Methodology of assessing the production capacity of selected shipyards

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ABSTRACT

The paper deals with selected subjects in the European EUREKA „Baltecologicalship" E!2772 project. Within the project, preliminary designs of four feeder (short shipping) ships have been developed based on the market trend research, design knowledge and experimental investigations. The following tasks were to be performed for one of the ships: defining optimum building conditions (timescale, production technologies, ecological aspect), selecting shipyards meeting the minimum production capacity requirement. For that purpose an index method was developed (based on the design and production indices). Then an index analysis was performed of the production capacities of selected shipyards (and also different configurations of cooperation between them) and results were presented in a form of the Gantt diagrams. Final conclusions were drawn.

Keywords : structural and production process coefficients, index method, labour demand, worstand - hours (Stg)

PROBLEM DEFINITION

An increasing competition for contracts to build new cargo ships requires continuous watching the shipbuilding market as well as improving production methods and capabilities. At present, Polish shipyards have an order book large enough to ensure survival of the industry but they are not free of the shortage of capital [2]. This is a temporary situation and it makes shipyards seek solutions necessary to win the competition. An example of such action is implementing the conception of the so called fractal factories [1].

In view of a complex and multistage process of building a ship from conception to delivery, certain stages may be distinguished where solutions should be sought to improve economic competitiveness and to meet the ecological production requirements.

In the current economic conditions in the country and capital weakness of the large production enterprises, one can hardly expect any significant investments in the shipyard technical infrastructure in the nearest future. Therefore, solutions should be looked for in the production engineering and organization. With so defined strategy of competitiveness, the following aims may be formulated :

In the technological conditions of Polish shipyards, a broad collaboration between shipyards and the cooperating enterprises, particularly from the small and medium enterprise (SME) group, should be developed in order to use the production and innovative potential in an optimum way. Such cooperation should be based on mutual economic benefits and long-term planning as well as on the shipbuilding market development trends.

Such collaboration depends
on fulfilling the following conditions :

1. The manufacturers have a well prepared (small number of modifications) and easily accessible (e.g. in an electronic form) documentation for customers. The present level of computer software and hardware allows to prepare complete ship construction documentation. [3, 4, 5].
2. Ship structure production quality standards for the project in question are implemented at the leading shipyard and at subcontractor plants, together with agreements between the quality control units.
3. Specialist teams are shifted between the cooperating enterprises to perform specific tasks, or production of some structural sections is outsourced and then transported to the leading shipyard for assembly in dock.
4. An efficient and effective transport operates between the enterprises (between the Gdańsk-Gdynia area and the Szczecin area shipyards the waterway transport will be most appropriate).
5. Technologies not meeting the ecological production requirements are eliminated.
6. A clear and unified ship construction process is developed (together with all the quality control instruments) and implemented in the project executing enterprises.
7. A unified algorithm of assessment of the subcontractor production capacity is used to subdivide the tasks in a rational way.

The above listed conditions comprise a broad range of different problems. The problems of optimum production process planning and subdivision of technical tasks among the subcontractors were chosen for further analysis.

With those conditions, a process algorithm was proposed in order to perform the main task. In view of the broad range of conditions, items 1, 2, 3, 4, 5 were assumed fulfilled and the emphasis was placed on the production process conditions 6,7.

The analysis was performed on the SINE-203 product tanker hull [6], Fig.1. A series of simplifying assumptions related to the structure and production process were adopted. The more significant ones include :

- the subject of analysis is **steel hull** of the ship, without outfitting
- the hull structure was simplified, with panel and stiffener elements only (the plate thicknesses and diversity of stiffeners were maintained) and with subdivision into flat and bent elements
- real arrangement of external shell seams was replaced with a virtual arrangement of the same total length (without locating seams on the shell).

With the above listed assumptions, a material balance
and weld quantification were prepared.

Main dimensions :

Length overall :	L_{oa} = 138.100 m	Speed :	V_s = 14.0 knots
Length b. perpendiculars :	L_{pp} = 132.000 m	Hull weight :	M_k = 4 250 t
Width :	B = 22.50 m	Draught :	T = 8.70 m
Depth :	H = 12.80 m	Underdeck volume (at T) :	V = 19 375 m^3

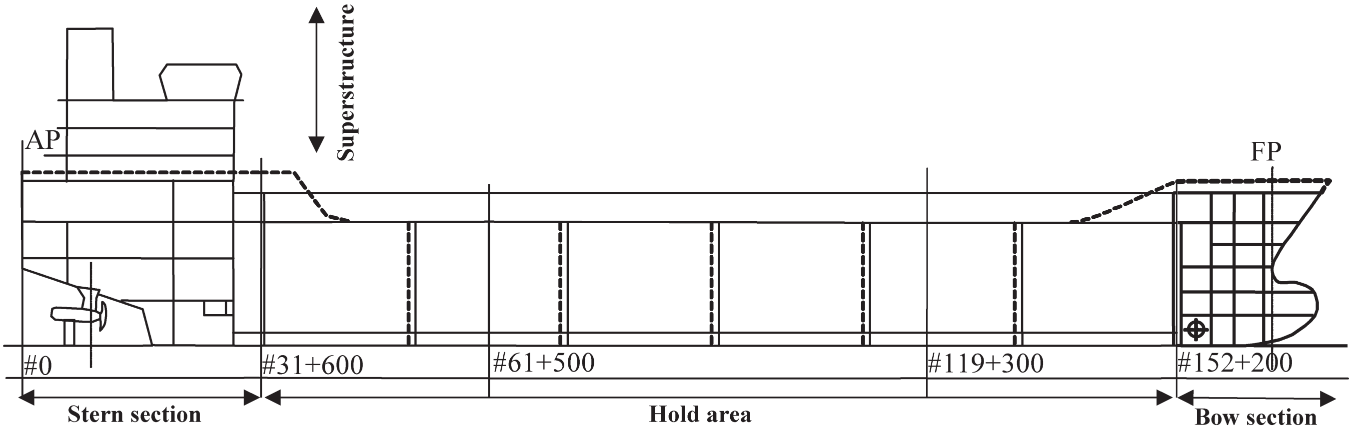

Fig. 1. *Subdivision of the SINE 203 ship into structural areas*

UNIFICATION OF THE TECHNOLOGICAL PROCESS OF SHIP HULL CONSTRUCTION

Unification (schematisation) of the technological process was prepared to make comparisons possible between technological capabilities of different shipyards. The process schematic diagram is presented in Fig.2. The most important stages of a technological process are included.

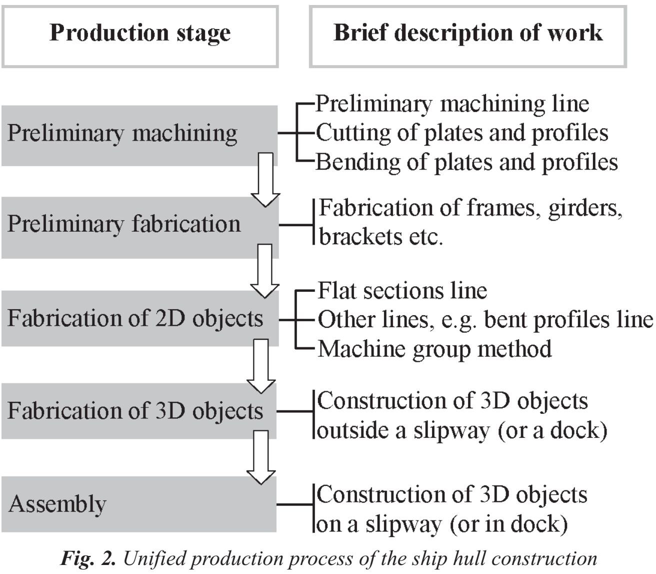

Fig. 2. *Unified production process of the ship hull construction*

SELECTION OF SHIPYARDS FOR THE COOPERATION ANALYSIS

Analysis was performed with reference shipyards A, B and C of different production capacities. A hull production cycle of six months was assumed.

Shipyard A has much greater production capacity than that required by the SINE 203 oil product tanker.

Shipyard B covers a variant of cooperation between **Shipyard A** and a small production capacity shipyard. Cooperation includes the preliminary machining, preliminary fabrication and 2D object fabrication stages.

Shipyard C covers a variant of cooperation between shipyards of similar production capacities, where the preliminary machining, preliminary fabrication, 2D object fabrication and 3D object fabrication is performed by one shipyard and assembly in dock is performed by the other shipyard. This is a production cycle often practiced by the SME sector shipyards.

INDEX METHOD OF ASSESSING THE SHIPYARD PRODUCTION CAPACITY

Traditional method

Assessing the capability of constructing a hull in the existing production conditions requires an individual approach, i.e. an optimum production process should be found for a given hull geometry in a given shipyard with its existing infrastructure.

Index method

The indices determine the structure and production process (coefficients) assigned to the characteristic operations of individual construction stages, which allows to express objectively (in workstand-hours - Stg) the labour demand of respective stages. By determining the indices of individual shipyards, we obtain a picture of production capacities, which helps to take cooperation decisions (Fig.3).

The **production process coefficients T_i** are determined in relation to the shipyard infrastructure and they describe :

- productivity, expressed by [t/Stg], [m^2/Stg], [m/Stg]
- size and weight, expressed by dimensions - a, b, c [m] and structure weight [t].

The T_i values may be determined in several ways from :

- counting the basic production operation times - classic approach [7]
- an adopted system of integrated calculation coefficients [8]
- experience, i.e. an average value of annual production balance.

The **structural coefficients W_i** are determined in relation to the hull structure (quantity of material to be processed in the production stages in order to obtain a hull) and they are :

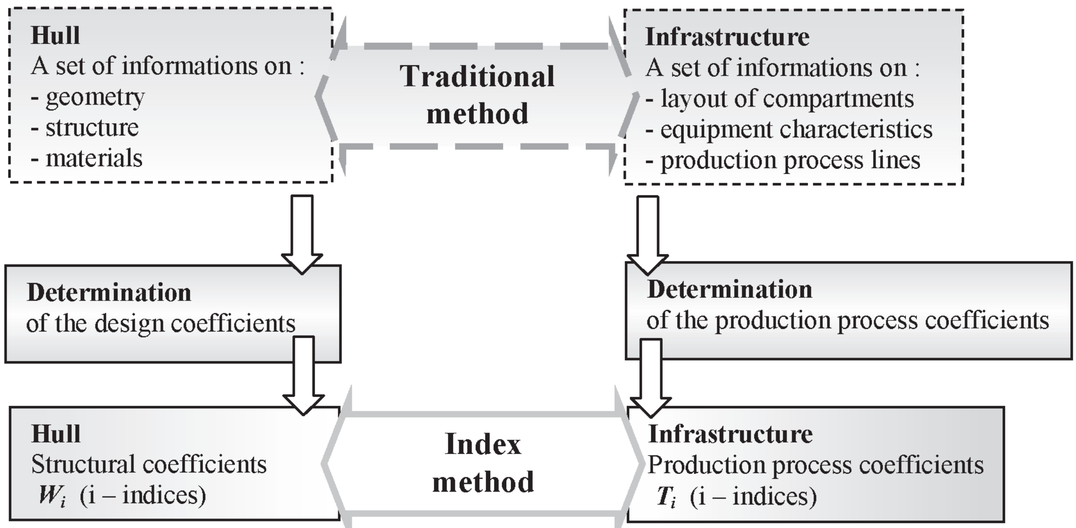

Fig. 3. *Flow diagram of the methods of comparing known hull structural and material conditions with production capabilities of a given shipyard*

- productivity related, expressed by [t], [m^2], [m], [pcs]
- size and weight related, expressed by dimensions - a, b, c [m] and structure weight [t].

Production process coefficients. Using the adopted unified production process divided into five stages (Fig. 2), coefficients were assigned to the respective work scopes. Their values were determined by evaluation of the production capacities (from the integrated calculation indices [7]) for specific work scopes in each of the analysed shipyards. The coefficients are presented in Table 1.

Structural coefficients. From the documentation and the prepared material and weld length balance, coefficients were assigned to the respective work scopes. The coefficients correspond with the quantities of material to be processed in the production stages. The coefficients are presented in Table 2.

A total of 15 production process coefficients and corresponding structural coefficients were adopted. In assigning values to the structural coefficients, a different hull structure subdivision was assumed for each shipyard.

RESULT OF ANALYSIS

By linking the production process coefficients and structural coefficients, the operation times $\mathbf{R_i}$, expressed in [Stg], were obtained for the respective workstands, in accordance with the work scope assumed (Table 3).

Gantt diagrams were prepared from the tables for different variants. Examples of hull construction schedules are presented here below for the proposed **A, B, C** shipyards.

The schedules presented here for the selected shipyards are one of the feasible variants with the assumed coefficients.

Table 1. *Identification of production process coefficients*

Item	Coefficients	Description / Unit / Productivity	Scope of operations
Preliminary machining line			
1.	T_1	Productivity in [m^2 / Stg]	Plate straightening/cleaning/painting
2.	T_2	Productivity in [m / Stg]	Profile straightening/cleaning/painting
Fabrication of 3D objects			
12.	T_{12}	Fillet weld length [m/Stg] related to the 2D stage	Construction of 3D objects outside the slipway (or dock)
13.	T_{13}	Field dimensions (a/b/c) and load lifting capacity (t_{min}) depending on the structure subdivision	Demand for the operating area and crane lifting capacity needed to fabricate the object
The 1, 2, 12, 14 coefficients are of the productivity evaluation character The 13, 15 coefficients are of the size and weight character [Stg] - workstand-hours. Time needed to perform a given scope of work on the workstand. Number of workers is not taken into account			

Table 2. *Identification of structural coefficients*

Item	Coefficients	Description / Unit / Productivity	Quantity of material to be processed
Preliminary machining line			
1.	W_1	Determination of the plate sheet area in the structure [m^2] (3x12) - assumed sheet size	Plate sheet area in the structure
2.	W_2	Determination of the length of stiffeners in the structure [m]	Total length of stiffeners in the structure
Fabrication of 3D objects			
12.	W_{12}	Fillet weld length [m/man-hour] related to the 3D stage	List of welds differentiated according to type
13.	W_{13}	Field dimensions (a/b/c) and load carrying capacity (t_{min}) depending on the structure subdivision	For a given hull structure subdivision, demand for the operating area and carrying capacity of the transport means
The 1, 2, 12, 14 coefficients are of the productivity evaluation character The 13, 15 coefficients are of the size and weight character [Stg] - workstand-hours. Time needed to perform a given scope of work on the workstand. Number of workers is not taken into account			

Table 3. *List of reference coefficients for the SINE 203 ship*

		Preliminary machining line	Type of result	R_i [man-hours]
1.	$\mathbf{R_1}$	$\mathbf{W_1}$ [m^2] / $\mathbf{T_1}$ [m^2/Stg]	Number	R_1
2.	$\mathbf{R_2}$	$\mathbf{W_2}$ [m] / $\mathbf{T_2}$ [m/Stg]	Number	R_2
		Fabrication of 3D objects		
12.	$\mathbf{R_{12}}$	$\mathbf{W_{12}}$ [m] / $\mathbf{T_{12}}$ [m/Stg]	Number	R_{12}
13.	$\mathbf{R_{13}}$	$\mathbf{T_{13}}$ - Constructed object (a/b/c), object weight [t] $\mathbf{W_{13}}$ - Workstand dimensions (a/b/c), load carying capacity [t]	Yes / No	R_{13}
One working month has 178 hours, with 3-shift work it is 534 [h]				

$\mathbf{R_i}$ is a coefficient with index **i**. If it is a productivity-type coefficient then it assumes an assigned value [Stg]. The size and weight coefficients are assigned logical values: 1 when the operation is possible or 0 when the operation is not possible.

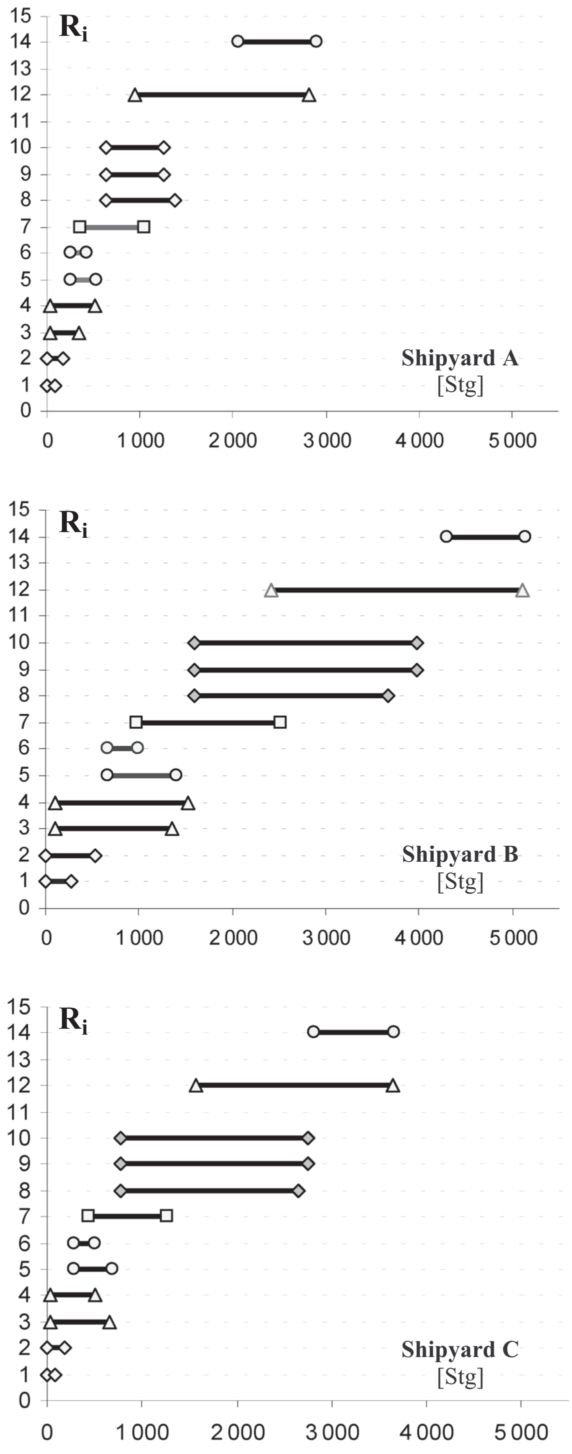

Fig. 4. *Three hull construction schedules*

In the analysed cases, the size and weight coefficients were assigned the 1 values.

The **Shipyard A** schedule shows a correct hull construction process with the assumed coefficients.

The **Shipyard B** schedule presents an incorrect process. Too large percentage (scope) of the tasks were entrusted to a weaker partner, which caused lengthening of the process.

The **Shipyard C** schedule presents a correct process of the cooperation of shipyards, none of which would be individually able to build the hull in the planned time of 6 months. With such way of determining the labour demand, the question of calculating the values of [Stg] and man-hours in different shipyards remains open. Negotiations between the parties may be expected.

ECONOMIC ASPECT OF THE CONSTRUCTION

With so determined construction schedules (Fig. 4), the hull construction cost analysis may be carried out. The simplifying assumptions are the following :

- the [Stg] cost is the same for each construction stage
- the [Stg] cost for different subcontractors is the same.

The schedules may be presented in a form of the so called logistic curve (S curve) - Fig. 5.

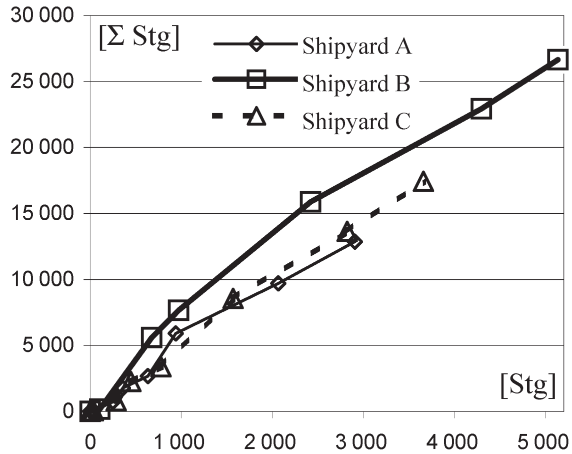

Fig. 5. *The S curves for shipyard A, B, C*

Three S Curves, reflecting the work intensiveness, were obtained for three shipyards (the assumed construction conditions).

Shipyard A - carries out the hull construction in a most productive way, i.e. very intensively and in a short time.

Shipyard B - carries out the hull construction in a least productive way and in a long time.

Shipyard C - carries out the hull construction in a slightly worse way than Shipyard **A**, but still within acceptable limits.

If we assume that the whole sum needed for the construction, e.g. 100 units, is borrowed with an e.g. 20% per annum interest, then the total cost will be as shown in Fig.6.

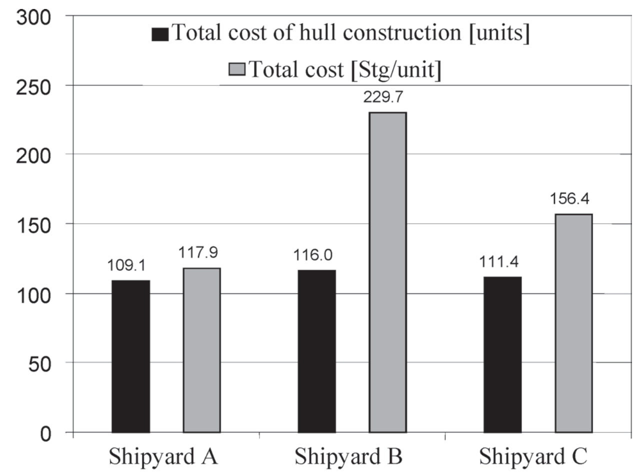

Fig. 6. *Construction costs and [Stg] costs for the analysed shipyards*

If a [Σ Stg/total hull construction cost (units)] relation is formed then the Stg cost will be obtained (Fig.6). The following results were obtained for the analysed cases: **Shipyard A** had the best and **Shipyard B** the worst result. Although **Shipyard C** had only a little longer construction time than **Shipyard A**, the increase of [Stg/unit] is evident. The reason of distinct differences in the analysis (Total cost [Stg/unit]) is simultaneous cumulation of the longer construction time (**Shipyard B** and **C**) and longer credit interest payments. The hull outfitting was not taken into account in the analysis but it may be expected with certainty that cost differences ([Σ Stg / Σ units], Fig.6) between shipyards will be significantly increased.

With the use of parametric description of a greater number of ships (structural coefficients) and parametric description of shipyard (and subcontractor) infrastructure, the following studies may be performed :

❖ production program for the leading shipyard, which may be optimized in respect of the distribution of tasks between the shipyard itself and the subcontractors

❖ methods of financing the individual tasks

❖ determination of a minimum profitable production treshold and maximum production capacity of the leading shipyard

❖ from the above studies, determination of a long-term production schedule for the whole industry branch; such preparatory work will allow to survive the low demand period and to start production of new ships as soon as the demand for them returns.

These studies may be performed by building a mathematical model of the shipbuilding industry branch. This is an interdisciplinary task for the shipbuilding, banking, environmental engineering etc. experts.

SUMMARY

➲ The **index method** gives an answer whether in the technical conditions characteristic of a shipyard the construction is possible, how long time it will take (with the assumed parameters), what will be the construction process „efficiency".

➲ The index-based analysis may be applied to any type of ship. The differences between ship hull types will consist in the values of the structural coefficients, particularly those connected with the structural subdivision of hull, i.e. weights and sizes of sections and blocks.

➲ Comparison of the indices characteristic of a hull structure with indices characteristic of a shipyard infrastructure allows to assess the construction capability in a rational (objective) way.

➲ The accuracy (reliability) of the proposed approach depends on correct indication of important points in the production process and proper correlation with the indices (characteristics) of the constructed hull.

➲ The method allows to compare in a simplified way the production capabilities of several shipyards in relation to the construction of the same hull. That gives a technical basis for the choice of contractor(s).

Advantages of the index method.
with precise identification of the production
capabilities of Shipyard A, B, C :

❈ the proposed index method allows to perform a variant preliminary assessment of the hull construction effectiveness

❈ an exact information is obtained, in the form of a number or a logical value, related to the index character

❈ the index structure (method of calculation) reflects its scope and role from the point of view of efficient execution of the process

❈ the whole construction process may be covered with an appropriate number of indices

❈ by increasing the number of indices, the construction process may be more precisely modelled together with cost estimations of individual operations (if needed)

❈ by carrying out a similar index analysis, one can easily learn of the strong and weak points of another shipyard.

Disadvantages of the index method are the following :

★ some operations of the construction process are left out

★ too big scope of work represented by one index may lower the priority of an important operation, which in turn may lead to a too low (or too high) index value

★ partial overlapping of the index ranges, which leads to too high end values

★ the indices must be calculated by the same method for all the compared shipyards, regardless of their production profiles.

Change of the method of calculation of one index makes it necessary to recalculate the indices for other shipyards.

Directions of development: some actions
may be indicated to improve the proposed method :

⅄ appoint a group of potential partners in the region

⅄ determine the indices, by the proposed method, for the appointed group of partners

⅄ analyse the so far achieved results in hull construction :
option 1 - individual work of a shipyard,
option 2 - in cooperation with other partners

⅄ compare and summarize the results.

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