DESIGN OF A 4-PASSENGER COST-EFFICIENT COMMERCIAL VESSEL

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ÖZET

In this paper, a 4-passenger cost-efficient vessel which can form a new transportation alternative in Istanbul has been designed. The design process has been progressed within the framework of speed, flexibility and cost. Detailed route analysis was carried out to understand the necessity for this product for transportation in Istanbul. Concept design, preliminary design, and cost estimation of the vessel was carried out to accomplish the objectives.

Keywords: Design, Route analysis

1. Introduction

In our modern world, traffic became a crucial issue for metropolises with the contribution of population growth and migration. This issue especially shows itself on the land transportation. Local governments trying to solve this problem with improving and varying land mass transportation alternatives. However, metropolitan cities commonly have limited space for the improvements. Therefore, other solutions like subways; trams etc. are becoming logical options. Another alternative is the usage of sea, canals or lakes for coastal cities. Because some of metropolitans are generally placed near a sea, river or lake, this fact can be an important advantage for transportation.

As an example of those metropolitans Istanbul which according to Castrol and TomTom Start-Stop Index has the first place in the traffic jam list, transportation on water can be an alternative solution for this problem [1]. Bosporus Strait divides Istanbul into two regions: Europe and Asia. This allows transportation between two regions vertically and horizontally. Istanbul's mass transportation system takes advantage of this opportunity by varisized vessels and many routes. Unlike the capacity of transportation on water of Istanbul, as Aycı and Barlas stated, only 2.54 % of passengers choose marine transportation [2]. Additionally, the capacity usage ratios are around 20% [3]. Mass transportation fail to satisfy passengers' rapid and flexible trip expectations and private sea cabs' prohibitory pricing conception move people away from the sea. In relation to these facts an alternative transportation is proposed depending on deficiency of marine transportation in Istanbul. A cost-efficient 4-passenger vessel was designed based on the mentioned criteria.

2. Transportation in Istanbul

Before designing the vessel, a comprehensive research was made for understanding current situation of transportation in Istanbul. The demographic structure, frequently used lines and passengers carried were examined; mass transportation alternatives of the Bosporus were inspected. Transportation in Istanbul is conducted by Şehir Hatları A.Ş. of Municipality of İstanbul, recently privatized İstanbul Deniz Otobüsleri A.Ş. and private companies such as Turyol and Dentur. Local government body and private companies have a total of 481 sea transportation vessels. Sea transportation lines in İstanbul are mainly operated between Asia and Europe as well as Princes' Islands. In Table 1 the number of daily passengers in Istanbul sea transportation is given.

Table 1. 2013 sea transportation numbers of daily passengers in Istanbul.

Company	**Vessel numbers**	**Daily passengers**	**Percentage in total commuters**
Şehir Hatları A.Ş	34	146798	1,08%
İDO	53	94806	0,70%
Private vessels	393	100250	0,74%
Total	**481**	**341854**	**2,53%**
Private	**447**	**195056**	**1,44%**
Municipal	**34**	**146798**	**1,08%**

The total number of moving daily passengers in Istanbul is over 8 million on roads. Additionally, 3 million are carried by railed transportation. Demographical data of Istanbul between 2010-2015 is given in Table 2. Insufficiency of land transportation in Istanbul motivates improving new rotas and contemporary solutions for sea transportation.

Table 2. Demographical data of Istanbul between 2010-2015.

Year	**Population**	**Population growth rate**
2010	13,255,685	
2011	13,624,240	2.78%
2012	13,854,740	1.69%
2013	14,160,467	2.21%
2014	14,377,018	1.53%
2015	14,561,865	1.29%

3. Design Phase

3.1 Requirements

In the beginning of the design process of vessel, requirements must be determined. Unlike the existing vessels, capacity is constrained by 4 passengers, less than any other alternative. Urban citizens are forced to act alone due to nowadays' present routine. This lifestyle, inevitably influences how they travel in the city. Hanson and Giuliano indicated that on roads more than 90% of the urbanites drive alone and this level keeps rising every year [4]. Clearly, this data shows the transformation of our transportation habits. Because of this reason and failure of sea transportation in Istanbul, nearly 20% of capacity usage and downgrading trend of this data, indicates to set the capacity of the vessel to 4 passengers. By this limitation, being an alternative between private and mass transportation, land taxis were targeted. From this point of view, the vessel must have less initial and running costs than the current alternatives. Additionally, the vessel should have flexibility to access almost every coastal region for taking an advantage in front of strict routed mass transportation alternatives. Moreover, it has to reach a certain speed as the time spent in the vessel probably will be the primary feature for passengers.

3.2 Concept and Preliminary Design

According to the requirements, the hull form was chosen as a planning body with a chine and the main dimensions are 6.50 m in length, 2.45 m in breath, 0.44 m draft with 2.40 t displacement.

Neufert's Architect's Data was used in terms of ergonomics [5]. On this basis, passengers' seating plan was planned as 2 rows and 2 columns. In front of passengers, captain's area was located with a seat and a control panel in front of her/him. Bicycle and luggage zone was located on port aft of the vessel. In face of that zone, handicapped area was located with 1.2 meters along the ship length for providing enough space for a wheelchair. Main entrance located at abaft with 1.2 meters width with a 0.9 meters long platform. Gangway was designed to be adjustable sloped to integrate every different freeboard value of ports, thus has 1 meter width for ergonomics. This element designed to be powered either with manpower by ropes which are lied through entrance sides in bars or with electrical motor supplied by batteries. Moreover, seats were designed to provide maximum comfort for passengers. For this reason seat dimensions was selected as; width 620 mm, pitch 1350 mm. Also, height of accommodation zone was chosen 2000 mm for a comfortable inside volume. Captain's deck 110 mm lower than main deck to provide 2000 mm height for that reason his/her seat selected as elevation controlled to provide maximum view angle.

Upper structure of the vessel was designed depending on Conformité Européenne's (CE) related regulation [6]. Therefore minimum window opening was raised 600 mm from gunwale. Fiber-reinforced plastic material was selected for upper structure because of its physical properties and low weight. Besides, glasses on superstructure kept as much as possible for a natural atmosphere and vision. Lastly, entrances are also designed taking into consideration the related regulations of CE and The Maritime and Coastguard Agency (MCA) [6,7]. Main entrance, which located aft of the vessel, has sliding doors for easy entrance and exit. The height of the door is 1.9 meters for ergonomic and structural needs. Additionally, an emergency exit was located in front of the control panel which is positioned fore-end of the vessel. The general arrangement is given in Figure 1.

Hull form can be categorized as planning hull according to International Maritime Organization's (IMO), International Code of Safety for High-Speed Craft 2000 (2000 HSC Code). Guidance of determined main dimensions, suitable sample form selected from Maxsurf Modeler's library and manipulated according to the requirements. Additional hydrodynamic lift that support planning regime, one chine was added into the hull form. All engineering calculations were completed by using Maxsurf program.

Equipment was selected based on MCA Brown Code, International Regulations for Preventing Collisions at Sea (COLREG),1972 and International Convention for Safety of life at Sea (SOLAS),1974 [8, 9]. Additionally, navigation lights were located according to COLREG-72.

Main engine is the key element of the vessel that determines speed, weight, fuel consumption and initial cost. Optimal engine option for certain course speeds which were mentioned at resistance calculations, is searched. Then suitable engine options were compared and best fit for this study which is Yanmar 6BY3-220 was selected.

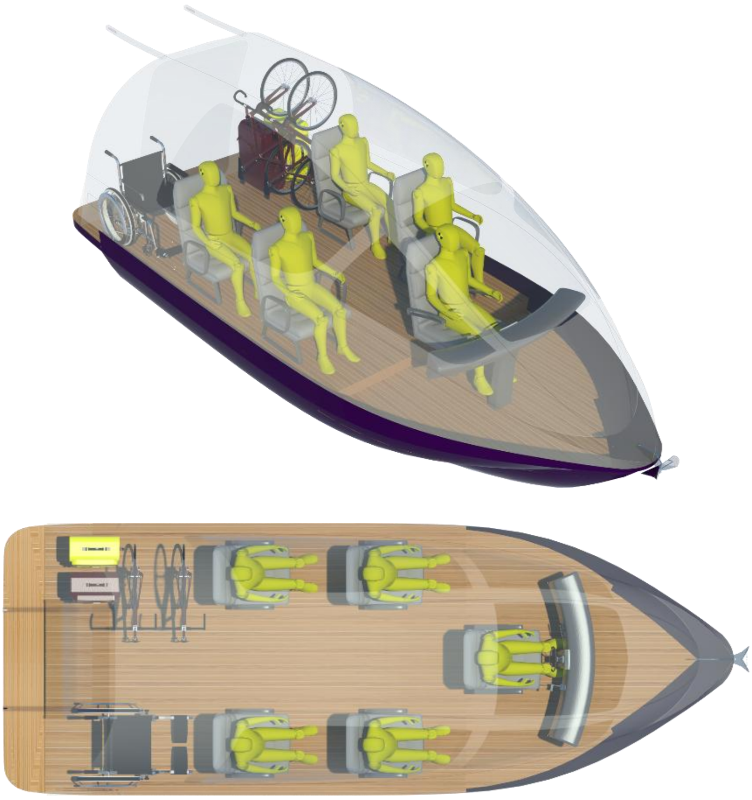

Figure 1. General arrangement

Fuel tank capacity was determined by estimated fuel consumption data based on resistance calculations. Selected main engine consumes 20 liters diesel per hour at fast course that means 0.615 liters per knot. Even at fast course to ensure 500 nautical miles range 300 liters fuel tank was placed.

Superstructure, fiber-reinforced plastic composite was chosen to use for its low weight and excellent physical properties. Moreover, high-density polyethylene (HDPE) which has low manufacturing cost, high strength values and recyclable characteristic; aluminum that has low weight and easier production conditions than other options, at last fiber-reinforced plastic which has mentioned superior properties were selected as possible materials to manufacture the hull. Suitable material for the hull can be chosen according to production conditions (budget, time, location, available resources and etc.).

Scantling calculations were made for each hull material alternative depending on related regulations. Det Norske Veritas' (DNV) Standard for Certification No. 2:21 was used for HDPE, ISO 12215-5:2008 was used for aluminum and FRP scantlings [10].

Detailed weight estimation was made based on the equipment list, scantling calculation, engine selection, general arrangement and some additional features. HDPE hull option was used for this estimation because of its higher weight value.

Stability calculation was made on Maxsurf Stability Module with the data taken by detailed weight estimation. Fuel tank permeability taken as 95% and calculations were made for the fully loaded condition. Seakeeping analysis was made by using Maxsurf Motions Module for determination of motion sickness incidence (MSI) risks. Analysis was made for all passengers and captain's position. 15, 25 and 32.5 knots for 90, 120, 150 and 180 degree headings were calculated by software.

3.3 Cost Estimation

One of the goals of this study is designing a low-cost vessel. To achieve this goal, vessel has to be budget-friendly, both initial and running costs. Initial cost of the vessel includes 2 main components which are manufacturing and outfitting costs. Hull form was selected as one chined to decrease the manufacturing costs. Additionally, HDPE was projected for reducing material cost. Initial cost estimation can be seen in Table 3.

Table 3. Initial cost estimation.

Material		*HDPE*	*Aluminum*	*FRP*
Hull *		$4000	$5500	
Superstructure *				$4000
Main Engine	$41500			
Equipment	$5800			
Labor	$5000			
Unexpected Expenses	$5000			
Total **		$65300	$66800	

**Estimations based on material prices in market and expert opinions. Material and labor costs included.*

***Prices given as U.S. Dollar ($)*

Running costs include management expenses, salaries, fuel cost and maintenance. Operation (rent, office, etc.) expenses foreseen as 1000$ per month, 2 office employees will be hired for 850$ per month salary. Also, salary of the captain assumed as 1200$ per month. Furthermore, monthly maintenance fee foreseen as 1000$. Fuel cost calculation depends on the trip and its specifications. For that reason, basic fuel consumption data calculated for further use in scenario based estimation. Fuel prices were taken from up-to-date databases and are shown as U.S. Dollar currency for decent comparison [11-13].

4. Results

Aim of this study is to design a vessel that can be an alternative for sea transportation of Istanbul with its flexibility, speed and low construction and operation costs. Most of the design parameters which are important to provide every specification for the outcome have been taken. Detailed route analysis was carried out to understand the necessity for this product for Istanbul. Different berths were examined to decide on the design restrictions. Different materials were surveyed to resolve production cost as well as the aesthetic.

After the research phase concept and preliminary design stages were completed. Shortcomings of the design were looked into. A rough cost estimation for production and a more detailed cost estimation for operation were made for the vessel. As a result of this study, flexibility goal was attained by vessel's overmuch inner volume and its adjustable gangway. Additional, speed target was reached by low displacement and planning hull form. Lastly, low-cost objective was provided by less horsepower need and cost-efficient materials. Briefly, main technical goals of this study were achieved.

On the other hand, design of the vessel exceedingly influenced by regulations and technical requirements. Correspondingly, in an aesthetical aspect, vessel was not provided to get a desired view. In future studies, enhanced structural calculations for manufacturing, detailed market research, more professional cost estimation and completely new upper structure design can be made in order to improve the current study. Consequently, despite some deficiencies, Chloris concept can be an alternative vessel for Istanbul's existing sea transportation systems.

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