Journal of Water Resources and Ocean Science
2017; 6(5): 65-70
http://www.sciencepublishinggroup.com/j/wros
doi: 10.11648/j.wros.20170605.12
ISSN: 2328-7969 (Print); ISSN: 2328-7993 (Online)

Shallow-Draft Ro-Pax Ships for Various Cargos and Short Lines

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To cite this article:
Victor Anatolevich Dubrovsky. Shallow-Draft Ro-Pax Ships for Various Cargos and Short Lines. *Journal of Water Resources and Ocean Science*. Vol. 6, No. 5, 2017, pp. 65-70. doi: 10.11648/j.wros.20170605.12

Received: April 12, 2017; **Accepted**: April 27, 2017; **Published**: October 23, 2017

Abstract: Today a lot of coastal countries need for sea transportation of passengers and small lots of very diverse cargos. The problem is more complete one, if the corresponded harbors have sufficiently restricted depth. Selection of the optimal ship type for needed cargos and conditions of exploitation. Two new concepts of universal shallow-draft ships for transporting of passengers and small lots of trade cargos at short enough coastal lines are proposed.

Keywords: Coastal Line, Universal Ship, Catamaran, Shallow-Draft Vessel, Passenger Ship, Ro-ro Ship

1. Introduction

Mr. Pavlos Pefanis, Greece, have informed the author on the following problem of sea transportation in the world: some developing regions need for sea transportation of passengers and various cargos by small lots and at short enough coastal lines. The problem is more complete one, if there are only shallow enough harbors at the corresponded coasts.

It means, there is a need for shallow-draft ships with very diverse payloads, including passengers, various wheeled vehicles, various containers, dry and liquid cargo.

Usually the corresponded harbors have not corresponded wharfs; it means, the ships must have own ramps for loading-unloading of wheeled cargos.

Type of such ship is selected in accordance with the desired cargos and conditions of exploitation.

Two options of shallow-draft catamarans were designed conceptually for transportation of passengers at various route length, i.e. various time of route, and very various cargos.

At the case, the ship architecture of a catamaran (a ship from two identical hulls of conventional shape) ensures high relative area of decks, high initial and damage transverse stability, permissible level of seakeeping for small enough design draft (for example, [1]).

The service speed of such ships can be not so big because of short lines and for most cheap building and exploitation.

The wheeled vehicles of bigger, than 2.5 m, height, are transported at the open part of the upper deck, cars can be arranged at the closer part.

The first ship is intended for longer routes (one-way trip more, than 10 hours): there are some cabins for passengers, who travel to maximal length of the line, and a saloon for the passengers, who travel to smaller line length.

The second ship is intended for shorter lines (one-way trip time no more, than 10 hours). The passengers are sitting at a saloon.

Both ships have bow ramp for loading and unloading of wheeled vehicles, but the bigger ship has an added separate ramp for passengers.

Common water-tight structure of the upper deck and wet deck ensures the transverse strength of these ships and their non-sinkability. The super-structures of both ships can be changed by the other blocks for a modernization.

Hulls, upper-wet deck structures, and super-structures are from steel for most cheap building and exploitation. The hulls have simplified shape for most cheap building too.

2. Ship Type Selection

The ship type selection is based in main on the list of ship types are shown below.

Firstly, the strong enough restriction of draft means avoiding all types of ships with small water-plane area, even with varied draft. The examined ship type is selected from multi-hulls with traditional shape of hulls.

The types of studied vessels with a traditional hull shape are shown in Figure 1.

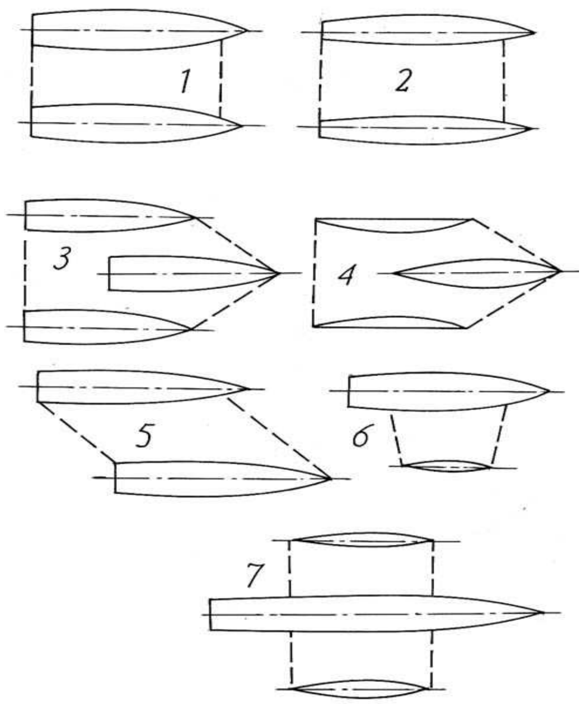


Figure 1. *Studied types of multi-hulls with the traditional shape of hull: 1, 2- catamarans; 3, 4 - trimarans (as Russian terms); 5- catamaran with shifted hulls; 6- proa; 7 - ship with outriggers [2].*

Catamaran as a special type of vessel has the highest transverse stability for a given displacement. The transverse stability of the catamaran can be equal to, and even exceed the longitudinal stability. (In Japan, usually any twin-ship is called a "catamaran', even though it seems awkward in the sense of ship types with different characteristics).

A trimaran consists of three identical hulls of usual shape and can ensure the greatest possibility for the favorable interaction of wave systems, as some examples [3], [4]. (It should be noted that in English-speaking countries "trimaran" refers to any object consisting of three separate hulls of any dimensions, i.e. any triple-hull ship, for example, [5]; it seems not convenient and not exact definition).

Catamarans and trimarans may include asymmetry with respect to their own hulls, and some hulls are so small in width that their stability before assembly to a vessel as a whole must be provided with special measures.

Catamaran hulls that are shifted to a certain extent have mixed qualities of a two- and triple-hull vessel: the transverse stability of a catamaran; and the intensive interaction wave systems of a trimaran [6]. This type does not have a name of its own, and has some unique features, such as close-coupled heel and trim. In addition, to ensure the stability of the course also requires special measures.

A proa consists of a larger and a smaller hull, which provide improved transverse stability and deck area, as compared to single main hull. It also needs special measures to ensure course stability, and it has the smallest weight of hull structure relative to the displacement of all multi-hulls.

Ships with two outriggers have higher transverse stability and deck area compared to the single main hull.

Evidently, the examined ships for some passengers and wheeled cargo need for maximally relative big area of decks. Therefore, these ships must be multi-hull ones, because big relative area of decks is the main specificity of multi-hulls – and theirs main advantage.

As an example, the Table 1 contains a brief comparison of relative deck area of a high-speed mono-hull and some multi-hulls of the same displacement.

Table 1. *Relative deck area and possible correlations of main dimensions [7].*

Ship type	Relative length of hull	Main dimensions	Relative deck area
Mono-hull	$l_{MON}=L/V^{1/3}$	$L/B=8$; A_D~0.8	$0.1*L^2$
Catamaran	$l_1 = l_{MON}$	$L_C=0.8*L$; $B_1=0.8*B$; A_D~0.95; $B_{OA}=(3÷5)B_1$	$(0.24÷0.4)*L^2$
Two outriggers, traditional main hull	$l_M=1.2*l_{MON}$	$L_M/B_M=12$; A_D~0.8; $L_A=(0.3÷0.4)*L_M$; $B_{OA}=(0.2÷0.3)*L_M$;	$(0.16÷0.23)*L^2$
Trimaran	$l_1= 0.6*l_{MON}$	$L_1=0.42*L$; A_D~0.75; $L_{OA}=1.6*L_1$; $B_{OA}=(0.4÷0.5)*L_1$;	$(0.25÷0.35)*L^2$

Here: L,V,B – length, displacement and beam of the initial mono-hull, A_D – fullness coefficient of upper deck; B_1, B_{OA} – beam of a single hull and overall beam; L_{SW} – water-line length; L_O-outrigger length; L_M-main hull length; l_{MON}, l_1 – relative length of the mono-hull and a single hull.

Evidently, a catamaran, even of any average dimension correlations, can have relative biggest a rea of decks.

The examined ships are intended for exploitation in not so developed regions; it means, incidentally, not so strong fulfilling of all demands of safety service, including often overloading by deck cargo and corresponded danger of over-heeling. Evidently, a catamaran has the bigger transverse stability from the other types of ships with traditional hulls, see more detail data at the Table 2.

Table 2. *Main dimensions and initial transverse stability of various 1000-t ships.(outrigger dimensions are in the brackets) [7].*

Ship type	Mono-hull	Catamaran	Trimaran	Usual hull + outriggers
A hull length, m	80	65, 80	50	95 (30)
Overall length, m	80	65, 80	80	95
A hull beam, m	10	6, 4	5	7 (1)
Overall beam, m	10	18, 16	20	16
Water-plane area, sq m	(640)	2 x 310, 2 x 250	(2) x 200	2 x 30
Design draft, m	3	3	3	3 (2)
Height of volume center, m	2	2	2	2

Ship type	Mono-hull	Catamaran	Trimaran	Usual hull + outriggers
Hull depth, m	6	9	9	9
Height of mass center, m	4	6	6	6
Metacentric radii, m	4	37, 19	23	6.5
Metacentric height, m	2	33, 15	19	2.5

* to bulkhead deck

Strong enough restriction of the ship draft means flat enough hulls. The division of under-water volume by to parts (catamaran instead of mono-hull of the same displacement) means, by a way, bigger inclination of bow frames to the horizon, i.e. smaller shock pressure of the catamaran hull bottoms. For example, Figure 2 shows the coefficient of the inclination influence on pressure of bottom slamming.

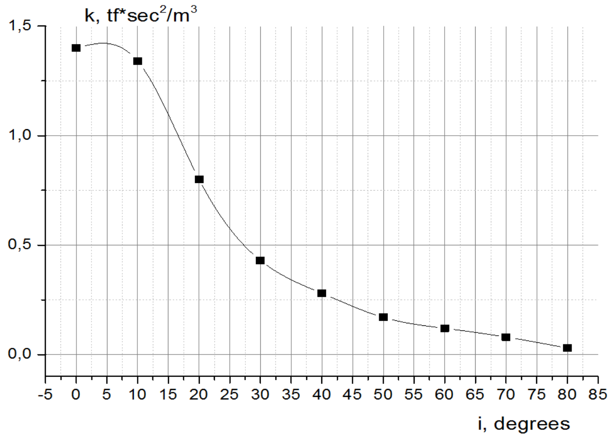


Figure 2. *Empirical coefficient of inclination influence versus the angles of surface inclination relative to the horizon, degrees [8].*

For example, if there is a 500-t mono-hull of draft 1.5 m, and a catamaran of the same displacement, the average angle of mono-hull bow frames is approximately 10-15 degrees, and the angle of a catamaran hull is about 25-30 degrees; it means, the first will have about twice bigger coefficient "k", i.e. about twice bigger pressure of slamming. It is the next reason of a catamaran type selection for the examined ships with restricted draft.

Therefore, bigger deck area, bigger initial transverse stability, slightly better seakeeping are the reasons of a catamaran selection for examined ships with strongly selected draft.

3. Ship for Longer Lines

Figure 3 presents the external view of the ship for longer, than 10 hours, routes. The evident specificity of the general arrangement is the long enough open part of the upper deck, where vehicles of big enough height can be transported.

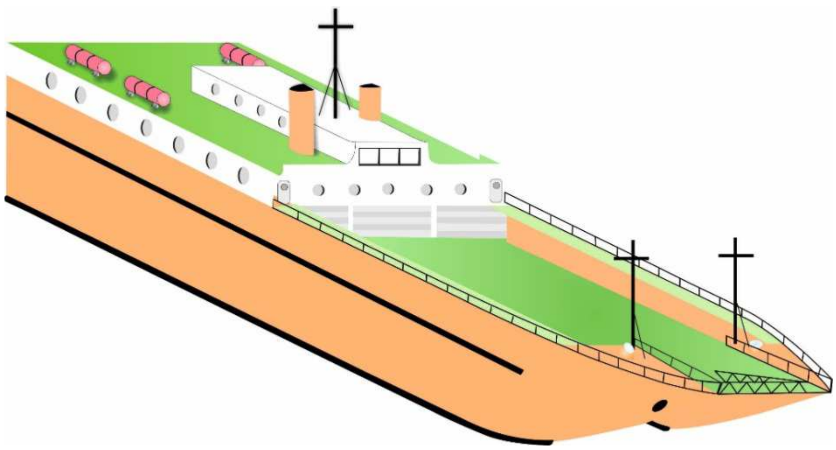


Figure 3. *The supposed external view of the shallow-water RO-PAX ship for longer lines.*

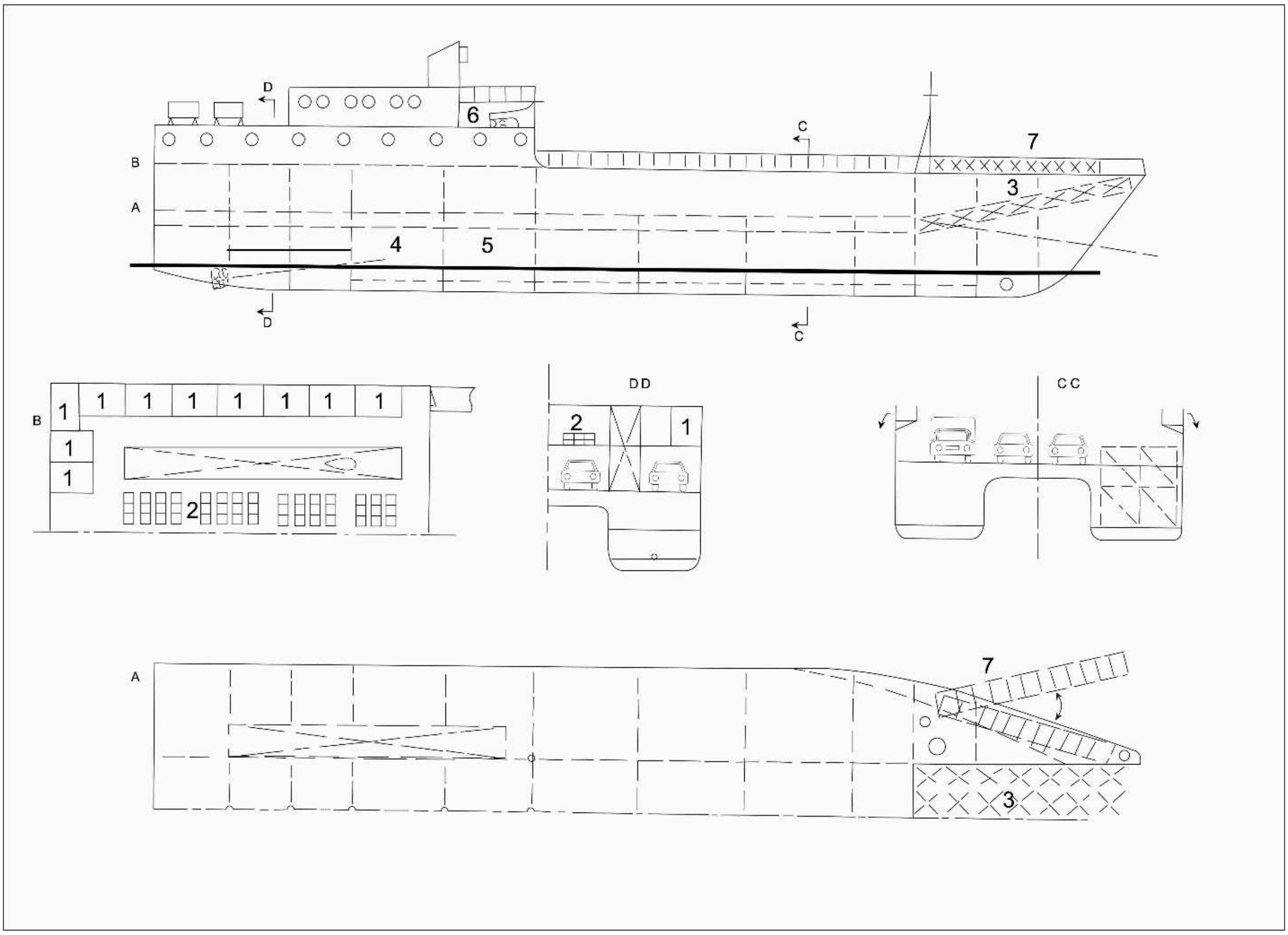
Steel shallow-draft ro-ro-passenger catamaran is intended for transporting passengers in the cabins and a saloon, and wheeled cargo of any types, and general or liquid cargo in the holds and universal tanks, see Table 3.

Table 3. *Main dimensions and general characteristics of the ship 1.*

Full displacement, t,	abt. 750-800
Deadweight, t	Abt. 250-300
Overall length, m	65
Overall beam, m	19
Design draft, m	1.5
Hull depth, m	5.0
Main engine type	diesels
Main engine power, MWt,	Abt. 2 x 2.0
Electric station power, MWt	2 x 0.5
Full speed at full displacement and full power, kn	16
Thruster power, MWt	2 x 0.3
Range at economy speed. nm	2500
Economy speed at full displacement and 85% power, kn	15
Endurance, days	15
Possible deadweight at the draft 2.0 m, t	500-600

Figure 4 contains the scheme of general arrangement with some added notes. The payload is described below.

1. Passengers: 88 persons in 4-place cabins, 24 persons in 2-place cabins, 90 persons in a saloon. Total passenger area - about 400 sq m. Medical cabins of total area 60 sq m can be added at superstructure deck.
2. Hold cargo: 6 holds of total inner volume 840 cub meters of general or liquid cargo under a part of open deck, or 24x 20ft -containers as maximal volume of hold cargo. The ship can transport wheeled crane(s) at the open part of deck; 5x40ft containers on trailers. Some holds can be refrigerated, if needed, but refrigerated containers are preferable.
3. Wheeled cargo: 20 Jeeps (line 100 m, area 150 sq m) at the closed part of car deck; open part of car deck 25 x 18 m (450 sq m) for any cars, trucks, trailers, dump tracks, etc. Total car deck area about 600 sq m, total line 200 m. Separate bow ramps for vehicles and for passengers. Total cargo mass about 200 - 250 t for the design draft 1.5 m, it will be defined more exactly by the future designing by a design bureau.



1 – a cabin for 4 persons; 2 – seats in the saloon; 3 – ramp for wheeled vehicles; 4 – engine room; 5 – electric station; 6 – wheel house; 7 – passenger ramp.

Figure 4. *General arrangement of the ship for longer lines.*

Some added structure measurements will be used for pitch and slamming decreasing in waves.

It must be noted 20-ft containers of various purpose, including refrigerated ones, can be transported in the holds in hulls; and 40-ft containers can be transported with their trailers on the bow part of upper deck only.

If needed, the holds can be serviced by wheeled cranes; the liquid cargo will transported in the special flexible bags in the holds; the corresponded system of tubes must be foreseen.

Both ramps, for vehicles and for passengers, can be put down to the level of the ship base plane (for unloading to a coast without piers).

The ship has the relative speed (Froude number by a hull length) about 0.3. It means the towing resistance of the ship at full speed can`t be decreased sufficiently by changing of two hulls by three ones (for example, [9]).

4. The Ship for Shorter Lines

Figure 5 shows the external view of the smaller (for shorter lines) ship.

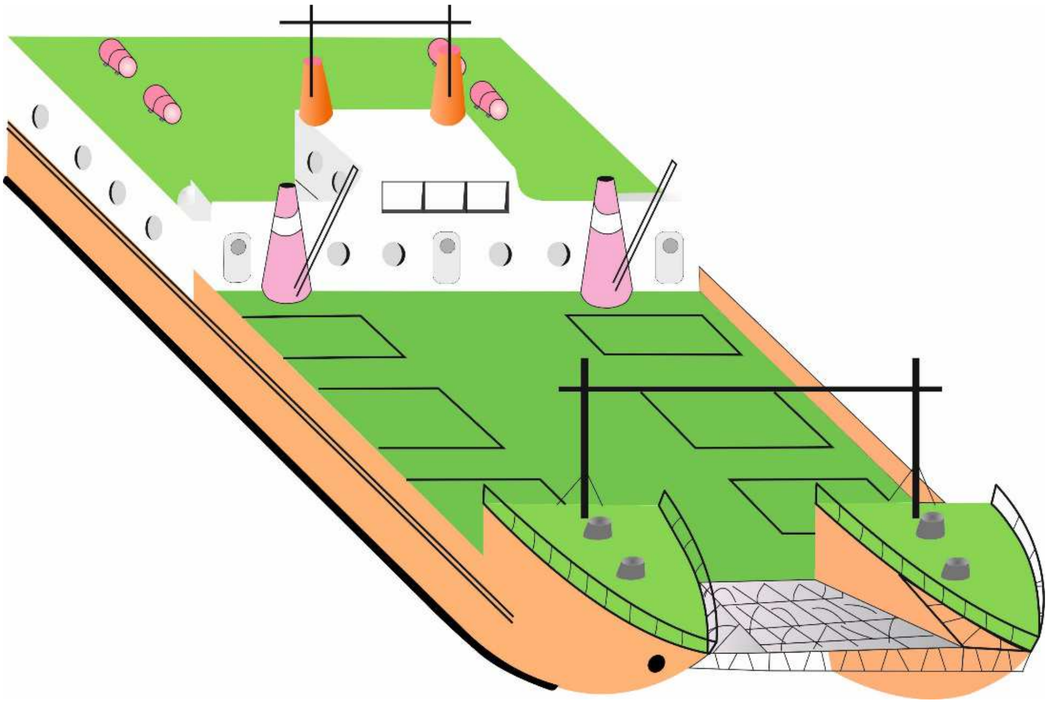


Figure 5. *The external view of the ship for short lines.*

Evidently, the ship 2 (for short lines) is of the same architectural type: a catamaran with partially open bow of the upper deck and the super-structure at stern part. Two cranes can be installed.

Steel shallow-draft ro-passenger catamaran for transporting passengers in a saloon, wheeled cargo of any types, general or liquid cargo, see Table 4.

Table 4. *Main dimensions and general characteristics of the ship 1.*

Full displacement, t,	abt. 400-450
Deadweight, t	Abt. 150-200
Overall length, m	40
Overall beam, m	15
Design draft, m	12.0
Hull depth, m	5.0
Main engine type	diesels
Main engine power, MWt,	Abt. 2 x 1.0
Electric station power, MWt	2 x 0.3
Full speed at full displacement and full power, kn	15
Thruster power, MWt	2 x 0.2
Range at economy speed. nm	1000
Economy speed at full displacement and 85% power, kn	14
Endurance, days	5

Figure 6 shows the scheme of general arrangement.

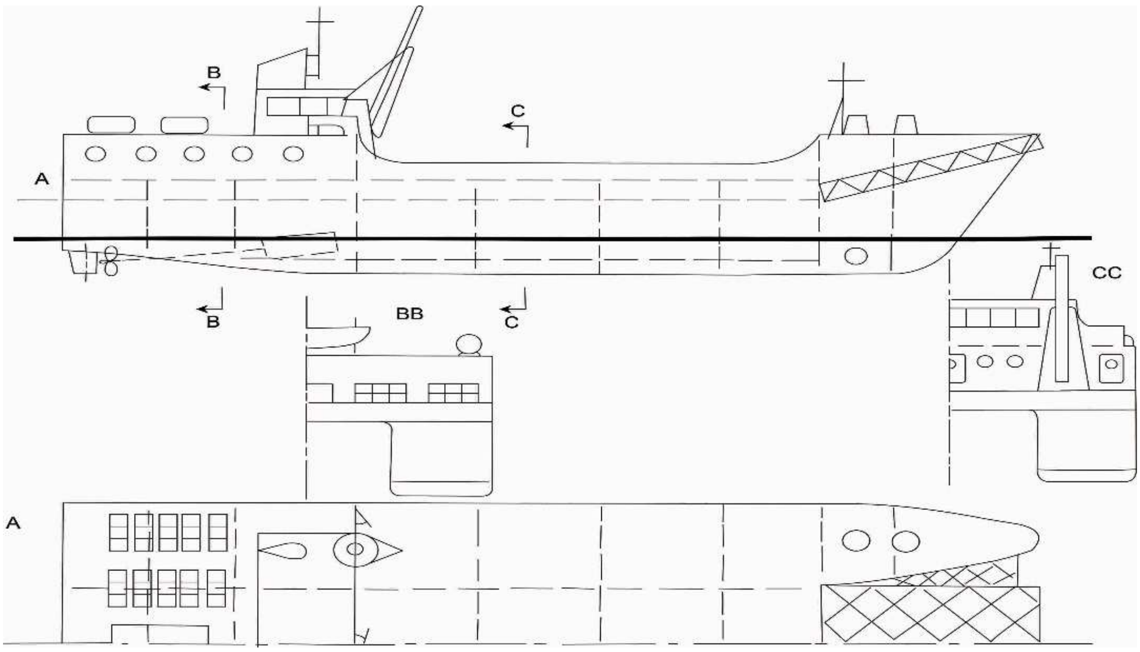


Figure 6. *The general arrangement of the ship for short lines.*

Possible options of payload:

1. Passengers: 60 persons in a saloon. Total passenger area - about 120 sq m.
2. Hold cargo: 8 holds of total inner volume 600 cub meters of general or liquid cargo under a part of open deck. Two cranes at the open part of deck; up to 4 x 40ft containers on trailers. Some holds can be refrigerated, if needed, but refrigerated containers are preferable.
3. Alternative wheeled cargo: 15 Jeeps (line 75 m, area 275 sq m), or any list of cars, trucks, trailers, dump tracks, etc. Total car deck area about 275 sq m, total line 75 m. Bow ramp for vehicles and for passengers. Total cargo mass about 120 - 150 t, it will be defined more exactly by the future designing of a design bureau.

The relative speed (Froude number by length of a hull) of the ship 2 at full speed is about 0.4; it means the installed power can be decreased slightly by changing two hulls by three ones [10]. But general effectiveness of such changing will be examined at the next stages of designing.

5. Conclusions, Recommendation

1. The proposed vessels differ by the following advantages:
   a. Minimal draft for shallow-water waters;
   b. Good passenger comfort for various short lines;
   c. Wide line of varied cargoes of various kinds, as wheeled, container, general or liquid ones;
   d. Increased seakeeping at such small design draft;
   e. Small enough cost of building because of steel structures, simple shape of hulls and the above water structures, and moderate design speed.
2. The shown vessels are recommended for further designing and realization for transport service on lines with small lots of very diverse cargos.

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