010), Chadzynski (2001), Buczkowski (1974), Rawson (2001) and Watson (2002) argue that the preliminary design stage consists of:

- a parametric design phase, in which the external geometric dimensions of the hull are defined, and parameters describing key ship characteristics such as velocity, deadweight capacity, gross tonnage and others,
- a geometric design phase, in which the hull shape is precisely defined on the basis of design parameters set out in the parametric phase.

As noted by (Chadzynski 2001, Schneekluth and Bertram 1998), the final price of the vessel depends on the unit costs of ship construction, which in turn include the costs of materials, equipment, labour and the additional yard costs. As noted by (Celik et al. 2013) detailed cost analyses are required at the preliminary design stage as ship building projects have need high levels of financing. Lin and Shaw argue that the preliminary ship cost estimation methods provide only rough estimates of the labour, materials, and equipment based on the overall ship parameters. In general, the total costs are not known at the parametric design stage, because the detailed specification of materials and equipment is not known. During the parametric stage only general design parameters of the ship are known, such as main hull dimensions, general geometric indicators, general assumptions regarding the quantity of cargo or ship speed.
Ship designers would benefit from an estimate of the final price of the vessel in all phases of design. As the final price of the ship in the main depends on main ship characteristics, the estimating of a final price would offer greatest effectiveness best at the parametric phase of design. With this in mind, the objective of this research was to develop simplified, accurate

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relationships enabling a clear assessment the final price of the ship by using main ship characteristics at the parametric design phase, which is a very challenging task.

In contrast, the later design stages, when more information is available on the ship to be built, a detailed estimation is performed, which considers the unit costs of materials, equipment, labour and any additional shipyard costs. The methods presented in (Michalski, 2004) apply to a detailed estimation of vessel production costs.

Regression equations to estimate final container ship price have already been presented by the author in (Cepowski, 2016). These functions were developed using standard multiplicative regression methods. But it is possible that the regression methods presented in these papers are not satisfactory accurate in comparison with formulas obtained using a curve fitting method. The aim of the study was to develop an accurate regression formula of higher accuracy to estimate container ship final cost, than equations presented in (Cepowski, 2016) using a curve fitting method. The practical aim of this research was to develop new regression formulas (*f*) for estimating the final container ship price (*P*) using technical parameters ($X_1, X_2 ... X_n$):

$$\mathrm{P} \approx f(X_1, X_2, \dots, X_n) \tag{1}$$

where:

P – final price,

$X_1, X_2 ... X_n$ – container ship technical parameters,

n – a number of parameters,

f – searched regression formula.

RESEARCH METHOD

Regression formulas were developed using the author's algorithm based on a curve fitting method. The most suitable combinations of independent variable equations were searched in all their possible combinations in this algorithm. The general algorithm scheme is shown in Fig. 1. The base function collection included 120 arrays of nonlinear, exponential, power and logarithmic functions. NdCurveMaster software was developed on the basis of this algorithm by the author.

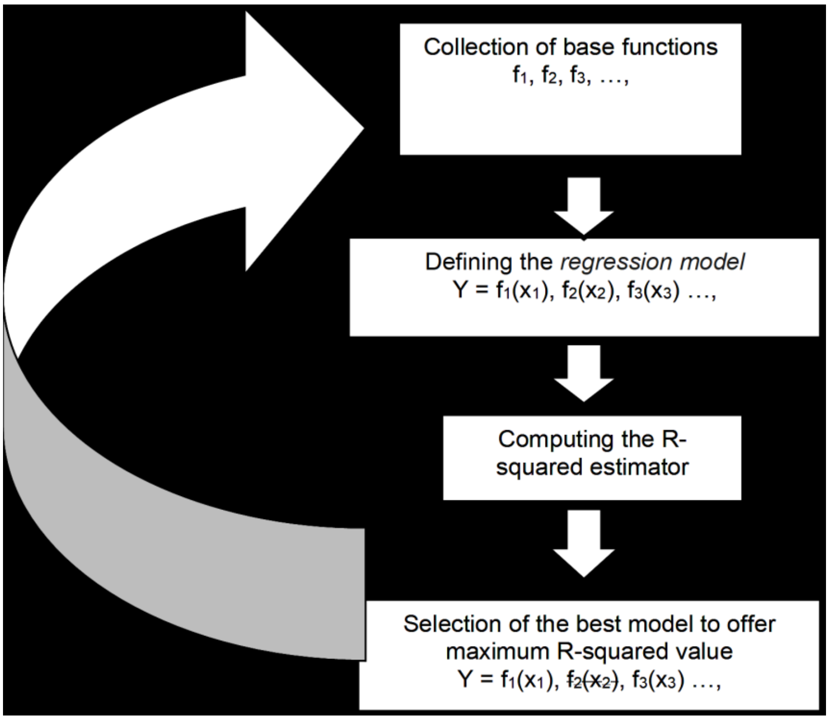

Fig. 1. A general algorithm scheme, where:
f – base function, x – independent variable, Y – depended variable

The software was applied to develop regression equations presented in the next part of the article. The ndCurveMaster user interface is shown in Fig. 2.

The analysis took into account a set of 241 new container ships built from 2005-2015, whose parameters ranged as follows:
- DWT from 2,310 t to 165,538 t,
- number of containers (TEUs): from 58 to 13,344,
- service speed: 10 to 27 knots,
- sale price: 2.5 million to 170 million USD.

In addition to the above parameters the study included:
- displacement, light ship weight,
- gross tonnage GT,
- main hull dimensions: perpendicular length, breadth, moulded depth, moulded draft,
- power plant output, fuel consumption.

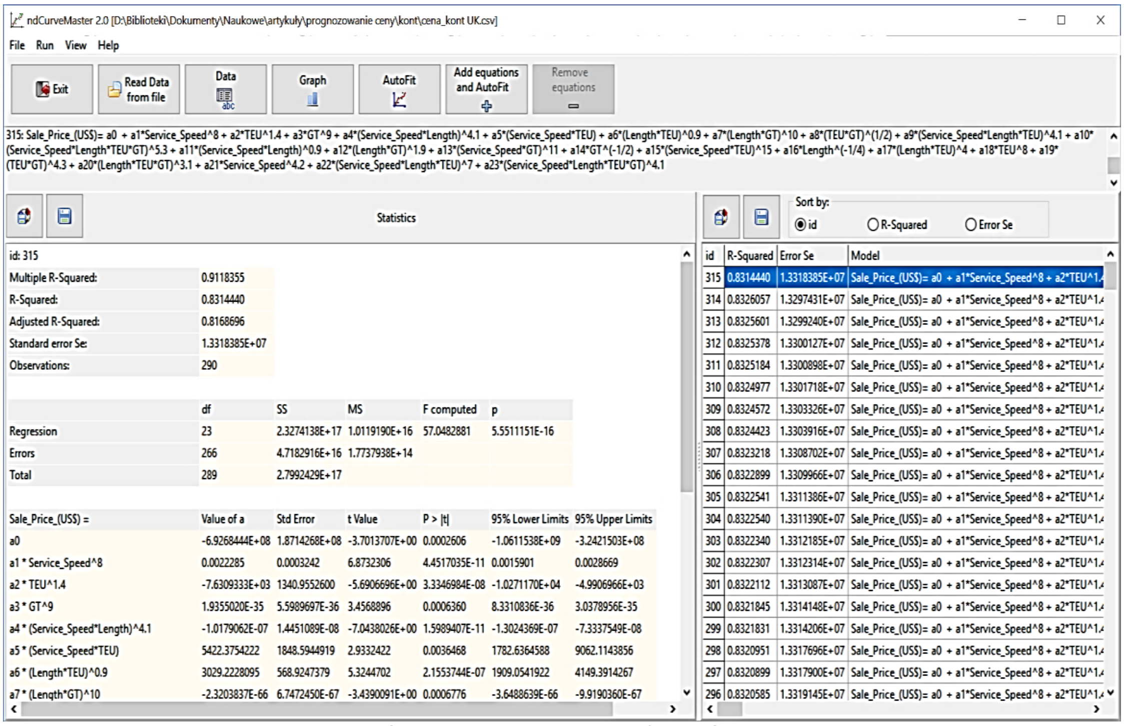

Fig. 2. The ndCurveMaster user interface (SigmaLab, 2017)

RESULTS

Statistical analysis presented in (Cepowski, 2016) showed that the price of a container ship is mainly dependent on container capacity (TEUs) and DWT capacity. The following statistical relationships were investigated in this author's paper:

$$P = 21{,}241{,}378 + 0.818 \cdot TEU^2 \qquad (2)$$

$$P = 19{,}146{,}189 + 0{,}006 \cdot DWT^2 \qquad (3)$$

$$P = -40{,}849{,}078 + 639{,}829 \cdot \ln(DWT)^2 \quad 4.913 \cdot 10^{-5} \cdot TEU^2 \qquad (4)$$

where:
P – final price of a container ship in USD,
TEU – number of containers,
DWT – deadweight capacity [t].

The values of standard SE and the R-squared errors relating to formulas (2) – (3) presented in (Cepowski, 2016) are given in Table1.

Table 1.
The values of standard SE and the R-squared errors relating to formulas (2) – (4)

Item	Input design parameter	Equation no	Standard error SE	R-Squared
1.	TEU	(2)	$ 16.8 million	0.73
2.	DWT	(3)	$ 17.2 million	0.73
3.	DWT, TEU	(4)	$ 16.8 million	0.73

In contrast, new regression formulas for estimating the final price of a container ship were developed using the author's own method:

$$P = 13{,}936{,}995 + 93.63 \cdot TEU^{1.5} \quad (5)$$

$$P = 5{,}402{,}156 + 106.37 \cdot \ln^{6}(TEU) + 8.9E\text{-}26 \cdot TEU^{8} \quad (6)$$

$$P = 14{,}147{,}655 + 3{,}456{,}085{,}900 \cdot (DWT \cdot 10^{-6})^{1.7} \quad (7)$$

$$P = 47{,}353{,}312 + 40{,}311{,}027{,}000 \cdot (DWT \cdot 10^{-6})^{3.1} - 999.6 \cdot \ln^{7}(DWT \cdot 10^{-6}) - 794479.46 \cdot (DWT \cdot 10^{-6})^{-1} \quad (8)$$

$$P = 7{,}846{,}123 + 1.3E\text{-}21 \cdot TEU^{7} + 1{,}151{,}698 \cdot \ln^{2}(TEU \cdot DWT \cdot 10^{-6}) \quad (9)$$

$$P = 60{,}645{,}181 - 1.37E\text{-}07 \cdot v^{11} + 3.96E\text{-}18 \cdot LBP^{11} + 6.61E\text{-}42 \cdot GT^{10} + 0.093 \cdot v^{2.5} + 2.17E\text{-}73 \cdot v^{15} - 2.54 \cdot (v \cdot GT)^{1.3} + 3.61E\text{-}13 \cdot (LBP \cdot TEU)^{3.5} - 2.50E\text{-}12 \cdot (LBP \cdot GT)^{2.9} - 9.56E\text{-}17 \cdot (TEU \cdot GT)^{2.9} + 0.0577 \cdot LBP \cdot GT \cdot TEU - 2.12E\text{-}96 \cdot v \cdot LBP \cdot TEU \cdot GT - 3.57E\text{-}08 \cdot (LBP \cdot TEU)^{2.7} + 1.03E\text{-}19 \cdot (v \cdot GT)^{4.5} - 1.20E\text{-}15 \cdot LBP^{10} - 758.048 \cdot (TEU \cdot GT)^{0.8} + 1.08E\text{-}10 \cdot GT^{4} + 95906.18 \cdot (LPB \cdot TEU \cdot GT)^{0.4} + 5387.905 \cdot \ln^{5}(v \cdot TEU) - 5.86E\text{-}14 \cdot (v \cdot LBP \cdot TEU \cdot GT)^{1.8} - 1.90E\text{-}50 \cdot (v \cdot LBP)^{15} - 1073.067 \cdot \ln^{5}(v \cdot LBP \cdot TEU) + 1.26E\text{-}14 \cdot v^{16} \quad (10)$$

where:
P – final price of container ship in USD,
TEU – number of containers,
DWT – deadweight capacity [t],
v – service speed [kts.],
GT – gross tonnage [-],
LBP – length between perpendiculars [m].

The values of standard SE and the R-squared errors relating to elaborated relationships (5) – (10) are given in Table 2. A variance analysis showed that all predictors in the equations (5) – (10) are significant.

Table 2.
The values of standard SE and the R-squared errors relating to formulas (2) – (4)

Item	Input design parameter	Equation no	Standard error SE	R-Squared
1.	TEU	(5)	\$ 15.8 million	0.74
2.	TEU	(6)	\$ 15.0 million	0.77
3.	DWT	(7)	\$ 16.2 million	0.74
4.	DWT	(8)	\$ 15.5 million	0.76
5.	TEU, DWT	(9)	\$ 14.8 million	0.77
6.	TEU, GT, v, LBP	(10)	\$ 12.6 million	0.85

Figures (2) and (3) show the relationship between final price and the number of containers (Fig. 2) or the deadweight capacity (Fig. 3) calculated using formulas (2), (3) and (5) – (8) relative to reference data.

It can be seen that the results in Table 2 show that that equation (10) offers the lowest standard error value and the highest R-squared coefficient value. This standard error equals only \$ 12.6 million with the R-squared being only 0.85. Equation (10) can be seen as more accurate than other equations, but is far more complex.

Equations (2) – (5) are characterized by lower correlation and a large value of standard error than when compared with equations (5) – (9) shown in Table 1 and 2. Equations (5) – (9) can be seen as offering greater accuracy than equations presented in (Cepowski, 2016). We can see that the results from Figures 2 and 3 offer curves that are calculated using formulas (6) and (8), and are fitted to reference data more effectively than the other equations. Figure (4) shows the relationship between number of containers, deadweight capacity and final price calculated using regression (9). An analysis of equations (9) and Fig. 4 show that increasing TEU and DWT capacity pushes up the final price.

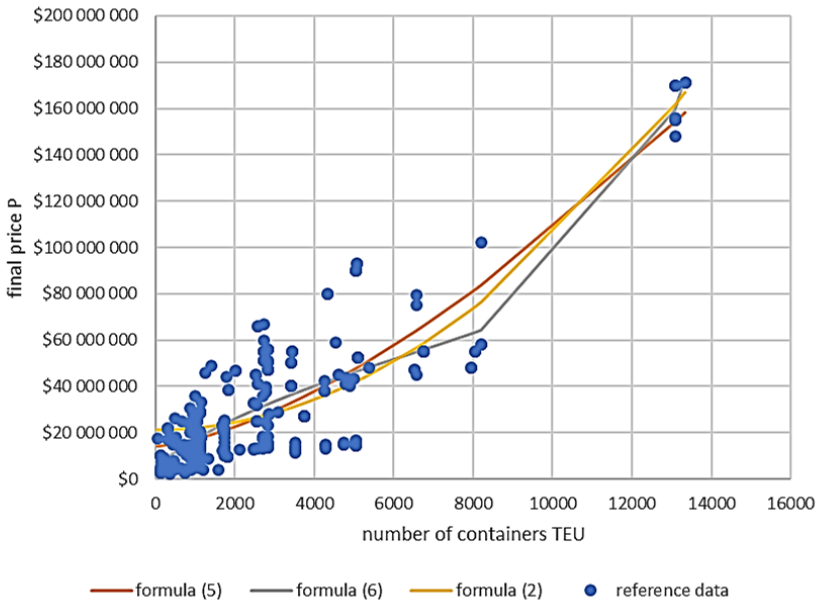

Fig. 2. Approximations of container ship final price depending on the number of containers, formulas (2), (5) and (6) in comparison to reference data

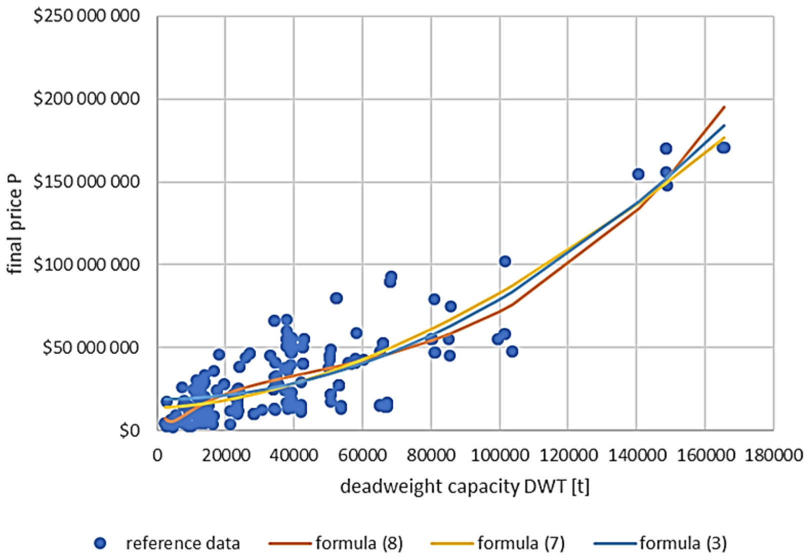

Fig. 3. Approximations of container ship final price depending on DWT capacity, formulas (3), (7) and (8) in comparison to reference data

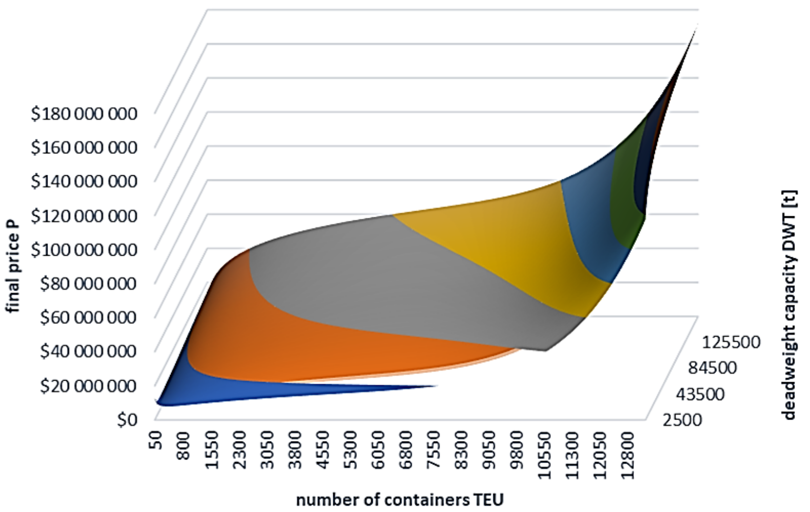

Fig. 4. Estimating the final price of a container ship depending on DWT and TEU capacity according to formula (9)

CONCLUSIONS

This study confirms that the final price estimate of a new container ship is strongly influenced by TEU and deadweight capacity. But the more elaborated relationship (10) shows that service speed, length between perpendicular and gross tonnage also have an influence on the final price.

Elaborated equations (5) – (9) are more accurate than equations (2) – (4) presented in (Cepowski, 2017). This leads to a conclusion above that the use of the author's method to predict final price offers more accurate solutions than any standard regression method. The author's method enabled the creation of accurate estimations, which were characterized by low standard error.

The methods presented by the author were carried out in ndCurveMaster software, that was developed by the author, with a curve fitting method implemented in the software at a much greater level of efficiently. NdCurveMaster was applied in the development of regression equations presented in the article, and is highly effective, which leads to significant time savings being made throughout the search for any suitable equations.

Formulas (5) – (10) depend on design ship parameters and may have practical application at a preliminary design stage of any container ship. While equations (5) – (10) may be used in the most up to date vessels and aid in the modernisation of ship design theory.

REFERENCES

Cepowski T. (2016). Projecting sale prices of new container ships built in 2005-2015 based on DWT and TEU capacities. Scientific Journals of the Maritime University of Szczecin, no. 48/2016, pp. 171-175

Celik F., Erturk I, Turan E. (2013) Investigation of main particulars subject to minimum building cost for chemical tankers. OCEAN ENGINEERING, Volume: 73 pp. 32-37.

Buczkowski L. (1974). Podstawy budownictwa okrętowego. Gdańsk: Politechnika Gdańska

Chądzyński W. (2001). Elementy współczesnej metodyki projektowania obiektów pływających. Prace naukowe Politechniki Szczecińskiej

Lin C., Shaw H. (2017) Feature-based estimation of preliminary costs in shipbuilding. OCEAN ENGINEERING, Volume: 144, pp. 305-319

Michalski J.P. Parametric method of preliminary prediction of the building costs, Polish Maritime Research, Special Issue, 2004

Papanikolaou A. (2010). Holistic ship design optimization. COMPUTER-AIDED DESIGN Volume: 42 Issue: 11 Special Issue: SI pp. 1028-1044

Rawson, K.J. Tupper, E.C. (2001). Basic Ship Theory (5th Edition), Elsevier

Schneekluth H. and Bertram V. (1998). Ship Design for Efficiency and Economy, Butterworth/Heinemann

SigmaLab (2017). ndCurveMaster [Computer software] Available from: www.ndcurvemaster.com [Accessed: 4 Jan. 2017]. Szczecin, Poland.

Watson D.G.M. (2002). Practical Ship Design, Gulf Professional Publishing

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