# Analysis of multipurpose ship performance accounting for SME shipyard building limitations

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ABSTRACT: This study analyses the performance of new design multipurpose ships, accounting for the constraints of a small and medium sized shipyard during the building process of new ships. The conceptual design of ships with a deadweight in the range of 5,000 to 8,000 tons with and without shipyard building constraints is performed. The ship hulls, for all studied ships, are developed based on the combined Scale and Lackenby transformation approach using 3D models of existing already built ships. The evaluation of the performance includes the total resistance of ship at three different speeds, intact stability, cargo volume and number of containers on the deck. The impact of the shipyard building constraints is evaluated by comparing the performance index of studied ships with the same deadweight with and without shipbuilding restrictions. Based on the present analysis, several important conclusions are derived.

## 1 INTRODUCTION

Nowadays, the European maritime industry relies on small and medium-sized enterprises, SME to restore traditional European shipbuilding industry while ensuring the youth employment. According to the European Association of Craft, Small And Medium-sized Enterprises, (UEAPME, 2014), 99.8% of the more than 20 million enterprises in the EU are SMEs. The average European enterprise provides a job for six employees, including the owner-manager, and SMEs count for 2/3 of the private employment and produces about 60% of the added value in the European economy. In the last decade, SMEs created 80% of the new jobs.

According to the EU Craft and SME Barometer (http://www.ueapme.com), for the second half of 2017, the SME Climate Index reached 80.2 ppts and it is the highest score ever achieved since the outbreak of the global financial crisis in 2007-08. The SME Climate Index is calculated as the average of the companies that have reported positive or stable business growth and expect a positive or stable development for the next period. Therefore, the index can vary from 100 (all positive or neutral) to 0 (all negative).

In this respect, the EU funded Project Shiplys main objectives are to respond to the needs of the SME shipyard designers, shipbuilders and ship-owners (Bharadwaj et al., 2017) in the development of a ship risk-based design framework a framework tool will be developed to support the competitiveness of SMEs in design, shipbuilding and retrofitting.

The shipbuilding is strongly related to the transportation of cargoes. For the general/dry cargo shipping in the Black Sea and Mediterranean regions, the Istanbul Freight Index, ISTFIX (http://en.istfix.com) provides information that can be used for any type of shipping analysis. ISTFIX is an internet reference website that contains statistical information derived from various sources.

The analysed routes, taken by the ship's operation are:

- Route 1: Black Sea – Marmara;
- Route 2: Black Sea - East Mediterranean;
- Route 3: Black Sea - Central Mediterranean;
- Route 4: Black Sea - West Mediterranean;
- Route 5: Black Sea – Continent.

Four groups of ships are analysed:

- Group 1: 2,000 – 4,000 DWT;
- Group 2: 4,000 – 6,000 DWT;
- Group 3: 6,000 – 8,000 DWT;
- Group 4: 8,000 – 12,000 DWT.

The ISTFIX provides a unique freight index in the short sea coaster shipping, starting from January 1st, 2008. A study shows that the market risk in the ISTFIX shipping area is much lower than in the international Baltic handy size index, BHSI (Ünal & Derindere, 2014).

The shipping in Route 1 to 5 are a part of the Short Sea Shipping that operates in the EU coastline of about 70,000 km.

According to a recent study, the current short sea transportation capacity is inefficient, especially in the dry bulk and general cargo segments (Gustafsson et al., 2016). This study highlighted five directions for improvement of the competitiveness:

- increase the freight market efficiency through transparency,
- dynamic and integrated production and logistics planning,
- efficient cargo handling,
- performance-driven shipbuilding and operation, and
- sustainable investment and governance models for the system-wide transition.

The goal of the present study is to analyse the importance of the SME shipyard building limitations on the performance of new design ships built in the conditions of SME shipyard. The study considers the shipbuilding capacity of an SME shipyard and the demand of the ship-owners for an efficient ship, operating in the Black sea - Mediterranean region. The building limitations considered in the present study are as follows (Atanasova et al., 2018):

- maximum docking capacity – 1,800 t;
- maximum dock dimensions that allow a ship to be built with a length not greater than 135.8 meters and a breadth not greater than 16 meters;
- the depth of the fairway determines the draft of the ship to be not more than 8 meters.

The software tool "Expert" has been used in defining design solutions for multipurpose ships subjected to shipbuilding, operational and functional constraints (Damyanliev et al., 2017, Garbatov et al., 2017a). This software is structured as an open system allowing the search design solution by Sequential Unconstrained Minimization Technique (SUMT) for different types of ships for which a suitable mathematical model can be generated. Different mathematical models can be employed in identifying the main dimensions of ship, ship hull form, mass and volume distributions, general arrangement, ship hull structures and equipment; propulsion complex; freeboard requirements; stability; sea-keeping; manoeuvrability etc. The conceptual framework is capable of accounting for series of constraints.

Analysing the SME ship repair yard capacity in building new ships (Atanasova, et al., 2018) the authors considered two groups of ships in the range of 5,000 – 8,000 DWT developed by the software tool "Expert". The same ships are used in this study too. The main dimensions of the ships are obtained using CAPEX as an optimization criterion. The first group consists of ships without shipbuilding restrictions and the second one is for ships with a 16 m restricted breadth that is related to a specific SME shipyard (Atanasova, et al., 2018). The main ship dimensions of both groups are presented in Table 1 and Table 2 respectively.

The length of the second group of ships increases to compensate the restricted breadth and at the same time the draught decreases, which can be explained by the condition of reaching the minimum required ship stability criterion.

Table 1. Main ship dimensions of non-restricted ships

| DWT | 5,000 | 6,000 | 7,000 | 8,000 |
|---|---|---|---|---|
| Ship | S1 | S2 | S3 | S4 |
| L, m | 86.79 | 93.21 | 96.71 | 99.98 |
| B, m | 16.17 | 16.87 | 18.60 | 19.23 |
| d, m | 7.18 | 7.33 | 7.98 | 8.53 |
| D, m | 8.90 | 9.32 | 10.06 | 10.81 |
| L/B | 5.37 | 5.52 | 5.20 | 5.20 |
| B/d | 2.25 | 2.30 | 2.33 | 2.26 |
| L/D | 9.76 | 10.00 | 9.61 | 9.25 |
| Cb | 0.685 | 0..76 | 0,67 | 0.669 |
| Δ, t | 7,068 | 7,981 | 9,853 | 11,241 |

Table 2. Main ship dimensions of restricted breadth B = 16 m

| DWT | 5,000 | 6,000 | 7,000 | 8,000 |
|---|---|---|---|---|
| Ship | $S1_R$ | $S2_R$ | $S3_R$ | $S4_R$ |
| L, m | 88.63 | 106.60 | 120.62 | 135.06 |
| B, m | 16.00 | 16.00 | 16.00 | 16.00 |
| d, m | 7.08 | 6.88 | 6.67 | 6.57 |
| D, m | 8.81 | 8.93 | 9.03 | 9.17 |
| L/B | 5.54 | 6.66 | 7.54 | 8.44 |
| B/d | 2.26 | 2.33 | 2.40 | 2.44 |
| L/D | 10.06 | 11.93 | 13.36 | 14.73 |
| Cb | 0.69 | 0.721 | 0.772 | 0.812 |
| Δ, t | 7,091 | 8,665 | 10,181 | 11,809 |

## 2 SHIP HULL FORM

### 2.1 *Hull form transformation*

The evaluation of the ship performance is based on the hull form obtained by a transformation of an existing parent ship hull, PSH.

For the hull transformation a combined linear scaling and Lackenby transformation approach in two steps is used. The first step consists of a scale transformation of the longitudinal, transverse and vertical coordinates multiplying them by a factor. The linear scaling keeps hull coefficients unchanged.

The second step implements the Lackenby (1950) method to estimate the desired displacement (block coefficient, $C_B$). The limits of the changes in parameters, which still lead to decent hull forms, depend on the hull form. Due to the wide range of $C_B$ for all eight ships, from 0.67 to 0.812, two different parent hulls are used taken from the database of Freeship Plus software (https://freeship-plus.en.softo nic.com). The first one is for the ships of 5,000 and 6,000 DWT and the second one for the rest of the ships. Figure 2 and Figure 3 present the PSH1 and PSH2.

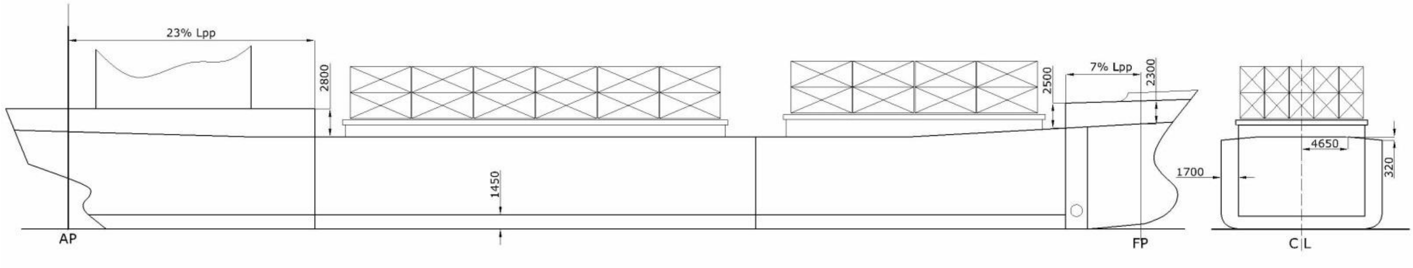


Figure 1. Multipurpose ship typical profile and cross section

### 2.2 *General arrangement of ships*

The analysed multipurpose ships are with a forecastle and poop and the superstructure is in the aft. The length of the forecastle and the poop is 7% and 23% of the length between the perpendiculars of the ship respectively.

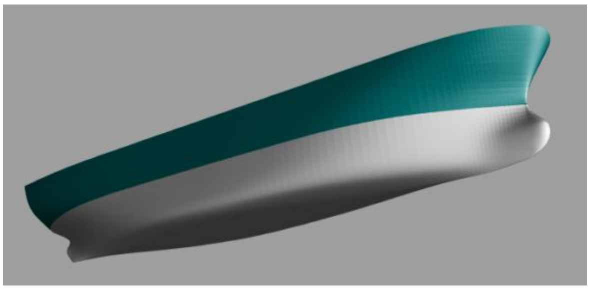

Figure 2. 5,000 DWT ship hull with restricted breadth, PSH 1

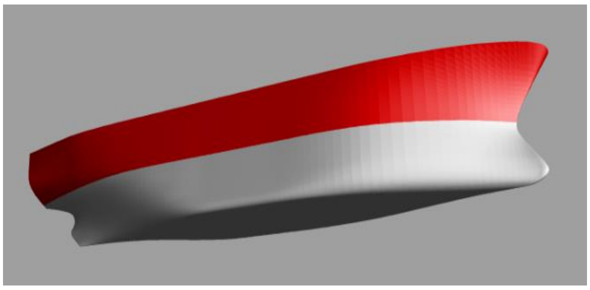

Figure 3. 8,000 DWT ship hull without restrictions, PSH 2

There are several constant dimensions like, the height of the superstructures and double bottom, breadth of the double side, chamber, etc. The side view and cross section of the ship are shown in Figure 1.

The ship is intended only to carry containers on the deck, but the breadth of the cargo holds is consistent with 5 rows of containers.

## 3 SHIP HULL PERFORMANCE

The overall performance of both groups of ships is evaluated by the total resistance of the ship for 3 different speeds, intact stability, according to the IS Code, and the cargo capacity measured by the total volume of the cargo holds, excluding hatches and the number of containers on the deck.

Table 3. Total resistance of ships, kN

| Ship | DWT | Speed, kn | | |
|---|---|---|---|---|
| | | 10.5 | 12.5 | 15.0 |
| $S1_R$ | 5,000 | 92.1 | 142.4 | 251.0 |
| $S2_R$ | 6,000 | 105.3 | 157.5 | 261.3 |
| $S3_R$ | 7,000 | 114.6 | 176.4 | 304.2 |
| $S4_R$ | 8,000 | 129.1 | 196.0 | 328.0 |
| S1 | 5,000 | 91.3 | 142.0 | 253.0 |
| S2 | 6,000 | 95.6 | 145.8 | 252.9 |
| S3 | 7,000 | 105.4 | 164.4 | 303.4 |
| S4 | 8,000 | 113.3 | 175.0 | 320.3 |

### 3.1 *Ship Resistance*

The total resistance, $R_T$, kN is calculated by the Holtrop & Mennen (1982) method, where only, three speeds are considered, i.e. 10.5 kn; 12.5 kn and 15.0 kn. The relative total resistance is defined as:

$$R_{RT} = R_T/(\gamma\nabla) \quad (1)$$

where $R_{RT}$ is the relative total resistance, $\gamma$ is the specific weight of the sea water, 10.055 kN/m$^3$, and $\nabla$ is the immersed volume, m$^3$. The total resistance is shown in
Table 3
Table 3. Total resistance of ships, kN.

### 3.2 *Intact stability*

The intact stability is evaluated by the maximum permissible vertical centre of gravity, $KG_{max}$, related to the ship depth, calculated according to the Part A, Chapter 2.2.2 of the Intact Stability Code (MSC.267(85), 2008) for several draughts in the range of 0.6 to 1.05 of the summer draught.

The relative intact stability, $R_{IS}$ is defined as:

$$R_{IS} = KG_{max}/D \quad (2)$$

Figure 4 presents $R_{IS}$ for all ships, $Si_R$ and Si. The non-restricted ships, Si are presented by a dot curve.

### 3.3 *Cargo volume and stowage*

The cargo volume is calculated based on several assumptions:

– the breadth of the double side of the midship section is constant for all ship equals to 1.70 m;
– the cargo space is located from the ER bulkhead to the most forward bulkhead that coincides with the forecastle wall;

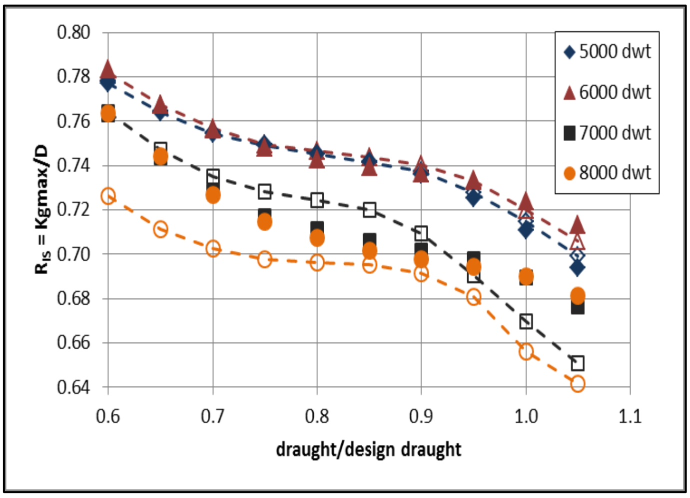


Figure 4. Relative intact stability vs. relative draught

– the total length of the cargo holds is 70% of the length between the perpendiculars of the ship;

– there is not double side at the forward and aft ends of the cargo space. The shape in this area needs especial design.

– the volume of hatches is not considered, which will compensate the fact that the double side at the ends is not accounted for.

The relative value of the cargo volume, RCV is estimated as:

$$R_{CV} = CV/LBD \tag{3}$$

where CV is the cargo volume, $m^3$.

It is envisaged to transport containers only on the hatch covers. The longest ships may carry containers on the poop deck too.

The relative container capacity, $R_{CC}$, -/$m^2$ is defined as:

$$R_{CC} = Nc/LB, \text{-/m}^2 \tag{4}$$

where Nc is the number of containers, TEU.

Table 4. Ships performance

| | Restricted breadth | | | | Non-restricted breadth | | | |
|---|---|---|---|---|---|---|---|---|
| **Ship** | $S1_R$ | $S2_R$ | $S3_R$ | $S4_R$ | S1 | S2 | S3 | S4 |
| DWT | 5,000 | 6,000 | 7,000 | 8,000 | 5,000 | 6,000 | 7,000 | 8,000 |
| L, m | 88.63 | 106.60 | 120.62 | 135.06 | 86.79 | 93.21 | 96.71 | 99.98 |
| B, m | 16.00 | 16.00 | 16.00 | 16.00 | 16.17 | 16.87 | 18.60 | 19.23 |
| d, m | 7.08 | 6.88 | 6.67 | 6.57 | 7.18 | 7.33 | 7.98 | 8.53 |
| D, m | 8.81 | 8.93 | 9.03 | 9.17 | 8.90 | 9.32 | 10.06 | 10.81 |
| Cb | 0.690 | 0.721 | 0.772 | 0.812 | 0.685 | 0.676 | 0.670 | 0.669 |
| Δ, t | 7,090 | 8,665 | 10,181 | 11,809 | 7,068 | 7,981 | 9,853 | 11,241 |
| L/B | 5.539 | 6.663 | 7.539 | 8.441 | 5.367 | 5.525 | 5.199 | 5.199 |
| B/d | 2.260 | 2.326 | 2.399 | 2.435 | 2.252 | 2.302 | 2.331 | 2.254 |
| L/D | 10.060 | 11.937 | 13.358 | 14.728 | 9.752 | 10.001 | 9.613 | 9.249 |
| Cm | 0.974 | 0.974 | 0.994 | 0.994 | 0.974 | 0.974 | 0.994 | 0.994 |
| Cw | 0.844 | 0.867 | 0.861 | 0.894 | 0.841 | 0.831 | 0.778 | 0.778 |
| Cp | 0.708 | 0.740 | 0.776 | 0.816 | 0.703 | 0.694 | 0.674 | 0.672 |
| LCB, m | 43.832 | 52.741 | 64.313 | 72.016 | 42.933 | 46.112 | 51.554 | 53.295 |
| LCB/Lpp | 0.4946 | 0.4948 | 0.5332 | 0.5332 | 0.4947 | 0.4947 | 0.5331 | 0.5331 |
| Slenderness, - | 4.6515 | 5.2330 | 5.6114 | 5.9799 | 4.5597 | 4.7028 | 4.5484 | 4.5001 |
| **Resistance** | | | | | | | | |
| $R_T$(Vs =10.5), kN | 92.1 | 105.3 | 114.6 | 129.1 | 91.3 | 95.6 | 105.4 | 113.3 |
| $R_T$(Vs= 12.5),kN | 142.4 | 157.5 | 176.4 | 196.0 | 142.0 | 145.8 | 164.4 | 175.0 |
| $R_T$(Vs=15), kN | 251.0 | 261.3 | 304.2 | 328.0 | 253.0 | 252.9 | 303.4 | 320.3 |
| Δ, kN | 69,558 | 85,001 | 99,872 | 115,847 | 69,341 | 78,290 | 96,656 | 110,270 |
| $R_{RT}*10^3$, (10.5 kn) | 1.3241 | 1.2388 | 1.1475 | 1.1144 | 1.3167 | 1.2211 | 1.0905 | 1.0275 |
| $R_{RT}*10^3$, (12.5 kn) | 2.0472 | 1.8529 | 1.7663 | 1.6919 | 2.0479 | 1.8623 | 1.7009 | 1.5870 |
| $R_{RT}*10^3$, (15.0 kn) | 3.6085 | 3.0741 | 3.0459 | 2.8313 | 3.6486 | 3.2303 | 3.1390 | 2.9047 |
| **Stability** | | | | | | | | |
| $R_{IS}$ | 0.7109 | 0.7145 | 0.7239 | 0.7201 | 0.6895 | 0.6698 | 0.6899 | 0.6561 |
| **Cargo capacity** | | | | | | | | |
| CV, $m^3$ | 5,828 | 6,996 | 8,235 | 9,440 | 5,616 | 6,668 | 8,568 | 9,966 |
| $R_{CV}$ | 0.4665 | 0.4594 | 0.4726 | 0.4764 | 0.4496 | 0.4550 | 0.4735 | 0.4795 |
| Nc | 82 | 92 | 116 | 126 | 82 | 88 | 108 | 108 |
| $R_{CC}*100$, 1/$m^2$ | 5.7825 | 5.3940 | 6.0106 | 5.8307 | 5.8430 | 5.5964 | 6.0040 | 5.6173 |

The estimation of the number of containers considers the shape of the deck and hatch cover at the forward end and the reduced number of tiers in the first or second bays.

The cargo volume and container capacity are presented in Table 5.

Table 5. Cargo volume and container capacity

| Ship | CV, $m^3$ | $R_{CV}$, - | Nc | $R_{CC}$*100, -/$m^2$ |
|---|---|---|---|---|
| S1$_R$ | 5,829 | 0.4665 | 82 | 5.7825 |
| S2$_R$ | 6,996 | 0.4594 | 92 | 5.3940 |
| S3$_R$ | 8,235 | 0.4726 | 116 | 6.0106 |
| S4$_R$ | 9,440 | 0.4764 | 126 | 5.8307 |
| S1 | 5,616 | 0.4496 | 82 | 5.8430 |
| S2 | 6,668 | 0.4550 | 88 | 5.5964 |
| S3 | 8,568 | 0.4735 | 108 | 6.0040 |
| S4 | 9,966 | 0.4795 | 108 | 5.6173 |

## 4 PERFORMANCE ANALYSIS

The performance evaluation for all analysed ships is based on the results presented in
Table 4.

The comparison of the analysed ships is made, for the same deadweight using the following criterion:

$$PI_{ij} = (V_R/V_{NR})_j \text{ if the performance } i \rightarrow \max \quad (5)$$

$$PI_{ij} = (V_{NR}/V_R)_j \text{ if the performance } i \rightarrow \min \quad (6)$$

where PI is the performance index, $i \in [1, 4]$ (resistance, intact stability, cargo volume, container capacity), $j \in [1, 4]$ (5,000, 6,000, 7,000 and 8,000 DWT), $V_R$ is the relative performance of the ship with a restricted breadth, $V_{NR}$ is the relative performance of the ship with a non-restricted breadth.

The maximum is looked for the intact stability, cargo volume and container capacity and the minimum is looked for the relative total resistance.

According to Eqn (5) and (6), the performance index, PI will be greater than 1.0 if the performance of the ship with a restricted breadth is superior to the non-restricted ship.

The relation of the relative total resistance $R_{RT}$ of the non-restricted to the restricted ships, $(R_{RT})_{NR}/(R_{RT})_R$, for the analysed range of speeds is presented in Figure 5.

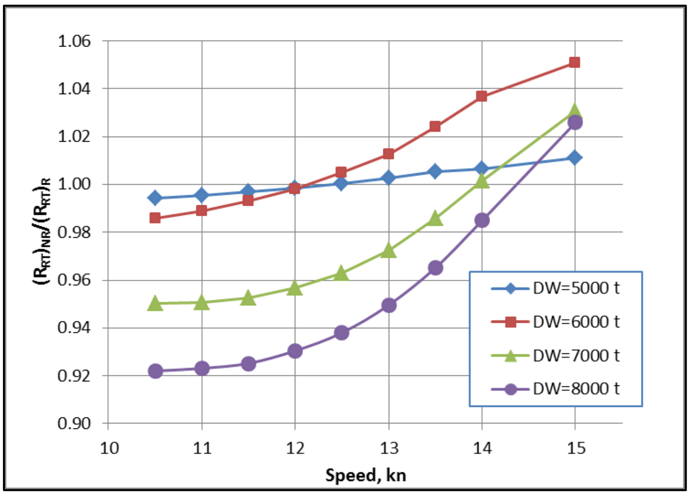


Figure 5. Relative total resistance

The non-parallel grow-up of the relative total resistance, as has been shown in Figure 5, can be explained by the existence of different block coefficients and slenderness of the ships. For the ships of 5,000 and 6,000 DWT, the $C_B$ is relatively low and comparable with the ones of the non-restricted ships and are combined with the higher values of the slenderness as can be seen in Table 4.

The high slenderness leads to a reduction of the intensity of the generated by the ship waves, and the wave resistance. That is why the restricted ship poses a higher PI in the total resistance for a speed greater than 12 kn. In the contrary, the higher block coefficient, which is about 20% for the 8,000 DWT ships, leads to a higher total resistance in the case of the 7,000 and 8,000 DWT ships, almost in the whole speed range.

The performance index for the relative intact stability, $R_{IS}$ versus draughts in the range of 0.6 to 1.05 of the summer draught is shown in Figure 6.

For the draughts close to the design one, the both groups of ships with deadweight of 5,000 and 6,000 tons the PI is about 1.0. For ships of 7,000 and 8,000 DWT, the PI with respect to the intact stability is 3-5% better for the restricted ships, which can be explained with the higher values of B/d and Cw (see Table 4).

The performance indices for the four values of the deadweight are presented in Table 6 and Figure 7. Bold type of numbers (green colour) indicates the indices where the ship with a restricted breadth has a better performance index with respect to the ships without a restriction with respect to the breadth.

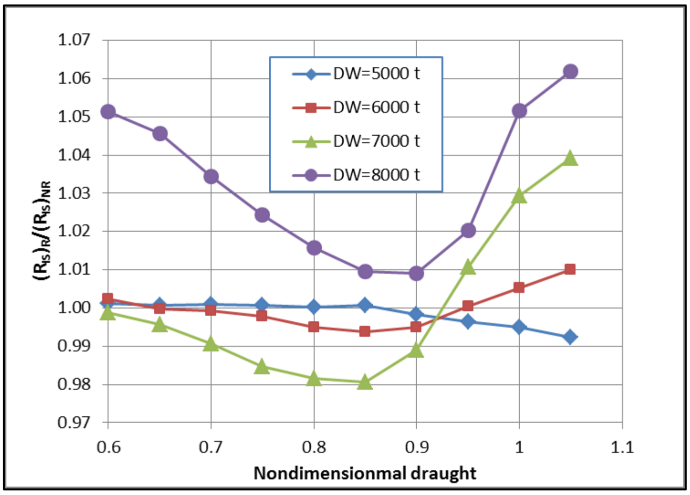


Figure 6. Relative intact stability $R_{IS}$

Table 6. Performance index, PI

| Performance index | Deadweight, t | | | |
|---|---|---|---|---|
| | 5,000 | 6,000 | 7,000 | 8,000 |
| $PI_{RRT}$ Vs=10.5 kn | 0.9944 | 0.9857 | 0.9503 | 0.9220 |
| $PI_{RRT}$ Vs=12.5 kn | **1.0003** | **1.0051** | 0.9630 | 0.9380 |
| $PI_{RRT}$ Vs=15.0 kn | **1.0111** | **1.0508** | **1.0306** | **1.0259** |
| $PI_{RIS}$ | 0.9950 | **1.0053** | **1.0293** | **1.0515** |
| $PI_{RCV}$ | **1.0376** | **1.0096** | 0.9980 | 0.9935 |
| $PI_{RCC}$ | 0.9896 | 0.9638 | **1.0011** | **1.0380** |

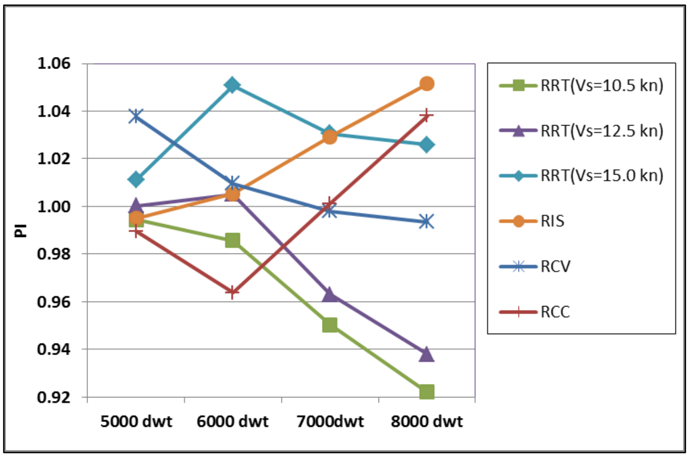


Figure 7. Performance index

The last two rows of Table 6 include the performance index for the cargo capacity. The higher relative cargo volume of 5,000 and 6,000 DWT ships with a restricted breadth is due to the greater ship length. For 7,000 and 8,000 DWT ships the breadth increases considerably and this leads to a higher cargo volume for the non-restricted ships.

The better performance index of the container capacity of the restricted ships with a 7,000 and 8,000 DWT is explained by the ship length. A bigger poop length permits a stowage of one or two bays of containers on the poop deck.

One can see from Table 6 that the performance of the ships with a restricted breadth for some of the operational characteristics is better than the corresponding ship with the same deadweight, but without a breadth restriction.

For all deadweights studied, the restricted ships have up to 5% lower relative total resistance at a speed of 15 kn. The all restricted ships, except the one of 5,000 DWT possess a belter intact stability. The cargo volume is relatively higher for smaller restricted ships of 5,000 and 6,000 DWT while the container capacity is better for the 7,000 and 8,000 DWT restricted ships.

## 5 CONCLUSIONS

The presented study analysed the impact of the specific SME shipyard limitations on the ship performance in building new ships with respect to the breadth of the ship.

The evaluation of the total ship resistance, intact stability and cargo capacity is estimated based on the transformation of two parent hulls. The comparison between the ships with the same deadweight with or without restrictions is based on the estimated performance index for the acceptable ship operational characteristics.

It was concluded that the designed ships with a constrained breadth, due to shipyard building limitations, doesn't lead to a considerable reduction of the ship performance, and in some cases the ship performance may be even better than the one of the ships with unrestricted breadth.

The analyses are based on 3D ship hull models of existing, already built ships. The conclusions may be influenced by other local parameters of the chosen parent hull like the U-V shape of the frames, location of LCB, LCF etc.

The obtained results may be confirmed when the conceptual design of ships is performed by minimizing the required freight rate, including the fast hull geometry prototyping as it was stipulated in the Shiplys Scenario 2 (Garbatov et al., 2017b).

## ACKNOWLEDGEMENT

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## REFERENCES

Atanasova, I., Damyanliev, T. P., Georgiev, P. & Garbatov, Y. 2018. Analysis of SME ship repair yard capacity in building new ships. *Proceedings of MARTECH*. London: Taylor & Francis Group.

Bharadwaj, U. R., Koch, T., Milat, A., Herrera, L., Randall, G., Volbeda, C., Garbatov, Y., Hirdaris, S., Tsouvalis, N., Carneros, A., Zhou, P. & Atanasova, I. 2017. Ship Lifecycle Software Solutions (SHIPLYS) - an overview of the project, its first phase of development and challenges. *Maritime Transportation and Harvesting of Sea Resources*. 889-897.

Damyanliev, T. P., Georgiev, P. & Garbatov, Y. 2017. Conceptual ship design framework for designing new commercial ships. *In:* Guedes Soares, C. & Garbatov, Y. (eds.) *Progress in the Analysis and Design of Marine Structures*. London: Taylor & Francis Group, 183-191.

Garbatov, Y., Ventura, M., Georgiev, P., Damyanliev, T. P. & Atanasova, I. 2017a. Investment cost estimate accounting for shipbuilding constraints. *In:* Guedes Soares, C. & Teixeira, A. (eds.) *Maritime Transportation and Harvesting of Sea Resources*. London: Taylor & Francis Group, 913-921.

Garbatov, Y., Ventura, M., Guedes Soares, C., Georgiev, P., Koch, T. & Atanasova, I. 2017b. Framework for conceptual ship design accounting for risk-based life cycle assessment. *In:* Guedes Soares, C. & Teixeira, A. (eds.) *Maritime Transportation and Harvesting of Sea Resources*. London: Taylor & Francis Group, 921-931.

Gustafsson, M., Nokelainen, T., Tsvetkova, A. & Wikstrom, K. 2016. Revolutionizing short sea shipping. *Positioning Report*. Åbo Akademi University.

Holtrop, J. & Mennen, G. G. J. 1982. An approximate power prediction. *International Shipbuilding Progress*, 29**,** 166 - 170.

Lackenby, H. 1950. On the Systematic Geometrical Variation of Ship Forms. *Transactions of INA*, 92**,** 289-315.

MSC.267(85) 2008. Adoption of the International Code on Intact Stability. London, UK: IMO.

UEAPME 2014. SMEs mean jobs and growth - Crafts and SMEs 2020. Brussels.

Ünal, G. & Derindere, S. 2014. Revealing the freight market risk in Istfix shipping area. *International Journal of Shipping and Transport Logistics*, 6**,** 593-610.