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Idea Number: **L1-106**

PILLAR / TRANSPORT MODE	
ROAD ☐	RAIL ☐
MARINE ☒	CROSS MODAL ☐
Project Related to:	☐ RA1: Environment – Decarb., Sustainability & Energy Efficiency ☒ RA2: Vehicle & Vessels Technology, Design & Production ☐ RA3: Urban and Long-Distance People Mobility – Systems and Services ☐ RA4: Freight Transport & Logistics ☐ RA5: Safe, Secure and Resilient Transport Systems ☐ RA6: Transport Infrastructures ☐ RA7: Human Factors, Socio-Economics and Foresights ☐ RA8: Automation and Connectivity ☐ RA9: Enabling Environment for Innovation Implementation

Project Title:

Chloris, An Alternative For Sea Transportation



1. INTRODUCTION

In our modern world, traffic became a crucial issue for metropolises with the contribution of population growth and migration. This issue especially show 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 not got enough space for these improvements. Therefore, another solutions like subways, trams etc. are becoming logical options for governors. On the other hand, these investments require significant capital and long span of time.

Another alternative is the usage of the sea, canals or lakes for metropolitan transportation. Obviously, usage area of this alternative restricted only for coastal cities. Because of metropolisans generally placed near by sea, river or lake, this fact cannot be an important obstacle for transportation on water (See Figure 1.1).

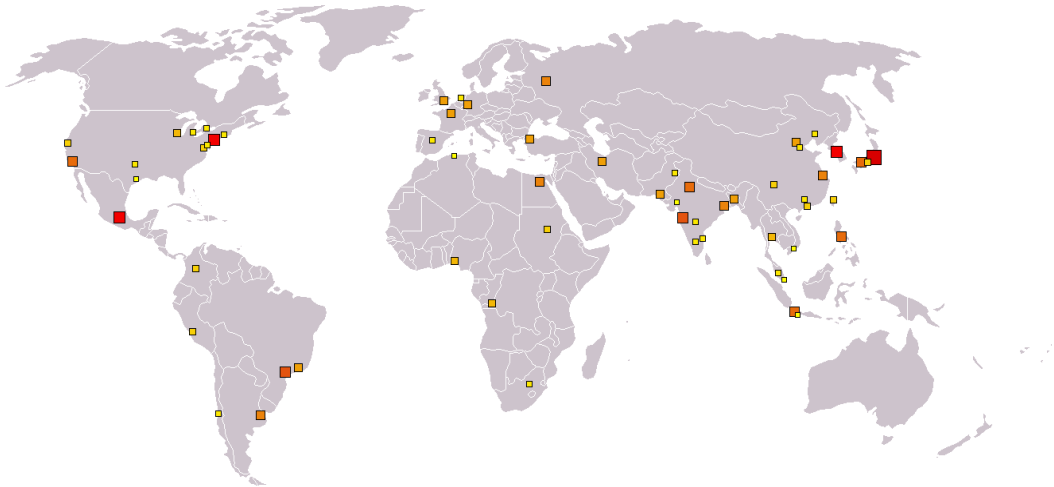


Figure 1.1 World's Most Crowded Metropolisans [1]

As an example of those metropolisans Istanbul which according to Castrol and TomTom Start-Stop Index has the first place in the traffic jam list, transportation on water can be alternative solution for this problem [2]. Bosphorus, the strait that divide Istanbul City into two sides Europe and Asia, allow transportation between two sides vertical and horizontally (See Appendix A). Istanbul's mass transportation system take advantage of this opportunity by varisized vessels and various routes. Unlike the capacity of transportation on water of Istanbul, as Aycı and Barlas stated in 2014, just 2.54 % of passengers choose marine transportation [3]. Additionally, according to I.

Istanbul I. Urban Transportation Council, marine alternatives' capacity usage ratios are around 20% level [4]. 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 the light of these facts an alternative transportation option requirement is came to light.

In this study, depending on deficiency of marine transportation in Istanbul City, a vessel, has 4 passenger capacity and cost-efficient, that disjunctive option of Istanbul's marine transportation, was designed based on mentioned criteria.

Briefly, in second chapter a route analysis about existing transportation alternatives was done. Then in third chapter extensive preliminary design was made for the vessel. Afterwards, in forth chapter initial and running cost estimation was made. Additionally, same trip scenarios was projected. Finally, in chapter five, design concept of the vessel was explained.

2. RESEARCH AREA

Marine transportation mode's RA2: Vehicle & Vessels Technology, Design & Production was selected as research area for this study. Aim to study on this subject is to create a better solution for diagnosed problem and establish a new alternative for sea transportation in metropolitans.

In the light of this objective, a cost-efficient, low capacity, flexible and fast vessel can be the solution of mentioned problems. Thus, this vessel can be a cheaper alternative for existent sea cabs and a faster and flexible alternative for ferries which are used for mass transportation.

Lastly, existent technology and methods were used intentionally on this study to ensure the feasibility of designed vessel.

3. ROUTE ANALYSIS

Before designing the vessel, comprehensive research was made for understanding current condition of the transportation on Bosphorus. As an important element on this research, lines that are used frequently and carried scores of people, were examined. Additionally, demographic structure of the city provide significative data to observe the system on water.

First of all, mass transportation alternatives of the Bosphorus was examined. That study indicate that Türkiye Denizcilik İşletmeleri (TDİ) Şehir Hatları's and private ferries', which carry 92.4 % of the passengers on sea (See Table 3.1), routes are set on south end of the Bosphorus (See Table 3.2, Table 3.3).

Table 3.1. Passengers Carried on the Sea at Istanbul [4]

<i>Passengers Carried on the Sea at Istanbul (2001)</i>				
<i>Corporation</i>	<i>Number of Ports</i>	<i>Daily Number of Carried Passengers</i>	<i>Capacity of Vessel</i>	<i>Capacity Usage Rate (%)</i>
TDİ	44	160000	N/A	21
İDO	16	19000	66000	33
Private Ferries	10	72000	270000	27
Total	70	251000	N/A	N/A

Table 3.2. TDİ Passenger Transportation Lines [4]

<i>TDİ Passenger Transportation Lines (2001)</i>	
<i>Line</i>	<i>Daily Number of Passengers</i>
Bostancı-Beşiktaş	820
Beşiktaş-Kadıköy	21745
Eminönü-Kadıköy	28755
Kadıköy-Karaköy	52800
Adalar-Bostancı	5510
Sirkeci-Adalar	7505
Eminönü-Bostancı	938
Eminönü-Üsküdar	37963
Beşiktaş-Üsküdar	7383
Boğaziçi	8476
Haliç	27
Kabataş-Üsküdar	38
Sirkeci-Harem	14414

Table 3.3. Daily Carried Passenger Number by Private Ferries at Given Ports [4]

<i>Daily Carried Passenger Number by Private Ferries at Given Ports</i>			
<i>Port</i>	<i>Number of Active Vessels</i>	<i>Number of Passengers</i>	<i>Capacity Usage Rate (%)</i>
Kadıköy	6	2755	13.7
Haydarpaşa	6	2445	12.1
Çayırbaşı	5	3164	36.1
Üsküdar	6	7638	30
Karaköy	11	2882	6.7
Eminönü	11	10687	25.2
Total/Average	45	25569	20.6

Other private transportation alternatives mostly independent from certain lines. Exceptionally, some vessels that have 6-7 passenger capacity, have specific routes like as Emirgan-Kanlıca line. But these alternatives often require a port for drop-off and pick-up.

In demographic aspect, Istanbul City is the fifth crowded city in the world and hosts likely 14.5 million people [5]. Population was not especially consternate on coastal zones but significant amount of population reside coast or near the Bosphorus [5]. Additionally, according to İstanbul Ulaşım Ana Planı, Hane Halkı Araştırması (Istanbul Transportation Master Plan, Household Research), activities based on regional zones in Istanbul focused on the Bosphorus coast. Moreover, home to work drafting is more than any other region at the Bosphorus coast [6]. In another aspect, Istanbul's wealthiest districts are placed in the middle and northern coasts of Bosphorus and the fact that usage of mass transportation drops with increase of household income occurs a suitable environment for people to choose other alternatives rather than mass transportation [6, 7].

In the light of these facts, designed vessel on this study was decided to have a flexible route to reach everywhere at coast of the Bosphorus and Marmara Sea coast of Istanbul. As an option, a port that supply maintenance and operational backup can be placed on Bebek-Arnavutköy-İstinye line, because of the mentioned reasons and other land transportation alternatives', as Metrobus, Marmaray and Bosphorus Bridge are share the same zone with fix routed sea transportation, located at the southern region of the strait.

4. PRELIMINARY DESIGN

4.1. Requirements

In the beginning of the design process of vessel, requirements must be determined. In this study, unlike the existent vessels, capacity is constrained by 4 passengers less than any other alternative. Urban citizens are forced to act alone because of today's modern routine. This lifestyle inevitably influence how they travel in the city. Hanson and Giuliano indicated that more than 90% people drive alone and this level keep rising every year [7]. 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 downgradient trend of this data, indicating to set capacity of the vessel as 4 passengers. By this limitation, being an alternative between private and mass transportation as land taxis was targeted. From this point of view, vessel must has less initial and running costs than current alternatives. Additionally, vessel has flexibility to access almost every coastal region for take an advantage in front of strict routed mass transportation alternatives. Moreover, has to reach certain speed because how much time spent in the vessel probably will be primary feature for passengers.

To sum up, aim of this study to design a vessel that flexible, fast and cheap. Main requirements can be list as;

- 4 passenger capacity
- Least resistive, planning hull form
- Flexible docking conditions
- Low manufacturing cost

4.2. Main Dimensions

First step of designing a vessel is to determine main dimensions. Based mentioned requirements, a one chined planning hull form was selected. Afterwards, length overall was determined 6.50 meters, in view of the fact that rowed 2 passenger seat, 1 captain, control panel, door and required space needs. Then, beam was chosen as 2.45 meters to supply enough space for 2 passenger seats and a hallway with margins. Additionally, draft set as 0.44 meters to provide estimated displacement at required conditions, 2.4 tonnes. Finally, design category for Conformité Européenne (CE) selected as C.

After all, main dimensions are shaped as listed on Table 4.2.1. ;

Table 4.2.1. Main Dimensions

<i>Main Dimensions</i>		
L	6.50	meters
B	2.45	meters
T	0.44	meters
Δ	2.40	tonnes

4.3. General Arrangement

As mentioned before vessel was determined to have 4 passenger and 1 crew capacity. As a reference of this arrangement Neufert's Architect's Data was used in terms of ergonomics [8]. On this basis passengers seating plan was planned that 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 (See Appendix B). 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, seat were designed to provide maximum comfort for passengers. For this reason seat dimensions was selected as; width 620 mm, pitch 1350 mm. Also, accommodation zone has 2000 mm height for a comfortably spacious environment. 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 [9]. 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 also designed taking into consideration of related regulations of CE and The Maritime and Coastguard Agency (MCA) [9,10]. Main entrance which

located aft of the vessel, has sliding doors for easy entrance and exit. Farther, has 1.9 meters height for ergonomic and structural needs. Additionally, an emergency exit was located in front of control panel which positioned fore end of the vessel.

Detailed drawings of general arrangement can be found on Appendix B.

4.4. Hull Form

Hull form was designed to fulfil determined requirements which have been mentioned earlier chapters. First provision is a planning hull form, that means vessel will be an high speed craft. There are some definitions given below about high speed craft and planning to determine studied vessel's characteristics.

- International Maritime Organization's (IMO), International Code of Safety for High-Speed Craft 2000 (2000 HSC Code) define a high speed craft as has a higher speed value than shown formula [11];

$$V = 3.7 * \nabla^{0.1667} \text{ (m/s)}$$

- Also some definitions about planning depends on Froude Number which is shown above [12];

$$F_n = V / [g * L_{WL}]$$

- Daniel Savitsky's definition of planning vessel [13];

$$F_n > 1.2$$

- According to Odd Magnus Faltinsen, planning vessel considered as [14];

$$F_n > 1.0$$

Guidance of determined main dimensions, suitable sample form selected from Maxsurf Modeler's library and manipulated according to requirements. In the light of mentioned definitions, for providing additional hydrodynamic lift that support planning regime, one chine was added into hull form. In every step of design hull form transformed based on current conditions. At the end of this process, final hull form was obtained. Hull form's hydrostatic specifications shown at Table 4.4.1. and for drawings and figures see Appendix C.

Table 4.4.1. Hydrostatic Specifications of Hull Form from Maxsurf Modeler

<i>Measurement</i>	<i>Value</i>	<i>Units</i>
Volume (displaced)	2.400	m ³
Draft Amidships	0.440	m
Immersed depth	0.475	m
Waterline Length	5.676	m
Beam max extents on WL	2.457	m
Wetted Area	12.409	m ²
Max section area	0.527	m ²
Waterplane Area	10.797	m ²
Prismatic coefficient (Cp)	0.802	
Block coefficient (Cb)	0.362	
Max Sect. area coefficient (Cm)	0.502	
Waterplane area coefficient (Cwp)	0.774	
LCB length	2.458	from zero pt. (+ve fwd) m
LCF length	2.416	from zero pt. (+ve fwd) m
LCB %	43.311	from zero pt. (+ve fwd) % Lwl
LCF %	42.561	from zero pt. (+ve fwd) % Lwl
KB	0.290	m
BMt	1.740	m
BML	9.587	m
GMt corrected	2.029	m
GML	9.877	m
KMt	2.029	m
KML	9.877	m
Length:Beam ratio	2.310	
Beam:Draft ratio	5.169	
Length:Vol ^{0.333} ratio	4.240	

4.4.1. Resistance

Performance of the hull form is determined by its resistance values. For this study constituted hull form's many different versions were tested in Maxsurf Resistance Module for minimizing resistance of the hull form. All of these trials were made at maximum loading conditions. Furthermore, to calculate resistance Savitsky Planning and Blount & Fox Planning methods were chosen which were suitable for hull of the vessel. Additionally, overall efficiency value selected as 55% and calculations were made in 10 to 35 knots range.

According to given results in Appendix D, three main course speed were selected. These speed values and calculated resistance estimations given at Table 4.4.1.1.

Table 4.4.1.1. Calculated Resistance Values at Selected Course Speeds

Speed	Froude No	Savitsky Planning Resistance	Savitsky Planning Power	Blount and Fox Planning Resistance	Blount and Fox Planning Power
(knots)		(kN)	(kW)	(kN)	(kW)
15	1.034	3.8	53.006	4.0	56.485
25	1.724	3.9	90.460	3.8	89.356
32.5	2.241	4.7	141.773	4.6	139.079

4.5. Equipment

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 [10, 15, 16]. Detailed specifications of equipment attached on Appendix E. Additionally, navigation lights were located according to COLREG-72 (See Appendix F).

4.5.1. Engine Selection

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 calculation, is searched. Then suitable engine options were compared and best fit for this study which is Yanmar 6BY3-220 was selected. Engine comparison shown at Table 4.5.1.2 with related data.

Table 4.5.1.1. Course Features

Course Type	Desired Speed (knots)	Required Power (kW)
Slow	15	60
Normal	25	95
Fast	32.5	145

Table 4.5.1.2. Engine Comparison

Engine	Power (kW)	Price (w/sterndrive)	Fuel Consumption @ Category (l/hr)		
			Slow	Normal	Fast
YANMAR 6BY3-220	162	\$41,500	5	8	20
YANMAR 4JH110 (x2)	162	\$50,200	6	8.5	22
MERCURY QSD 2.8	168	\$36,000	6.5	10	24.5

4.5.2. Fuel Tank Capacity

Fuel tank capacity was determined by estimated fuel consumption data based on resistance calculation. 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. Drawings attached on Appendix B.

4.6. Materials

On the vessel that have been designed in this study, 3 main material type projected to use in manufacturing stage. For 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.).

4.7. Scantling

Scantling calculations were made for each hull material alternative depending on related regulation. 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 [17, 9]. For this calculations maximum unsupported length (maximum frame space) selected as 1500 mm, fore collision bulkhead placed at 0.05 L_{WL} of fore perpendicular. Results can be seen on Table 4.7.1. Additionally, for drawings see Appendix B.

Table 4.7.1. Result of Scantling Calculations

<i>Construction Material of Hull</i>	<i>HDPE</i>	<i>Aluminum</i>	<i>Fiber-reinforced Plastic (FRP)</i>
<i>Specification</i>	PE 100	5086 H116	FRP
<i>Regulation</i>	DNV	CE - ISO 12215-5	CE - ISO 12215-5
<i>Calculated Min. Thickness in mm</i>	15.42	2.44	2.86
<i>Calculation Thickness in mm</i>	18	3	3
<i>Total Mass in kg</i>	460	250	180

4.8. Detailed Weight Estimation

Detailed weight estimation was made based on 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. Results of detailed weight estimation shown at Table 4.8.1.

Table 4.8.1. Detailed Weight Estimation

<i>Item Name</i>	<i>Total Mass (kg)</i>	<i>Longitudinal Arm (m)</i>	<i>Transverse Arm (m)</i>	<i>Vertical Arm (m)</i>
<i>Hull</i>	480.0	2.70	0.00	0.48
<i>Fuel</i>	258.0	1.68	0.00	0.30
<i>Battery</i>	80.0	4.47	0.00	0.15
<i>Engine</i>	450.0	0.50	0.00	0.40
<i>Passanger_1</i>	75.0	1.50	0.80	1.50
<i>Passanger_2</i>	75.0	1.50	-0.80	1.50
<i>Passanger_3</i>	75.0	3.00	0.80	1.50
<i>Passanger_4</i>	75.0	3.00	-0.80	1.50
<i>Captain</i>	75.0	4.30	0.00	1.30
<i>Anchorage</i>	90.0	6.50	0.00	1.17
<i>Windows</i>	120.0	3.23	0.00	2.28
<i>Superstructure</i>	150.0	1.97	0.00	1.84
<i>Seats</i>	100.0	2.50	0.00	1.10
<i>Control Panel</i>	150.0	4.90	0.00	1.40
<i>Gangway</i>	30.0	-0.80	0.00	1.33
<i>Luggage</i>	90.0	0.50	-0.80	0.90
<i>Cargo</i>	90.0	0.50	0.80	0.90
<i>Total Loadcase</i>	2463.0	2.29	0.00	0.91

4.9. Stability

Stability calculation was made on Maxsurf Stability Module with the data taken by detailed weight estimation. Fuel tank permeability taken as 95% and calculation was made for fully loaded condition. Results of equilibrium condition shown at Table 4.9.1.

Likewise, large angle stability and upright hydrostatics conditions were calculated and attached on Appendix G. Besides, related stability criteria of HSC Code 2000 – MSC 97(73), ISO 12217-3:2002(E), MARPOL MEPC.117 (52), MCA 11.1.2.5 were tested and passed (See Appendix G) [11, 18, 19, 10].

Table 4.9.1. Hydrostatic Values at Equilibrium

<i>Measurement</i>	<i>Value</i>
<i>Draft Amidships m</i>	0.440
<i>Displacement kg</i>	2473.0
<i>Heel deg.</i>	0.000
<i>Draft at FP m</i>	0.434
<i>Draft at AP m</i>	0.446
<i>Draft at LCF m</i>	0.441
<i>Trim (+ve by stern) m</i>	0.012
<i>Waterline Length m</i>	5.669
<i>Beam max extents on WL m</i>	2.464
<i>Wetted Area m²</i>	11.898
<i>Waterplane Area m²</i>	10.841
<i>Prismatic coeff. (Cp)</i>	0.785
<i>Block coeff. (Cb)</i>	0.365
<i>Max Sect. area coeff. (Cm)</i>	0.508
<i>Waterplane. area coeff. (Cwp)</i>	0.776
<i>LCB from zero pt. (+ve fwd) m</i>	2.435
<i>LCF from zero pt. (+ve fwd) m</i>	2.405
<i>KB m</i>	0.291
<i>KG fluid m</i>	0.846
<i>BMt m</i>	1.761
<i>BML m</i>	9.521
<i>GMt corrected m</i>	1.206
<i>GML m</i>	8.966
<i>KMt m</i>	2.052
<i>KML m</i>	9.811
<i>Immersion (TPc) tonne/cm</i>	0.111
<i>MTc tonne.m</i>	0.039
<i>RM at 1deg = GMt.Disp.sin(1) kg.m</i>	52.056
<i>Max deck inclination deg</i>	0.124
<i>Trim angle (+ve by stern) deg</i>	0.124

4.10. Seakeeping

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 on software. Output charts can be seen on Appendix H.

Analysis results shown that at 15 and 25 knots, all requirements were fulfilled. Only at 32.5 knots with 150 and 180 degree headings, severe discomfort boundary for 8 hours exposure limit lying on critical area.

5. 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.

5.1. Initial Cost

Initial cost of the vessel includes 2 main components which are manufacturing and outfitting costs. Hull form was selected one chined to decrease manufacturing cost. Additionally, HDPE was projected for reducing material cost. Initial cost estimation can be seen on Table 5.1.1 (Detailed equipment list with prices attached on Appendix E).

Table 5.1.1. 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 cost included.*

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

5.2. Running Costs

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\$ (See Table 5.2.1.)

Fuel cost calculation depends on trip and its specifications. For that reason, basic fuel consumption data calculated for further use in scenario based estimation (See Table 5.2.2.). Fuel prices were taken from up-to-date databases and shown as U.S. Dollar currency for decent comparison [20-22].

Table 5.2.1. Expenditure

<i>Description</i>	<i>Expense Value \$</i>		
	<i>Daily</i>	<i>Monthly</i>	<i>Yearly</i>
Captain	40	1200	14400
Office Employee	29	850	10200
Office Employee	29	850	10200
Operation	34	1000	12000
Maintenance	34	1000	12000
Total	166	4900	58800

Table 5.2.2. Fuel Consumption Estimation

U.S. Dollar per liter	
<i>EN 590 diesel</i>	<i>MGO</i>
0.445	0.314

<i>For EN 590</i>	<i>Slow</i>	<i>Normal</i>	<i>Fast</i>	<i>Unit</i>
Fuel Consumption per minute	0.083	0.133	0.333	liter/minute
Fuel Cost per minute	0.037	0.059	0.148	\$/minute
Fuel Cost per nautical mile	0.148	0.143	0.274	\$/nmi

<i>For MGO</i>	<i>Slow</i>	<i>Normal</i>	<i>Fast</i>	<i>Unit</i>
Fuel Consumption per minute	0.083	0.133	0.333	liter/minute
Fuel Cost per minute	0.026	0.042	0.105	\$/minute
Fuel Cost per nautical mile	0.105	0.100	0.193	\$/nmi

5.2.1. Trip Scenarios

Daily trip scenarios was studied to determine nautical based fee for transportation service. In the light of this projection, service fee was defined as 30 Turkish Liras (10.35 U.S. Dollars) for first 3 nautical miles then 10 Turkish Liras (3.45 U.S. Dollars) for every additional nautical mile. Different trip scenarios are shown at Table 5.2.1.1 with other alternatives for comparison¹.

¹ EN 590 Diesel was used for calculations.

Table 5.2.1.1. Trip Scenarios

<i>Bakırköy-Moda</i>	<i>Distance</i>	<i>Time (min)</i>	<i>Fuel Cost</i>	<i>Fee \$</i>	<i>Fee ₺</i>
Chloris*	13 km	18	\$1.06	24.1	70
Sea Taxi**	13 km	N/A	-	86.9	252
Taxi	30 km	60	-	24.1	70

<i>Sirkeci-Beykoz</i>	<i>Distance</i>	<i>Time (min)</i>	<i>Fuel Cost</i>	<i>Fee \$</i>	<i>Fee ₺</i>
Chloris*	19 km	25	\$1.48	34.5	100
Sea Taxi**	19 km	N/A	-	116.9	339
Taxi ²	24 km	46	-	21.7	63

<i>Arnavutköy-Kalamış</i>	<i>Distance</i>	<i>Time (min)</i>	<i>Fuel Cost</i>	<i>Fee \$</i>	<i>Fee ₺</i>
Chloris*	15 km	20	\$1.48	27.6	80
Sea Taxi**	15 km	N/A	-	96.9	281
Taxi	18 km	35	-	13.8	40

<i>Kadıköy-Sarıyer</i>	<i>Distance</i>	<i>Time (min)</i>	<i>Fuel Cost</i>	<i>Fee \$</i>	<i>Fee ₺</i>
Chloris*	23 km	30	\$1.77	41.4	120
Sea Taxi**	23 km	N/A	-	146.9	426
Taxi	28 km	40	-	21.4	62

<i>Bebek-Anadolu Hisarı</i>	<i>Distance</i>	<i>Time (min)</i>	<i>Fuel Cost</i>	<i>Fee \$</i>	<i>Fee ₺</i>
Chloris*	1.8 km	3	\$0.06	10.3	30
Sea Taxi**	1.8 km	N/A	-	26.9	78
Taxi	28 km	17	-	8.6	25

<i>Arnavutköy-Üsküdar</i>	<i>Distance</i>	<i>Time (min)</i>	<i>Fuel Cost</i>	<i>Fee \$</i>	<i>Fee ₺</i>
Chloris*	5.5 km	8	\$0.50	10.3	30
Sea Taxi**	5.5 km	N/A	-	46.9	136
Taxi	13 km	27	-	10.3	30

* Vessel that designed in this study
** Deniz Taksi - Teknomar A.Ş.

Exchange rate of dollar set as 1\$ = 2.90 ₺
₺ = Turkish Lira

Mentioned districts' location can be found on Appendix A.

² Taxi fees were estimated based on related regulation [23].

Accordingly, total cost and profit estimations were made. On daily basis 15 short range trip (3 nautical miles or less), 5 mid-range trip (between 3 to 15 nautical miles) and a long range trip (20 nautical miles) were assumed³. Results of the estimation can be seen on Table 5.2.1.2.

Table 5.2.1.2. Expenditure-Turnover-Profit Estimation

	<i>U.S. Dollars</i>		
	<i>Daily</i>	<i>Monthly</i>	<i>Yearly</i>
<i>Salaries</i>	97	2900	34800
<i>Operation</i>	34	1000	12000
<i>Maintenance</i>	34	1000	12000
<i>Fuel Cost</i>	15	450	5400
<i>Expenditure</i>	180	5400	64800
<i>Turnover</i>	380	11400	136800
<i>Profit</i>	200	6000	72000

³ Trips were assumed as given, short: 2 nmi for all; mid-range: 7nmi, 8nmi, 9nmi, 10nmi, 12nmi.

6. DESIGN CONCEPT

Aside from all calculations and regulations, vessel was designed based on a concept that inspired from a bird named European Greenfinch (*Chloris Chloris*) which can be seen often on Bosphorus. *Chloris chloris* is the binomial name of European Greenfinch also, in Greek mythology Chloris is a Nymph that associated with flowers and spring. For all of mentioned reasons, name of the vessel selected as Chloris.

Curves and contours was emulated by European Greenfinch and whole design endeavored to bear the same trace (See Figure 6.1, Figure 6.2. and Appendix I).

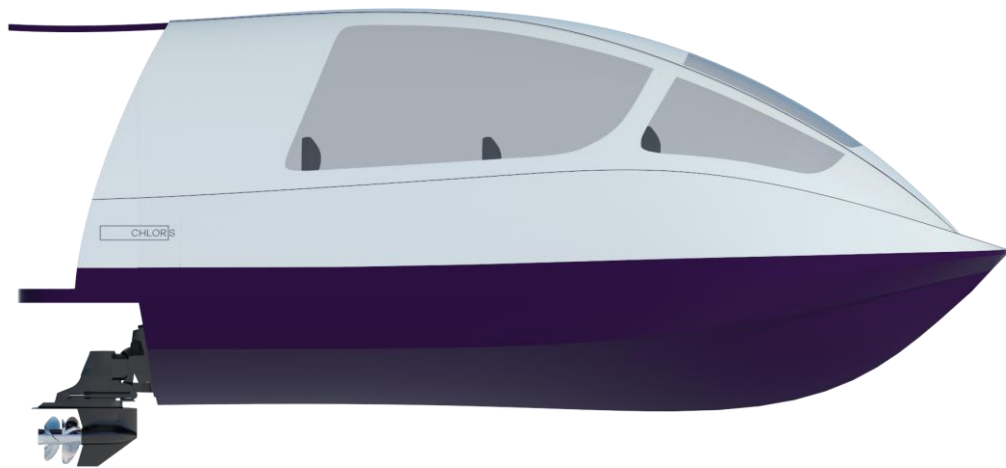


Figure 6.1. Profile View

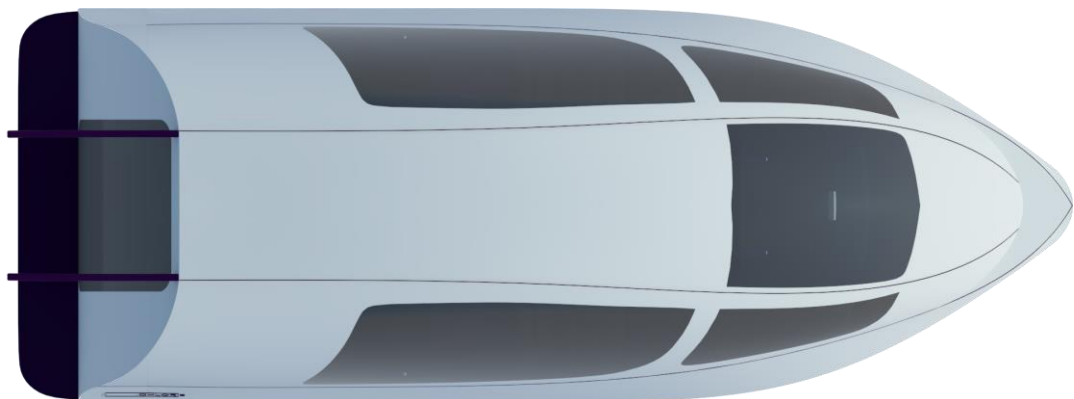


Figure 6.2. Plan View

7. CONCLUSION AND RECOMMENDATIONS

Aim of this study to design a vessel that can be an alternative for sea transportation of Istanbul with its flexibility, speed and low construction and operation cost. 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 design restrictions. Different materials were surveyed to resolve production cost as well as the aesthetic.

After the research phase concept and preliminary design stages completed. Shortcomings of the design were looked into.

Cost estimation for production roughly and operation more detailed 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 calculation for manufacture, detailed market research, more professional cost estimation and completely new upper structure design can be made in order to improve current study.

Consequently, despite some deficiencies Chloris concept can be an alternative vessel to Istanbul's existing sea transportation systems.

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