The sustainable economic development of Wallis and Futuna Islands and the maritime transport system

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ABSTRACT

The territory of Wallis and Futuna is one French oversea community and one European oversea territory located in the South Pacific Ocean at 16.000 kilometres from Paris. It is composed by two main islands: Wallis and Futuna, which are separated by 230 kilometres. In 2015, 11.700 inhabitants were living in the territory and 70% of them on the main island: Wallis. The territory encounters two challenges: to develop the local economy and to ensure the territorial continuity.

The local economy is traditional and heavily dependent of the public work. Some lever of growth had been identified but one of the main issue is the problematic inter-island connection. In fact, the transport concerns two components: the passengers and the cargo. Nowadays, one daily aerial connection is dedicated only to the transport of passengers using two small airplanes with a carrying capacity of 12 to14 passengers. Concerning the cargo transportation, it is ensured by vessels berthing monthly to Wallis and next to Futuna. Thereby, trade exchanges between both islands are very restricted, especially from Futuna to Wallis. To develop the local economy, studies highlighted the importance to develop one maritime inter-island connection which would be complementary to the actual transport system. Thus, the preliminary design of an inter-island passengers and cargo ferry would be researched.

First, the requirements for the vessel should be accurately defined based on previous studies but also in accordance with the actual economic situation. This leads to a maximum carrying capacity of 8 containers of twenty feet and 41 passengers for one overnight journey of 12 hours. On a weekly basis, three rotations should be ensured. Such rhythm, requires a crew reaching 11 members divided between the deck, engine and catering department.

Secondly, the design of the ferry considers the berth constraints, the navigation area, the classification society rules but also the national and local legislative framework. All these parameters combined with a parametric design study lead to the main dimension of the vessel: a length of 40 meters, a beam of 8.4 meters, a draught of 3.4 meters and one displacement of 480 tons. The design adopted is based on offshore service vessel which provide the aft deck for the cargo and in front is located the accommodation for the passengers and the crew.

Then, the iteration process of the design starts. The general arrangement plans and the hull form are designed to fit all the requirements for cargo, crew and passenger's area. The arrangements of the passenger area pay attention to provide a good level of comfort for customers in two different classes. Considering the structure, the selected material is steel for economic and geographic reasons. This is calculated in accordance with the rules of Bureau Veritas. Obtained values are cross-checked with help of MARS software. The definition of the propulsion system and of the arrangement of the engine room allow to define the distribution of weights on board. Nevertheless, the variation of displacement between the ballast and full load conditions, request careful analyses of the different loading cases. They are especially important for the stability of the vessel and the necessary ballast capacity to avoid one excess of longitudinal trim. Motions and accelerations of the vessel in head wave condition are also analysed to ensure a good comfort to the passengers using the CFD software FineMarine™.

The goal of the study is to provide a first preliminary design of a ferry especially dedicated to Wallis and Futuna territory. During all the iteration process some aspects are considered at every step: to be in accordance with the local environment, reduced construction and maintenance cost, and high reliability.

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1 INTRODUCTION

The territory of Wallis and Futuna is one French oversea community in the South Pacific Ocean. It is composed of two main islands separated by 230 kilometres. In 2015, only 11.700 inhabitants were living in the territory and 70% of them on the main island: Wallis. The territory encounters two challenges: to develop the local economy and to ensure the territorial continuity. To achieve them, new transport's alternatives are necessary. One of the solutions, supported by a study of the South Pacific Committee, is the creation of a direct maritime connection between Wallis and Futuna ensured by a new ferry. Therefore, the aim of this thesis is to provide a suitable preliminary design for this inter-island maritime connection.

Firstly, a study should be lead on the territory concerning the main issues of the vessel's characteristics: the geography, the harbour's infrastructure, the climate, the expectation of numbers of passengers and cargo and the maritime legislation. Then, the recommendations released by the SPC are studied to fix the requirements for the vessel.

Then, the iteration process of the design starts. The general arrangement plans and the hull form are designed to fit all the requirements for the cargo, the crew and passenger's requests. The arrangements of the passenger area pay attention to provide a high standard of comfort for customers in two different classes. Considering the structure, the selected material is steel for economic and geographic reasons. It is calculated in accordance with the rules of Bureau Veritas. The definition of the propulsion system and of the arrangement of the engine room allows to define the distribution of weights on board. Nevertheless, the variation of displacement between the ballast and full load conditions, requests careful analyses of the different loading cases. They are especially important for the stability of the vessel and the necessary ballast capacity to avoid an excess of longitudinal trim. Motions and accelerations of the vessel in head wave conditions are also analysed, with the CFD software FineMarine™, to ensure a good comfort to the passengers.

The goal of the study is to provide a first preliminary design of a ferry specifically dedicated to Wallis and Futuna's territory. During all the iteration process some aspects are considered at every steps: to be in accordance with the local environment, to reduce construction and maintenance cost, and to insure a high reliability.

2 WALLIS AND FUTUNA

The study is focused on the territory of Wallis and Futuna. It is one French oversea community[1] and one European oversea territory[2] located in the South Pacific Ocean. This is the further territory of the Republic, leading to many territorial specificities compared to the metropole. Then, it is mandatory to consider them at the first stage of the design in order to provide a suitable design which fulfils the local needs.

2.1 Geographic position

2.1.1 Relative position

The territory of Wallis and Futuna is in the South Pacific Ocean, at the proximity of the anti-meridian and of the equator. It is located at 16,000 kilometres from the metropole.

Figure 1 Distance between the metropole and the territory

Source: Google Maps

Nevertheless, this territory is at proximity with others French oversea territory located also in the South Pacific Ocean:

- The French New Caledonia: located at 2000 kilometres at the South West from Wallis Island

[1] Article 74 of the French Constitution of the 4th October 1958
[2] Article 198 of Treaty on the Functioning of the European Union

- The French New Polynesia located around 3000 kilometres at the East from Wallis Island.

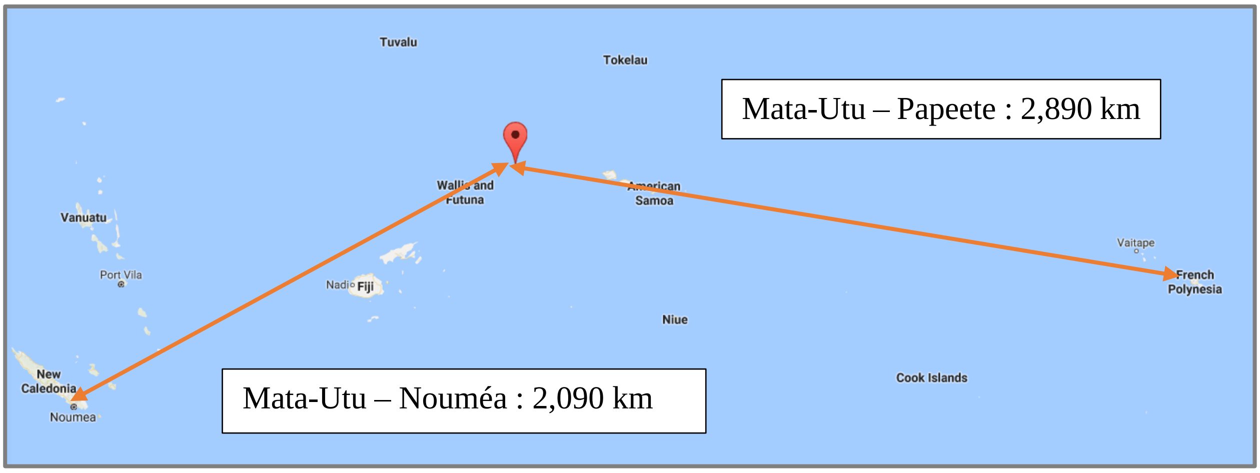

Figure 2 Distance with the French oversea territory located in the South Pacific ocean

Source: Google Maps

As these French territories are distant, the importance of the neighbour's countries is high. At proximity, of the territory these are the Fiji Islands which are considered as an economic centre in the region. This country of almost one million habitants is the closest one which can provide maintenance facilities for a sea-going vessel.

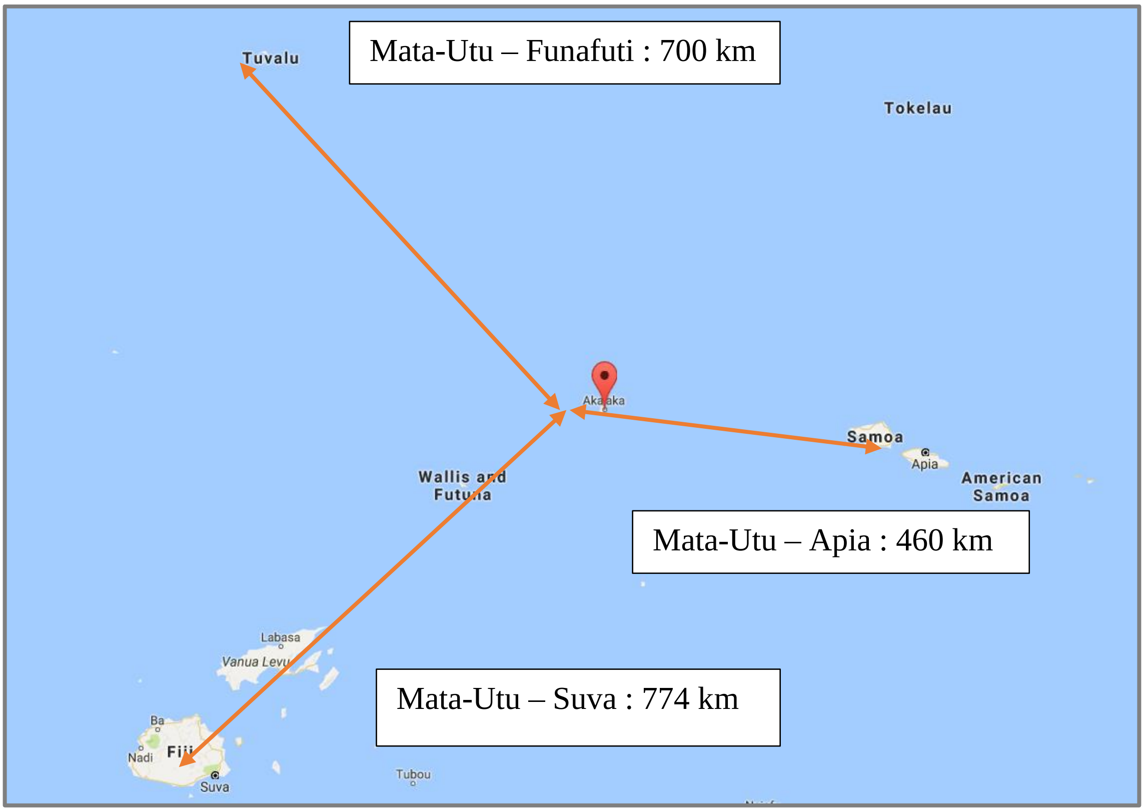

Figure 3 Distance between neighbour's country and Wallis and Futuna territory

Source: *Google Maps*

2.1.2 *Local geography*

The distance separating Wallis and Futuna Islands to the neighbour's country is problematic for the regional exchanges, but it is finally secondary compare to the geography of the territory which is a barrier to local exchanges. Indeed, it is composed of two main islands: Wallis and Futuna. Only both are habited. Futuna is located at 234 kilometres at the South West of Wallis.

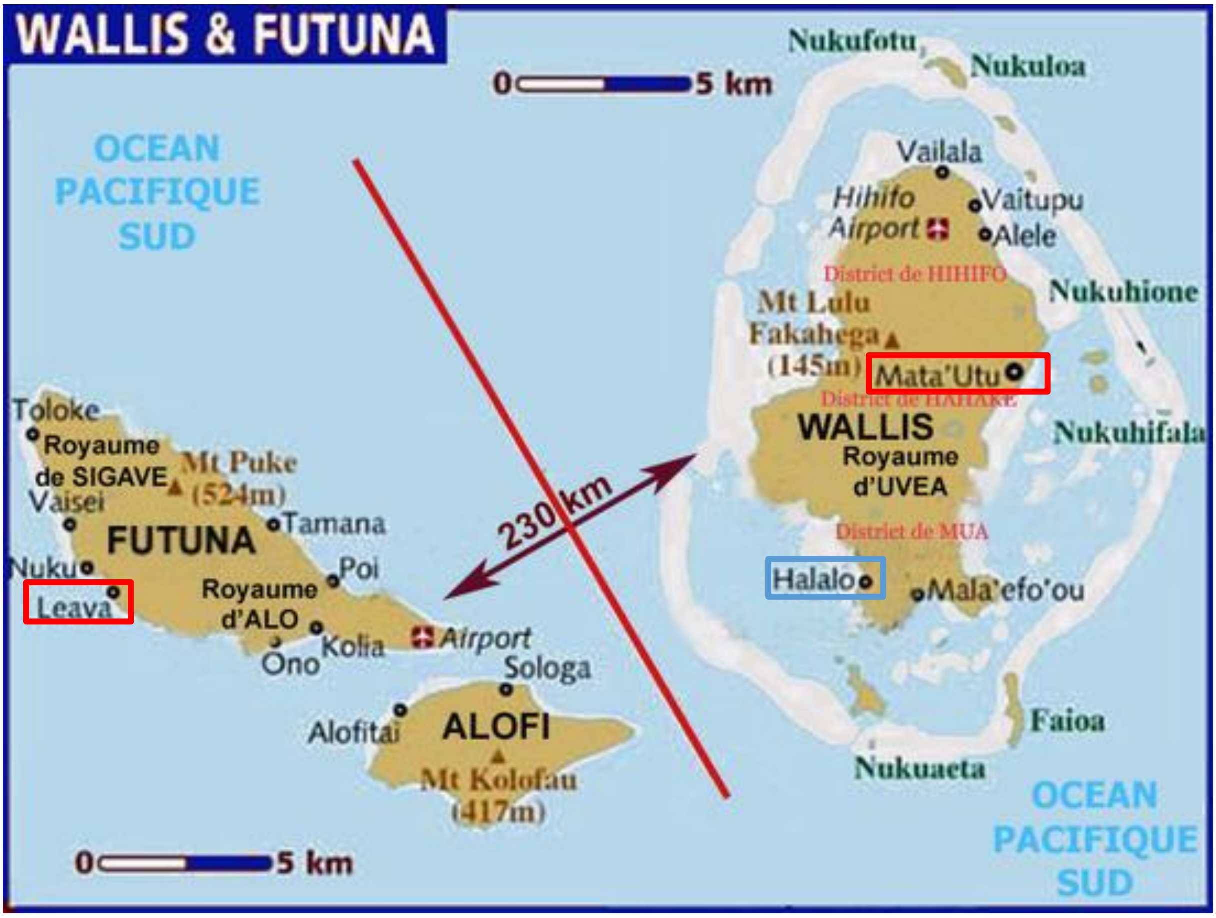

Figure 4 Local geography of the territory of Wallis and Futuna

Source: *Prefecture of Wallis and Futuna Islands, http://www.wallis-et-futuna.pref.gouv.fr/*

Wallis Island is the biggest one. Its superficies reaches 77.9 km². This is a low ground territory where the highest point is the Mount Lulu (151 meters). The Island is surrounded by a lagoon and a coral barrier with four passes. The pass of Honikulu located at the South of the Island is used by merchant's vessels to reach harbour's territory. Wallis Island has two harbours: Mata'Utu is used for the general cargo and Halalo is restricted to the fuel cargo. On the North, there is the international airport.

Futuna Island is a mountain territory with an area of 46.3 km². The highest point is the Mount Puke (524 meters). There is no coral barrier surrounding the country, then the harbour located in Leava is submitted to the swell. Alofi Island is separated by a channel of 2 km at the East of the territory. nevertheless, this Island of 17.8 km² is uninhabited.

For the transport of the passengers and cargo by a ferry. The two relevant harbours are Mata-Utu located on Wallis Island and the second one is Leava on Futuna Island. They are distanced by 137 nautical miles.

2.2 Information about the territory

2.2.1 Overview of the economic situation

The population of the territory is estimated at 11 700 habitants in 2015[3]was 12,197 at the last census of 2013[4]. Most of the population lives on the Wallis Island which counts 70% of the population. The others part of the population is living on the Futuna Island. Nevertheless, the tendency of the last decade shows a negative growth due to the departure of the emigration of the young population. And this tendency is twice stronger in Futuna Island which is more isolated.

The departure of the young active population is closely related to the absence of job opportunities in the territory. This is partially due to the absence of job opportunities which are mainly located in Wallis and especially in the district of Hahake where is located Mata-Utu and the main services of the administration. Thereby, they emigrate to another territory as French New Caledonia. The most important community outside of the territory is located there and count more than 20,000 people revendicating from Wallis and Futuna.

The last report about the economy in Wallis and Futuna issued by the French overseas currency issuing institute[5] states the public sector represents 60% of the employ on the territory. By comparison, in France, the employment in public sector represents 25% of the labour force[6].

The private sector is mainly presented in three domains of activity: the construction, the commerce, and the agriculture. Nevertheless, none of these activities leads to exportation from

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[3] Estimation based on the census of 2013 and variation of the natural growth and emigration of habitants. Annual report of IEOM, p27.
[4] https://www.insee.fr/fr/statistiques/1281314 [in French]
[5] Institut d'Emission d'Outre Mer - IEOM

the territory leading to a strong commercial deficit. Thus, the economy of the territory is based on the interior consumption.

To improve the economy of the territory, one of the main measures is to increase inter-island and international aerial connections. These measures supported during the visit of the French President in February 2016, should lead to one increasing of the frequentation of the territory. Nevertheless, the success of such measures should be associated with a decrease of the cost of plane tickets.

Then, the interest of an inter-island maritime connection is valuable. In fact, it provides the cheapest solution to travel due to the lower operational cost of a vessel compared to suitable airplanes for the inter-island connections.

2.2.2 International and domestic transport services

First, the transport of passengers towards the territory is ensured by the aerial company Aircalin which is in a situation of a monopole in the territory. It ensured three connections a week between New Caledonia and the international airport of Wallis Hihifo[7] with an Airbus A320. In 2015, 28.846 passengers took one international flight from and towards the airport.

The inter-islands connection is ensured by the same company which has two DHC-6 Twin Otter 300 providing one daily return flight. Nevertheless, the carrying capacity of the plane is restricted to 12-14 passengers due to safety measures reducing the normal capacity of these planes. The company transports 13.832 passengers in 2014, then almost 7.000 passengers in both directions. One increase of passengers on this aerial connection could be ensured only by one increase of the frequency as long as the airport is not suitable for bigger airplane.

Secondly, the transport of cargo is ensured at more than 99% by the maritime way. Two kinds of cargo should be considered: the fuel and the other kind of cargo. The transport of fuel is ensured by a tanker coming usually from Nouméa (French New Caledonia) and she deserves Wallis and Futuna Islands every month. The cargo transport is ensured by a container vessel, actually the "MV Southern Pearl" on a 3-week basis, berthing first in Wallis and next to Futuna. Limiting the inter-island trade exchange, especially in the way Futuna to Wallis, due to a delivery time of 21 days. The maritime transport on the Island of Wallis is summarized in Table

[7] http://www.ieom.fr/wallis-et-futuna/presentation/l-acces-au-territoire-119.html

1. On average, it is a total of 90 containers unload by trip: 60 for Wallis,10 for Futuna and 20 for both islands requesting to be unpacked in Wallis before to be sent for Futuna.

Table 1 Evolution of the maritime transport

Source: SPC Study, (original source: Customs service)

Hits	2011	2012	2013	2014	2015
Cargo traffic	18	19	27	18	17
Number of containers	1384	1253	1550	1382	1312
Oil transport	13	13	12	11	13
Oil tanker	8	8	7	6	9
Gas tanker	5	5	5	5	4
Others (mainly navy vessels)	3	2	1	1	1
Total	34	34	40	30	31

2.2.3 Harbours of the territory

In this study, we consider the two main harbours: Mata-Utu (Wallis Island) and Leava (Futuna Island).

Their locations are:

- Mata-Utu (Wallis Island):
    - Latitude: 13°16.9’S
    - Longitude: 176°10.4W
- Leava (Futuna Island):
    - Latitude: 14°18.0’S
    - Longitude: 178°09.4’W

Both are in the South Pacific Tropical Zone per the Load Line convention. The year is divided into two periods: from 1st April to 30th November, tropical zone and from 1st December to 31st March, summer zone. Further in the study, we would consider the vessel sailing in Summer zone which requests more consideration (less buoyancy, more advance resistance). Thus, results would be conservative considering the tropical zone.

Harbours are properties of the territory. The port authority is represented by the Maritime Affaires, Port, Lighthouses, and Beacons Department[8].

[8] In French, Service des Affaires Maritimes, des Ports, et des Phares et Balises - SAMPPB

It should be considered than both harbours welcome merchant vessels as the MV Southern Pearl of more than 100 meters. Then, the depth alongside the quay is high. But the distance from the quay to the waterline is also around 3 meters, depending on tide height which can reach 1.5 meters in Wallis and 1.8 meters in Futuna.

Harbours of the territory provide only maintenance service for small repairs. It doesn't exist a drydock.

Mata-Utu Harbour

Figure 5 Wharf of Mata-Utu at 15/07/2013

Source: Google Earth

This harbour is the main one of the territory. It was extended in the field of the 9th Program of the European Development Fund. The harbour is the property of the territory. The port authority is represented by the Maritime Affaires, Port, Lighthouses, and Beacons Department[9].

[9] In French, Service des Affaires Maritimes, des Ports, et des Phares et Balises - SAMPPB

The harbour is in a lagoon, so the barrier reef located at 5 kilometres a good protection from the swell to the vessel in normal condition. Nevertheless, the departure could be difficult during heavy winds and then one heavy mooring buoy could be used to unberth the vessel.

<u>Leava harbour</u>

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Figure 6 Top view of Leava harbour

Source: Google Maps

The port of Leava is the only one on the territory. It is located on the South West of the territory. Its location provides a protection against main wind directions but winds coming from NW-SW could be problematic. Moreover, the vessel could be hampered by the heavy swell. Therefore, the vessel could encounter difficulty to berth ship under poor weather conditions.

The harbour would benefit soon from a rehabilitation in the field of the 10^{th} program of the EDF. Nowadays, the quay is in a deteriorated condition.

2.2.4 The storing capacity of fuel

The delivery of fuel is ensured to both territories by a tanker. Nevertheless, the storing capacity is unequal between islands. This aspect is highlighted in the IEOM report of 2015.

In Wallis Island, the gasoil storing capacity reaches 1830m³ separated on two sites: Halalo harbour (storage) and one in Mata-Utu dedicated to the electrical plant. The storing capacity allows one autonomy of the territory of 110 days in diesel.

The diesel storage capacity in Futuna Islands is restricted to 400m³ providing on the autonomy of 97 days. As the storage capacity is lower, the bunkering should be mainly done in the Wallis Island.

2.3 Climate

The territory has a maritime tropical climate characterized by high temperature and humidity. The location close of the Equator leads to a climate not divided into seasons. The annual average temperature is around 27°C. There is a season of a tropical cyclone from 15th November to 15th April. The highest frequency of tropical cyclone is reached during the month of February.

More details about the climate on the sea between Islands is studied with Pilot Charts provided by the National Geospatial Intelligence Agency from the United States.

The area between both Islands is not often submitted to high waves[10]. Nevertheless, no database indicates one accurate average wave height. The prevailing winds are East winds with a force around 4 Beaufort. Then, transversal winds could be expected during the trips. Moreover, the combination of the oceanic current and opposite winds could occur during the journey from Futuna to Wallis. The sea water temperature has an average temperature of 28°C which is almost constant over the year.

Table 2 Summary of the climate information for the area between *Wallis and Futuna Islands*

Source: *South Pacific Ocean Pilot Charts, National Geospatial Intelligence Agency from the United States.*

	Frequency of waves higher than 12 feet	Prevailing winds: Main direction and force in Beaufort	Oceanic Current direction and speed in knots	Gales, wind over 8 Beaufort

[10] Pilot chart, probability of waves over 12 feet is below 10% which is the minimum indicated on the chart.

January	< 10%	NE 4	SW 0.5-1	0%
February	< 10%	N/E 3	SW 0.5-1	1%
March	< 10%	N/E 3	WSW 0.5-1	0%
April	< 10%	SE/E 4	WSW 0.5-1	0%
May	< 10%	SE/E 4	WSW 0.5-1	0%
June	< 10%	SE/E 4	WSW 0.5-1	2%
July	< 10%	SE/E 4	WSW 0.5-1	1%
August	< 10%	SE/E 4	WSW 0.5-1	0%
September	< 10%	SE/E 4	WSW 0.5	0%
October	< 10%	SE/E 4	WSW 0.5	0%
November	< 10%	SE/E 3	WSW 0.5	0%
December	< 10%	E 3	SW 0.5-1	0%

This climate data's highlight some parameters to consider for the vessel. First, the average air temperature requests one efficient ventilation and air-conditioning system on board. The sea water temperature which is high too is also one important parameter to be considered for the water cooling system of the main engines.

Furthermore, the prevailing winds in this area give the opportunities to expect transversal winds from April to December with a speed comprised between 7 to 16 knots. Main influences on the requested power of the vessel are expected from December to March with an opposite wind of the vessel when she is sailing from Futuna towards Wallis Island. Moreover, oceanic current is also in opposite directions for this trip.

2.4 The Legislation

2.4.1 The status of the territory

Wallis and Futuna is one French oversea collectivity. This status is recognized by the article 74 of the French Constitution and considers the specificity of the territory. The law of 29 July 1961 sets the territory's organisation and legal framework the French government's representatives and the territorial institution. Nevertheless, the organisation of the territory remains original compared to other overseas territories due to the strong influence of the tradition represented by the three traditional kingdoms existing in the territory. Then, everything is a matter of compromised and equilibrium between the different authorities.

The Head of the territory is the Chief Administrator, nominated by the French government. He detains the executive powers and takes after notice of the territorial council, the regulation acts deliberate the territorial assembly in his field of competency[11].

The Territorial assembly counts 20 elected members based on five electoral districts. They were in accordance with the distribution of the population in 1961. Nowadays, due to the emigration of the population which is especially important on Futuna Island, their elected representing Futuna get one extra weight on this assembly.

The territorial Council is compound by the Chief Administrator as chair. The three traditional leaders are vice-chairs. Three others members are nominated by the Chief Administrator after approval of the territorial assembly[12].

The competencies of the Chief Administrator, the Territorial Council, and the Territorial Assembly are set by a Decree of 1957[13]. In the bunch of competencies, the territorial assembly could take regulations over domestic sea transports within the framework of the general rules governing safety and standards.

2.4.2 The maritime legislation

As an oversea territory, Wallis and Futuna are submitted to the principle of "legislative specificity". It means only the laws and regulations issued by France and stating it applies to Wallis and Futuna are in force in the territory. This level of autonomy of Wallis and Futuna provide them the ability to have a legislation very different from the Metropolitan France. This differs on the matter of the Labour Code, Transport Code, Customs Code. The main difference is a much lighter legislation. The time of adaptation is also longer, the implementation of Maritime Labour Convention into the Labour Code occurs only in October[14].

The territory has also his own shipping registers which present an interest compare to another national register: one specific Labour Code which is lighter than the Labour Code of the metropole. Nowadays, all the vessel of "La compagnie du Ponant" registers these vessels in Wallis and Futuna for this reason. Nevertheless, if they can save money thanks to the labour cost and the tax system, they cannot save money on the safety. Indeed, the French safety law

[11] Article 9 of the law 61-814 dated 29 July 1961 endowing the Islands of Wallis and Futuna with the stats of Overseas Territory.
[12] Article 10 of the law 61-814 dated 29 July 1961 endowing the Islands of Wallis and Futuna with the stats of Overseas Territory.
[13] Decree n°57-811 from 22nd July 1957 related to the attributions of territorial assembly, territorial council and Chief Administrator of the Territory of Wallis and Futuna Islands
[14] Ordonnance n°2016-1314 dated 6th October 2016

for vessels, issued in 1987 and updated on a regular basis applied for all French flag vessel. This law contents all the requirements a vessel has to fulfil in accordance with the international conventions issued by International Maritime Organisation and International Labour Organisation[15]. In the study, it is considered the vessel is registered in Wallis and Futuna. Therefore, this law applies.

To design the ferry, the maritime legislative framework should also be acknowledged. Nevertheless, due to the specificity of the territory, many legislations are not issued by the territory. The maritime legislation and the maritime regulation applied on the territory depend on of different actors. Some of them are related to the territory but interactions with the New Caledonia, the Metropolitan France, and international conventions are important too.

At sea, the competences are also widespread. The competences of the territory are in fact only restricted to the harbour. Therefore, they issue the harbour's regulations (procedure of arrival and depart, loading, and unloading condition,)

Concerning the access to the territorial sea, the regulation is released by the French maritime governor presents in New Caledonia. These regulations concerning the access of the wharf of Mata-Utu and Leava set some restrictions for a vessel with a length overall superior at meters. It concerns the hours or arrival and departure and it provides one exemption of pilotage.

2.5 Focus on the maritime inter-island connection

2.5.1 Number of expected passengers

The aerial inter-island connection carries almost 14.000 passengers in 2014. Nevertheless, the affluence of passengers varies each month. Detailed statistics are provided in Table 3 Number of air passengers in 2014.

[15] The main maritime international conventions are:
- Safety Of Life At Sea Convention (SOLAS)
- International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (MARPOL)
- Load Line Convention (LLC)
- International Maritime Labour Convention (MLC)

Table 3 Number of air passengers in 2014

Month	Number of passengers Wallis/Futuna	Weekly average	Number of passengers Futuna/Wallis	Weekly average
January 2014	515	117	587	133
February 2014	538	135	688	172
Mars 2014	349	79	416	94
April 2014	760	178	688	161
May 2014	355	81	456	103
June 2014	748	175	702	164
July 2014	299	68	260	59
August 2014	642	145	671	152
September 2014	467	109	416	98
October 2014	792	179	814	184
November 2014	491	115	589	138
December 2014	985	223	604	137
2014	6941	134	6891	133

Source: SPC Study, (original source: Subdivision of Public Work of Futuna 2014)

The frequentation of aerial inter-island connection from Wallis to Futuna has a weekly average during the year of 134 passengers but with weekly average variation from 68 in July to 223 in December. That means a median value of 126 and a standard deviation of 48 passengers.

In the opposite direction, the weekly average reaches 133 with a minimum value of 59 in July and a peak of 184 in October. The weekly median value is 138 and a standard deviation of 37.

The weekly flight schedule is based on 10 return flights a week. But each year, about 150 return flights are scheduled during peak period but also for special services (as medical evacuation).

The carrying capacity of aircrafts varies, then it is difficult to provide accurately one maximum carrying capacity. In fact, each DH-6 Twin-Otter has 16 seats for passengers. Initially, they disposed of 19 seats but 3 were removed to install a life raft[16]. Then, the restriction is not only based on the arrangement of the cabins but also the carrying weight. Indeed, they transport also freight which reached 35.6 tons in 2015[17]. Thereby, only 11 seats are open for booking but more

[16] Plan of the cabin of Twin Otter, AirCalin http://nc.aircalin.com/sites/default/files/Plan%20Twin%20otter%20DHC6%20-%2016%20pax.pdf
[17] Report on Wallis and Futuna of IEOM, p.70

passengers could travel depending on the loading of the aircraft and could reach between 12 to 14 passengers.

Using one average value of 13 passengers, the weekly schedule allows the transport of 130 passengers a week. Per the average value of passenger's transport weekly released in Table 3 Number of air passengers in 2014, it is not sufficient half of the year, requesting the running of 150 extra flights.

This is one overview of the actual situation, nevertheless, it is interesting to have a look in the past during the 90's. At this period, one ferry, the M/V Moana III was ensuring monthly the inter-island connection. Moreover, one DH-6 Twin Otter was also operating flights. The increased of the fleet to two DH-6 Twin Otter coincides with the withdraw of the ferry. The return trip transported monthly almost 100 passengers in average, then around 50 passengers in each direction. The number of passengers of the ferry is summarized in Table 4 providing the statistics for 1993 to 1997.

Table 4 Sea passengers of M/V MOANA III from 1993 to 1997

Year	**1993**	**1994**	**1995**	**1996**	**1997**	**Average**
Passenger for return trips WF	1371	1335	1327	1353	447*	
Number of trips a year	13	13	14	14	5*	
Passenger per return trip	105	103	98	97	90	99

** Remark: the vessel stop to ensure the return trips before the end of the year, it explains the low values compared to previous year.*

Source: SPC Study, p. 28-29

The existence of this trip shows the interest of a maritime connection in supplement of the aerial connection during this decade. Nevertheless, the evolution of the situation between now and twenty years ago does not allow to ensure the relevance of maritime inter-island nowadays. Indeed, some parameters change:

- The population of the territory decreases from 14.166 habitants in 1996 to 11.700 in 2015.

Table 5 Evolution of the population of the territory between 1996 to 2013

Population	1996	2013	Variation

Territory	14.166	12.197	-13.9%
Wallis	9.528	8.584	-9.9%
Futuna	4.638	3.613	-22.1%

Source: INSEE

- The aerial connection is now ensured by two DH-6 Twin Otter instead of one.
- Nowadays, the population from the age group of 20 to 40 years old decreased significantly, and this part of the population is assessed to be one using the most the transport system[18].

Finally, it is difficult to do anticipate the future amount of passengers. Especially the lack of information's and statistics about the territory request to careful about carrying capacity of a ferry.

Nevertheless, it is valuable to defend the creation of one maritime connection. Indeed, the process of the renewal of the wharf of Futuna starts under the scope of the 10th EDF Fund. At the same time, the airport of Futuna is still not able to operate bigger aircrafts, then the only solutions to transport more passengers is the increased of rotation. But airplanes need also to be replaced for newer one soon. Then, it could be the moment to change the transport system.

2.5.2 Expectation on freight

The maritime freight from Wallis to Futuna Islands considers two origins of cargo: the imported one and the inter-island cargo. The goods traffic by sea is summarized in Table 6.

Table 6 Imported containers on the Futuna Islands from 2010 to 2014

Containers	2010	2011	2012	2013	2014	Average
Imported	288	279	184	245	205	240
Inter-island shipping	351	341	293	298	275	312
Total	639	620	477	543	480	552

Remark: the statistics of the territory doesn't do a difference between the different kind of containers, then the appellation "containers" concern as TEU, FEU and refrigerated TEU.

Source: SPC Study (original source: Custom Services)

Nowadays, the situation presents two main disadvantages:

[18] In 2008 in metropolitan France, this population represents 43% of the users of aircrafts. (The mobility of French citizens issued by the Minister of the Ecology, Sustainable Development, Transports and Accommodation; p.154)

- Rotation every 21 days restricting the inter-island maritime exchange. It concerns especially fresh products produce in Futuna which can difficulty be sent to Wallis. In fact, that request to inhabitant from Futuna to keep stock and some exchange are problematic. For instance, to refill propane bottle in Wallis, the exchange of vehicles or equipment, the cultural and traditional exchanges.
- The requirement to unpack containers in Wallis before to deliver them to Futuna. It occurs one loss of time of the vessel in Mata-Utu harbor.

Nevertheless, a new ferry should be a complement of a container vessel. It would avoid a monopolistic situation and the dependence to only one vessel. Then, two actors would have to share this small market. Considering only the inter-island shipping containers, it represents 6 containers a week. The first goal of this new maritime connection is to add 100 containers to the inter-island shipping at the short term. Then, the average of imported containers towards Futuna would be about 8 a week.

3 REQUIREMENTS

The requirements for the vessel are based on the recommendations stated by the study of the South Pacific Committed hold in 2014. They are divided into three categories:

- Cargo requirements;
- Vessel requirements;
- Service requirements;

These requirements stated by the SPC are adapted per a study of literature and observations lead on the territory. In this section, the status of each requirement is discussed to provide finally the requirements which would be considered for the ferry.

They had been fixed after the tests of several designs of the general arrangement to provide a good solution for the considered parameters.

3.1 Cargo requirements

3.1.1 Considered cargo requirements

Table 7 Cargo requirements

Cargo recommendations issued by the SPC Study	**Status**
200 tons of goods including:	Cargo capacity of 8 TEU: 152 tons
• bulk goods, including refrigerated and frozen goods kept in cold storage facilities;	Yes
• dangerous goods – Class 2 (gases and oil products in packages);	Yes
• light-weight vehicles and public work equipment;	Yes
• live animals	Yes
Lifting equipment that can handle at least five tons in safe working load	No

3.1.2 Discussions about cargo requirements

To transport a different kind of cargo, the more usable and flexible system is to use containers. It should be only considered specific devices on the cargo deck or specific slots. Stowing devices for containers should be installed on the deck.

Concerning the refrigerated and frozen goods, the transport by refrigerated containers is possible. It requests only the installation of electrical supplies on the cargo deck once containers are equipped with the cooling unit. Estimating the vessel would not carry the important amount of this kind of cargo only one slot for a TEU container. The electrical consumption of one container could be estimated around 7 kWh[19] and should be considered in the electrical balance.

Dangerous goods which can be transported are restricted, it is mainly diesel, gasoline, and butane. They can be transported in containers and storage information's and safety measures are available on Safety Data Sheets for those products. The recommendations for storage and fire fighting for these cargoes are summarized in the table below.

Table 8 Flammable products transported on board

Cargo	IMDG Class	Storage	Fire fighting
Gas oil[20]	3	Store in a well-ventilated place. Keep cool. Keep away from fire sparks and heated surfaces. No smoking.	dry chemical, carbon dioxide (CO2), water spray or firefighting foam
Gasoline[21]	3	Store in a well-ventilated place. Keep cool. Keep away from fire sparks and heated surfaces. No smoking.	dry chemical, carbon dioxide (CO2), water spray or firefighting foam
Butane[22]	2.1	Store in well-ventilated. Protect from sunlight. Keep away from the fire, sparks, and heated surfaces. No smoking	dry chemical, carbon dioxide (CO2), water spray or firefighting foam

A fixed firefighting equipment should be provided on the cargo deck. It could be one installation of dry chemical, water spray or firefighting. whether containers are stored on the deck carbon dioxide is not usable.

[19] Guidelines for the Carriage of Refrigerated Containers on Board Ships, DNV-GL, Edition 2003, page A-2 http://rules.dnvgl.com/docs/pdf/gl/maritimerules/gl_i-1-19_e.pdf
[20] Safety Data Sheet of Gasoline, TESORO, https://tsocorpsite.files.wordpress.com/2015/07/gas-oil-virgin.pdf
[21] Safety Data Sheet of Gasoline, TESORO, https://tsocorpsite.files.wordpress.com/2015/07/gasoline-unleaded.pdf
[22] https://tsocorpsite.files.wordpress.com/2014/08/butane.pdf

Vehicles and public work equipment's could be transported inside containers to protect them during the journey but it is not mandatory. In this case, securing devices for transport of this cargo should be available on board.

Live animals could also be transported in dedicated containers. On the territory, the main animals raised in farms are pigs, thus recommendations of the Council of Europe for the transport of this animal by sea would be considered[23]. The containers transporting pigs should be secured as necessary, so they cannot be displaced by the motion of the vessel or the effects of the wind and sea. The stocking density for pigs weighting about 100kg should be around 200kg/m² for reasons of animal welfare and meat quality. Pigs don't have to be fed and watered for journey inferior at 24 hours. The livestock container should be provided with a bedding material for the journey. One safe access to the container should be always provided. Per these recommendations, livestock containers would be set on the aft of the cargo area.

The lifting equipment is not considered necessary. On both islands, gears are available and they would be used for the loading and unloading of cargo. The reduction of equipment increased the reliability of the vessel and decrease the cost of construction and the cost of maintenance.

3.2 Vessel requirements

3.2.1 Considered vessel requirements

Table 9 Vessel requirements

Vessel recommendations issued by SPC study	**Considered vessel requirements**
Stern landing vessel	Design inspired of Offshore Supply Vessel, without a ramp. Cargo deck on the aft and accommodation in the front part with higher passenger deck
Improved head-sea keep capability due to a sharper, longer bow, substantially increasing speed	Sea Axe Design Concept/LEADGE Concept
Improved visibility as the wide ramp is located at the stern and allows the handling of wide loads;	Not considered, but specific attention to the visibility.

[23] Recommendation No. R(88)15 of the Committee of Ministers to Member States on the Transport of Pigs. https://rm.coe.int/CoERMPublicCommonSearchServices/DisplayDCTMContent?documentId=09000016804bda11

improved crew comfort and reduced fatigue as accommodation is located in the bow, away from the engine room;	Accommodation located in the front part, assessment of the motion in head wave condition.
Improved power available when de-beaching with the forward propellers working efficiently;	Twin screw propellers combined with high power engine.
improved stability due to a higher profile GZ curve, improved freeboard and higher deck-edge immersion angle resulting in improved deadweight capacity;	Freeboard height of 1.0 meter
improved block coefficient and stability;	Block coefficient around 0.57
Length over all between 50 and 60 meters;	Length overall of 40 meters

3.2.2 Discussion about vessel requirements

A stern landing vessel could be a good solution for a ferry berthing in Mata-Utu harbour. Nevertheless, such kind of berthing could be problematic for the harbour of Leava. As stated in the sub-subsection 2.2.3 Harbours of the territory, the vessel could be hampered by the heavy swell. Then, the Mediterranean mooring could be problematic, thus a classical mooring alongside the berth would be the retained solution.

Thereby, the stern ramp is not relevant anymore. Thus, for this size of vessel two solutions are possible: a side ramp or no ramp at all. In fact, the principle of the ramp is useful, but it requests a cargo deck located around 3 meters above the waterline. It could lead to stability problem if all the cargo is loaded on the deck. Moreover, a ramp requests maintenance and structure adaptation. Then, the building and operational running cost of the vessel could rise. Thus, the solution without a ramp is preferred. Gears are available in the territory for the loading and unloading of the cargo. Nevertheless, the passenger deck would be higher than the cargo deck and would allow the use of a simple gangway. Then, the design would be inspired of Offshore Supply Vessels.

Concerning the hull design, it is retained the idea of one hull improving the head-sea keeping capability. To achieve it, the hull design is inspiring from the Sea Axe Hull Design developed by Damen. They provide good seakeeping ability and allow to restrict the length of the vessel.

The principle of the accommodation in the front part of the vessel requests the location of all cargo in the aft deck. Then, if the vibrations of the engine room are avoided. The problem could be the motion of the vessel in adverse conditions. Nevertheless, the hull design emphasizes on the comfort for the passengers and the crew.

The propulsion of the vessel would be twin screw with fixed pitch propellers. It allows a good manoeuvrability and a good reliability. Both aspects are primordial for this vessel. To improve the manoeuvrability in berthing and unberthing operations, one bow thruster is installed.

The choice to not install a ramp on board is done to not set cargo on high position to improve the stability the vessel. Nevertheless, the location of one open cargo deck lower restricts the freeboard. To keep one good stability and avoid immersion of the aft deck, the height of the freeboard is set at 1.2 meters.

Concerning the block coefficient, the value would be around the normal value of ferry, around 0.55. The profile bow is necessary to improve the seakeeping abilities. In spite of the front part, the midship coefficient would be high to permit one simpler construction and maintenance of the double bottom.

After several designs, it had been realized than the requirements could be achieved for a smaller length overall of 40 meters. This overall length is the limit to get an exemption for pilotage services and restriction to access harbour's territory during the night. This is a valuable advantage to have more flexibility in the schedule. Service requirements

3.3 Service requirements

3.3.1 Considered service requirements

Table 10 Service requirements

Service requirements from SPC study	**Considered service requirements**
Weekly service of at least three return trips between Wallis and Futuna;	2 Return trips a week
Passenger transport capacity of at least 30 people;	Carrying passenger's capacity of 41 people
Uninterrupted service – replacement vessel for all planned and unplanned stoppages of more than one week;	Not considered but she is designing for one high reliability to reduce maintenance.

Vessel with a certified "deep sea" hull and equipped for navigation to Samoa, Tonga, and Fiji;	Classification society rules applied for unrestricted navigation
Lifesaving equipment for passenger transport;	SOLAS requirements
Ship flying the flag of a State that has ratified and implemented the main international maritime safety and pollution prevention conventions;	The vessel is designed to be registered in the Wallis and Futuna register
Working conditions that comply, at the very least, with international labour standards;	Maritime Labour Convention is mandatory on board French flag vessel.
Training for French seafarers who reside in Wallis and Futuna;	The use of French register request to hire a minimum number of French seafarers
Equipped to comfortably accommodate passengers for one night at sea and to provide food services;	Two different classes provided on passenger deck to provide services depending of expectation of customers.
Capable of transporting at least 100 kg of goods per passenger	A storage place is designed for passengers.
Medical facilities for medical evacuations	One infirmary is provided easily accessible. It is also designed for disabled people.

3.3.2 Discussion about service recommendations

The passenger capacity of the reaches 41 passengers separated in 2 classes: economic and business. The purpose is to provide a cheaper solution than for the airplane for people who have financial constraints. The business class are mainly for workers who should come only for one or two days on the territory and would appreciate more comfort and the possibility to work during the journey. As the passenger capacity is increased, it would be considered in this study two return trips a week between Wallis and Futuna. Indeed, the needs for inter-island transport are low and the airplane connections would not be withdrawn.

The vessel would be equipped with a deep-sea hull. It is mandatory due to the fact it is impossible to build a vessel on the territory and has to go on a yearly basis in Suva (Fiji Islands) for a drydock inspection.

The study considers the vessel is registered in the Wallis and Futuna register. Then, she has to fulfil the obligations of the French law which applied to all French flag vessels.

The medical evacuation is possible on board, one infirmary would be set at the entrance of the accommodation to allow one easy access. Moreover, the sick bay, would permit to transport one disabled as requested by the French law. Thus, the room is be equipped with adapted sanitary.

3.4 Crew requirements

The overview of the requirements permits to consider the size of the crew to navigate safely and to provide the requested services. The estimation of crew members is estimated to 11 members: 5 officers and 6 ratings.

3.4.1 Operation of the vessel

One example of a weekly schedule is provided by the SPC study. It is based on two return trips a week and we will consider this one as a reference. This frequency provides a maximum weekly carrying transport capacity of 164 passengers and 300 tons of cargo. This a high capacity which should allow absorbing the expected growth of inter-island transport.

Table 11 Weekly schedule for 2 return trips a week

WEEKLY SCHEDULE - INTER-ISLAND SEA TRANSPORT					
Day	**Ports**	**Movements**	**Time**	**Time duration**	**Comments**
Monday	Wallis	Arrival	07:00	(14h)	Offload ship's cargo – allows Futunans to go to Wallis and come back on Tuesday evening or Friday evening
				34h	Ship maintenance *Bunkering*
Tuesday		Departure	17:00		Load ship's cargo during the day

				14h	Departure
Wednesday	Futuna	Arrival	07:00		Offload ship's cargo
				34h	Allows professionals to go to Futuna 2 days
					Ship maintenance
Thursday		Departure	17:00		Load ship's cargo during the day
				14h	Departure
Friday	Wallis	Arrival	07:00		Offload ship's cargo – allows Futunans to go to Wallis for a day or until Tuesday evening
				10h	*Bunkering* Load ship's cargo during the day
		Departure	17:00		Departure
				14h	
Saturday	Futuna	Arrival	07:00		Offload ship's cargo – allows Wallisians to go to Futuna for the week-end
				34h	
Sunday		Departure	17:00		Load ship's cargo during the day
				(14h)	Departure

As indicated in the table, such schedule set four stays at night on board a week. Per this, it is important to provide correct accommodation on board for seafarers.

3.4.2 Tasks of the crew

Per the service requirements and the schedule considered, the size of the crew could be defined according to the Principles of Minimum Safe Manning[24]. Per this resolution, the main task that the crew should be capable are:

- to maintain safe navigational, port, engineering and radio watch;
- moor and unmoor the ship safely;
- manage the safety function of the ship;
- perform operations, as appropriate, for the prevention of damage to the marine environment;

[24] IMO, Resolution A.1047(27), Principles of Minimum Safe Manning

- maintain the safety arrangements and the cleanliness of all accessible spaces to minimize the risk of fire;
- provide for medical care on board ship;
- ensure the safe carriage of cargo during transit;
- inspect and maintain, as appropriate the structural integrity of the ship;
- operate in accordance with the approved Ship's Security Plan

These requirements lead to consider a crew of 11 members consisted of 5 officers and 6 ratings. Three officers are issued from the deck department to ensure the navigation watch and two from engine department to ensure the engine watch.

Four members of the crew are issued from the catering department in order to provide the services to the passengers and also for the crew. Two extra ratings could be hired to assist officers in their duties.

The vessel would be continuously in operation, then it requires one crew of an adequate size which can handle the different watch to ensure the tasks and to be in accordance with the international regulations.

Table 12 Organisation of tasks on board for 11 crew members

Crew member	**Working hours**	**Tasks**
Captain	0400-0800 1600-2000	Navigation watch Arrival manoeuvre Preparation/Departure
1st Deck Officer	0000-0400 1200-1600	Navigation watch Loading of the cargo Maintenance
2nd Deck Officer	0800-1200 2000-2400	Navigation watch Unloading of the cargo Maintenance
Chief Engineer	0600-1400	Engine watch/maintenance Un manned engine
2nd Engineer Officer	1400-2200	Engine watch/maintenance Unmanned engine
Chief cook	1100-1400 1600-2100	

Assistant cook	0600-1100 1600-2200	
1st Steward	1500-0300	Cleaning Service to passengers and crew
2nd Steward	0300-1100	Cleaning Service to passengers and crew
Rating 1	0400-0800 1600-2000	Assisting officers
Rating 2	0800-1200 2000-2400	Assisting officers

4 PRINCIPAL DIMENSIONS

The requirements for the vessel are not common. In fact, it is common to transport cargo and passengers at the same time on board ferry but for much bigger dimensions. When ferries are of smaller size, usually the dedicated trip is also shorter. Nevertheless, in this situation, it lasts one night and requests adapted accommodation. Thereby, the principal dimensions are based on parametric design study based on the literature.

- Parametric design based on the literature
- A parent analysis of Offshore Vessel

The purpose of the first one was to set appropriated dimensions during the first step of the designs.

Then, the parent analysis allows getting one overview of the requirements for the weights on board due to more detailed informations.

4.1 Parametric design

The parametric design is done to get a good relationship between the main dimensions of the vessel. In fact, they have an important influence on the future characteristics of the vessel and the behaviour (seakeeping, stability…). This study was based on the book issued by SNAME, “Ship Design and Construction Vol.1”.

Table 13 Primary influence of hull dimensions
Source: ship design and construction, p 11-7

Parameter	**Primary influence of Dimensions**
Length	Resistance, capital cost, manoeuvrability, longitudinal strength, hull volume, seakeeping
Beam	Transverse stability, resistance, manoeuvrability, capital cost, hull volume
Depth	Hull volume, longitudinal strength, transverse stability, capital cost, freeboard
Draught	Displacement, freeboard, resistance, transverse stability

Even though it is obvious, the first rule to be observed for a vessel is the Archimedes principle ensuring the floatability.

$$P_A = L \times B \times T \times \rho \times C_B$$ [25]

In between all these dimensions, the main restriction is coming from the width. In fact, the beam overall of the vessel depends on of two aspects: the configuration of transport of passengers and of the freight. The ferry should transport containers, TEU and FEU, not so many solutions exist. The retained solution consists of two rows of two TEU with two tiers. Thus, that represents already a width of 5 meters. Moreover, some spaces should be available for access to the aft part of the vessel and it should be considered the side shell. Then, the overall beam was set to 8.4 meters.

Apart, the sea water density which is fixed. The others parameters could be set freely. Considering the waterline length, equal to the overall length, was set to 40 meters. Then, the draught is directly depending on the displacement of the vessel which was estimated around 470 tons. The minimal depth located on the cargo deck is related to the draught, because the freeboard was fixed in the requirements to 1.2 meters.

The block coefficient was set for the calculation in accordance with the literature, a value of 0.55 was set during the first step of the design. Its value reaches the last step of design iteration process, a value equals to 0.576.

The main dimensions are summarized in Table 14.

Table 14 Main dimensions of the vessel

Dimensions	**Values**	**Units**
Length	40	*m*
Beam Overall	8.4	*m*
Draught	2.4	*m*
Depth	3.6	*m*
Block coefficient	0.576	
Waterplane coefficient	0.877	

The setting of the main dimensions was set in accordance with three non-dimensional ratios:

[25] With P_A : Archimedes Force ; L : Length at the waterline ; B : Beam overall ; T : Draugth ; ρ: sea water density; C_B: block coefficient.

- Length to beam ratio;
- Beam to depth ratio;
- Draft to depth ratio;

4.1.1 Length/Beam ratio

The length to beam ratio has limited minimal value. A too small value would increase the resistance to advancement of the ship. Then, the ship requires one high propulsion plant compared to its displacement and speed. Moreover, this relation is also needed to ensure that the ship is directionally stable.

A small vessel as coasters, fishing vessels have a small L/B Ratio which is around 4 meters. Long vessels, usually have a value over 6 which can be even. For a vessel with a length from 30 to 130 meters, one av erage L/B ratio varies according to the Formula 1:

$$\frac{L}{B} = 4 + 0.025 \times (L - 30) \qquad [1]$$

Then, the provided design is 12% above the average value which means a lower expense for machinery and fuel. Moreover, the length of 40 meters doesn't state any restriction to operate in territorial harbours.

Table 15 Length over beam ratio

Dimensions	Values	Units
LOA	40	*m*
BOA	8.4	*m*
Average L/B	4.25	
Design L/B	4.76	
Difference	12%	

4.1.2 Beam/depth ratio

The vertical centre of gravity is a function of the depth and the metacentre location is a function of the beam. Then, the influence is direct on the stability by the consequences on the metacentric height, GM.

Vessels in excess compared to minimum stability requirements get a value of B/D ratio about 1.90. Moreover, three requirements of the vessel request high values of the ratio: high standards of stability; reductions in the main hull weight and in machinery weight and the carriage of deck cargo.

Table 16 Beam over depth ratio

Dimensions	Values	Units
Depth	3.6	*m*
BOA	8.4	*m*
Average B/D	1.90	
Design L/B	2.33	
Difference	23%	

4.1.3 The Depth/Length ratio

This ratio is in relation to "structural strength of the ship and especially about the strength of the ship and the deflection of the hull girder under the bending moments induced by waves". Thus, this ration should remain low. Values are going from 10 (a vessel built in high tensile steel) to 16 (tanker with longitudinal framing).

Table 17Depth over length ratio

Dimensions	Values	Units
Depth	3.6	*m*
Length	40	*m*
Average D/L	13	
Design D/L	11.1	
Difference	-15%	

4.2 Hull form

4.2.1 The concept

The vessel is designed for a speed of 15 knots for a length of 40 meters. Nevertheless, this speed is to ensure a service speed in all weather conditions of 11 knots. Thus, the vessel is operating in displacement mode for a medium Froude number value, $Fr = 0.29$.

Per the requirements, the bow of the vessel should be sharper and longer than a classical one. In the past years, new bow designs had been produced to improve the performance. Most emblematic one is the Axe-bow concept from DAMEN and the LEADGE concept[26]. They have in common a vertical stem, a deep forefoot of the hull reducing the risk of slamming and a sharp bow with a small half angle of entrance. This shape allows the vessel to pierce wave efficiently and then the pitching motion is reduced. The outcome is a significant reduction of the resistance due to waves approximating 20 to 30% compared to the conventional hull.

Both designed had been adopted by high speed vessel of the navy.

Several manufacturers were done on this kind of wave piercing bow. The design lead by the manufacturer as Damen target mainly the fast monohull vessel as a patrol vessel. Nevertheless, it exists also the LEADGE concept issue by … which concerns low speed vessel as a tanker.

Therefore, the hull design would be inspired by this type of hull. Indeed, it provides

- A reduction of the resistance, consequently a decrease of the main engine size;
- Good seakeeping ability in wave conditions which will improve the comfort on board.

Nevertheless, the midship sections are more classical with a midship coefficient. That provides a good transversal stability but also a good solution to constrain the draught. Moreover, from a production point of view, it will be more convenient.

4.2.2 Hull lines

An overview of the hull lines is provided with the Figure 7. The spacing of the lines is:

- Waterplane line spacing: 0.30 m
- Buttock line spacing: 0.50 m
- Station line spacing: 2.00 m

[26] Development of bow Shape to reduce the added resistance due to waves and verification on full scale measurements, Hirota et Al, 2005

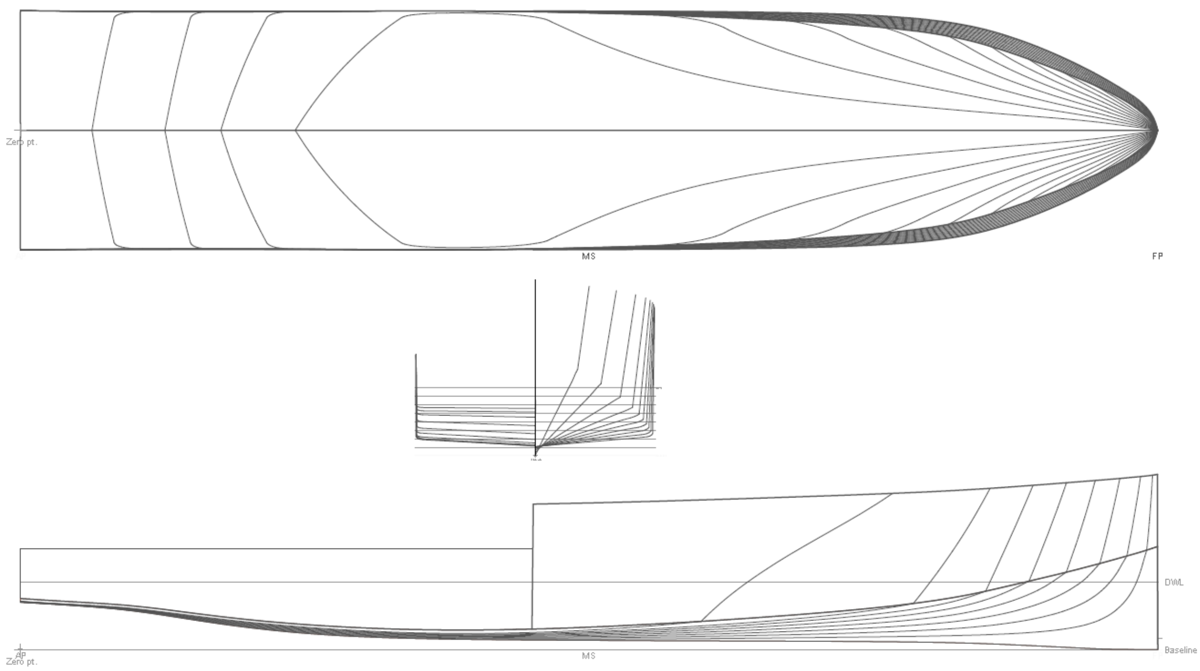


Figure 7 Hull lines

More detailed hull lines are provided in **Annex.**

5 GENERAL ARRANGEMENT

The challenge of this vessel is to deal with a wide variety and quantity of cargo and with few dozens of passengers, who move for different reasons. For the cargo area, the main concept is the modularity. The vessel should not reject any kind of cargo and the stability should not be endangered if few or only 1 TEU is carried. Passengers are another challenge. Some of them are looking for the cheapest price than the airplane fees, for them, the time of the journey is not a problem and the comfort is not important. The second category looks for an alternative to the airplane. The vessel could not be faster but it could be more comfortable. Therefore, more comfortable arrangements should be provided to this second category of traveller to provide them a nice travelling experience.

The vessel is also designed for seafarers. the communication between the different area is ensured vertically by a central stair going from the engine deck to the bridge deck. And the second axe is the corridor of the bridge deck.

5.1 Main area

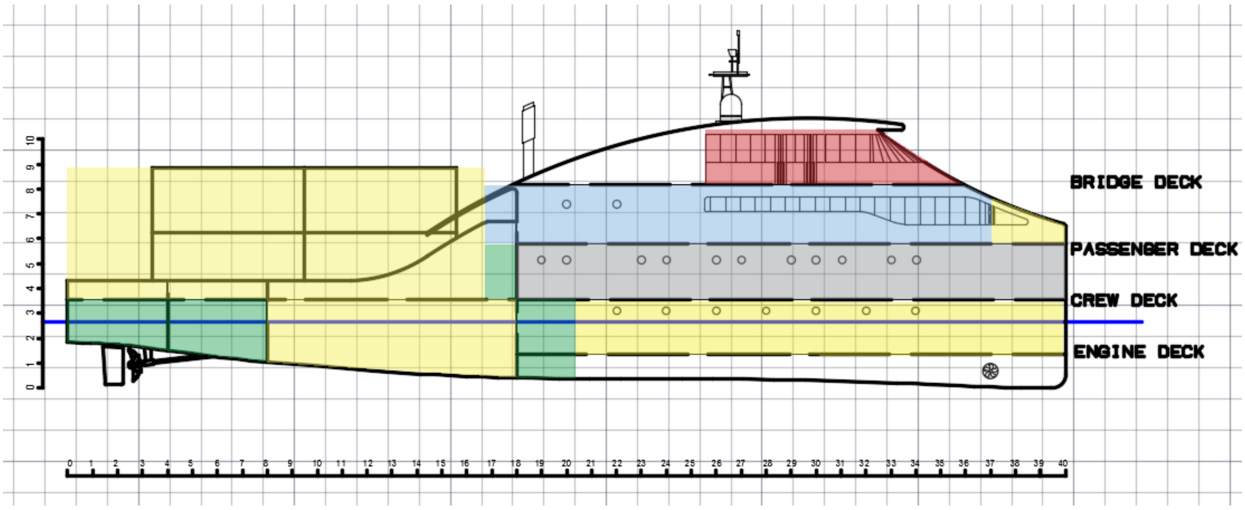


Figure 8 Representation of the main areas

The vessel is composed of 4 levels of deck represented in dash line in the figure Figure 8:

- Bridge deck
- Passenger deck
- Cargo/Crew deck

- Engine deck

They are divided in to 5 areas represent in different colours in Figure 8:

- The passenger area (blue)
- The working area (yellow)
- The crew accommodation area (grey)
- The navigation bridge (red)
- The storage area and tanks (green)
- The mooring area

The detailed information about the arrangement is provided in the next pages. Several key points would be highlighted for each part: the design constraints, the classification and regulations requirements and general explanation.

Description of the area is done deck by deck starting from the bridge towards the engine deck.

5.2 Bridge deck

The bridge deck is mainly constituted of the bridge which provides all the equipment to ensure a safe and efficient navigation. Then, the most important are to provide one good visibility to the officer in charge of the navigation. The purpose is to provide a view as close as possible of 360°. Furthermore, it is also important to consider the visibility over the side shell for the mooring and unmooring manoeuvre. That’s why a wing is provided on each side. to ensure a good visibility.

The legislation requirements for this area are mainly related to the navigation and safety equipments. They are coming from international convention and implemented on board French registers by the Maritime Safety Law of 1987. Most equipment’s of navigation should be in twice exemplars to ensure the safety of navigation in case of failure of one of them. Then, the bridge is equipped with the following aid to navigations: Electronic Chart Display System (ECDIS), Radars, GPS, Gyrocompass, Automatic Identification System (AIS), Communication device (VHF, Navtex, MF), Echo sounder, Voyage Data Recorder. For more convenience, the equipment’s are installed in a navigation desk including the propulsion command, monitoring screens and emergency information.

One water closet with a sink is also installed on the bridge as requested by the regulation[27].

All the antennas requested by the electronical equipment's are located above the bridge, on the monkey bridge. The redundancy of the equipments is also necessary for antennae.

The emergency power system is also installed on the bridge. The bank of battery is in the front part of the bridge deck in a non-accessible area. The emergency panel is installed on the bridge, therefore in the case of problem in the engine room, the supply from energy could be supplied from the further place from this area.

Outside of the bridge is installed two life rafts, each with a capacity of 28 passengers. It is also located the exhaust and intake pipe for engines and ventilations in the aft part. Vents of tans are also located on this deck.

Above the bridge deck is set the navigations equipped with the navigation lights and all antennas requested for navigations equipment.

5.3 Passenger deck

The passenger deck is located at 5.8m above the baseline. The height between deck is of 2.4 meters to provide a sensation of space to passengers. On this deck, the effecting breadth subtracted from the scantling is 8.1 meters. Over the surface of 160 m² of the deck, 130 m² is dedicated to the accommodation for passengers. They are divided into 2 main parts: the economical and the business class. The connection with others deck is ensured by a stair located in the middle of the accommodation. Its access is restricted to the crew.

To decrease the loss of spaces on the passenger deck, the large luggage's of passengers are not stored in the superstructure but in locker situated below the access way to the vessel.

5.3.1 Business class

The business class is in the front part equipped with large windows offering a panoramic view of the sea and at the stars during the night without light pollution. Moreover, the location in the front part avoids circulation of passengers from the others class, even during boarding or unboarding.

[27] Article 215.12 paragraph 2, Sanitary Installation, Order of 23th November 1987 on the safety of ships.

The business class is in the front part of the accommodation and divided into 2 parts: the salon and the lounge. The salon measures 26m² and is equipped with 14 seats in the sailing direction offering a panoramic view of the front part of the vessel. The seats provide a good comfort for a night trip and respect high standards compared to the airplane: inclinable seat, the effective width of 600 mm and a spacing for legs of 500 mm. The access to the sea is provided by a corridor of 1200 mm, allowing one easy access to all the seats.

The lounge for the business passengers has located few meters aft. A direct service is provided by a steward at the bar equipped with 4 stools. A table is also set to allow people to hold a discussion in good condition.

Dedicated bathrooms are also provided to the passengers: one for women and another one for men. They are equipped with shower, sink, and water-closet. Showers on board are justified by the climate of the territory, the relatively high temperature and high level of humidity.

In total, the business class occupies 60 m², then 4.3m² are dedicated per passenger.

5.3.2 Economical class

The economical class is located on the aft the accommodation. A salon is equipped with 27 seats. Their dimensions are a bit smaller than for business one but remain at one equivalent level of comfort than the economical seat of long haul airplane. In detailed, the effective width is 460mm for a leg spacing of 350 mm.

The economical lounge has 6 stools for passengers and a self-vending machine.

Two bathrooms are also dedicated to the economical passengers and they are also divided between women and men. They are provided with the same equipment: shower, sink, and water-closet.

The total area for economical passenger reaches 43 m² representing one area of 1.6m² per passenger.

5.3.3 Infirmary

The request to ensure medical evacuation from Futuna Islands ask for some specific arrangement if a stretcher should be transported. The width of the external door and of the infirmary is increased to 1200mm to allow them to pass. The room is equipped with one adapted bathroom per the French regulation on the matter.

Inside the infirmary, a small room of 3.5m² is dedicated to the material dedicated to the infirmary. It is separated from the room so it can be locked.

Moreover, this specific accommodation provides one advantage: to provide one area available for a disabled passenger. Indeed, the law requests the possibility to transport one disabled passenger. It requests to consider specific access with appropriate width but also dedicated to sanitary.

5.3.4 Forecastle

The forecastle is strictly restricted to the crew. It is only used for the mooring, unmooring and anchoring operations. The necessary equipment's for these operations are considered carefully due to the small available area. One access to the chain locker located in front of the bulkhead is provided.

5.4 The crew and cargo deck

This deck is divided into the aft part withstanding the deck cargo and the front part which is the accommodation for the crew.

5.4.1 Cargo deck

The cargo deck measures 123m² and the central area is used to transport containers whom the main characteristics are provided for remembering in Table 18.

Table 18 Main dimensions of containers

Dimensions	**Units**	**TEU**	**FEU**
Maximal exterior dimensions			
Length	*mm*	6058	12192
Height	*mm*	2591	2591
Beam	*mm*	2438	2438
Exterior maximal	*m²*	14.77	29.72
Payload[28]	*kg*	28,300	28,870
Tare weight	*kg*	2,180	3,630

[28] Data of payload and tare weight of container are issued from the Maersk website. These characteristics vary depending of the manufacturer or shipping companies. Nevertheless, the order of magnitude is similar and Maersk is actually the leader on the container market, then it is set as the reference.

The deck is surrounded by one extension of the side shell 800 mm above the deck.

At the aft, the mooring equipment is installed with two capstans located on the centreline and bollards are on the side. Details are provided in the part related to the mooring.

5.4.2 Crew accommodation.

Three different kinds of cabins is provided on board depending on the ranking of the seafarer. They are designed per the fact they will remain on board several days and would not be host ashore. By the law, there are some minimal equipments with minimal dimensions: bed, shelf, sink.

First, the cabins of the Captain and the Chief Engineer. They measured around 14 square meters and are composed by a room including one desk and one private bathroom. The office part is considered important to provide to work to these officers to fulfil their management tasks. They are also necessary for the storage of all the documents transported on board.

Secondly, there are three officer's rooms, which measure around 9m². They are equipped with a single bed, a private bathroom and the minimum equipments.

The third one, are the cabins for the ratings. They are a double room equipped with bunk bed measuring 6m². They are equipped with all the minimum equipments. The 6 ratings share a bathroom located in the front part of the deck.

The mess for all the crew is in the front part of the deck. It is the same for all the crew but two tables are provided: one for officer and another one for ratings. Some extra equipments could be set in this room for the free time of the crew according to the need of the crew.

Considering the crew is living on board for one week, one cook should be able to provide some good and varied dishes. Moreover, food could also be cooked for passengers. Then, the galley should be equipped to cook at least for 30 people and it could not be only a place to warm dishes. Without entering the details of the equipment, it is considered than 13m² would permit to fulfil this task efficiently.

Moreover, one food lift is set in the galley. It connects directly the galley to the business lounge on the top. And it connects also to the food store located on the lowest deck.

5.5 Engine deck

5.5.1 Steering gear compartment

The compartment is equipped with a steering gear pump acting on both rudders. In the case of failure, one auxiliary steering gear pump is available to keep the control of the vessel. Nevertheless, this one has smaller power, then the rudder angle will be restricted.

Access to this space is provided by one hatch cover in the aft of the cargo deck.

5.5.2 Storing compartment

The front part of the engine deck is separated into different storage rooms (for food and spare parts) and a workshop. The large room dedicated to the maintenance is due to the high level of reliability requested by the vessel. Indeed, no vessels are available at proximity to rescue the crew and the vessel in case of emergency, then the problems should be solved by the crew. Nevertheless, they need enough material and spare parts to fix the problem in the case of emergency.

5.5.3 Engine room

Details are provided in the Section 11

5.5.4 Tank compartments

Details are provided in the Section 13

6 STRUCTURE DEFINITION

The definition of the structure of the vessel has two main goals:

- Ensure the seaworthiness of the vessel which is ensured by the compliance with the rules of the classification society, Bureau Veritas.
- Define (and decrease) the main component of the lightship mass[29].

6.1 Parametric estimation of the weight of the structure

To get one order of magnitude of the weight of the structure one estimation of the weight is achieved using a method released by Watson and Gilfillan[30]. The first step considered to calculate the hull numeral with the Formula [2].

$$E = L\,(B+T) + 0{,}85\,\sum l_1 h_1 + \sum l_2 h_2 \qquad [2]$$

Where:

- l_1 and h_1: length and height of full width erections [m]
- l_2 and h_2: length and height of the superstructure [m]

According to the design of the vessel, the value obtained for the numerical hull number is:

$$E = 789$$

First, the steel weight of the ship is calculated considering reference ship with a block coefficient equals to 0,7 using the Formula [3]: To use it, a low value of the value K for ferries is selected.

$$W_{s7} = K.E^{1,36} \qquad [3]$$

$$W_{s7} = 0{,}024.789^{1,36} = 209.1\ tons$$

Secondly, the steel weight is calculated for the block coefficient of the ferry which is lower with the Formula [4]:

$$W_s = W_{s7}.[1 + 0{,}5.(C_{B1} - 0{,}7)] \qquad [4]$$

[29] The lightship mass is the weight of the ship in metric tons without cargo, passengers, crew and consumables (MDO, LO, FW,…)

[30] 'Ship Design and Construction' edited by Thomas Lab, SNAME, 2003

Where:

- $C_{B1} = C_B + (1 - C_B).\left(\frac{0,8D-T}{3T}\right) = 0.598$

Finally, an estimated value of the steel weight for the vessel is provided:

$$W_s = 198.4\ tons$$

Nevertheless, this value should be considered as a maximum value. The study leads by Watson and Gilfillan is based on old design and bigger vessel. Compared to design of nowadays, this formula provides value until 10% higher.

6.2 Classification society rules selection

The rules of the classification society Bureau Veritas are followed for the design of the vessel. Then, the rules which applied to her should be selected considering the characteristics of the ship:

- Passenger capacity over 36 passengers;
- Cargo capacity of 154 tons;
- Length overall of 40 metres;
- Gross Tonnage inferior at 500;
- Mild steel construction material;
- International voyage;

Per these parameters, the vessel would fulfil the requirements of the rules for non-cargo vessel of less than 90 meters[31]. Some requirements of the rules for Steel ships should also be fulfilled due to the type of the ship and her service notation: ‘unrestricted navigation’. This notation is assigned to ship operating in any area at any period of the year.

Table 19 Rules applicable to the vessel

Item	**Rules applicable in this situation**
Ship arrangement	NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non-Cargo Ships less than 90 m.

[31] Rules for ships with less than 500 GT but they do not apply to ship with the service notation: unrestricted navigation.

Hull	NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non-Cargo Ships less than 90 m.
Stability	Steel Ship: Part B + Ch 11, Sec 2
Machinery and cargo systems	Steel Ship: Part C + Ch 11, Sec 4
Electrical installations	Steel Ship: Part C + Ch11, Sec 5
Automation	Steel Ship: Part C
Fire protection, detection and extinction	Steel Ship: Part C

The selected material is then steel, the minimum mechanical properties are the following:

Table 20 Mechanicql properties of hull steels

Source: Reproduction BV rules refer to NR216 Materials and Welding, Ch 2, Sec 1, [2]

Steel grades t<100mm	Minimum yield stress R_{eH}, in N/mm²	Ultimate minimum tensile strength R_m in N/mm²
A-B-D-E	235	400-520

The material factor, k, is 1.00. That provide a minimum yield stress for scantling criteria of hull structure equals to $Ry = 235/k = 235\ N/mm^2$

6.3 Compartment arrangement

Watertight bulkheads

The vessel is equipped with one engine room located aft of amidships. This is the only space on board considered as machinery space of category A. Then, the vessel must be equipped with 3 transverse watertight bulkheads which should ensure the water tightness until the Cargo/Crew deck. They are distributed like this:

- One collision bulkhead
- One after peak bulkhead[32]
- A bulkhead forward of the machinery space[33]

[32] Due to the service notation passenger ship
[33] The engine is located at the aft of the ship

An additional bulkhead is installed at the aft of the engine space, in front of the ballast tank compartments. Nevertheless, this one does not have to be watertight. Moreover, access through this bulkhead would be provided to ballast tanks.

The location of the collision bulkhead is set in accordance with the rules which states the following range:

- 5% of L_{LL} < collision bulkhead < 8% of L_{LL} or 5% of L_{LL} + 3m
- The location of the collision bulkhead is set at 2 m.

Double bottom

A double bottom is fitted from the collision bulkhead to the bulkhead forward of the engine room. The height of it is set to have a minimal height superior at 800 mm in the central part. Access to the inner bottom is provided by manholes of 400*400 mm.

Access to steering gear compartment

Per the rules, the access to the steering gear compartment is provided by 2 manholes installed on the deck on each side of the deck.

6.4 Scantling definition

6.4.1 Working method

The vessel does not have fix requirements; therefore, the main dimensions were not fixed. For this reason, a parametric spreadsheet is used to run calculations in functions of the main dimensions of the vessel. As the weight of the steel structure represents more than half of the lightship it is necessary to avoid overestimation in the scantlings definition. Moreover, the presence of the superstructure leads to a logical trim by the head. It is compensated by cargo or ballast, nevertheless, the lighter the structure is, smaller will be the ballast capacity.

As the superstructure represents more than 40% of the length, it could be considered as part of the structure.

To achieve the weight of the scantling the following procedure is followed:

- Definition of the elementary panel;
- Definition of all design loads in function of their locations and the kind of elements it is applied for;
- Calculation of the thickness of the platings;

- Definition of four different dimensions for each type of scantling;
- Definition of the section modulus and shear area in accordance within the range of the thickness of the plating;
- Selection of the highest design load for each element and then selection of the lighter stiffeners fulfilling the requirements.

6.4.2 Definition of the elementary plate panel

- μ: aspect ratio coefficient of the elementary plate panel

$$\mu = 1{,}21\sqrt{1 + 0{,}33(\frac{s}{l})^2} - 0{,}69\left(\frac{s}{l}\right) \leq 1$$

Where:

- s: length in meter of the shorter side of the plate panel
- l: length in m of the longer side of the plate panel

The value of the elementary plate panel was defined as below:

- s = 600 mm
- l = 2000m

Considering the length of the vessel a longitudinal construction system is selected and therefore the spacing between frames would reach 2 metres and the spacing of stiffeners would be equalled to 0,6 metres.

The primary longitudinal stiffeners systems is composed of two different systems;

- From the aft to the front engine bulkhead: one central girder and two side girders at 2.4 metres from the central girder.
- From the front engine bulkhead to the collision bulkhead: the presence of the double bottom request another system, the main girder is split into two plating from the height of the double bottom to create a trunk and the side girders are plating too.

6.4.3 Design load

First the design load issued by local external pressures are calculated. They are composed by the sea pressures and the dynamic load is divided into two components: the side shell impacts and the bottom impact pressure. They are defined in relation of the ship relative motion in function of the localisation along the length. Therefore, the pressure applied on elements varies in function of the localisation. Even more because the hull has a deep forefoot stem, then the sea pressure on the bottom hull is much higher than in the aft part were the hull has a low depth to set the propellers. Therefore, the calculations of design loads are done for the following longitudinal position:

- From aft part to 0,25L_{WL};
- From 0,25L_{WL} to 0,70L_{WL}
- From 0,70L_{WL} to 0,85L_{WL}
- From 0,85L_{WL} to fore part

As the sea pressure is varying along depth, the design pressure along the side shell is also assessed in function of the depth. The reference for this one is the double bottom located at 1.3 metres above the baseline.

From the sea pressure calculations, it is also calculated the design loads applied to exposed deck in function of their vertical and longitudinal locations.

Above the waterlines, the dynamic pressure issued by waves have their main influences on side shells. Their values decreasing per the increased of the vertical location; .

- From the waterline to one meter above;
- From one meter above the waterline to 3 metres above;
- Above;

Internal loads are defined by compartments in function of the type of the deck. There values vary also in function of the longitudinal position. The cargo load is done in accordance with carrying capacity defined.

Values of calculated design loads are provided in Annex 1.

6.4.4 Definition of the dimensions of the scantling

By iterations four dimensions of scantling are defined for the following items:

- Primary longitudinal stiffeners;
- Secondary longitudinal stiffeners;
- Vertical frames;
- Frames

Detailed characteristics are provided in Annex 2.

6.4.5 Selection of the scantling

The defined scantlings are provided with the defined plating's in Annex 3.

6.5 Midship section

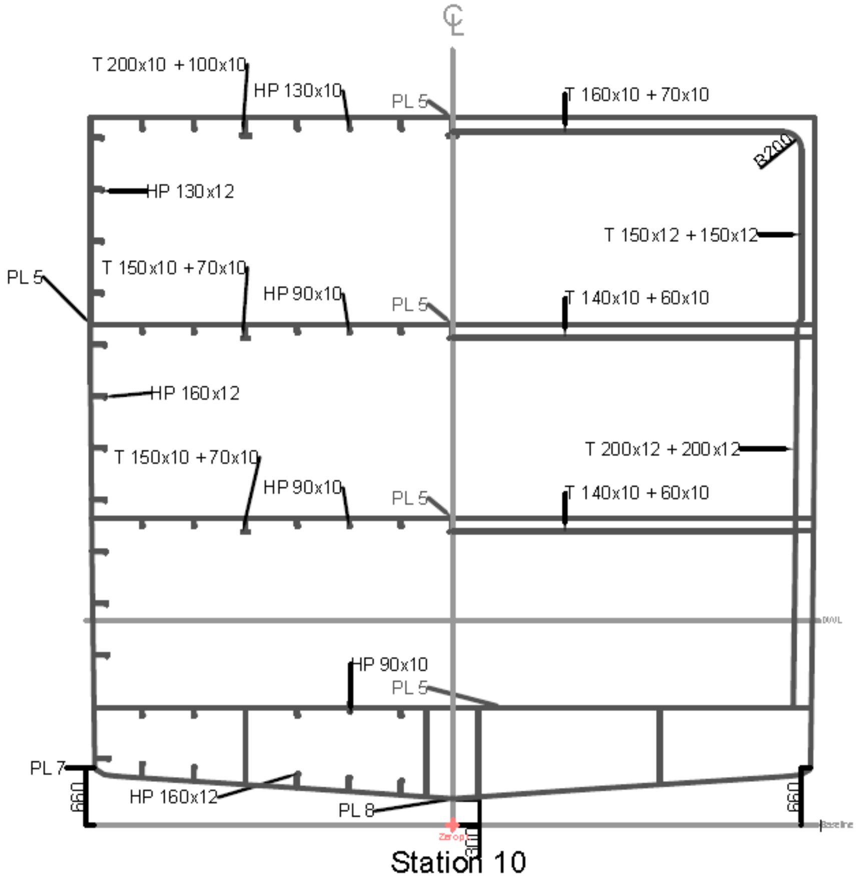


Figure 9 Midship section

6.6 Weight of the structure

The weight of the structure is defined by the definition of the area of each station considering the plating and each scantling elements. Then the multiplication by the distance between frames and the density of mild steel give the weight of each station with a good accuracy.

Table 21 Lightship weight of the vessel

Station	Weights	LCG	TCG	VCG	Long.moment	Trans. Moment	Vert.moment
	tons	*m*	*m*	*m*	*tons.m*	*tons.m*	*tons.m*
Station 0	5.43	0.63	0.00	3.23	3.45E+00	0.00E+00	1.76E+01

Station 1	4.03	2.92	0.00	2.76	1.18E+01	0.00E+00	1.11E+01
Station 2	7.08	4.56	0.00	2.57	3.22E+01	0.00E+00	1.82E+01
Station 3	5.87	6.85	0.00	2.58	4.02E+01	0.00E+00	1.51E+01
Station 4	6.08	8.85	0.00	2.47	5.38E+01	0.00E+00	1.50E+01
Station 5	6.21	10.84	0.00	2.35	6.73E+01	0.00E+00	1.46E+01
Station 6	6.46	12.84	0.00	2.17	8.30E+01	0.00E+00	1.40E+01
Station 7	6.24	14.83	0.00	2.08	9.25E+01	0.00E+00	1.30E+01
Station 8	6.23	16.83	0.00	2.08	1.05E+02	0.00E+00	1.30E+01
Station 9	15.62	18.53	0.00	3.72	2.90E+02	0.00E+00	5.81E+01
Station 10	9.73	20.85	0.00	3.60	2.03E+02	0.00E+00	3.50E+01
Station 11	9.42	22.84	0.00	3.79	2.15E+02	0.00E+00	3.57E+01
Station 12	9.31	24.85	0.00	3.88	2.31E+02	0.00E+00	3.61E+01
Station 13	10.79	26.85	0.00	4.84	2.90E+02	0.00E+00	5.22E+01
Station 14	11.77	28.85	0.00	4.67	3.40E+02	0.00E+00	5.50E+01
Station 15	10.98	30.87	0.00	4.87	3.39E+02	0.00E+00	5.35E+01
Station 16	10.44	32.87	0.00	4.96	3.43E+02	0.00E+00	5.18E+01
Station 17	7.91	34.86	0.00	4.16	2.76E+02	0.00E+00	3.29E+01
Station 18	6.12	36.86	0.00	4.32	2.25E+02	0.00E+00	2.64E+01
Station 19	5.60	38.61	0.00	3.09	2.16E+02	0.00E+00	1.73E+01
Subtotal	1.61E+02	21.43	0.00	3.63	3.46E+03	0.00E+00	5.86E+02
Welding 5%	8.07E+00	21.43	0.00	3.63	1.73E+02	0.00E+00	2.93E+01
Pipes/ Reinforcements… 7%	1.13E+01	21.43	0.00	3.63	2.42E+02	0.00E+00	4.10E+01
Total structure	**180.68**	**21.428**	**0.000**	**3.631**	**3.87E+03**	**0.00E+00**	**6.56E+02**

The weight obtained is multiplied by two coefficients:

- 5% due to the added mass during the welding process
- 7% for the local reinforcements and the pipes.

The detailed calculation is provided in Annex 4.

7 LIGHTSHIP WEIGHT ESTIMATION

The lightship weight is the mass of the vessel without cargo, crew, passengers and consumables. Therefore, a precise estimation of elements present on board is lead. Detailed results are provided in Annex 5.

7.1 Forecastle Deck

The deck host mainly all the weight for anchoring and mooring which are not defined yet.

Anchor and chains

The requirements for anchoring equipment's are defined using the classification society rules. The main principle is to define the dynamic force acting on the ship when the speed of the wind reaches 50 knots and the current 5 knots. After calculations, the value of the dynamic force, F_{EN} is equal to 64.5 kN. In accordance with these values and to avoid excessive weight in the front part, High Holding Power anchors are selected and steel of quality Q2. Furthermore, the vessel is equipped with three anchors, one is in spare.

Table 22 Selection of anchors and chains

The retained solution		
3 HHP anchors	1936	kg
2 Q2 chain cable	2403	kg
Total minimum rules	4339	kg
Total provided (5% SM)	4556.29206	kg

Windlass

Due to the arrangement of the fore peak and the restricted available area, two windlass would be provided. Moreover, the top part should be able to tight the hawsers.

The pulling capacity of the windlass should be able to withstand 1.2 times the dynamic force $F_{EN,}$ which is equal to 77.4 kN. Then it requests a pulling capacity equivalent to 7.9 tons.

Mooring ropes

According to the rules for Steel ships, the vessel has to equipped with one towline and four mooring lines. To provide one easy way to manipulate the hawsers they would be in polypropylene

- **One wire towline:** length 180 meters (minimum length) with a breaking load of 207 kN
- **4 polypropylene mooring lines:** length of 140 meters (minimum) with a breaking loads of minimum 101,4 kN and minimum diameter of 20 mm.

It is provided on board the following where the data are issued by manufacturers. One extra hawser would be stored in technical local.

- **5 polypropylene hawsers[34]:** 140m, BL 121,64kN, diameter 26 mm, weight: 43 kilos
- **One wire towline[35]:** 180m, BL 208kN, 250kg, diameter 20mm

7.2 Weight equipment's

A summary of all the weights in functions of the compartments are provided in the Table 23. The detailed calculation are in Annex 6.

Table 23 Weight equipment's

Compartment	Total weight	LCG	TCG	VCG	Long.Moment	Trans.Moment	Vert.Moment
	kg	*m*	*m*	*m*	*kg.m*	*kg.m*	*kg.m*
CARGO DECK	2962	6.43	-0.02	3.98	1.90E+04	-7.00E+01	1.18E+04
INTERIOR PASSENGER DECK	6947	27.59	0.01	6.75	1.92E+05	1.01E+02	4.69E+04
FORECASTLE DECK	8795.2	40.29	0.00	4.17	3.54E+05	0.00E+00	3.67E+04
CREW DECK	6947	27.59	0.01	6.75	1.92E+05	1.01E+02	4.69E+04
ENGINE DECK	46910	16.72	0.00	1.47	7.84E+05	-1.72E+02	6.88E+04
BRIDGE DECK	3786.9	28.90	0.00	9.92	1.09E+05	0.00E+00	3.76E+04
PAINT	1450	21.91	0.00	3.66	3.18E+04	0.00E+00	5.31E+03
TOTAL	**77798.0902**	**21.62**	**0.00**	**3.26**	**1.68E+06**	**-3.93E+01**	**2.54E+05**
TOTAL [tons]	**77.7980902**	**21.62**	**0.00**	**3.26**	**1.68E+03**	**-3.93E-02**	**2.54E+02**

7.3 Lightship weight

Station	Weights	LCG	TCG	VCG	Long.moment	Trans. Moment	Vert.moment
	tons	m	m	m	tons.m	tons.m	tons.m
Structure	180.68				3.87E+03	0.00E+00	6.56E+02
Equipment	77.7980902				1.68E+03	-3.93E-02	2.54E+02
Lightship	**258.48**	**21.49**	**0.00**	**3.52**	**5.55E+03**	**-3.93E-02**	**9.10E+02**

[34] Survitec Nutech® 3, 4 & 8 Strand, p.4 http://www.survitecgroup.com/downloads/survitec_mooring_ropes_brochure.pdf

[35] Galvanised Wire Ropes for Marine and General Purposes Round Strand 6 x 7, p.36 http://www.nobles.com.au/getattachment/2378a752-1da8-48bc-93eb-9e61d093b543/PDF.aspx

8 RESISTANCE PREDICTION

8.1 Estimation of the Resistance

The vessel should reach a speed of 11 knots in different weather conditions to be in accordance with the defined schedule. Nevertheless, in functions of the weather conditions the resistance to advancement will vary. For this reason, the design speed is 15 knots in order to do the trip in the allocated time even in adverse weather conditions.

Estimation are handled with the Software ‘Maxsurf Resistance’. The resistance is calculated with the Holtrop algorithm. It is designed for displacement Ships. Compare to others methods it has the advantage to consider more components of the total resistance.

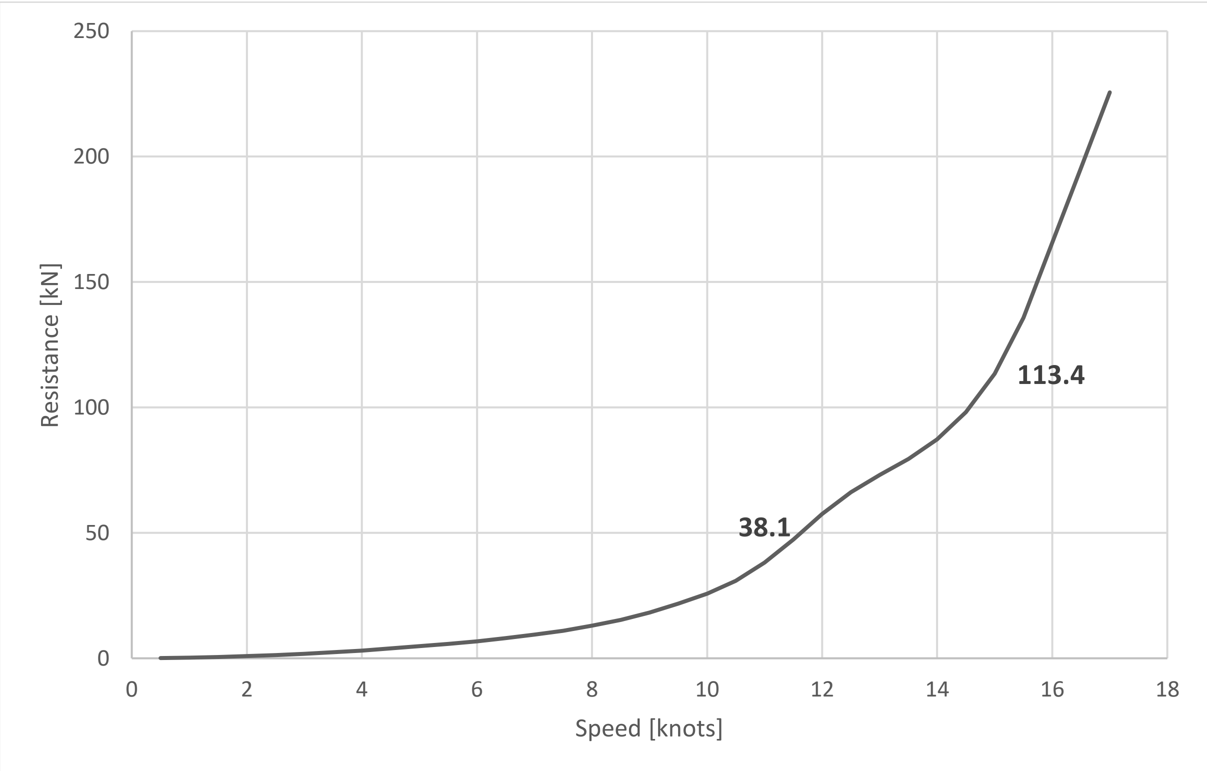
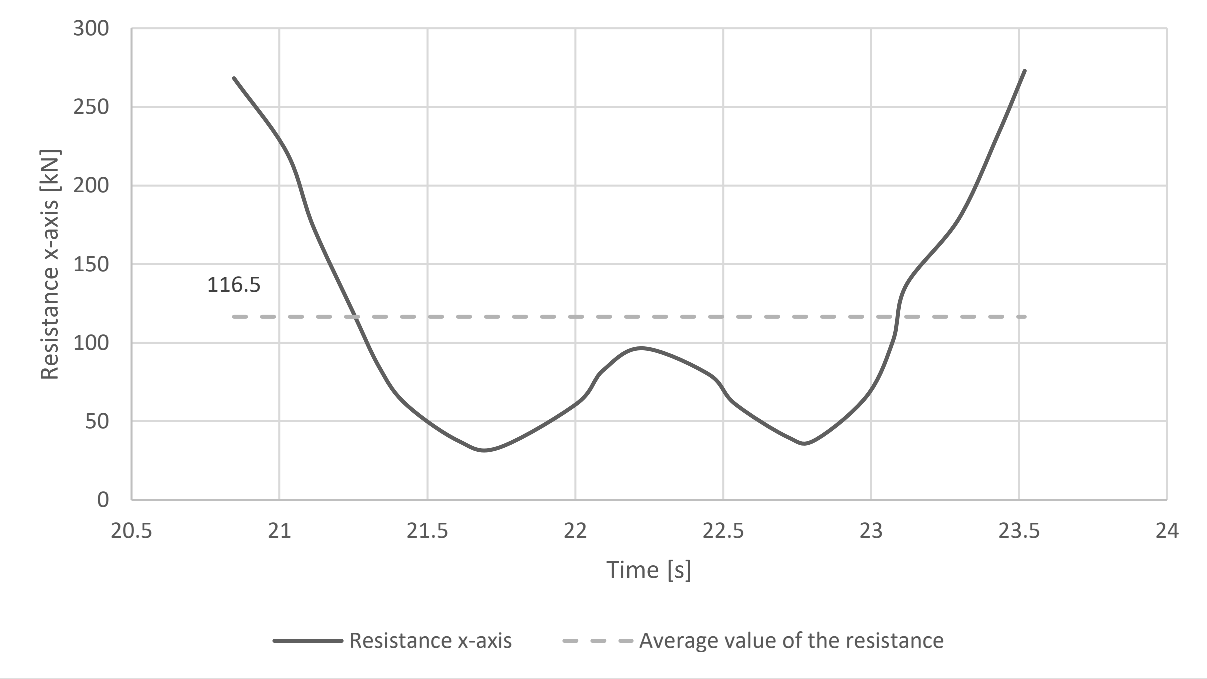


Figure 10 Resistance prediction using Holtrop algorithm with the software ‘Maxsurf Resistance’

8.2 Resistance prediction in harsh weather condition

The calculation of the resistance to advancement is asses on the simulation run with FineMarine in the Section 15 Assesment of the motion.

A period of the resistance had been selected to get the average value of the resistance during one period of wave. To reminder, the vessel in this situation is running at a speed of 11 knots. for an equivalent resistance than for the design speed in still water.



9 PROPELLER DESIGN

The selection of the type of the propeller should considered four parameters: high reliability, high manoeuvrability, low cost and the design constraints. According to these, a twin screw vessel with fixed pitch propeller is the best solution compared to controllable pitch propellers:

- The better reliability due to the absence of moving pieces;
- A cost until three times lower;
- A better efficiency for a same diameter due to a smaller hub;

Furthermore, the manoeuvrability would remain high due to the presence two independent propellers with their associated rudder which provide a good capacity to manoeuvre in all conditions.

9.1 Hull constraints

A moving propeller induces interactions with the surrounding items which are the hull and the rudders and they can induce vibrations and additional resistance. To contain them, recommendations issued by DNV-GL[36] on the relative position of propellers are followed. The concerned distances are drawn on the Figure 11.

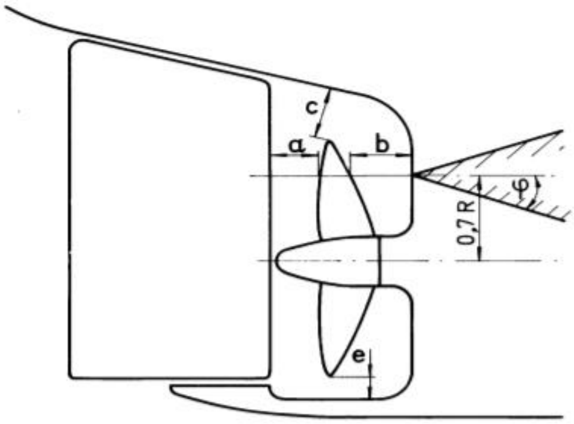


Figure 11 Minimum propeller clearances

- The distance ‘c’ represents the space between the top of the propeller and the bottom of the hull. This value should be as small as possible to increase the diameter and then its efficiency. Nevertheless, it is recommended to keep a minimal distance equal to: $c \geq (0{,}6 - 0{,}02 \times Z_p).R\ [m]$[37]
- The distance ‘a’, representing the distance between the end of the rudder and the propeller backward edge should be small to improve the manoeuvrability. The recommendation is to get a distance superior at $a \geq 0{,}2.R\ [m]$.
- The distance ‘b’ between the forward propeller edge and the propeller post is better with a large distance. It provides a better hull efficiency and decrease the risk of vibration. The recommended distance is $b \geq (0{,}7 - 0{,}04Z_p).R\ [m]$
- Whereas Z_P represents the number of blades and R the radius of the propeller in meters.

The rudder stock would be set on the first frame located at 2 m from the stern. Then, the location of the propeller depends of the end of rudders, the bottom of the hull and from the baseline. Considering the set of equations states in the previous paragraph, the optimal diameter and

[36] https://rules.dnvgl.com/docs/pdf/DNV/rulesship/2001-01/ts303.pdf
[37] Formula provided for twin screw propellers

location of the propeller is defined by one iteration process for a propeller with 4 blades. The optimal solution is set in the Figure 12.

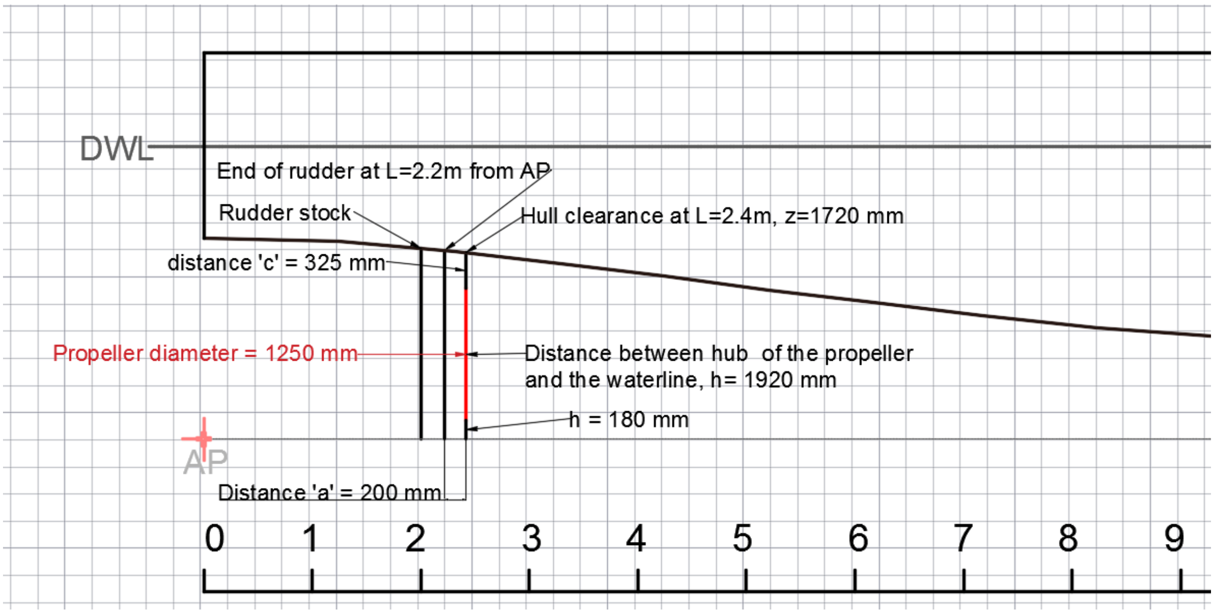


Figure 12 Dimensioning and relative position of the propeller

Per the defined dimensions, a research on catalogue of manufacturers[38] give us one overview of characteristics of propellers of this dimension:

Table 24 Manufacturer's characteristics of propeller

Characteristics	**Values**
Diameter	1250 mm
Weight	192 kg
Bore	Ø 7.6 cm (3 inches)
E.A.R.	0.86

[38] Reference for propellers were fund on the website of the company Michigan Wheel. Dimensions of the propeller were defined by one iteration process.

9.2 Optimal design

9.2.1 Assumptions

Before to start the design of the propeller two values should be assumed. It would be done in accordance with the literature[39], it the values are too different, the iteration process should be restarted.

- The thrust deduction coefficient, t

The rotation of the propeller involved one augment of resistance which is called the "loss of thrust". In fact, the water in front of it is sucked back to the propeller. Then, the power requirements should overcome the total resistance, R_T, defined previously and this "loss of thrust", F. The sum of them is the Thrust force, T. This value is used in the calculation for the design of the propeller. The thrust deduction coefficient is expressed by this relation:

$$t = \frac{F}{T} = \frac{T - R_T}{T}$$

This value is between 0.12 to 0.30 for single screw propeller. This coefficient increases with the block coefficient. Twin screw propellers vessels get a lower value because the "sucking" phenomena occur further from the hull. Then, the minimal value, t=0.12, seems a good estimation[40] to calculate the total Thrust force.

$$T_{total} = \frac{R_T}{1 - t}$$

$$T_{total} = \frac{113.4}{1 - 0.12} = 129\ kN$$

Into the next calculation, the requested Thrust force per propeller, T, would be used. As the vessel is equipped with 2 propellers, $T = \frac{T_{total}}{2} = 65\ kN$

- The wake fraction coefficient, w

The movement of the vessel creates a boundary layer around the hull. Along its surface, the velocity of the water is equal to the speed of the vessel but as much the distance increases, the

[39] https://marine.man.eu/docs/librariesprovider6/propeller-aftship/basic-principles-of-propulsion.pdf?sfvrsn=0
[40] During the calculation, the value of thrust force are round to kN due to the estimation of the coefficient. Indeed, it is not possible to be more accurate in this condition.

water velocity reaches its normal speed outside from the layer. This means there is a certain wake velocity. There is also the creation of a wake field due to the displacement of water by the vessel. Then, the water velocity at the propeller is different from the ship's speed, it has an effective wake velocity, V_w, which has the same direction than the ship's speed, V. Thus, the velocity of arriving water on the propeller, V_A, is lower than V. The relation is expressed by the next equation:

$$V_A = V - V_W$$

A dimensionless form of this relation is expressed by the wake fraction coefficient equal to:

$$w = \frac{V_w}{V} = \frac{V_A - V}{V}$$

Nevertheless, the propeller calculations are handled with the velocity of arriving water at the propeller. Thus, the effective wake velocity as to be estimated. Values of the wake fraction coefficient, w, varies per the hull's form and on the propeller's location and size. For single propelled ship, w, is usually between 0.20 to 0.45. This value increased according to the block coefficient. For ships equipped with two propeller and a convention hull's form, the value is low because propellers are outside of the boundary layer. As it is the situation of this ferry, the value w is set to 0.2 providing us the following velocity of water arriving on the propeller:

$$V_A = V.(1 - w) = (15.0{,}514).(1 - 0{,}2) = 6{,}17\ m.s^{-1}$$

9.2.2 Keller's formula

The design of the propeller should consider the cavitation to minimize this risk. Indeed, the cavitation causes thrust breakdown and it could be avoided by increasing the blade surface area. One of the way to estimate the minimum blade area is the Keller Formula:

$$\frac{A_E}{A_0} = \frac{(1.3 + 0.3Z)T}{(P_0 - P_V)D^2} + K$$

Where:

- P_0 is the static pressure at the shaft: $p_{atm} + \rho g z_{propeller\ hub}$ [Pa]
- p_v is the vapour pressure [Pa]
- T: is the propeller thrust [N]
- Z: the number of blades

- D: the propeller diameter [m]
- K = 0.00 (twin screw vessel)

$$\frac{A_E}{A_0} = \frac{(1,3+0,3.4)\times 65}{(115200-1700)\times 1,25^2} = 0,913$$

The Keller formula provide the minimum blade area. The next step is then to define the others characteristics of the propeller:

- Pitch over diameter ratio: P/D
- Thrust coefficient, K_T
- Torque coefficient, K_Q
- Advance coefficient, J
- Open water efficiency, ρ_0

This is done using the Wageningen B-Series for 4 blades with a value of $\frac{A_E}{A_0} = 0,950$ which is slightly over the value provided by the Keller's formula. To use the diagram the relation between the Thrust coefficient and Advance coefficient is calculated.:

- Thrust coefficient defined as: $K_T = \frac{T}{\rho n^2 D^4}$
- Advance coefficient defined as: $J = \frac{V_A}{nD}$
- Then, $\frac{K_T}{J^2} = \frac{T}{\rho {V_A}^2 D^2} = \frac{65.10^3}{1025.(6,17)^2.(1,25)^2} = 1.06$

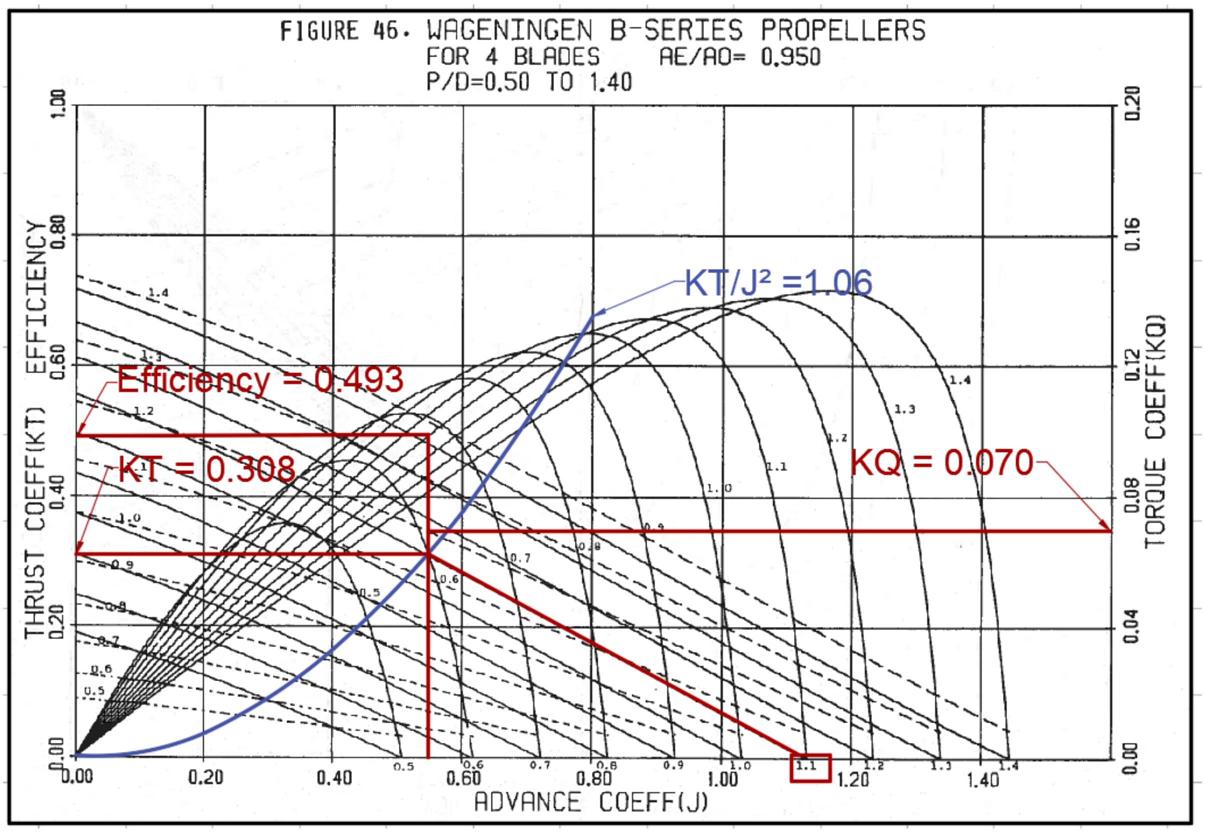


Figure 13 Wageningen B-Series Propellers for Z=4 and A_E/A_O 0.95

According to the diagram, the most efficient propeller would have the following characteristics:

- P/D = 1.1
- $K_T = 0.308$
- $K_Q = 0.070$
- $\eta_0 = 0.493$
- J = 0.54

Then, the rate of rotation, N and the delivered power, P_D could be calculated:

- $n = \frac{V_A}{JD} = \frac{6{,}17}{0.54 \times 1.25} = 9.14\ rps$
- N = n.60 = 548 RPM
- $K = K_Q.\rho_{SW}.D^5.n^2 = 18.3\ kN.m$
- $P_D = Q.2\pi n = 1050\ kW$

10 POWER PREDICTION

Once the calculation for the propeller are done we can define the suitable engine. It is a process following several steps:

- Definition of the brake power
- Selection of an appropriate engine
- Definition of the propeller curve
- Selection of gear box
- Engine – Propeller Operating point
- Marine diesel consumption

10.1 Definition of the requested brake power

The brake power delivered by the engine is higher than the delivered power to the propeller. Indeed, it is submitted to the losses due to the shaft lines and the gear box represented by the shaft efficiency, η_B.

$$\eta_B = \frac{P_D}{P_B}$$

The value of η_B is estimated to 0.98 by the literature providing us a first estimation of the requested brake power.

$$P_{B,design} = \frac{P_D}{\eta_B} = \frac{1050}{0,98} = 1071\ kW$$

Considering the propeller calculations were done with the design speed of 15 knots was used for calculation, instead of the service speed of 11 knots, extra margins would not be added in the calculation. Indeed, the sea margin is already considered.

Nevertheless, the engine margin could be considered. Per the manufacturer of the engine, this margin is between 10 to 15% of its maximum continuous rating. It is recommended to lower fuel consumption and decrease the maintenance cost and eventually a reserve of power. Then, the selection of the engine would set one engine margin of 10%:

$$P_{B,100\%\,MCR} = \frac{P_{B,design}}{0.9} = 1190\ kW$$

A matching engine for this brake power is the Wartsila 6L20 with a brake power of 1200 kW.

10.2 Engine specification

Figure 14 Photo of the engine Wärtsilä 6L20

Source : *http://www.machineto.com/*

The engine model Wärtsilä 6L20 is a four strokes and intercooled diesel engine with direct injection of fuel. It is composed with 6 cylinders in-line. Each one is equipped with 2 inlets and 2 exhaust valves. This cylinder configuration runs at a speed of 1000 RPM delivering a brake power of 1200 kW (1630 bhp).

The overall dimensions of the engine are:

- Length: 3108 mm
- Breadth: 1579 mm
- Height: 1972 mm
- Weight: 9.3 tons

10.3 Engine Operating Range

The engine operating range for Fixed Pitch propeller is provided in the Figure 15. The blue curve represents the Maximum Continuous Rating of the engine. The grey line above is the overload limit. The engine could be operated in the area between these two lines but only for limited time.

The minimum speed of the engine is 350 RPM.

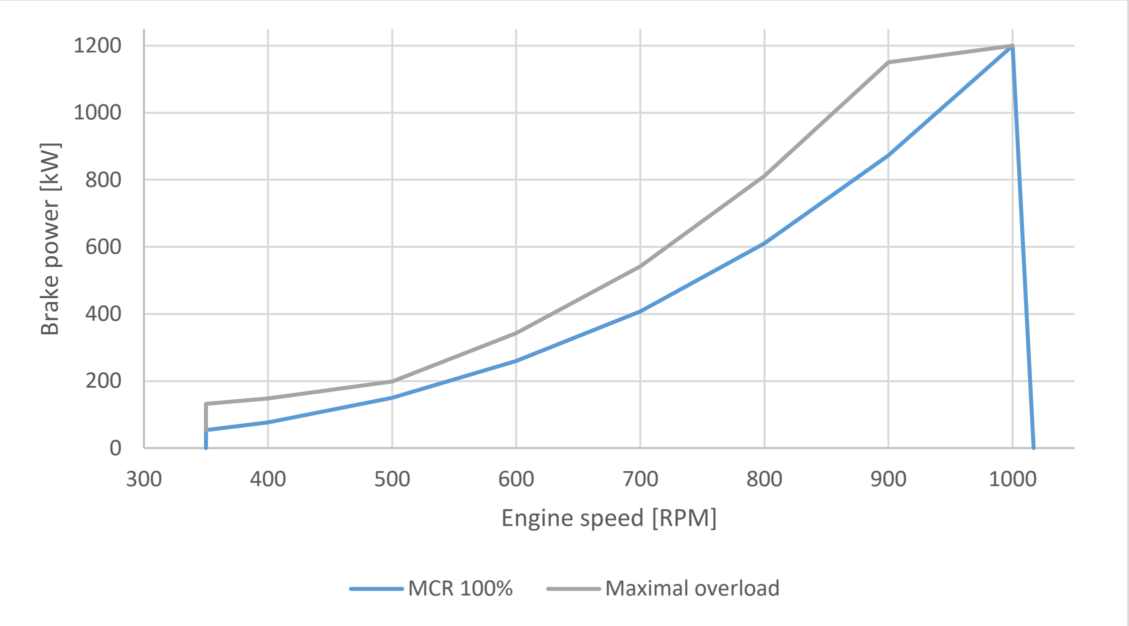


Figure 15 Operating range of the engine Wärtsilä 6L20

Source: Data issued from figure provided by the manufacturer Wärtsila

10.4 Propeller curve

The propeller law states a relation between the required power and the rate of revolution of the propeller:

$$P = c.n^e$$

Where:

- P: is the required power [W]
- c: a constant
- N: rate of revolution per second [RPM]
- e: 3.5, it is a coefficient depending of the type and speed of a ship[41].

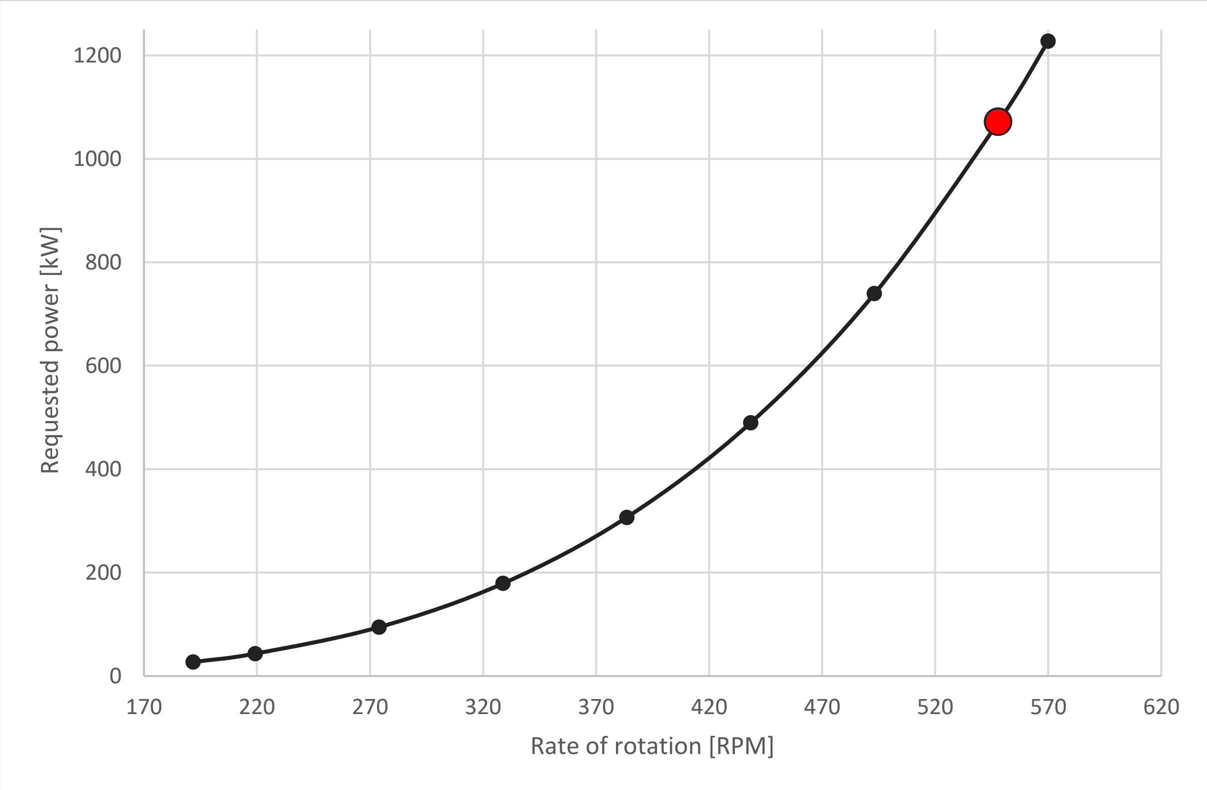
[41] The value provide by the Document « Basic Principles of Ship Propulsion » provide this value at p.21

Type and speed of vessel	Value of the coefficient e
Large high speed ships like container vessels	4.0
Medium sized, medium speed like feeder container ships, reefers, RoRo ships, etc.	3.5
Low speed ships like tankers and bulk carriers	.3.2

The constant is defined using the optimal operating condition, the brake power at 90% of MCR and the rate of revolution calculated in the previous part. Then, the rate of revolution per second of the propeller could be defined for a selected power.

$$c = \frac{P_{B,design}}{N^e} = \frac{1071.10^3}{548^{3,5}} = 2{,}78.10^{-4}$$

According to the propeller law, a curve is design making the relation between the requested power and rate of rotation. In red is indicated the optimum point for a brake power of 1071 kW and rate of rotation of 548 RPM.



10.5 Gearbox selection

The engine selected is a medium speed engine. Nevertheless, the difference between the rate of rotation of the propeller and the engine speed is too high. Then, a gearbox has to be installed on board.

$$Reduction\ factor = \frac{Maximal\ engine\ speed}{Optimum\ rate\ of\ rotation\ of\ the\ propeller} = \frac{1000}{548} = 1.83$$

The optimal and maximum reduction factor of the gearbox is 1.83

The manufacturer Hitachi has in its catalogue the model MGN632[42] which is suitable to this vessel and providing a reduction factor of 1,83. It is also a compact design of which the main dimensions are:

- Length: 960 mm
- Breadth: 1120 mm
- Height of the shaft line: 400 mm
- Weight: 1450 kg

Then, the defined running speed of the engine could be defined for the optimal rate of rotation of the propeller.

$$Engine\ speed = Optimum\ propeller\ speed \times reduction\ factor = 1003\ RPM$$

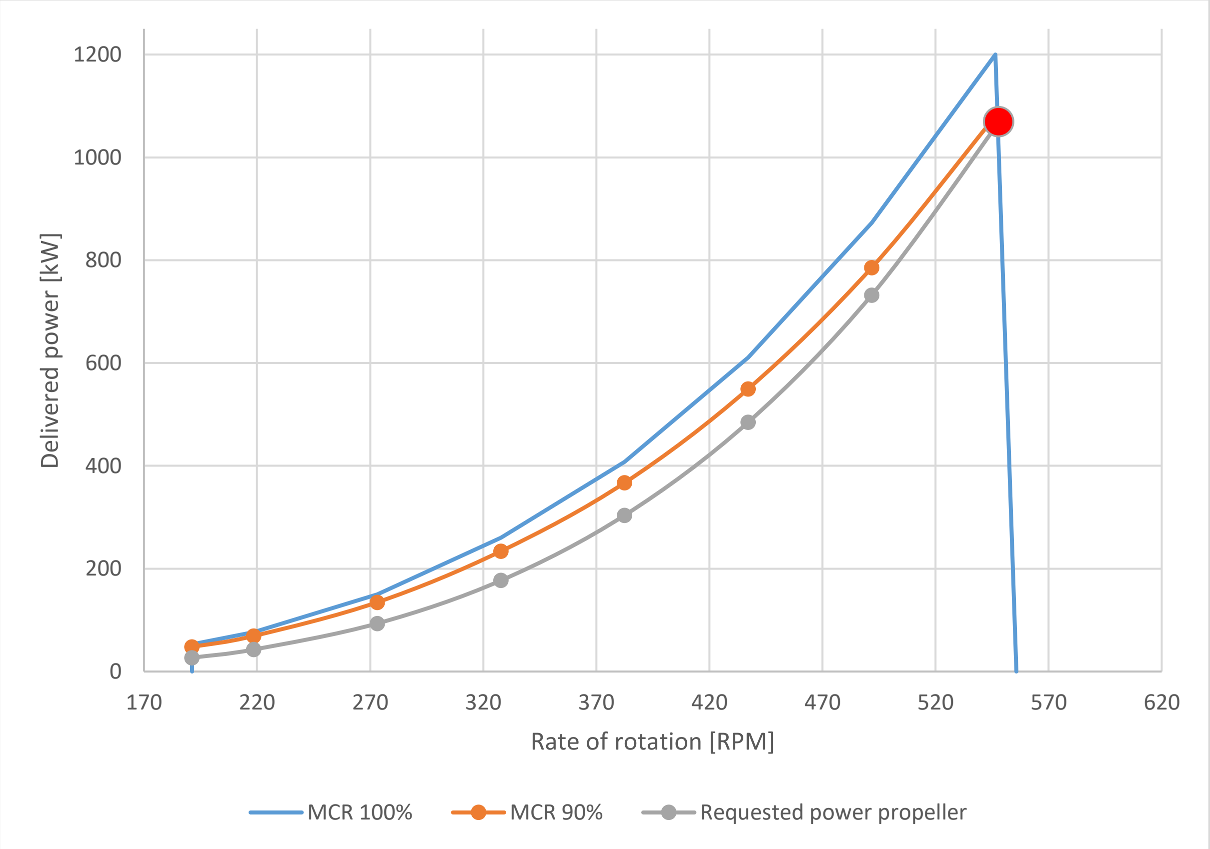


Figure 16 Operating range of the engine

The operating point is located on the calculated point and then in the engine working range.

[42]http://www.marind.ca/medias/pdf/produits_marins/twindisc/TwinDisc_Hitachi_Nico_Marine_Transmissions_CapacityTable.pdf

10.6 Engine consumption

The consumption of one engine is varying is function of the engine rating. At a rate of 90%, the specific consumption reaches 192g/kWh. At the maximal spend engine and at 90% of the MCR, the brake power is 1080 kW, then the consumption per hour is equal to 207 kg/hour which is equivalent to 253L/h of diesel[43].

The curve of the consumption at a rate of 90% of the MCR is given in the Figure 17.

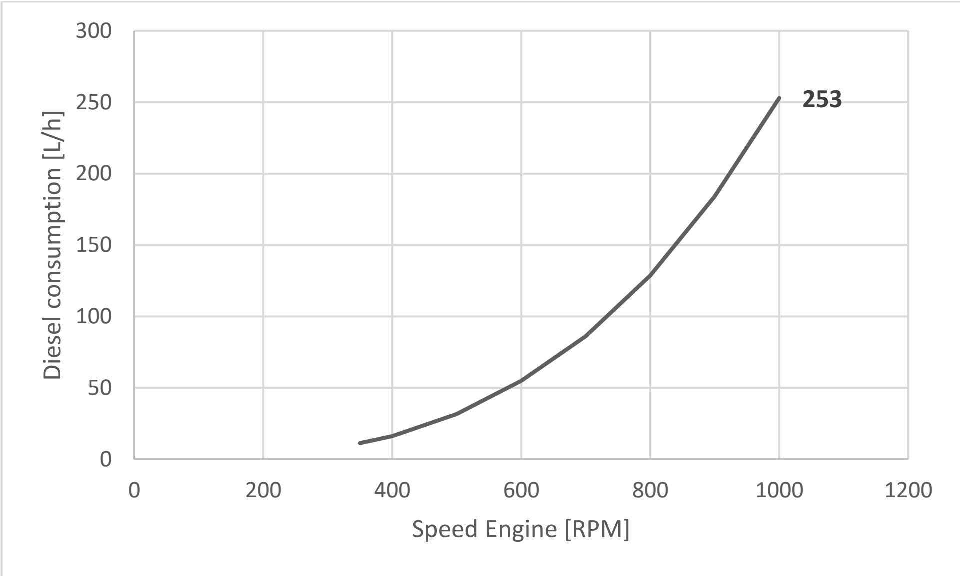


Figure 17 Fuel consumption at 90% of the load

[43] Considering a density of MDO of 0.82 tons/m³

11 ENGINE ROOM

The engine room includes the two engines Wärtsilä 6L20 and all the devices requested to operate them. There are also all the different equipment's necessary to operate properly the vessel.

To ensure the reliability of the operation, the maximum of elements are redundant. Then the two engines are independent. Thus, the vessel would be able to operate in case of failure of one them.

11.1 Propulsion auxiliaries

MDO Circulating pump

Each engine is connected to a circulation pump which maintain the pressure at the injections pumps and ensure the circulation of the diesel between the engine and the daily tank. The recommended capacity is 5 times the total consumption, then it should be around 21 L/min.

Two others pumps are requested to do the connection between the service and storage fuel tanks.

LO Circulating pumps

The engine should be connected to a LO tank of 1.6m³ according to the technical data of the engine. The connection is ensured with a LO pump of screw type. The engines consume up to 10 grams per minute at maximal speed.

These pumps ensure the connection between the engine and the LO tank of 1.6 m³ Its minimum capacity

Sea Water pump

The cooling system of one engine request a flow of sea water of 53m³/h, considering a margin of 20% it represents 64m³/h.

The body pump and impeller is in resistance-corrosion bronze.

Freshwater pump

The cooling system of engine is a close system which will not to be fed by water only on a non-regular basis.

These pumps are mainly used to supply water for sanitary equipment's. The requested capacity of these pumps is estimated to 100 L/min[44] divided into 3 pumps (including one for fresh hot water).

<u>Black/grey water pump</u>

Two pumps are used to discharge black and grey water.

11.2 Ship service auxiliaries

11.2.1 Fresh water system

The vessel is equipped with a seawater desalinisation plant as requested by the law[45]. Therefore, the capacity of the FW tanks is designed for a maximal consumption of 4 hours. The water consumption per head is estimated to 400 litres per day. Only a part of this amount is directly used by person. In fact, it concerns the use of sanitary installations but also the consumption of the galley, boiler water and fresh water machinery.

Table 25 Definition of the fresh water tank capacity

FW consumption per person	16.7	L/hour
Persons on board (11 crew +41 pax)	52	
FW Autonomy	4	hours
FW tank capacity	**3.5**	**m³**

The seawater desalinisation plant should produce enough fresh water to cover the consumption of 52 persons on board, then the requested FW production reaches 0.9m³/h. To achieve it a compact seawater desalinisation plant from the company ROCHEM® is selected with the following capacity:

[44] Considering a consumption of 10L/min per shower, 5L/min per sink, the maximal water consumption of all sanitary equipment used at the same time reaches 200 L/min. Nevertheless such value will never be reached, then is considered half of this value, which allow to use without restrictions all the equipment's on the passenger desk.
[45] Article 215.22. French Maritime Safety Law 1987. Vessels transporting more than 30 persons during 4 hours should be equipped with a seawater desalinisation plant.

Figure 18 Freshwater Desalinisation plant

- Reference name: Generator System Type RO 1530 255
- Capacity: 25m³/day
- Power supply[46]: 2.2kWh/m³
- Type: Reverse Osmosis plant

The next concern is the sewage: the grey and black water. The black water represents the sewage issued from water closet and infirmary. The grey water is sewages issued by other equipment's using fresh water (galley, shower…). According to the Annex IV of MARPOL Convention[47], black water could be discharged without specific treatment when the vessel is under way at more than 12 nautical miles from the shore. Grey water is not submitted to any restrictions.

At approach of harbours of the territory, the sewage has to be kept on holding tanks. The capacity of these tanks are equivalents to the FW tanks with an extra capacity of 10%. The ratio between Black and Grey water is set to 25/75. Once the vessel is berthed, she is connected to the shore to empty the tanks[48].

Table 26 Definition of the black and grey water tanks capacity

Black water tank capacity	1	m³
Grey water tank capacity	2.9	m³

[46] The power supply is based on estimation from data provided by the manufacturer Culligan® on the same kind of product.
[47] The Annex IV of MARPOL applied for vessel over 400 GT and carrying more than 12 passengers. The black water could be discharged overboard at more than 12 nautical miles from the closest shore if sewages are not comminuted and not disinfected. It should be operated at a correct discharge rate. The vessel should be under way at a minimal speed of 4 knots. The Annex IV is implemented in the French regulations under the chapter 213-4 of the French Maritime Safety Law 1987. The grey water could be discharge at any times unless in harbour due to harbour's regulations.
[48] In case of no facilities are available to discharge the black and grey waters, the black waters would be hold on board and the grey water would be discharged. Harbour's regulations of the territory does not state is forbidden to discharge this type of sewage. Then, the capacity of tanks are enough.

Black/Grey water tank capacity	**3.9**	**m³**

11.2.2 Bilge pumps

Two bilge pumps are installed on board to remove possible leak of liquid. They are set at proximity of bulkheads to allow the removal of liquids in all compartments. One are installed at the lowest part of the engine room, which is in front of it (due to the hull shape). The second one is set just aft of the collision bulkhead.

The capacity of the bilge pump is superior than to delivering capacity of the fire pump.

11.2.3 Fire pump

The fire pump is set on board in case of emergency. It is usable in the accommodation and on the cargo deck.

11.3 Ventilation

The calculation of the ventilation is divided in two parts: the engine room and the superstructure.

First the engine room ventilation could be estimated per the power of main and auxiliary engines based on this formula[49] expressed in m³/h:

$$ER\ Ventilation = 1{,}5.\left[\sum BHP_{main\ engine}.6 + \sum BHP_{auxiliary\ engine}.4.75\right]$$

$$ER\ Ventilation = 1{,}5.[2400.6 + 100.4{,}75] = 22313\frac{m^3}{h} = 372\ \frac{m^3}{min}$$

To provide this amount of air supply, 3 centrifugal blowers[50] having a total blowing capacity of 420m³/min are installed.

The accommodation ventilation depends of the nature of each compartment. The calculations would be based on recommendations issued by DNV-GL[51]. Indeed, the air change rates vary

[49] http://www.wartsila.com/encyclopedia/term/engine-room-ventilation
[50] Model VCP451/D from the manufacturer Jabsco. Detailled characteristics for each centrifugal blower:
- Power: 3 kW
- Maximum flow of 140 m³/min
- (L/B/H)=715/750/925 mm
- Weight: 120 kg
[51] http://rules.dnvgl.com/docs/pdf/gl/maritimerules/gl_i-1-21_e.pdf

from 6 (living quarters) to a maximum of 40 for the galley. The requested ventilation is summarized in the Table 27.

Table 27 Requested ventilation in the accomodation

Ventilated space	**Air changes rates /hour Supply air**	**Volume spaces**	**Requested Ventilation**
		m³	*m³/h*
Living/sleeping quarters	6	440	2640
Messes, saloons, offices	12	211	2530
Galley	12+28	26	1040
Pantry	8	16	128
Dry provision rooms	5	37	185
Technical local	5	72	360
Total			**6883 m³/h** **115m³/min**

For the accommodation, two smaller centrifugal blowers[52] with a total capacity of 142 m³/h.

11.4 Summary of the pump

Table 28 Summary of the pump models

	Quantity	Model	Recommended capacity	Max. Capacity	Power requirements
					kW
Engine Ventilation blowers	3	Jabsco VCP451/D	123	140m³/min	3

[52] Model VCP251/B from the manufacturer Jabsco. Detailled characteristics for each centrifugal blower:
- Power: 4 kW
- Maximum flow of 71 m³/min
- (L/B/H)=580/440/550 mm
-Weight: 60 kg

Accommodation ventilation blowers	2	Jabsco VCP251/B	57.5	60 m³/min	
MDO Circulating pump	2	Calpeda **CW446**	21	up to 40L/min	0.55
LO Circulating pump	2	KRAL L32-54	10	16gpm	0.5
Sea water pump	2	FP pumps CM100-175	53	64m³/h	4.2 kW[53]
Fresh water pump	3	CP26/A1	33L/min	45 L/min	0.2kW
Black/Grey water pump out	2	Jabsco 53081-2061-230		80 L/min	0.55 kW
Bilge pump	2	Xylem 512200		195L/min	1.8 kW
Fire pump	1	CP40		125 L/min	0.75 kW

[53] Based on the estimating formula provided by the paper 'Some important naval architectural terms' released by Foreship Ltd. : $P_{el}[kW] = \frac{h\,[m].flow[\frac{m^3}{h}]}{228}$ where h is the pump pressure head.

12 ELECTRICAL SYSTEM

The electrical installation should supply all the equipment's fitted on board in different conditions. To achieve the most appropriate system, the next steps will be followed:

- Define the electrical load balance
- Selection of the generators
- Emergency installation

12.1 Electrical Balance Analysis

The analysis of equipment's is lead compartments by compartments to define accurately the electrical load on board. They include as well the AC consumers (pumps, ventilation…) than the lighter DC consumers (lights and small equipment's). To provide accurate analysis, the requested capacity of all equipment's was assessed and existing items were used as references.

Usually consumers are not run on maximal capacity but at lower rate which is defined by the load factor. This one should be around 0.8. For this reason, the maximal capacity of equipment's is higher than the requested value for the equipment's.

Next, the electrical balance analysis considers three different operating conditions. In each one the user load varies in function of the estimated uses. A short explanation about each condition is provided below:

- Harbour: In this condition the vessel is without passengers and the crew is ensuring the (un)loading the cargo or the maintenance of the vessel. In the engine room, only the generators are running. The ventilation system is used at a low rate. The loading or unloading of cargo does not influence because it is done with one external lifting equipment.
- Sailing conditions: Now, the electrical load is higher. The ventilation is on high load and air conditioning too. The presence of passenger's request the use of extra equipment's in the accommodation.
- Manoeuvring: This is the maximum condition. The higher load is mainly issued by the used of the bow thruster, mooring and anchoring equipment's. Then this load is high but temporary.

The main data of the Electrical Load Balance Analysis defines by this method are summarized in the Table 29. The details are provided in Annex 6.

Table 29 Electrical Load Balance Analysis

	Consumers load [kW]		
	Harbour	**Manoeuvring**	**Sailing**
Propulsion auxiliairies	7.10	11.74	11.79
Ship service auxiliaries	16.82	55.40	12.00
HVAC Equipment	19.20	27.60	27.60
Passenger deck	0.14	2.42	3.26
Crew deck	2.08	2.08	2.08
Engine deck	8.84	6.63	6.63
Bridge deck	2.00	7.08	7.08
Total	**56.18**	**112.95**	**70.43**

12.2 Generators selection

The maximum load is reached in the manoeuvring mode but this load is applied for a short duration time. Considering than one important characteristics of the vessel should be one high level of the reliability it is selected 3 AC generators of 40 kW. The supply of DC-current to DC-consumers would be done using a transformer from AC to DC-current. Selected generators are released by the company Cummins[54] with the following characteristics:

- Reference name: Quiet Diesel™ Series Marine Generator Set 40 kW MDDCF
- Power rating: 40 kW
- Weight: 1090 kg
- Overall dimensions (L/B/H): 1738/840/1039 mm
- MDO Consumption [L/h]: 9.0 (3/4 load); 11.5 (Full load)

Per each sailing condition the regime of each generator are indicated in the Table 30.

Table 30 Load on the generators in function of the sailing conditions

	Harbour	**Manoeuvring**	**Sailing**
Required power [kW]	56.18	112.95	70.43
N° of 40kW generator	2	3	2
Load factor	70.2%	94.1%	88.0%

[54] https://marine.cummins.com/brochure-download.aspx?brochureid=1417

These configurations with 3 generators provide a good flexibility for running the operations and they are run in a good load range.

Moreover, the presence of 3 generators on board provide the ability to the vessel to continue her operations in the case of the failure of one.

12.3 Electrical emergency installation

The emergency electrical system should ensure the operation of the vital equipment for a period of 4 hours. These concern the following equipment's:

- Emergency lightning
- Navigation lights
- The fire detection and fire alarm system
- Emergency fire pump
- Bilge pumps

The supply of energy would be ensured by a bank of battery located outside of the engine room. Thus, the electrical load balance analysis of this condition is defined and in accordance with it, a battery charger and suitable batteries are selected.

Table 31 Electrical Load Balance Analysis in emergency condition

	Consumers load [kW]
	Emergency Condition
Propulsion auxiliaries	6.21
Ship service auxiliaries	0.00
HVAC Equipment	0.00
Passenger deck	0.15
Crew deck	0.20
Engine deck	0.20
Bridge deck	4.43
Total	**11.19**

For a period of autonomy of 4 hours, it requests battery with a minimum capacity of 44.8 kWh. Considering the battery would be recharge every time they reach 90 % of their capacity, it is installed 10% of extra capacity. A suitable battery for this requested power is issued by the company Torpedo™ with the following characteristics:

- Reference Name: Deep Blue High-voltage battery
- Type: lithium battery
- Usable energy per battery: 12.8 kWh
- Charge: 40 Ah
- Rated voltage 325 V
- Weight per unit: 150 kg
- Main dimension (L/B/H): 1191/498/265 mm

Table 32 Number of emergency battery installed on board

Requested power supply [kWh]	49.3
Energy per battery [kWh]	12.8
Number of battery installed	5

The battery bank is used only in emergency situations. Therefore, the discharge would be only based due to the loss of power of battery over time. Then, it requests a battery charger with a small charging capacity. Indeed, the battery should remain charged above 90% at every time. It is set, the battery charger should be able to charge 10% of batteries in 2 hours. It represents 6.4 kWh using the onboard voltage of 230 V, it requests a charge current of 28Ah. To achieve it a battery charger of company Mastervolt™ is used with the following characteristics:

- Model Name: ChargeMaster 24/20-3[55]
- Total charge current 20 A
- Nominal input voltage 120/230 V, 50/60Hz
- Dimensions (H/W/D): 291/210/131 mm
- Weight: 4 kg
- Full load consumption: 660 W

[55] http://www.mastervolt.com/products/chargemaster-24v/chargemaster-24-20-3/

13 CAPACITY PLAN

The capacity plan regroups all the tanks set on board to ensure the service of the vessel in full load condition for this maximum range, 600 nm at the service speed of 11 knots but considering bad weather conditions. Therefore, the fuel consumption is equivalent than at the design speed of 15 knots

For information, the requested tank capacity for a return trip to Wallis and Futuna is also provided. As the requested range autonomy for a return trip is half of the distance from Wallis to Suva (Fidji Islands), the sailing consumption is half of it. It is also added the consumptions of harbour which is not negligible because the vessel remains 34 hours at the wharf of Leava. These two different trips would be considered to decrease the free surface effects of the vessel when the vessel is loaded to ensure the territorial inter-island connection.

The tanks are divided into:

- Marine diesel tanks
- Lubricating oil tanks
- Lubricating oil used tanks
- Fresh water tanks
- Black/Grey water tanks
- Hydraulic tank
- Sludge tanks
- Ballast tanks

It should be noticed than all the tanks are not part of the structure but. They are independent tanks build in steel because they are in contact with the steel structure. Their inside would be recovered with one appropriate coating in function of the carrying liquid to avoid corrosion.

13.1 Marine Diesel tanks

The storage fuel tank should be located outside of the engine room for safety reason. Then, they are in front of the fore engine bulkhead. Service tanks are installed at proximity of the engines along the side shell.

Table 33 Calculation of MDO Consumption

	Fidji Islands	Return trip WF	
Requested autonomy	600	300	*nm*
Speed	11	11	*knots*
Equivalent sailing time	55	28	*hours*
Harbour time[56]	-	34	*hours*
ME consumptions	506		*L/hours*
Generator consumptions (sailing/harbour conditions)	23		*L/hours*
Total consumption	529		*L/hours*
Total consumption	28.9	15.2	*m³*

MDO tanks are divided into the service tank and the storage tanks. The service tanks should ensure fuel supply to the main engine for 8 hours.

$$Service\ tank\ capacity = 8 \times ME\ consumptions = 4.1\ m^3$$

Deducing the service tank capacity from the total consumption, the MDO tanks are defined as summarized in the Table 34.

Table 34 Distribution of the MDO tanks

	Volume capacity [m³]
MDO Service tank 1,2	2.1
MDO Storage tank 1,2,3,4	6.2
Total capacity	29.0

13.2 Lubricating oil tanks

The main consumer of lubricating oil are the main engines which requested both a tank of a minimal capacity of 1,6m³ each. A small extra capacity is provided to supply also the generators. Then, the capacity of each tank is set 1.8 m³.

Table 35 Distribution of the LO tanks

	Volume capacity [m³]
LO Storage tank 1,2	1.8
Total capacity	3.6

[56] Two hours are added to the sailing time obtained by the division distance over speed. It represents the time when the engines are running but

13.3 Lubricating oil used tanks

The capacity of these tanks are increased by 10% compared to LO tanks.

Table 36 Distribution of the LO used tanks

	Volume capacity [m³]
LO Storage tank 1,2	2
Total capacity	4

13.4 Fresh Water tanks

The Fresh water system detailed in the part 11.2.1 defines the capacity of FW tanks. Two separated tanks would be installed.

Table 37 Distribution of the FW tanks

FW tanks 1,2	1.75	m³
FW tank capacity	**3.5**	**m³**

13.5 Black and Grey water tanks

The Fresh water system detailed in the part 11.2.1 defines the capacity of Black and Grey water tanks. Two tanks of each type would be installed.

Table 38 Distribution of the Black and !Grey Water tanks

Black water tank 1,2	0.5	m³
Grey water tank 1,2	1.45	m³
Black/Grey water tank capacity	**3.9**	**m³**

13.6 Hydraulic tank

Hydraulic oil should be supplied mainly for the steering gear and the auxiliary steering gear pumps. 100 Litres should be provided.

Table 39 Distribution of Hydraulic tank

Hydraulic tank	**0.1**	**m³**

13.7 Sludge tank

Liquids and residues coming from the engine room pump by bilges pumps could not be discharged overboard[57]. Then, they should be kept on board until the delivering to appropriate facilities ashore. The capacity of these tanks are designed for 2 m³

Table 40 Distribution of Sludge tanks

Sludge tank 1,2	1	m³
Sludge tanks capacity	**2**	**m³**

13.8 Ballast tanks

Ballast are set in the aft part of the vessel between the aft peak bulkhead and the aft bulkhead of the engine room. Their goal is to ensure a positive and not excessive trim in the different loading conditions of the vessel. Therefore, ballast tank capacity are designed during the stability test of the vessel in ballast condition.

All the available volume is used for ballast. Only one access is provided from the deck by a hatch cover and a narrow corridor to provide the ability to do one inspection of the condition of the ballast.

Table 41 Distribution of the ballast tanks

Ballast tank 1,2	22.5	m³
Ballast tank 3,4	21.0	m³
Ballast tank capacity	**87**	**m³**

[57] MARPOL Convention Annexe I

13.9 Capacity plan

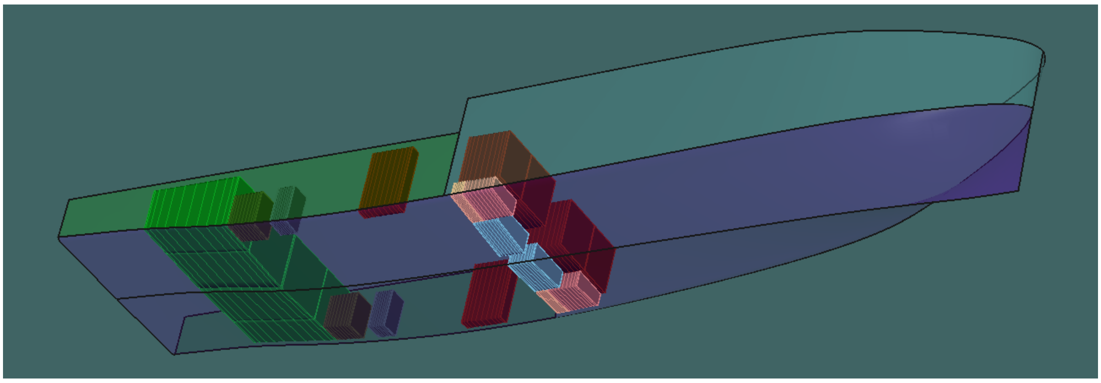


Figure 19 View of the distribution of the tanks with MaSurf

14 STABILITY

At the stage of the design, the assessment of the stability is focused on the intact stability criteria. The assessment will be lead in accordance with the rules of BV for Steel ships which have to be fulfilled by passenger's ships.

14.1 IMO Stability Intact Criteria

The stability booklet concerning IMO Stability Criteria should content 3 situations:

- Lightship
- Ship in ballast in the departure condition, without cargo but with full stores and full
- Ship in ballast in the arrival condition, without cargo and with 10% stores and fuel remaining

14.1.1 Lightship condition

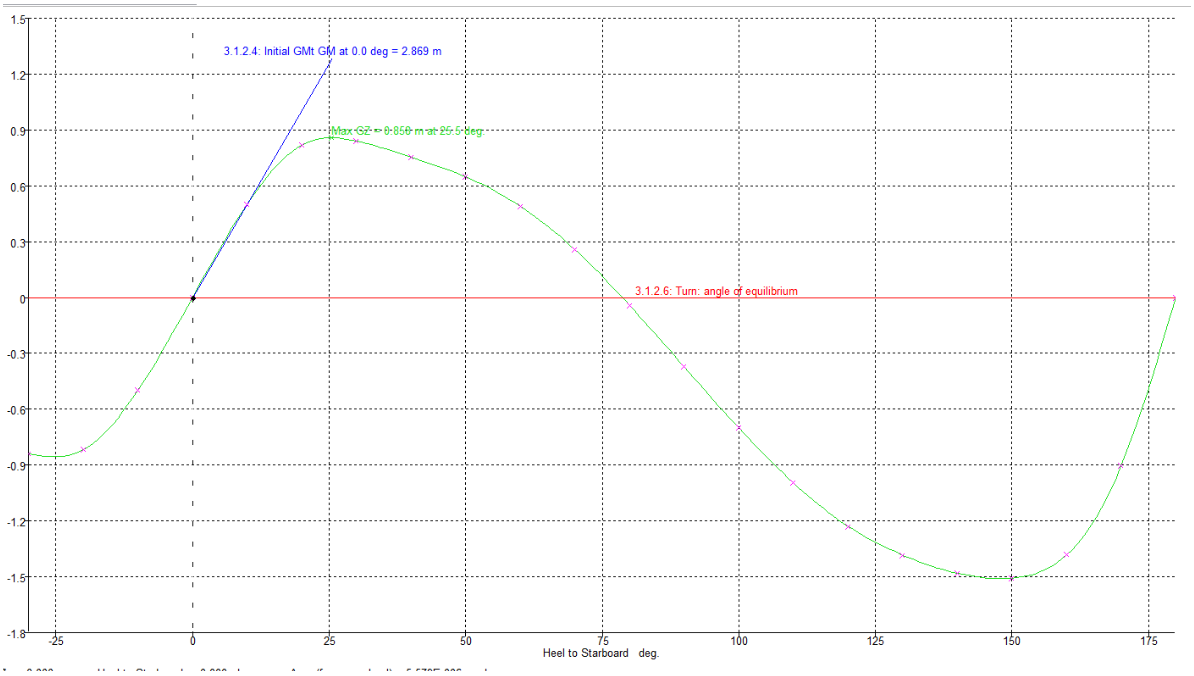


Figure 20 GZ Curve Lightship condition

A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.1: Area 0 to 30**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.1: Area 0 to 40**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.1: Area 30 to 40**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.2: Max GZ at 30 or greater**	**Pass**

A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.3: Angle of maximum GZ**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.4: Initial GMt**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.6: Turn: angle of equilibrium**	**Pass**

14.1.2 Ship in ballast departure condition

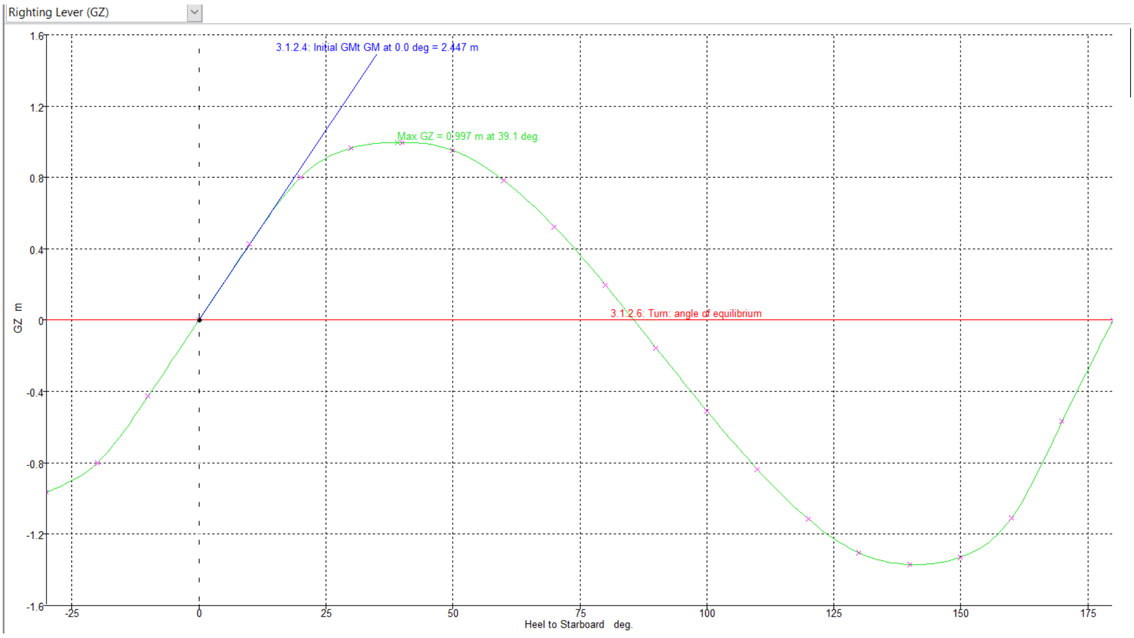


Figure 21 GZ Curve Ballast condition departure mode

A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.1: Area 0 to 30**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.1: Area 0 to 40**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.1: Area 30 to 40**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.2: Max GZ at 30 or greater**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.3: Angle of maximum GZ**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.4: Initial GMt**	**Pass**
A.749(18) Ch3 - Design criteria applicable to all ships	**3.1.2.6: Turn: angle of equilibrium**	**Pass**

14.1.3 Ship in ballast in the arrival condition

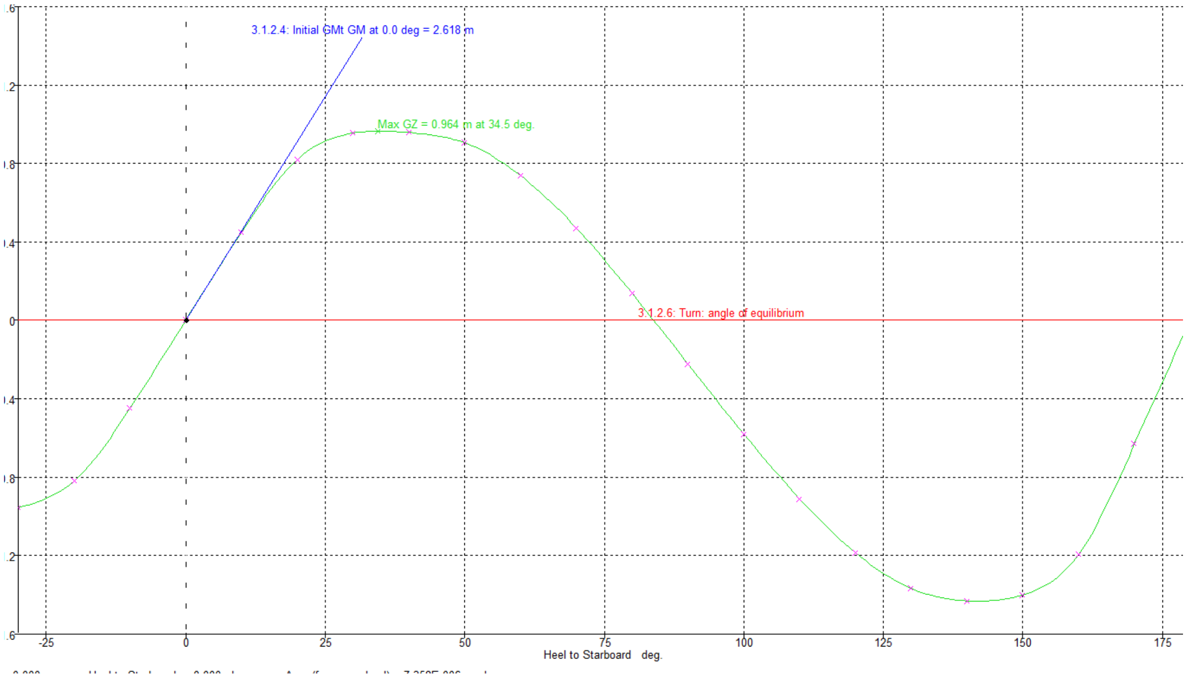


Figure 22 GZ Curve in bgallast condition in arrival condition

15 ASSESMENT OF THE MOTION

The initial conditions of the simulation are done with wave characteristics provided by the rules dedicated to the definition of the hull girder loads. The classification society defines the waves loads which are assumed to be periodic and can be reached with a probability of 10^{-5} for this vessel. The characteristics of the waves are the following:

- Wave height, $C_W = 2.59$ m (crest to through)
- Period, T = 5.06 s
- Encountered Period, $T_e = 2.95$ s
- Steepness wave = 0.2

Further it assumed the vessel would not move through wave at highest speed, therefore the vessel runs at service speed of 11 knots.

Due to the wish to test the most dangerous case possible, the ship is in full load condition.

The model of the vessel is set in multi-fluid domain with interface on the waterline. Conditions defined above are inputted in the software and heave and pitch motions are released.

Forward speed of 11 knots is introduced in form of 1/2sinusoidal ramp to reduce the level of irregularities within the solution. The time step is quite small: t=0.03second is set to increase the convergence speed as visible in Figure 23**.**

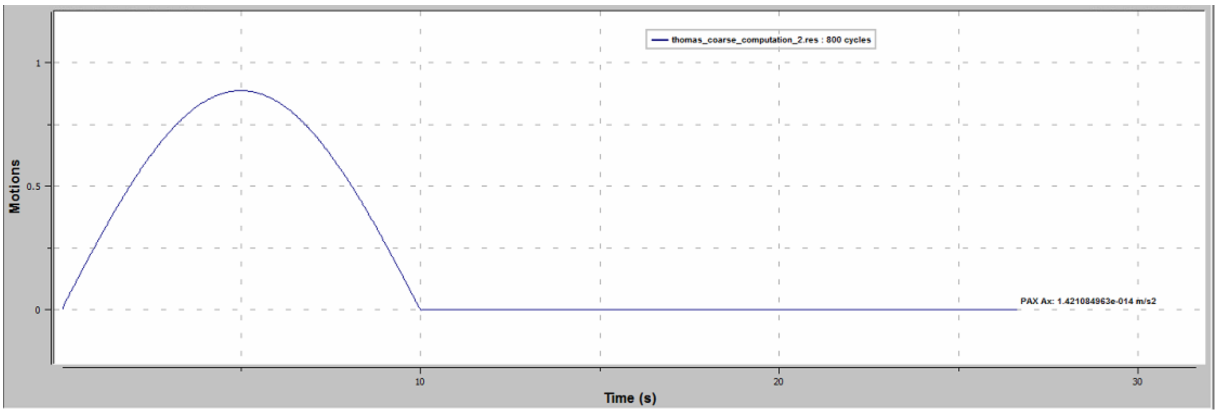


Figure 23 Acceleration of the vessel in x-direction

From the result, we can see the first part that represents model accelerating from 0 to its maximum speed. It is also obvious than the results converge quite fast when maximum speed is achieved due to previously mentioned reason.

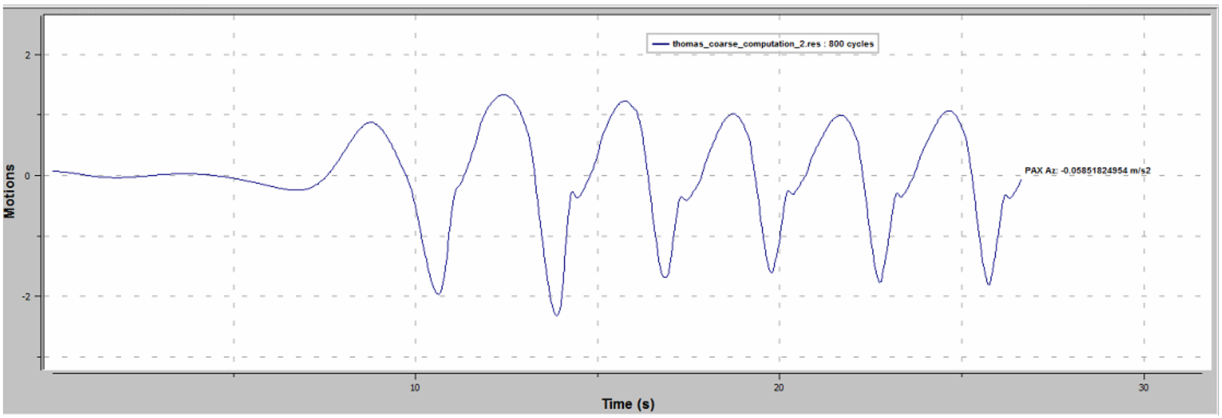


Figure 24 Vertical acceleration of the vessel in harsh conditions

Further on, analysis of obtained data give maximum vertical accelerations of 0.18g which is well under the recommendations released by the study of Savitsky[58] which state a limited value of 0.60 g concerning fare paying passengers. Concerning High Speed Craft, Guidelines[59] about limitation for High Speed Craft concerning Vertical Accelerations, states the maximum vertical acceleration should set for the first safety level at 0,40g.

[58] Savitsky, D. & Koebel, J.G. 'Seakeeping of Hard Chine Planin Hulls', Report for Technical and Research Panel SC-1 (Power Craft), SNAME

[59] IMO DE50 Correspondence Group on Guidelines for Operating Limitation for High Speed Craft, Vertical Accelerations

16 CONCLUSION

The goal of the study, providing a preliminary design of a ferry dedicated to the maritime inter island connection, is reached.

First, considering the cargo requirement, the capacity of transport reached 154 tons, so 8 TEU. The capacity to transport wide kind of cargo is ensured by the location of the containers on the deck. Nevertheless, this heavy load in the back for this vessel requests one important capacity of ballast water in aft to counteract their absence.

Concerning the vessel, the reliability was the leitmotiv. Indeed, the loss of propulsion in the middle of the sea without Safety services at proximity is problematic and could transform a small danger in a disaster. For this reason, the vessel is well equipped for emergency situations. Moreover, she is also designed for harsh weather. The simulation runs in FineMarine shows a good behaviour in adverse conditions.

Nevertheless, the good behaviour of the vessel could be hampered by the stability problem due to the heavy load on the aft and one excessive positive trim.

17 REFERENCES

17.1 Legislation

Article 74 of the *French Constitution* of the 4th October 1958

Article 198 of *Treaty on the Functioning of the European Union*

Article 9, 29 July 1961. *Law 61-814 endowing the Islands of Wallis and Futuna with the stats of Overseas Territory.*

Article 10, 29 July 1961. *Law 61-814 endowing the Islands of Wallis and Futuna with the stats of Overseas Territory.*

Decree n°57-811, 22 July 1957, *Attributions of territorial assembly, territorial council and Chief Administrator of the Territory of Wallis and Futuna Islands*

Minister of the Ecology, Sustainable Development, Transports and Accommodation. *The mobility of French citizens*, p.154

IMO, 30 November 2011. *Resolution A.1047(27), Principles of Minimum Safe Manning*

Order of 23th November 1987 on the safety of ships.

IMO, 6 November 1991. *Resolution A.714(17), Code of Safe Practice for Cargo Stowage and Securing.*

World Organisation for Animal Health, *Terrestrial Animal Health Code*

Council of Europe, Committee of Ministers, 1988. *Recommendation No. R (88)15 of the Committee of Ministers to Member States on the Transport of Pigs* [online], Available from: https://rm.coe.int/CoERMPublicCommonSearchServices/DisplayDCTMContent?documentId=09000016804bda11

17.2 Publications

IEOM, Annual report of 2013. Variation of the natural growth and emigration of habitants, p27.

IEOM. Report on Wallis and Futuna, p.70

Hirota et Al, 2005. Development of bow Shape to reduce the added resistance due to waves and verification on full scale measurements.

Pacific Community, Report of a 2014 study. Air and sea transport in Wallis and Futuna.

Thomas Lamb, 2003. Ship Design and Construction. Society of Naval Architects and Marine Engineers (SNAME).

J.-B. Champion, A. Houlou-Garcia, C. Pfister, V. Quénechdu, Août 2014. Wallis et Futuna a perdu près de la moitié de sa population en 10 ans (Wallis and Futuna has lost almost half of its population in 10 years) [online]. Insee Premiere, n°1511, Available from : https://www.insee.fr/fr/statistiques/1281314 [in French]

C.Dorwling-Carter, Avril 2016. L'économie de Wallis et Futuna en 2015, une économie portée par la consommation intérieure (Wallis and Futuna's economy in 2015, an economy focused on domestic consumption) [online]. Note expresse, IEOM, n°1511, Available from: http://www.ieom.fr/IMG/pdf/ne187_portrait_l_economie_de_wallis-et-futuna_.pdf [in French]

Institut d'emission d'Outre-Mer. L'accès au territoire (Access to the territory) [online], Available from : http://www.ieom.fr/wallis-et-futuna/presentation/l-acces-au-territoire-119.html [in French]

Germanischer Lloyd Aktiengesellschaft, Edition 2003. Guidelines for the Carriage of Refrigerated Containers on Board Ships [online], page A-2, Available from: http://rules.dnvgl.com/docs/pdf/gl/maritimerules/gl_i-1-19_e.pdf

IMO DE50 Correspondence Group on Guidelines for Operating Limitation for High Speed Craft, Vertical Accelerations

Savitsky, D. & Koebel, J.G. 'Seakeeping of Hard Chine Planin Hulls', Report for Technical and Research Panel SC-1 (Power Craft), SNAME

17.3 Website

Maersk http://www.maerskline.com

18 ANNEXES

18.1 Annex 1: Design Load Calculations

Local external loads

Sea pressure

Ship relative motion

Location	Location		Relative motion h_1 for non cargo ship		
From aft part to 0,25 L_{WL}	0	12	$h_{1,A}$	1.41	*m*
From 0,25 L_{WL} to 0,70 L_{WL}	12	30	$h_{1,m}$	1.28	*m*
From 0,70 L_{WL} to 0,85 L_{WL}	30	36	$h_{1,E}$	2.15	*m*
From 0,85 L_{WL} to fore part	36	42	$h_{1,FE}$	3.58	*m*

Pressure on bottom structure

	z_0	h_1	P_S
Location	m	m	*kN/m²*
From aft part to 0,25 L_{WL}	0.88	1.41	29
From 0,25 L_{WL} to 0,70 L_{WL}	0.6	1.28	31
From 0,70 L_{WL} to 0,85 L_{WL}	0.2	2.15	43
From 0,85 L_{WL} to fore part	0	3.58	60

Pressure on side shell structure with reference on lower deck

	z	h_1	$P_{S\,(1)}$	$P_{S\,(2)}$	P_S
Location	m	m	*kN/m²*	*kN/m²*	*kN/m²*
From aft part to 0,25 L_{WL}	1.353	1.41	24	24	24
From 0,25 L_{WL} to 0,70 L_{WL}	1.353	1.28	23	24	24
From 0,70 L_{WL} to 0,85 L_{WL}	1.353	2.15	32	24	32
From 0,85 L_{WL} to fore part	1.353	3.58	46	24	46

Pressure on side shell structure with reference on crew deck

	z	h_1	$P_{S\,(1)}$	$P_{S\,(2)}$	P_S
Location	m	m	*kN/m²*	*kN/m²*	*kN/m²*
From aft part to 0,25 L_{WL}	3.558	1.41	2	2	2
From 0,25 L_{WL} to 0,70 L_{WL}	3.558	1.28	1	2	2
From 0,70 L_{WL} to 0,85 L_{WL}	3.558	2.15	10	2	10
From 0,85 L_{WL} to fore part	3.558	3.58	24	2	24

Pressure on exposed deck

Location	z_d m	h_1 m	p_0 kN/m²	φ_1	φ_2	φ_3	p_d kN/m²	p_{dmin} kN/m²
Cargo deck								
From aft part to 0,25 L_{WL}	3.558	1.41	29	1.00	0.42	0.7	-1.88	3.60
From 0,25 L_{WL} to 0,70 L_{WL}	3.558	1.28	31	1.00	0.42	0.7	-1.43	3.60
							Design pressure on cargo deck	**3.60**
Passenger deck								
From 0,25 L_{WL} to 0,70 L_{WL}	5.805	1.28	31	1.00	0.42	0.7	-8.04	5.15
From 0,70 L_{WL} to 0,85 L_{WL}	5.805	2.15	43	1.00	0.42	0.7	-4.29	7.00
From 0,85 L_{WL} to fore part	5.805	3.58	60	1.00	0.42	0.7	0.53	7.00
							Design pressure on passenger deck	**7.00**
Bridge deck								
From 0,25 L_{WL} to 0,70 L_{WL}	8.205	1.28	31	0.75	0.42	0.7	-11.32	5.00
From 0,70 L_{WL} to 0,85 L_{WL}	8.205	2.15	43	0.75	0.42	0.7	-8.51	7.00
From 0,85 L_{WL} to fore part	8.205	3.58	60	0.75	0.42	0.7	-4.89	7.00
							Design pressure on bridge deck	**7.00**
Monkey bridge								
From 0,25 L_{WL} to 0,70 L_{WL}	8.205	1.28	31	0.56	0.42	0.7	-8.45	7.00
From 0,70 L_{WL} to 0,85 L_{WL}	10.41	2.15	43	0.56	0.42	0.7	-9.98	7.00
							Design pressure on monkey bridge	**7.00**

Dynamic loads

Side shell impact pressure

p_{ss1}	From T to T +1 m	From T +1m to T+3m	Above
From aft to 0,70.L_{WL}	60	45	30
From 0,70.L_{WL} to fore part	80	60	30

Plating and side scuttle : K_2= 0.5

p_{ssmin} [kN/m²]	From T to T +1 m	From T +1m to T+3m	Above
From aft to 0,70.L_{WL}	30	22.5	15
From 0,70.L_{WL} to fore part	40	30	15

Secondary stiffeners K_2= 0.45

p_{ssmin} [kN/m²]	From T to T +1 m	From T +1m to T+3m	Above
From aft to 0,70.L_{WL}	27	20.25	13.5
From 0,70.L_{WL} to fore part	36	27	13.5

Primary stiffeners K_2= 0.35

p_{ssmin} [kN.m²]	From T to T +1 m	From T +1m to T+3m	Above
From aft to 0,70.L_{WL}	21	15.75	10.5
From 0,70.L_{WL} to fore part	28	21	10.5

Internal loads

M	152	tons
a_z	8.174448343	m/s²
η	1	
z	6.158	
F_Z	2733.636148	kN
F_T	368.0503874	kN
F_{total}	3101.686536	kN
area	60	m²
p_{cargo}	51.69477559	kN/m²

Accomodation deck

Passenger superstructure

p_s	5	kN/m²
η	1	
From 0,25 L_{WL} to 0,70 L_{WL}	8.29037266	kN/m²
From 0,70 L_{WL} to 0,85 L_{WL}	9.1663855	kN/m²
From 0,85 L_{WL} to fore part	11.1856171	kN/m²

Crew deck

p_s	3	kN/m²
η	1	
From 0,25 L_{WL} to 0,70 L_{WL}	4.97422359	kN/m²
From 0,70 L_{WL} to 0,85 L_{WL}	5.4998313	kN/m²
From 0,85 L_{WL} to fore part	6.71137026	kN/m²

Lower deck

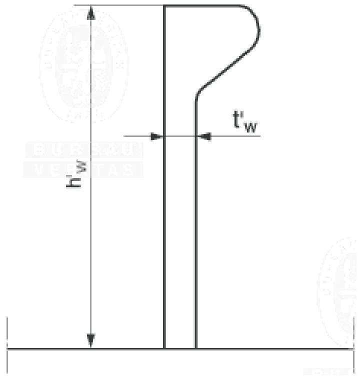
p_s	3	kN/m²
η	1	
From 0,25 L_{WL} to 0,70 L_{WL}	4.97422359	kN/m²
From 0,70 L_{WL} to 0,85 L_{WL}	5.4998313	kN/m²
From 0,85 L_{WL} to fore part	6.71137026	kN/m²

Machinery spaces

p_s	10	kN/m²
η	1	
From aft part to 0,25 L_{WL}	18.332771	kN/m²
From 0,25 L_{WL} to 0,70 L_{WL}	16.5807453	kN/m²

18.2 Annex 2: Dimensions of main scantlings

Figure 1 - Dimension of a steel bulb section



$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

$$b_f = \alpha[t'_w + \frac{h'_w}{6,7} - 2]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

Girder 1			Girder 2			Girder 3			Girder 4		
T profile			**T profile**			**T profile**			**T profile**		
h_w	150	mm	h_w	200	mm	h_w	250	mm	h_w	300	mm
t_w	10	mm	t_w	10	mm	t_w	10	mm	t_w	14	mm
b_f	70	mm	b_f	100	mm	b_f	125	mm	b_f	150	mm
t_f	10	mm	t_f	10	mm	t_f	10	mm	t_f	12	mm

SECONDARY LONGITUDINAL DECK STIFFENER (BULB PROFILE)S

Stiffener 1			Stiffener 2			Stiffener 3			Stiffener 4		
Bulb profile			**Bulb profile**			**Bulb profile**			**Bulb profile**		
h'_w	100	mm	h'_w	145	mm	h'_w	178	mm	h'_w	195	mm
h_w	91.1304348	mm	h_w	131.23913	mm	h_w	160.652174	mm	h_w	175.804348	mm
t_w	10	mm	t_w	10	mm	t_w	12	mm	t_w	12	mm
t'_w	10	mm	t'_w	10	mm	t'_w	12	mm	t'_w	12	mm
b_f	28.2746269	mm	b_f	29.641791	mm	b_f	36.5671642	mm	b_f	39.1044776	mm
t_f	8.86956522	mm	t_f	13.7608696	mm	t_f	17.3478261	mm	t_f	19.1956522	mm
α	1.23333333		α	1		α	1		α	1	

Vertical Frame 1			Vertical Frame 2			Vertical Frame 3			Vertical Frame 4		
T profile			**T profile**			**T profile**			**T profile**		
h_w	120	mm	h_w	150	mm	h_w	200	mm	h_w	220	mm
t_w	12	mm	t_w	12	mm	t_w	12	mm	t_w	12	mm
b_f	120	mm	b_f	150	mm	b_f	200	mm	b_f	220	mm
t_f	12	mm	t_f	12	mm	t_f	12	mm	t_f	12	mm

Frame 1 **Frame 2** 1 **Frame 3** 2 **Frame 4**

T profile			T profile			T profile			T profile		
h_w	140	mm	h_w	160	mm	h_w	200	mm	h_w	260	mm
t_w	10	mm	t_w	10	mm	t_w	12	mm	t_w	12	mm
b_f	60	mm	b_f	70	mm	b_f	200	mm	b_f	260	mm
t_f	10	mm	t_f	10	mm	t_f	12	mm	t_f	12	mm

18.3 Annex 3 : Calculation of the thickness of plating and selection of stiffeners

Deck plating

Deck plating	σ_{locam}	From aft part to 0,25 L_{WL}			From 0,25 L_{WL} to 0,70 L_{WL}			From 0,70 L_{WL} to 0,85 L_{WL}			From 0,85 L_{WL} to fore part		
		Local pressure *kN/m²*	Min.Thickness *mm*	Thickness *mm*	Local pressure *kN/m²*	Min.Thickness *mm*	Thickness *mm*	Local pressure *kN/m²*	Min.Thickness *mm*	Thickness *mm*	Local pressure *kN/m²*	Min.Thickness *mm*	Thickness *mm*
Bottom plating	141	29	6.87	7	31	7.04	8	43	8.38	11	60	9.83	11
Lower deck	141	18	5.44	6	5	5.00	5	5	5	5	7	5.00	5
Crew deck	141				5	5.00	5	5	5	5	7	5.00	5
Cargo deck plating	141	55.30	9.45	10	55.30	9.45	10						
Passenger deck plating	141				8.29	5.00	5	9.17	5	5	11.19	5.00	5
Bridge deck plating	164.5				5.00	5.00	5	7.00	5	5	7.00	5.00	5
Monkey bridge plating	164.5				7.00	5.00	5	7.00	5	5			
Bottom impact pressure	211.5										102.07	10.48	11

Side shell plating

Side shell plating	σ_{locam}	From aft to 0,70.L_{WL}			From 0,70.L_{WL} to fore part		
		Local pressure kN/m²	Min. Thickness mm	Thickness mm	Local pressure kN/m²	Min. Thickness mm	Thickness mm
Below T	141	32	7.18	8	60	9.83	10
From T to T +1 m	141	30	6.96	7	40	8.04	9
From T +1m to T+3m	141	22.5	6.03	7	30	6.96	7
Above	141	15	5	5	15	5	5

Girders

Primary Long stiffeners	τ_{locam}	σ_{locam}	From aft part to 0,25 L_{WL}							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Girder 1	Girder 2	Girder 3	Girder 4	**Primary LS Selected**
Bottom stiffeners	94	105.75	29	121.4382099	3.415	26.476	61.436	114.459	230.698	**4**
Lower deck	94	105.75	18	76.27819609	2.145	25.807	59.743	110.994	221.870	**3**
Crew deck stiffeners	94	105.75								
Cargo deck stiffeners	94	105.75	55	230.0743382	6.471	28.080	65.213	122.026	250.163	**4**
Passenger deck plating	94	105.75								
Bridge deck plating	94	105.75								
Monkey bridge plating	94	105.75								
Bottom impact pressure	117.5	211.5								

Primary Long stiffeners	τ_{locam}	σ_{locam}	From 0,25 LWL to 0,70 LWL							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Girder 1	Girder 2	Girder 3	Girder 4	**Primary LS Selected**
Bottom stiffeners	94	105.75	31	127.77993	3.594	27.060	62.865	117.356	238.142	**4**
Lower deck	94	105.75	5	20.69653316	0.582	25.008	57.662	106.712	211.140	**1**
Crew deck stiffeners	94	105.75	5	20.69653316	0.582	25.008	57.662	106.712	211.140	**1**
Cargo deck stiffeners	94	105.75	55	230.0743382	6.471	28.080	65.213	122.026	250.163	**4**
Passenger deck plating	94	105.75	8	34.49422193	0.970	25.008	57.662	106.712	211.140	**2**
Bridge deck plating	94	105.75	5	20.80378251	0.585	25.008	57.662	106.712	211.140	**1**
Monkey bridge plating	94	105.75	7	29.12529551	0.819	25.008	57.662	106.712	211.140	**2**
Bottom impact pressure	117.5	211.5								

Primary Long stiffeners	τ_{locam}	σ_{locam}	From 0,70 L_{WL} to 0,85 L_{WL}							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Girder 1	Girder 2	Girder 3	Girder 4	**Primary LS Selected**
Bottom stiffeners	94	105.75	43	180.85	5.086	28.547	66.215	123.976	255.151	**4**
Lower deck	94	105.75	5	22.88	0.644	25.008	57.662	106.712	211.140	**1**
Crew deck stiffeners	94	105.75	5	22.88	0.644	25.008	57.662	106.712	211.140	**1**
Cargo deck stiffeners	94	105.75								
Passenger deck plating	94	105.75	9	38.14	1.073	25.008	57.662	106.712	211.140	**2**
Bridge deck plating	94	105.75	7	29.13	0.819	25.008	57.662	106.712	211.140	**2**
Monkey bridge plating	94	105.75	7	29.13	0.819	25.008	57.662	106.712	211.140	**2**
Bottom impact pressure	117.5	211.5								

Primary Long stiffeners	τ_{locam}	σ_{locam}	From 0,85 L_{WL} to fore part							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Girder 1	Girder 2	Girder 3	Girder 4	**Primary LS Selected**
Bottom stiffeners	94	105.75	60	249.03	7.004	28.547	66.215	123.976	255.151	**4**
Lower deck	94	105.75	7	27.92	0.785	25.008	57.662	106.712	211.140	**2**
Crew deck stiffeners	94	105.75	7	27.92	0.785	25.008	57.662	106.712	211.140	**2**
Cargo deck stiffeners	94	105.75								
Passenger deck plating	94	105.75	11	46.54	1.309	25.008	57.662	106.712	211.140	**2**
Bridge deck plating	94	105.75	7	29.13	0.819	25.008	57.662	106.712	211.140	**2**
Monkey bridge plating	94	105.75								
Bottom impact pressure	117.5	211.5	102	212.35	9.556	28.547	66.215	123.976	255.151	**4**

Longitudinal stiffeners

Secondary Long stiffeners	τ_{locam}	σ_{locam}	From aft part to 0,25 L_{WL}							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffeners 4 cm³	**Stiffeners Selected**
Bottom stiffeners	105.75	129.25	29	50.673	1.55	14.674	42.114	85.980	113.416	**3**
Lower deck	105.75	129.25	18	31.829	0.97	14.099	40.359	81.901	107.865	**2**
Crew deck stiffeners	105.75	129.25								
Cargo deck stiffeners	105.75	129.25	55.30	96.004	2.93	16.129	46.282	95.627	126.546	**4**
Passenger deck plating	105.75	129.25								
Bridge deck plating	105.75	188								
Monkey bridge plating	105.75	188								
Bottom impact pressure	129.25	211.5								

Secondary Long stiffeners	τ_{locam}	σ_{locam}	From 0,25 LWL to 0,70 LWL							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffeners 4 cm³	**Stiffeners Selected**
Bottom stiffeners	105.75	129.25	31	53.319	1.63	15.192	43.650	89.554	118.285	**3**
Lower deck	105.75	129.25	5	12.000	0.26	13.439	38.297	77.149	101.417	**1**
Crew deck stiffeners	105.75	129.25	5	12.000	0.26	13.439	38.297	77.149	101.417	**1**
Cargo deck stiffeners	105.75	129.25	55.30	96.004	2.93	16.129	46.282	95.627	126.546	**4**
Passenger deck plating	105.75	129.25	8.29	14.393	0.44	13.439	38.297	77.149	101.417	**2**
Bridge deck plating	105.75	129.25	5.00	12.000	0.27	13.439	38.297	77.149	101.417	**1**
Monkey bridge plating	105.75	129.25	7.00	12.153	0.37	13.439	38.297	77.149	101.417	**1**
Bottom impact pressure	129.25	211.5								

Secondary Long stiffeners	τ_{locam}	σ_{locam}	From 0,70 L_{WL} to 0,85 L_{WL}							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffeners 4 cm³	**Stiffeners Selected**
Bottom stiffeners	105.75	129.25	43	75.46	2.3058562	16.57042469	47.4479988	98.27379339	130.131348	**3**
Lower deck	105.75	129.25	5	12.00	0.2917641	13.43909982	38.2970018	77.14901436	101.417379	**1**
Crew deck stiffeners	105.75	129.25	5	12.00	0.2917641	13.43909982	38.2970018	77.14901436	101.417379	**1**
Cargo deck stiffeners	105.75	129.25								
Passenger deck plating	105.75	129.25	9.17	15.91	0.28564089	13.43909982	38.2970018	77.14901436	101.417379	**2**
Bridge deck plating	105.75	129.25	7.00	12.15	0.37134752	13.43909982	38.2970018	77.14901436	101.417379	**1**
Monkey bridge plating	105.75	129.25	7.00	12.15	0.37134752	13.43909982	38.2970018	77.14901436	101.417379	**1**
Bottom impact pressure	129.25	211.5								

Secondary Long stiffeners	τ_{locam}	σ_{locam}	From 0,85 L_{WL} to fore part							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffeners 4 cm³	**Stiffeners Selected**
Bottom stiffeners	105.75	129.25	60	103.91	3.17507839	16.57042469	47.4479988	98.27379339	130.131348	**4**
Lower deck	105.75	129.25	7	12.00	0.35603581	13.43909982	38.2970018	77.14901436	101.417379	**1**
Crew deck stiffeners	105.75	129.25	7	12.00	0.35603581	13.43909982	38.2970018	77.14901436	101.417379	**1**
Cargo deck stiffeners	105.75	129.25								
Passenger deck plating	105.75	129.25	11.19	19.42	0.59339302	13.43909982	38.2970018	77.14901436	101.417379	**2**
Bridge deck plating	105.75	129.25	7.00	12.15	0.37134752	13.43909982	38.2970018	77.14901436	101.417379	**1**
Monkey bridge plating	105.75	129.25								
Bottom impact pressure	129.25	211.5	102.07	108.30	4.4302935	16.57042469	47.4479988	98.27379339	130.131348	**4**

Secondary transversal stiffeners

Secondary Trans stiffeners	τ_{locam}	σ_{locam}	From aft part to 0,25 L_{WL}							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Frame 1 cm³	Frame 2 cm³	Frame 3 cm³	Frame 4 cm³	**Frame Selected**
Bottom stiffeners	105.75	129.25	29	99.35853534	3.04	20.83933333	30.5868924	109.0705935	221.723325	**3**
Lower deck	105.75	129.25	18	62.40943316	0.97	20.32488095	29.826083	104.9571626	212.32927	**3**
Crew deck stiffeners	105.75	129.25								
Cargo deck stiffeners	105.75	129.25	55	188.2426403	2.93	22.10492424	32.3503902	118.1813215	242.485916	**4**
Passenger deck plating	105.75	129.25								
Bridge deck plating	105.75	188								
Monkey bridge plating	105.75	188								
Bottom impact pressure	129.25	211.5								

Secondary Trans stiffeners	τ_{locam}	σ_{locam}	From 0,25 LWL to 0,70 LWL							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Frame 1 cm³	Frame 2 cm³	Frame 3 cm³	Frame 4 cm³	**Frame Selected**
Bottom stiffeners	105.75	129.25	31	104.5472155	3.19	21.29461111	31.2412544	112.5413475	229.657511	**3**
Lower deck	105.75	129.25	5	16.93352713	0.26	19.71666667	28.9048258	99.93874278	200.934301	**1**
Crew deck stiffeners	105.75	129.25	5	16.93352713	0.26	19.71666667	28.9048258	99.93874278	200.934301	**1**
Cargo deck stiffeners	105.75	129.25	55	188.2426403	2.93	22.10492424	32.3503902	118.1813215	242.485916	**4**
Passenger deck plating	105.75	129.25	8	28.22254522	0.44	19.71666667	28.9048258	99.93874278	200.934301	**2**
Bridge deck plating	105.75	129.25	5	17.0212766	0.27	19.71666667	28.9048258	99.93874278	200.934301	**1**
Monkey bridge plating	105.75	129.25	7	23.82978723	0.37	19.71666667	28.9048258	99.93874278	200.934301	**2**
Bottom impact pressure	129.25	211.5								

Secondary Trans stiffeners	τ_{locam}	σ_{locam}	From 0,70 L_{WL} to 0,85 L_{WL}							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Frame 1 cm³	Frame 2 cm³	Frame 3 cm³	Frame 4 cm³	**Frame Selected**
Bottom stiffeners	105.75	129.25	43	147.97	4.5213	22.4833	32.8407	120.5471	247.8129	**4**
Lower deck	105.75	129.25	5	18.72	0.2918	19.7167	28.9048	99.9387	200.9343	**1**
Crew deck stiffeners	105.75	129.25	5	18.72	0.2918	19.7167	28.9048	99.9387	200.9343	**1**
Cargo deck stiffeners	105.75	129.25								
Passenger deck plating	105.75	129.25	9	31.20	0.4863	19.7167	28.9048	99.9387	200.9343	**3**
Bridge deck plating	105.75	129.25	7	23.83	0.3713	19.7167	28.9048	99.9387	200.9343	**2**
Monkey bridge plating	105.75	129.25	7	23.83	0.3713	19.7167	28.9048	99.9387	200.9343	**2**
Bottom impact pressure	129.25	211.5								

Secondary Trans stiffeners	τ_{locam}	σ_{locam}	From 0,85 L_{WL} to fore part							
			Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Frame 1 cm³	Frame 2 cm³	Frame 3 cm³	Frame 4 cm³	**Frame Selected**
Bottom stiffeners	105.75	129.25	60	204	6.226	22.483	32.841	120.547	247.813	**4**
Lower deck	105.75	129.25	7	23	0.356	19.717	28.905	99.939	200.934	**2**
Crew deck stiffeners	105.75	129.25	7	23	0.356	19.717	28.905	99.939	200.934	**2**
Cargo deck stiffeners	105.75	129.25								
Passenger deck plating	105.75	129.25	11	38	0.593	19.717	28.905	99.939	200.934	**3**
Bridge deck plating	105.75	129.25	7	24	0.371	19.717	28.905	99.939	200.934	**2**
Monkey bridge plating	105.75	129.25								
Bottom impact pressure	129.25	211.5	102	99	1.548	22.483	32.841	120.547	247.813	**1**

Secondary Londitudinal Side Shell Stiffeners

Secondary L.SS. stiffeners	τ_{locam}	σ_{locam}	From aft part to 0,25 L_{WL}									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffener 4 cm³	**SLSS Selected**
Bottom to Cargo deck	105.75	129.25	29	22.5	126	36.4228659	0.33	15.19233616	25.3550824	39.1589943	92.6575778	**3**
Cargo to Pax deck	105.75	129.25	27	13.5	95	27.34468085	0.25	14.67404486	24.4886272	37.7935138	88.9455664	**3**
Pax to Monkey bridge	105.75	129.25	14	13.5	68	19.53191489	0.18	13.43909982	22.3695484	34.4073397	79.7769831	**2**

Secondary L.SS. stiffeners	τ_{locam}	σ_{locam}	From 0,25 LWL to 0,70 LWL									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffener 4 cm³	**SLSS Selected**
Bottom to Cargo deck	105.75	129.25	32	20.25	125	36.04361104	0.33	15.19233616	25.3550824	39.1589943	92.6575778	**3**
Cargo to Pax deck	105.75	129.25	20	13.5	81	23.43829787	0.21	14.67404486	24.4886272	37.7935138	88.9455664	**2**
Pax to Monkey bridge	105.75	129.25	14	13.5	68	19.53191489	0.18	13.43909982	22.3695484	34.4073397	79.7769831	**2**

Secondary L.SS. stiffeners	τ_{locam}	σ_{locam}	From 0,70 L_{WL} to 0,85 L_{WL}									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffener 4 cm³	**SLSS Selected**
Bottom to Cargo deck	105.75	129.25	43	36	195	56.40585873	0.52	15.19233616	25.3550824	39.1589943	92.6575778	**4**
Cargo to Pax deck	105.75	129.25	36	27	153	44.27234043	0.41	14.67404486	24.4886272	37.7935138	88.9455664	**4**
Pax to Monkey bridge	105.75	129.25	14	13.5	68	19.53191489	0.18	13.43909982	22.3695484	34.4073397	79.7769831	**2**

Secondary L.SS. stiffeners	τ_{locam}	σ_{locam}	From 0,85 L_{WL} to fore part									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	Stiffener 1 cm³	Stiffener 2 cm³	Stiffener 3 cm³	Stiffener 4 cm³	**SLSS Selected**
Bottom to Cargo deck	105.75	129.25	60	36	228	65.88828267	0.60	15.19233616	25.3550824	39.1589943	92.6575778	**4**
Cargo to Pax deck	105.75	129.25	36	18.72282995	128	37.08705238	0.34	14.67404486	24.4886272	37.7935138	88.9455664	**3**
Pax to Monkey bridge	105.75	129.25	19	13.5	78	22.55448882	0.21	13.43909982	22.3695484	34.4073397	79.7769831	**3**

Secondary Vertically Stiffeners

Secondary Verti stiffeners	τ_{locam}	σ_{locam}	From aft part to 0,25 L_{WL}									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	S.V.Stiff 1	S.V.Stiff 2	S.V.Stiff 3	S.V.Stiff 4	**Sec. Vert. Selected**
Bottom to Cargo deck	105.75	129.25	29	20.25	119	67.58759689	0.62	27.93127232	51.2972061	112.541347	145.900498	**3**
Cargo to Pax deck	105.75	129.25	27	13.5	95	53.61702128	0.49	27.18224534	49.8730545	109.070594	141.217368	**3**
Pax to Monkey bridge	105.75	129.25	13.5	13.5	68	38.29787234	0.35	25.29553892	46.1662899	99.9387428	128.896859	**2**

Secondary Verti stiffeners	τ_{locam}	σ_{locam}	From 0,25 LWL to 0,70 LWL									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	S.V.Stiff 1	S.V.Stiff 2	S.V.Stiff 3	S.V.Stiff 4	**Sec. Vert. Selected**
Bottom to Cargo deck	105.75	129.25	32	20	125	70.67374713	0.65	27.93127232	51.2972061	112.541347	145.900498	**3**
Cargo to pax	105.75	129.25	20	13.5	81	45.95744681	0.42	27.18224534	49.8730545	109.070594	141.217368	**2**
Pax to Monkey bridge	105.75	129.25	13.5	13.5	68	38.29787234	0.35	25.29553892	46.1662899	99.9387428	128.896859	**2**

Secondary Verti stiffeners	τ_{locam}	σ_{locam}	From 0,70 L_{WL} to 0,85 L_{WL}									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	S.V.Stiff 1	S.V.Stiff 2	S.V.Stiff 3	S.V.Stiff 4	**Sec. Vert. Selected**
Bottom to Crew deck	105.75	129.25	43	36	195	111	1.01	29.22616876	53.6577107	118.181321	153.486165	**3**
Crew to Pax deck	105.75	129.25	36	27	153	87	0.80	28.60482414	52.5431571	115.53977	149.938724	**3**
Pax to Monkey bridge	105.75	129.25	18.72	13.5	78	44	0.41	25.29553892	46.1662899	99.9387428	128.896859	**2**

Secondary Verti stiffeners	τ_{locam}	σ_{locam}	From 0,85 L_{WL} to fore part									
			pslower kN/m²	psupper kN/m²	Local pressure kN/m²	Z_{RULES} cm³	A_{SH} cm²	S.V.Stiff 1	S.V.Stiff 2	S.V.Stiff 3	S.V.Stiff 4	**Sec. Vert. Selected**
Bottom to Cargo deck	105.75	129.25	60	36	228	129	1.18	29.22616876	53.6577107	118.181321	153.486165	**4**
Cargo to Pax deck	105.75	129.25	36	18.72	128	73	0.67	28.60482414	52.5431571	115.53977	149.938724	**3**
Pax to Monkey bridge	105.75	129.25	18.7228299	13.5	78	44	0.41	25.29553892	46.1662899	99.9387428	128.896859	**2**

18.4 Annex 4: Weight structure calculation

Items	Qty	L	Transversal dir Beam/thickness	Area$_{item}$	Vert. Direction Height/thickness	Volume$_{item}$	Weights	Center of gravity LCG	VCG	Moments Long.moment	Vert.moment
		m	*m*	*m²*	*m*	*m³*	*tons*	*m*	*m*	*tons.m*	*tons.m*
Section 0											
Bottom platings 8mm (+1)	1	2	8.50E+00		8.00E-03	1.36E-01	1.09E+00	1.00	1.65	1.09E+00	1.80E+00
Stern plating 7 mm	1			2.22E+01	7.00E-03	1.55E-01	1.24E+00	0.00	3.00	0.00E+00	3.73E+00
Bottom longitudinal stiffeners 2	10	2		1.72E-03		3.44E-03	2.75E-01	1.00	1.70	2.75E-01	4.68E-01
Bottom primary longitudinal girder 3	3	2		3.75E-03		7.50E-03	1.80E-01	1.00	1.75	1.80E-01	3.15E-01
Side shell plating 7mm	2	2	7.00E-03		2.60E+00	3.64E-02	5.82E-01	1.00	7.57	5.82E-01	4.41E+00
Long. S.S. stiffeners 3	6	2		2.86E-03		5.72E-03	2.75E-01	1.00	3.10	2.75E-01	8.51E-01
Cargo deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	1.00	3.60	6.72E-01	2.42E+00
Cargo deck longitudinal girder 1	3	2		2.20E-03		4.40E-03	1.06E-01	1.00	3.50	1.06E-01	3.70E-01
Cargo deck longitudinal stiffener 1	10	2		1.16E-03		2.32E-03	1.86E-01	1.00	3.50	1.86E-01	6.51E-01
Stern vertical stiffeners 2	13	2.2		3.60E-03		7.92E-03	8.24E-01	0.10	3.10	8.24E-02	2.55E+00
Subtotal							**5.43E+00**			**3.45E+00**	**1.76E+01**

Section 1											
Bottom plating 8mm (+1)	1	2	8.45E+00		8.00E-03	1.35E-01	1.08E+00	3.00	1.60	3.24E+00	1.73E+00
Bottom primary longitudinal girder 3	3	2		3.75E-03		7.50E-03	1.80E-01	3.00	1.70	5.40E-01	3.06E-01
Bottom longitudinal stiffeners 2	10	2		1.72E-03		3.44E-03	2.75E-01	3.00	1.70	8.26E-01	4.68E-01
Side shell plating 7mm	2	2	7.00E-03		2.70E+00	1.89E-02	3.02E-01	3.00	3.16	9.07E-01	9.56E-01
Long. S.S. stiffeners 3	6	2		2.56E-03		5.12E-03	2.46E-01	3.00	3.16	7.38E-01	7.78E-01
Cargo deck plating 10mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	3.00	3.60	4.03E+00	4.84E+00
Cargo deck longitudinal girder 1	3	2		2.20E-03		4.40E-03	1.06E-01	3.00	3.50	3.17E-01	3.70E-01
Cargo deck longitudinal stiffener 1	10	2		1.16E-03		2.32E-03	1.86E-01	3.00	3.50	5.58E-01	6.51E-01
Side shell frame 3	2			4.80E-03	2.30E+00	1.10E-02	1.77E-01	2.00	2.90	3.53E-01	5.12E-01
Cargo deck frame 1	2		4.10E+00	2.00E-03		8.20E-03	1.31E-01	2.00	3.80	2.62E-01	4.99E-01

Subtotal							**4.03E+00**			**1.18E+01**	**1.11E+01**
Section 2											
Bottom plating 8mm (+1)	1	2	8.54E+00		8.00E-03	1.37E-01	1.09E+00	5.00	1.40	5.47E+00	1.53E+00
Bottom primary longitudinal girder 3	3	2		3.75E-03		7.50E-03	1.80E-01	5.00	1.50	9.00E-01	2.70E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	5.00	1.50	2.05E+00	6.15E-01
Side shell plating 8mm	2	2	8.00E-03		2.90E+00	4.64E-02	7.42E-01	5.00	2.70	3.71E+00	2.00E+00
Long. S.S. stiffeners 3	6	2		2.56E-03		5.12E-03	2.46E-01	5.00	2.70	1.23E+00	6.64E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	8.40E-02	6.72E-01	5.00	3.60	3.36E+00	2.42E+00
Cargo deck longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	5.00	3.50	1.44E+00	1.01E+00
Cargo deck longitudinal stiffener 4	10	2		2.86E-03		5.72E-03	4.58E-01	5.00	3.50	2.29E+00	1.60E+00
Aft bulkhead	1			1.81E+01	1.00E-02	1.81E-01	1.45E+00	4.00	2.70	5.79E+00	3.91E+00
Bulkheads vertical stiffeners 4	13	2.8		5.28E-03		1.48E-02	1.54E+00	3.90	2.70	6.00E+00	4.15E+00
Subtotal							**7.08E+00**			**3.22E+01**	**1.82E+01**
Section 3											
Bottom plating 8 mm	1	2	8.28E+00		8.00E-03	1.32E-01	1.06E+00	7.00	1.10	7.42E+00	1.17E+00
Bottom primary longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	7.00	1.20	2.02E+00	3.46E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	7.00	1.20	2.87E+00	4.92E-01
Bottom frame 3	1		8.00E+00	4.80E-03		3.84E-02	3.07E-01	6.00	1.20	1.84E+00	3.69E-01
Side shell plating 8 mm	2	2	8.00E-03		3.10E+00	4.96E-02	7.94E-01	7.00	2.97	5.56E+00	2.36E+00
Side shell LS 3	8	2		2.56E-03		5.12E-03	3.28E-01	7.00	2.97	2.30E+00	9.75E-01
Side shell VS3	2			4.80E-03	2.30E+00	1.10E-02	1.77E-01	6.00	2.97	1.06E+00	5.25E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	7.00	3.60	9.41E+00	4.84E+00
Cargo G4	3	2		6.00E-03		1.20E-02	2.88E-01	7.00	3.50	2.02E+00	1.01E+00
Cargo LS4	10	2		2.86E-03		5.72E-03	4.58E-01	7.00	3.50	3.20E+00	1.60E+00
Cargo frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	6.00	3.50	2.52E+00	1.47E+00
Subtotal							**5.87E+00**			**4.02E+01**	**1.51E+01**
Section 4											

Bottom plating 8 mm	1	2	8.70E+00		8.00E-03	1.39E-01	1.11E+00	9.00	0.90	1.00E+01	1.00E+00
Bottom primary longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	9.00	1.00	2.59E+00	2.88E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	9.00	1.00	3.69E+00	4.10E-01
Bottom frame 3	1		8.00E+00	4.80E-03		3.84E-02	3.07E-01	8.00	1.00	2.46E+00	3.07E-01
Side shell plating 8 mm	2	2	8.00E-03		3.30E+00	5.28E-02	8.45E-01	9.00	2.83	7.60E+00	2.39E+00
Side shell LS 3	10	2		2.56E-03		5.12E-03	4.10E-01	9.00	2.83	3.69E+00	1.16E+00
Side shell VS3	2			4.80E-03	2.60E+00	1.25E-02	2.00E-01	8.00	2.83	1.60E+00	5.65E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	9.00	3.60	1.21E+01	4.84E+00
Cargo G4	3	2		6.00E-03		1.20E-02	2.88E-01	9.00	3.50	2.59E+00	1.01E+00
Cargo LS4	10	2		2.86E-03		5.72E-03	4.58E-01	9.00	3.50	4.12E+00	1.60E+00
Cargo frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	8.00	3.50	3.35E+00	1.47E+00
Subtotal							**6.08E+00**			**5.38E+01**	**1.50E+01**

Section 5											
Bottom plating 8 mm	1	2	8.59E+00		8.00E-03	1.38E-01	1.10E+00	11.00	0.70	1.21E+01	7.70E-01
Bottom primary longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	11.00	0.80	3.17E+00	2.30E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	11.00	0.80	4.51E+00	3.28E-01
Bottom frame 4	1		8.00E+00	6.24E-03		4.99E-02	3.99E-01	10.00	0.80	3.99E+00	3.19E-01
Side shell plating 8 mm	2	2	8.00E-03		3.50E+00	5.60E-02	8.96E-01	11.00	2.70	9.86E+00	2.42E+00
Side shell LS 3	10	2		2.56E-03		5.12E-03	4.10E-01	11.00	2.70	4.51E+00	1.11E+00
Side shell VS3	2			4.80E-03	2.60E+00	1.25E-02	2.00E-01	10.00	2.70	2.00E+00	5.39E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	11.00	3.60	1.48E+01	4.84E+00
Cargo G4	3	2		6.00E-03		1.20E-02	2.88E-01	11.00	3.50	3.17E+00	1.01E+00
Cargo LS4	10	2		2.86E-03		5.72E-03	4.58E-01	11.00	3.50	5.03E+00	1.60E+00
Cargo frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	10.00	3.50	4.19E+00	1.47E+00

Subtotal							**6.21E+00**			**6.73E+01**	**1.46E+01**

Section 6											
Bottom plating 8 mm	1	2	8.70E+00		8.00E-03	1.39E-01	1.11E+00	13.00	0.60	1.45E+01	6.68E-01
Bottom primary longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	13.00	0.70	3.74E+00	2.02E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	13.00	0.70	5.33E+00	2.87E-01
Bottom frame 4	1		8.00E+00	6.24E-03		4.99E-02	3.99E-01	12.00	0.70	4.79E+00	2.80E-01
Side shell plating 8 mm	2	2	8.00E-03		3.70E+00	5.92E-02	9.47E-01	13.00	2.10	1.23E+01	1.99E+00
Side shell LS 3	14	2		2.56E-03		5.12E-03	5.74E-01	13.00	2.10	7.46E+00	1.21E+00
Side shell VS3	2			4.80E-03	2.90E+00	1.39E-02	2.23E-01	12.00	2.10	2.67E+00	4.68E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	13.00	3.60	1.75E+01	4.84E+00
Cargo G4	3	2		6.00E-03		1.20E-02	2.88E-01	13.00	3.50	3.74E+00	1.01E+00
Cargo LS4	10	2		2.86E-03		5.72E-03	4.58E-01	13.00	3.50	5.95E+00	1.60E+00
Cargo frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	12.00	3.50	5.03E+00	1.47E+00
Subtotal							**6.46E+00**			**8.30E+01**	**1.40E+01**

Section 7											
Bottom plating 8 mm	1	2	8.69E+00		8.00E-03	1.39E-01	1.11E+00	15.00	0.50	1.67E+01	5.56E-01
Bottom primary longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	15.00	0.60	4.32E+00	1.73E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	15.00	0.60	6.15E+00	2.46E-01
Bottom frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	14.00	0.60	5.87E+00	2.52E-01
Side shell plating 8 mm	2	2	8.00E-03		3.70E+00	5.92E-02	9.47E-01	15.00	1.90	1.42E+01	1.80E+00

Side shell LS 3	8	2		2.56E-03		5.12E-03	3.28E-01	15.00	1.90	4.92E+00	6.23E-01
Side shell VS3	2			4.80E-03	2.90E+00	1.39E-02	2.23E-01	14.00	1.90	3.12E+00	4.23E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	15.00	3.60	2.02E+01	4.84E+00
Cargo G4	3	2		6.00E-03		1.20E-02	2.88E-01	15.00	3.50	4.32E+00	1.01E+00
Cargo LS4	10	2		2.86E-03		5.72E-03	4.58E-01	15.00	3.50	6.86E+00	1.60E+00
Cargo frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	14.00	3.50	5.87E+00	1.47E+00
Subtotal							**6.24E+00**			**9.25E+01**	**1.30E+01**

Section 8											
Bottom plating 8 mm	1	2	8.65E+00		8.00E-03	1.38E-01	1.11E+00	17.00	0.50	1.88E+01	5.54E-01
Bottom primary longitudinal girder 4	3	2		6.00E-03		1.20E-02	2.88E-01	17.00	0.60	4.90E+00	1.73E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	17.00	0.60	6.97E+00	2.46E-01
Bottom frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	16.00	0.60	6.71E+00	2.52E-01
Side shell plating 8 mm	2	2	8.00E-03		3.70E+00	5.92E-02	9.47E-01	17.00	1.90	1.61E+01	1.80E+00
Side shell LS 3	8	2		2.56E-03		5.12E-03	3.28E-01	17.00	1.90	5.58E+00	6.23E-01
Side shell VS3	2			4.80E-03	2.90E+00	1.39E-02	2.23E-01	16.00	1.90	3.56E+00	4.23E-01
Cargo deck plating 10 mm	1	2	8.40E+00		1.00E-02	1.68E-01	1.34E+00	17.00	3.60	2.28E+01	4.84E+00
Cargo G4	3	2		6.00E-03		1.20E-02	2.88E-01	17.00	3.50	4.90E+00	1.01E+00
Cargo LS4	10	2		2.86E-03		5.72E-03	4.58E-01	17.00	3.50	7.78E+00	1.60E+00
Cargo frame 4	1		8.40E+00	6.24E-03		5.24E-02	4.19E-01	16.00	3.50	6.71E+00	1.47E+00
Subtotal							**6.23E+00**			**1.05E+02**	**1.30E+01**

Section 9											
Bottom plating 8 mm	1	2	8.57E+00		8.00E-03	1.37E-01	1.10E+00	19.00	0.50	2.09E+01	5.49E-01
Bottom girder plate	3	2	7.00E-03		9.00E-01	1.26E-02	3.02E-01	19.00	0.60	5.75E+00	1.81E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	19.00	0.60	7.79E+00	2.46E-01
Engine bulkhead 10mm	1	0.01		4.40E+01		4.40E-01	3.52E+00	18.00	2.70	6.34E+01	9.50E+00
Engine bulkhead VS 3	13			4.80E-03	4.80E+00	2.30E-02	2.40E+00	18.10	2.70	4.34E+01	6.47E+00
Aft plate superstrucutre 5 mm	1	0.005		2.00E+01		1.00E-01	8.00E-01	18.00	7.00	1.44E+01	5.60E+00
Aft superstructure VS 2	13			3.60E-03	2.40E+00	8.64E-03	8.99E-01	18.10	7.00	1.63E+01	6.29E+00
Engine deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	19.00	1.40	1.28E+01	9.41E-01
Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	19.00	1.30	3.53E+00	2.42E-01
Side shell low plating 7 mm	2	2	7.00E-03		5.10E+00	7.14E-02	1.14E+00	19.00	3.60	2.17E+01	4.11E+00
Side shell low LS 3	14	2		2.56E-03		5.12E-03	5.74E-01	19.00	3.20	1.09E+01	1.84E+00
Side shell top plating 5 mm	2	2	5.00E-03		2.40E+00	2.40E-02	3.84E-01	19.00	7.00	7.30E+00	2.69E+00
Side shell top LS 2	8	2		1.72E-03		3.44E-03	2.20E-01	19.00	7.00	4.18E+00	1.54E+00
Crew deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	19.00	3.60	1.28E+01	2.42E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	19.00	3.50	2.01E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	19.00	3.50	3.53E+00	6.51E-01
Pax deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	19.00	5.80	1.28E+01	3.90E+00
Pax G1	3	2		2.20E-03		4.40E-03	1.06E-01	19.00	5.70	2.01E+00	6.02E-01
Pax LS1	10	2		1.16E-03		2.32E-03	1.86E-01	19.00	5.70	3.53E+00	1.06E+00

Bridge deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	19.00	8.20	1.28E+01	5.51E+00
Bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	19.00	8.10	2.74E+00	1.17E+00
Bridge LS 2	10	2		1.72E-03		3.44E-03	2.75E-01	19.00	8.10	5.23E+00	2.23E+00
Subtotal							1.56E+01			2.90E+02	5.81E+01

Section 10											
Bottom plating 8 mm	1	2	8.48E+00		8.00E-03	1.36E-01	1.09E+00	21.00	0.50	2.28E+01	5.43E-01
Bottom primary longitudinal girder 4	3	2	1.00E-02		9.00E-01	1.80E-02	4.32E-01	21.00	0.90	9.07E+00	3.89E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	21.00	0.60	8.61E+00	2.46E-01
Bottom frame 4	2	0.01		3.70E+00		3.70E-02	5.92E-01	20.00	0.90	1.18E+01	5.33E-01
Engine deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	21.00	1.40	1.41E+01	9.41E-01
Engine primary longitudinal girder 1	3	2		2.20E-03		4.40E-03	1.06E-01	21.00	1.30	2.22E+00	1.37E-01
Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	21.00	1.30	3.90E+00	2.42E-01
Side shell low plating 7 mm	2	2	7.00E-03		5.10E+00	7.14E-02	1.14E+00	21.00	3.10	2.40E+01	3.54E+00
Side shell low LS 3	14	2		2.56E-03		5.12E-03	5.74E-01	21.00	3.10	1.21E+01	1.78E+00
Side shell low VS3	2			4.80E-03	4.50E+00	2.16E-02	3.46E-01	20.00	3.10	6.91E+00	1.07E+00
Side shell top plating 5 mm	2	2	5.00E-03		2.40E+00	2.40E-02	3.84E-01	21.00	7.00	8.06E+00	2.69E+00
Side shell top LS 2	8	2		1.72E-03		3.44E-03	2.20E-01	21.00	7.00	4.62E+00	1.54E+00
Side shell top VS2	2			3.60E-03	2.40E+00	8.64E-03	1.38E-01	20.00	7.00	2.76E+00	9.68E-01
Crew deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	21.00	3.60	1.41E+01	2.42E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	21.00	3.50	2.22E+00	3.70E-01

Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	21.00	3.50	3.90E+00	6.51E-01
Crew deck frame 1	1		8.40E+00	2.00E-03		1.68E-02	1.34E-01	20.00	3.50	2.69E+00	4.70E-01
Pax deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	21.00	5.80	1.41E+01	3.90E+00
Pax G1	3	2		2.20E-03		4.40E-03	1.06E-01	21.00	5.70	2.22E+00	6.02E-01
Pax LS1	10	2		1.16E-03		2.32E-03	1.86E-01	21.00	5.70	3.90E+00	1.06E+00
Pax frame 1	1		8.40E+00	2.00E-03		1.68E-02	1.34E-01	20.00	5.70	2.69E+00	7.66E-01
Bridge deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	21.00	8.20	1.41E+01	5.51E+00
Bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	21.00	8.10	3.02E+00	1.17E+00
Bridge LS 2	10	2		1.72E-03		3.44E-03	2.75E-01	21.00	8.10	5.78E+00	2.23E+00
Brdige frame 2	1		8.40E+00	2.30E-03		1.93E-02	1.55E-01	20.00	8.10	3.09E+00	1.25E+00
Subtotal							**9.73E+00**			**2.03E+02**	**3.50E+01**

Section 11											
Bottom plating 8 mm	1	2	8.34E+00		8.00E-03	1.34E-01	1.07E+00	23.00	0.50	2.46E+01	5.34E-01
Bottom primary longitudinal girder 4	3	2	7.00E-03		9.00E-01	1.26E-02	3.02E-01	23.00	0.90	6.96E+00	2.72E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	23.00	0.60	9.43E+00	2.46E-01
Bottom frame 4	2	0.01		3.50E+00		3.50E-02	5.60E-01	22.00	0.90	1.23E+01	5.04E-01
Engine deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	23.00	1.40	1.55E+01	9.41E-01
Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	23.00	1.30	4.28E+00	2.42E-01
Side shell low plating 7 mm	2	2	7.00E-03		5.00E+00	7.00E-02	1.12E+00	23.00	3.60	2.58E+01	4.03E+00
Side shell low LS 3	14	2		2.56E-03		5.12E-03	5.74E-01	23.00	3.60	1.32E+01	2.07E+00

Side shell low VS3	2			4.80E-03	4.50E+00	2.16E-02	3.46E-01	22.0 0	3.60	7.60E+00	1.24E+00
Side shell top plating 5 mm	2	2	5.00E-03		2.40E+00	2.40E-02	3.84E-01	23.0 0	7.00	8.83E+00	2.69E+00
Side shell top LS 2	8	2		1.72E-03		3.44E-03	2.20E-01	23.0 0	7.00	5.06E+00	1.54E+00
Side shell top VS2	2			3.60E-03	2.40E+00	8.64E-03	1.38E-01	22.0 0	7.00	3.04E+00	9.68E-01
Crew deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	23.0 0	3.60	1.55E+01	2.42E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	23.0 0	3.50	2.43E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	23.0 0	3.50	4.28E+00	6.51E-01
Crew deck frame 1	1		8.40E+00	2.00E-03		1.68E-02	1.34E-01	22.0 0	3.50	2.96E+00	4.70E-01
Pax deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	23.0 0	5.80	1.55E+01	3.90E+00
Pax G1	3	2		2.20E-03		4.40E-03	1.06E-01	23.0 0	5.70	2.43E+00	6.02E-01
Pax LS1	10	2		1.16E-03		2.32E-03	1.86E-01	23.0 0	5.70	4.28E+00	1.06E+00
Pax frame 1	1		8.40E+00	2.00E-03		1.68E-02	1.34E-01	22.0 0	5.70	2.96E+00	7.66E-01
Bridge deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	23.0 0	8.20	1.55E+01	5.51E+00
Bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	23.0 0	8.10	3.31E+00	1.17E+00
Bridge LS 2	10	2		1.72E-03		3.44E-03	2.75E-01	23.0 0	8.10	6.33E+00	2.23E+00
Brdige frame 2	1		8.40E+00	2.30E-03		1.93E-02	1.55E-01	22.0 0	8.10	3.40E+00	1.25E+00
Subtotal							**9.42E+00**			**2.15E+02**	**3.57E+01**

Section 12											
Bottom plating 8 mm	1	2	8.14E+00		8.00E-03	1.30E-01	1.04E+00	25.0 0	1.00	2.61E+01	1.04E+00
Bottom primary longitudinal girder 4	3	2	7.00E-03		9.00E-01	1.26E-02	3.02E-01	25.0 0	1.10	7.56E+00	3.33E-01

Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	25.00	1.10	1.02E+01	4.51E-01
Double bottom frame	2	0.01		3.20E+00		3.20E-02	5.12E-01	24.00	1.10	1.23E+01	5.63E-01
Engine deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	25.00	1.40	1.68E+01	9.41E-01
Engine primary longitudinal girder 1	3	2		2.20E-03		4.40E-03	1.06E-01	25.00	1.30	2.64E+00	1.37E-01
Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	25.00	1.30	4.65E+00	2.42E-01
Side shell low plating 7 mm	2	2	7.00E-03		4.40E+00	6.16E-02	9.86E-01	25.00	3.60	2.46E+01	3.55E+00
Side shell low LS 3	14	2		2.56E-03		5.12E-03	5.74E-01	25.00	3.60	1.43E+01	2.07E+00
Side shell low VS3	2			4.80E-03	4.40E+00	2.11E-02	3.38E-01	24.00	3.60	8.11E+00	1.22E+00
Side shell top plating 5 mm	2	2	5.00E-03		2.40E+00	2.40E-02	3.84E-01	25.00	7.00	9.60E+00	2.69E+00
Side shell top LS 2	8	2		1.72E-03		3.44E-03	2.20E-01	25.00	7.00	5.50E+00	1.54E+00
Side shell top VS2	2			3.60E-03	2.40E+00	8.64E-03	1.38E-01	24.00	7.00	3.32E+00	9.68E-01
Crew deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	25.00	3.60	1.68E+01	2.42E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	25.00	3.50	2.64E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	25.00	3.50	4.65E+00	6.51E-01
Crew deck frame 1	1		8.40E+00	2.00E-03		1.68E-02	1.34E-01	24.00	3.50	3.23E+00	4.70E-01
Pax deck plating 5mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	25.00	5.80	1.68E+01	3.90E+00
Pax G1	3	2		2.20E-03		4.40E-03	1.06E-01	25.00	5.70	2.64E+00	6.02E-01
Pax LS1	10	2		1.16E-03		2.32E-03	1.86E-01	25.00	5.70	4.65E+00	1.06E+00
Pax frame 1	1		8.40E+00	2.00E-03		1.68E-02	1.34E-01	24.00	5.70	3.23E+00	7.66E-01
Bridge deck plating 5 mm	1	2	8.40E+00		5.00E-03	8.40E-02	6.72E-01	25.00	8.20	1.68E+01	5.51E+00

Bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	25.00	8.10	3.60E+00	1.17E+00
Bridge LS 2	10	2		1.72E-03		3.44E-03	2.75E-01	25.00	8.10	6.88E+00	2.23E+00
Brdige frame 2	1		8.40E+00	2.30E-03		1.93E-02	1.55E-01	24.00	8.10	3.71E+00	1.25E+00
Subtotal							**9.31E+00**			**2.31E+02**	**3.61E+01**

Section 13											
Bottom plating 8 mm	1	2	8.00E+00		8.00E-03	1.28E-01	1.02E+00	27.00	0.60	2.76E+01	6.14E-01
Bottom primary longitudinal girder 4	3	2	7.00E-03		8.00E-01	1.12E-02	2.69E-01	27.00	0.90	7.26E+00	2.42E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	27.00	0.70	1.11E+01	2.87E-01
Double bottom frame 4	2		1.00E-02	2.80E+00		2.80E-02	4.48E-01	26.00	0.70	1.16E+01	3.14E-01
Engine deck plating 5mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	27.00	1.40	1.79E+01	9.30E-01
Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	27.00	1.30	5.02E+00	2.42E-01
Side shell low plating 7 mm	2	2	7.00E-03		4.40E+00	6.16E-02	9.86E-01	27.00	3.60	2.66E+01	3.55E+00
Side shell low LS 3	14	2		2.56E-03		5.12E-03	5.74E-01	27.00	3.60	1.55E+01	2.07E+00
Side shell low VS3	2			4.80E-03	4.40E+00	2.11E-02	3.38E-01	26.00	3.60	8.79E+00	1.22E+00
Side shell top plating 5 mm	2	2	5.00E-03		4.60E+00	4.60E-02	7.36E-01	27.00	8.10	1.99E+01	5.96E+00
Side shell top LS 2	14	2		1.72E-03		3.44E-03	3.85E-01	27.00	8.10	1.04E+01	3.12E+00
Side shell top VS2	2			3.60E-03	4.60E+00	1.66E-02	2.65E-01	26.00	8.10	6.89E+00	2.15E+00
Crew deck plating 5 mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	27.00	3.60	1.79E+01	2.39E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	27.00	3.50	2.85E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	27.00	3.50	5.02E+00	6.51E-01

Crew deck frame 1	1		8.30E+00	2.00E-03		1.66E-02	1.33E-01	26.00	3.50	3.45E+00	4.65E-01
Pax deck plating 5mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	27.00	5.80	1.79E+01	3.85E+00
Pax G1	3	2		2.20E-03		4.40E-03	1.06E-01	27.00	5.70	2.85E+00	6.02E-01
Pax LS1	10	2		1.16E-03		2.32E-03	1.86E-01	27.00	5.70	5.02E+00	1.06E+00
Pax frame 1	1		8.30E+00	2.00E-03		1.66E-02	1.33E-01	26.00	5.70	3.45E+00	7.57E-01
Bridge deck plating 5 mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	27.00	8.20	1.79E+01	5.44E+00
Bridge deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	27.00	8.10	3.89E+00	1.17E+00
Bridge deck LS 2	10	2		1.72E-03		3.44E-03	2.75E-01	27.00	8.10	7.43E+00	2.23E+00
Bridge deck frame 2	1		8.30E+00	2.30E-03		1.91E-02	1.53E-01	26.00	8.10	3.97E+00	1.24E+00
Monkey bridge plating 5 mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	27.00	10.40	1.79E+01	6.91E+00
Monkey bridge G1	3	2		2.20E-03		4.40E-03	1.06E-01	27.00	10.30	2.85E+00	1.09E+00
Monkey bridge LS1	10	2		1.16E-03		2.32E-03	1.86E-01	27.00	10.30	5.02E+00	1.92E+00
Monkey bridge F1	1		8.30E+00	2.00E-03		1.66E-02	1.33E-01	26.00	10.30	3.45E+00	1.37E+00
Subtotal							**1.08E+01**			**2.90E+02**	**5.22E+01**

Section 14											
Bottom plating 8 mm	1	2	7.80E+00		1.10E-02	1.72E-01	1.37E+00	29.00	0.70	3.98E+01	9.61E-01
Bottom primary longitudinal girder 4	3	2	7.00E-03		9.00E-01	1.26E-02	3.02E-01	29.00	0.90	8.77E+00	2.72E-01
Bottom longitudinal stiffeners 3	10	2		2.56E-03		5.12E-03	4.10E-01	29.00	0.80	1.19E+01	3.28E-01
Double bottom frame	2	0.01		3.20E+00		3.20E-02	5.12E-01	28.00	0.90	1.43E+01	4.61E-01
Engine deck plating 5mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	29.00	1.40	1.93E+01	9.30E-01

Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	29.00	1.30	5.39E+00	2.42E-01
Side shell low plating 9 mm	2	2	9.00E-03		4.60E+00	8.28E-02	1.32E+00	29.00	3.60	3.84E+01	4.77E+00
Side shell low LS 4	14	2		2.86E-03		5.72E-03	6.41E-01	29.00	3.60	1.86E+01	2.31E+00
Side shell low VS3	2			4.80E-03	4.60E+00	2.21E-02	3.53E-01	28.00	3.60	9.89E+00	1.27E+00
Side shell top plating 5 mm	2	2	5.00E-03		4.60E+00	4.60E-02	7.36E-01	29.00	8.10	2.13E+01	5.96E+00
Side shell top LS 2	14	2		1.72E-03		3.44E-03	3.85E-01	29.00	8.10	1.12E+01	3.12E+00
Side shell top VS2	2			3.60E-03	4.60E+00	1.66E-02	2.65E-01	28.00	8.10	7.42E+00	2.15E+00
Crew deck plating 5 mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	29.00	3.60	1.93E+01	2.39E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	29.00	3.50	3.06E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	29.00	3.50	5.39E+00	6.51E-01
Crew deck frame 1	1		8.30E+00	2.00E-03		1.66E-02	1.33E-01	28.00	3.50	3.72E+00	4.65E-01
Pax deck plating 5mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	29.00	5.80	1.93E+01	3.85E+00
Pax G2	3	2		3.00E-03		6.00E-03	1.44E-01	29.00	5.70	4.18E+00	8.21E-01
Pax LS2	10	2		1.72E-03		3.44E-03	2.75E-01	29.00	5.70	7.98E+00	1.57E+00
Pax frame 2	1		8.30E+00	2.30E-03		1.91E-02	1.53E-01	28.00	5.70	4.28E+00	8.71E-01
Bridge deck plating 5 mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	29.00	8.20	1.93E+01	5.44E+00
Bridge deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	29.00	8.10	4.18E+00	1.17E+00
Bridge deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	29.00	8.10	5.39E+00	1.51E+00
Bridge deck frame 2	1		8.30E+00	2.30E-03		1.91E-02	1.53E-01	28.00	8.10	4.28E+00	1.24E+00
Monkey bridge plating 5 mm	1	2	8.30E+00		5.00E-03	8.30E-02	6.64E-01	29.00	10.40	1.93E+01	6.91E+00

Monkey bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	29.00	10.30	4.18E+00	1.48E+00
Monkey bridge LS1	10	2		1.16E-03		2.32E-03	1.86E-01	29.00	10.30	5.39E+00	1.92E+00
Monkey bridge F2	1		8.30E+00	2.30E-03		1.91E-02	1.53E-01	28.00	10.30	4.28E+00	1.57E+00
Subtotal							**1.18E+01**			**3.40E+02**	**5.50E+01**

Section 15 (at z=0.55m)											
Bottom plating 11 mm	1	2	7.70E+00		1.10E-02	1.69E-01	1.36E+00	31.00	0.80	4.20E+01	1.08E+00
Bottom primary longitudinal girder 4	3	2	7.00E-03		6.50E-01	9.10E-03	2.18E-01	31.00	0.90	6.77E+00	1.97E-01
Bottom longitudinal stiffeners 3	6	2		2.56E-03		5.12E-03	2.46E-01	31.00	0.90	7.63E+00	2.21E-01
Double bottom frame	2	0.01		1.90E+00		1.90E-02	3.04E-01	30.00	0.90	9.12E+00	2.74E-01
Engine deck plating 5mm	1	2	7.20E+00		5.00E-03	7.20E-02	5.76E-01	31.00	1.40	1.79E+01	8.06E-01
Engine secondary LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	31.00	1.30	5.76E+00	2.42E-01
Side shell low plating 9 mm	2	2	9.00E-03		4.30E+00	7.75E-02	1.24E+00	31.00	3.60	3.84E+01	4.46E+00
Side shell low LS 4	14	2		2.86E-03		5.72E-03	6.41E-01	31.00	3.60	1.99E+01	2.31E+00
Side shell low VS3	2			4.80E-03	4.30E+00	2.07E-02	3.31E-01	30.00	3.60	9.92E+00	1.19E+00
Side shell top plating 5 mm	2	2	5.00E-03		4.60E+00	4.60E-02	7.36E-01	31.00	8.10	2.28E+01	5.96E+00
Side shell top LS 2	14	2		1.72E-03		3.44E-03	3.85E-01	31.00	8.10	1.19E+01	3.12E+00
Side shell top VS2	2			3.60E-03	4.60E+00	1.66E-02	2.65E-01	30.00	8.10	7.95E+00	2.15E+00
Crew deck plating 5 mm	1	2	7.70E+00		5.00E-03	7.70E-02	6.16E-01	31.00	3.60	1.91E+01	2.22E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	31.00	3.50	3.27E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	31.00	3.50	5.76E+00	6.51E-01

Crew deck frame 1	1		7.70E+00	2.00E-03		1.54E-02	1.23E-01	30.00	3.50	3.70E+00	4.31E-01
Pax deck plating 5mm	1	2	8.10E+00		5.00E-03	8.10E-02	6.48E-01	31.00	5.80	2.01E+01	3.76E+00
Pax G2	3	2		3.00E-03		6.00E-03	1.44E-01	31.00	5.70	4.46E+00	8.21E-01
Pax LS2	10	2		1.72E-03		3.44E-03	2.75E-01	31.00	5.70	8.53E+00	1.57E+00
Pax frame 2	1		8.10E+00	2.30E-03		1.86E-02	1.49E-01	30.00	5.70	4.47E+00	8.50E-01
Bridge deck plating 5 mm	1	2	8.10E+00		5.00E-03	8.10E-02	6.48E-01	31.00	8.20	2.01E+01	5.31E+00
Bridge deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	31.00	8.10	4.46E+00	1.17E+00
Bridge deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	31.00	8.10	5.76E+00	1.51E+00
Bridge deck frame 2	1		8.10E+00	2.30E-03		1.86E-02	1.49E-01	30.00	8.10	4.47E+00	1.21E+00
Monkey bridge plating 5 mm	1	2	8.10E+00		5.00E-03	8.10E-02	6.48E-01	31.00	10.40	2.01E+01	6.74E+00
Monkey bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	31.00	10.30	4.46E+00	1.48E+00
Monkey bridge LS1	10	2		1.16E-03		2.32E-03	1.86E-01	31.00	10.30	5.76E+00	1.92E+00
Monkey bridge F2	1		8.10E+00	2.30E-03		1.86E-02	1.49E-01	30.00	10.30	4.47E+00	1.54E+00
Subtotal							**1.10E+01**			**3.39E+02**	**5.35E+01**

Section 16											
Bottom plating 11 mm	1	2	7.40E+00		1.10E-02	1.63E-01	1.30E+00	33.00	0.70	4.30E+01	9.12E-01
Bottom primary longitudinal girder 4	2	2	7.00E-03		1.00E+00	1.40E-02	2.24E-01	33.00	0.70	7.39E+00	1.57E-01
Bottom longitudinal stiffeners 3	6	2		2.56E-03		5.12E-03	2.46E-01	33.00	0.80	8.12E+00	1.97E-01
Double bottom frame	2	0.01		1.40E+00		1.40E-02	2.24E-01	32.00	0.70	7.17E+00	1.57E-01
Engine deck plating 5mm	1	2	5.20E+00		5.00E-03	5.20E-02	4.16E-01	33.00	1.40	1.37E+01	5.82E-01

Engine secondary LS 1	6	2		1.16E-03		2.32E-03	1.12E-01	33.00	1.30	3.68E+00	1.45E-01
Side shell low plating 9 mm	2	2	9.00E-03		4.10E+00	7.38E-02	1.18E+00	33.00	3.60	3.90E+01	4.25E+00
Side shell low LS 4	14	2		2.86E-03		5.72E-03	6.41E-01	33.00	3.60	2.11E+01	2.31E+00
Side shell low VS3	2			4.80E-03	4.30E+00	2.07E-02	3.31E-01	32.00	3.60	1.06E+01	1.19E+00
Side shell top plating 5 mm	2	2	5.00E-03		4.60E+00	4.60E-02	7.36E-01	33.00	8.10	2.43E+01	5.96E+00
Side shell top LS 2	14	2		1.72E-03		3.44E-03	3.85E-01	33.00	8.10	1.27E+01	3.12E+00
Side shell top VS2	2			3.60E-03	4.60E+00	1.66E-02	2.65E-01	32.00	8.10	8.48E+00	2.15E+00
Crew deck plating 5 mm	1	2	7.30E+00		5.00E-03	7.30E-02	5.84E-01	33.00	3.60	1.93E+01	2.10E+00
Crew deck G1	3	2		2.20E-03		4.40E-03	1.06E-01	33.00	3.50	3.48E+00	3.70E-01
Crew deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	33.00	3.50	6.14E+00	6.51E-01
Crew deck frame 1	1		7.30E+00	2.00E-03		1.46E-02	1.17E-01	32.00	3.50	3.74E+00	4.09E-01
Pax deck plating 5mm	1	2	7.80E+00		5.00E-03	7.80E-02	6.24E-01	33.00	5.80	2.06E+01	3.62E+00
Pax G2	3	2		3.00E-03		6.00E-03	1.44E-01	33.00	5.70	4.75E+00	8.21E-01
Pax LS2	10	2		1.72E-03		3.44E-03	2.75E-01	33.00	5.70	9.08E+00	1.57E+00
Pax frame 2	1		7.80E+00	2.30E-03		1.79E-02	1.44E-01	32.00	5.70	4.59E+00	8.18E-01
Bridge deck plating 5 mm	1	2	7.80E+00		5.00E-03	7.80E-02	6.24E-01	33.00	8.20	2.06E+01	5.12E+00
Bridge deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	33.00	8.10	4.75E+00	1.17E+00
Bridge deck LS 1	10	2		1.16E-03		2.32E-03	1.86E-01	33.00	8.10	6.14E+00	1.51E+00
Bridge deck frame 2	1		7.80E+00	2.30E-03		1.79E-02	1.44E-01	32.00	8.10	4.59E+00	1.16E+00
Monkey bridge plating 5 mm	1	2	7.80E+00		5.00E-03	7.80E-02	6.24E-01	33.00	10.40	2.06E+01	6.49E+00

Monkey bridge G2	3	2		3.00E-03		6.00E-03	1.44E-01	33.00	10.30	4.75E+00	1.48E+00
Monkey bridge LS1	10	2		1.16E-03		2.32E-03	1.86E-01	33.00	10.30	6.14E+00	1.92E+00
Monkey bridge F2	1		7.80E+00	2.30E-03		1.79E-02	1.44E-01	32.00	10.30	4.59E+00	1.48E+00
Subtotal							**1.04E+01**			**3.43E+02**	**5.18E+01**

Section 17											
Bottom plating 11 mm	1	2	7.00E+00		1.10E-02	1.54E-01	1.23E+00	35.00	0.70	4.31E+01	8.62E-01
Bottom primary longitudinal girder 4	2	2	7.00E-03		1.00E+00	1.40E-02	2.24E-01	35.00	0.90	7.84E+00	2.02E-01
Bottom longitudinal stiffeners 3	4	2		2.86E-03		5.72E-03	1.83E-01	35.00	0.80	6.41E+00	1.46E-01
Double bottom frame	2	0.01		1.00E+00		1.00E-02	1.60E-01	34.00	0.90	5.44E+00	1.44E-01
Engine deck plating 5mm	1	2	3.70E+00		5.00E-03	3.70E-02	2.96E-01	35.00	1.40	1.04E+01	4.14E-01
Engine secondary LS 1	4	2		1.16E-03		2.32E-03	7.44E-02	35.00	1.30	2.60E+00	9.67E-02
Side shell low plating 11 mm	2	2	1.10E-02		1.60E+00	3.52E-02	5.63E-01	35.00	2.80	1.97E+01	1.58E+00
Side shell low LS 4	6	2		2.86E-03		5.72E-03	2.75E-01	35.00	2.80	9.61E+00	7.69E-01
Side shell low VS4	2			5.28E-03	1.60E+00	8.45E-03	1.35E-01	34.00	2.80	4.60E+00	3.78E-01
Side shell middle plating 7 mm	2		7.00E-03		2.20E+00	1.54E-02	2.46E-01	35.00	4.70	8.62E+00	1.16E+00
Side shell middle LS4	8	2		2.86E-03		5.72E-03	3.66E-01	35.00	4.70	1.28E+01	1.72E+00
Side shell middle VS4	2			5.28E-03	2.20E+00	1.16E-02	1.86E-01	34.00	4.70	6.32E+00	8.74E-01
Side shell top plating 5 mm	2	2	5.00E-03		2.40E+00	2.40E-02	3.84E-01	35.00	7.20	1.34E+01	2.76E+00
Side shell top LS 2	14	2		1.72E-03		3.44E-03	3.85E-01	35.00	7.20	1.35E+01	2.77E+00
Side shell top VS2	2			3.60E-03	2.40E+00	8.64E-03	1.38E-01	34.00	7.20	4.70E+00	9.95E-01

Crew deck plating 5 mm	1	2	6.40E+00		5.00E-03	6.40E-02	5.12E-01	35.00	3.60	1.79E+01	1.84E+00
Crew deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	35.00	3.50	5.04E+00	5.04E-01
Crew deck LS 1	6	2		1.16E-03		2.32E-03	1.12E-01	35.00	3.50	3.90E+00	3.90E-01
Crew deck frame 2	1		6.40E+00	2.30E-03		1.47E-02	1.18E-01	34.00	3.50	4.00E+00	4.12E-01
Pax deck plating 5mm	1	2	7.00E+00		5.00E-03	7.00E-02	5.60E-01	35.00	5.80	1.96E+01	3.25E+00
Pax G2	3	2		3.00E-03		6.00E-03	1.44E-01	35.00	5.70	5.04E+00	8.21E-01
Pax LS2	8	2		1.72E-03		3.44E-03	2.20E-01	35.00	5.70	7.71E+00	1.26E+00
Pax frame 3	1		7.00E+00	4.80E-03		3.36E-02	2.69E-01	34.00	5.70	9.14E+00	1.53E+00
Bridge deck plating 5 mm	1	2	7.00E+00		5.00E-03	7.00E-02	5.60E-01	35.00	8.20	1.96E+01	4.59E+00
Bridge deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	35.00	8.10	5.04E+00	1.17E+00
Bridge deck LS 1	8	2		1.16E-03		2.32E-03	1.49E-01	35.00	8.10	5.21E+00	1.20E+00
Bridge deck frame 2	1		7.00E+00	2.30E-03		1.61E-02	1.29E-01	34.00	8.10	4.38E+00	1.04E+00
Subtotal							**7.91E+00**			**2.76E+02**	**3.29E+01**

Section 18											
Bottom plating 11 mm	1	2	6.60E+00		1.10E-02	1.45E-01	1.16E+00	37.00	1.00	4.30E+01	1.16E+00
Bottom primary longitudinal girder 4	2	2	7.00E-03		9.00E-01	0.00E+00	0.00E+00	37.00	1.00	0.00E+00	0.00E+00
Bottom longitudinal stiffeners 3	2	2		2.86E-03		5.72E-03	9.15E-02	37.00	1.00	3.39E+00	9.15E-02
Double bottom frame	2	0.01		7.00E-01		7.00E-03	1.12E-01	36.00	1.00	4.03E+00	1.12E-01
Engine deck plating 5mm	1	2	2.40E+00		5.00E-03	2.40E-02	1.92E-01	37.00	1.40	7.10E+00	2.69E-01
Engine secondary LS 1	2	2		1.16E-03		2.32E-03	3.72E-02	37.00	1.30	1.38E+00	4.83E-02

Side shell low plating 11 mm	2	2	1.10E-02		1.10E+00	2.42E-02	3.87E-01	37.00	2.80	1.43E+01	1.08E+00
Side shell low LS 4	4	2		2.86E-03		5.72E-03	1.83E-01	37.00	2.80	6.77E+00	5.13E-01
Side shell low VS4	2			5.28E-03	1.00E+00	5.28E-03	8.45E-02	36.00	2.80	3.04E+00	2.37E-01
Side shell middle plating 7 mm	2		7.00E-03		2.20E+00	1.54E-02	2.46E-01	37.00	4.70	9.12E+00	1.16E+00
Side shell middle LS4	8	2		2.86E-03		5.72E-03	3.66E-01	37.00	4.70	1.35E+01	1.72E+00
Side shell middle VS4	2			5.28E-03	2.20E+00	1.16E-02	1.86E-01	36.00	4.70	6.69E+00	8.74E-01
Side shell top plating 5 mm	2	2	5.00E-03		2.40E+00	2.40E-02	3.84E-01	37.00	7.20	1.42E+01	2.76E+00
Side shell top LS 2	8	2		1.72E-03		3.44E-03	2.20E-01	37.00	7.20	8.15E+00	1.59E+00
Side shell top VS2	2			3.60E-03	2.40E+00	8.64E-03	1.38E-01	36.00	7.20	4.98E+00	9.95E-01
Crew deck plating 5 mm	1	2	4.80E+00		5.00E-03	4.80E-02	3.84E-01	37.00	3.60	1.42E+01	1.38E+00
Crew deck G2	1	2		3.00E-03		6.00E-03	4.80E-02	37.00	3.50	1.78E+00	1.68E-01
Crew deck LS 1	6	2		1.16E-03		2.32E-03	1.12E-01	37.00	3.50	4.13E+00	3.90E-01
Crew deck frame 2	1		4.80E+00	2.30E-03		1.10E-02	8.83E-02	36.00	3.50	3.18E+00	3.09E-01
Pax deck plating 5mm	1	2	5.70E+00		5.00E-03	5.70E-02	4.56E-01	37.00	5.80	1.69E+01	2.64E+00
Pax G2	3	2		3.00E-03		6.00E-03	1.44E-01	37.00	5.70	5.33E+00	8.21E-01
Pax LS2	4	2		1.72E-03		3.44E-03	1.10E-01	37.00	5.70	4.07E+00	6.28E-01
Pax frame 3	1		5.70E+00	4.80E-03		2.74E-02	2.19E-01	36.00	5.70	7.88E+00	1.25E+00
Bridge deck plating 5 mm	1	2	5.70E+00		5.00E-03	5.70E-02	4.56E-01	37.00	8.20	1.69E+01	3.74E+00
Bridge deck G2	3	2		3.00E-03		6.00E-03	1.44E-01	37.00	8.10	5.33E+00	1.17E+00
Bridge deck LS 1	6	2		1.72E-03		3.44E-03	1.65E-01	37.00	8.10	6.11E+00	1.34E+00

Bridge deck frame 2	1		5.70E+00			0.00E+00	0.00E+00	36.0 0	8.10	0.00E+00	0.00E+00
Subtotal							**6.12E+00**			**2.25E+02**	**2.64E+01**

Section 19											
Bottom plating 11 mm	1	2	7.84E+00		1.10E-02	1.72E-01	1.38E+00	39.0 0	1.00	5.38E+01	1.38E+00
Bottom primary longitudinal girder 4	2	2	7.00E-03		7.00E-01	9.80E-03	1.57E-01	39.0 0	1.00	6.12E+00	1.57E-01
Collision bulkhead	1	0.011		1.36E+01		1.50E-01	1.20E+00	38.0 0	3.00	4.55E+01	3.59E+00
Colission bulkhead VS4	5			5.28E-03	4.80E+00	2.53E-02	1.01E+00	38.0 0	3.00	3.85E+01	3.04E+00
Engine deck plating 5mm	1	2	1.10E+00		5.00E-03	1.10E-02	8.80E-02	39.0 0	1.40	3.43E+00	1.23E-01
Engine secondary LS 1	2	2		1.16E-03		2.32E-03	3.72E-02	39.0 0	1.30	1.45E+00	4.83E-02
Side shell middle plating 7 mm	2		7.00E-03		2.20E+00	1.54E-02	2.46E-01	39.0 0	4.70	9.61E+00	1.16E+00
Side shell middle LS4	8	2		2.86E-03		5.72E-03	3.66E-01	39.0 0	4.70	1.43E+01	1.72E+00
Side shell top plating 5 mm	2	2	5.00E-03		1.20E+00	1.20E-02	1.92E-01	39.0 0	7.20	7.49E+00	1.38E+00
Side shell top LS 2	4	2		1.72E-03		3.44E-03	1.10E-01	39.0 0	7.20	4.29E+00	7.93E-01
Crew deck plating 5 mm	1	2	3.00E+00		5.00E-03	3.00E-02	2.40E-01	39.0 0	3.60	9.36E+00	8.64E-01
Crew deck G2	1	2		3.00E-03		6.00E-03	4.80E-02	39.0 0	3.50	1.87E+00	1.68E-01
Crew deck LS 1	4	2		1.16E-03		2.32E-03	7.44E-02	39.0 0	3.50	2.90E+00	2.60E-01
Pax deck plating 5mm	1	2	3.70E+00		5.00E-03	3.70E-02	2.96E-01	39.0 0	5.80	1.15E+01	1.72E+00
Pax G2	1	2		3.00E-03		6.00E-03	4.80E-02	39.0 0	5.70	1.87E+00	2.74E-01
Pax LS2	4	2		1.72E-03		3.44E-03	1.10E-01	39.0 0	5.70	4.29E+00	6.28E-01
Subtotal							**5.60E+00**			**2.16E+02**	**1.73E+01**

18.5 Annex 5: Weight Equipment's

Items	Qty	Weight items	Total weight	LCG	TCG	VCG	Long. Moment	Trans. Moment	Vert. Moment
		kg	kg	m	m	m	kg.m	kg.m	kg.m
CARGO DECK									
Equipment fors container (lashing/fixations)	1	200	200	9.0	0.0	4.0	1.80E+03	0.00E+00	8.00E+02
Liferaft 28 pax	2	100	200	1.0	0.0	4.2	2.00E+02	0.00E+00	8.40E+02
Life buoy	2	8	16	19.0	0.0	4.5	3.04E+02	0.00E+00	7.20E+01
Engine opening hatch cover	2	200	400	13.0	0.0	4.0	5.20E+03	0.00E+00	1.60E+03
Steering hatch cover	1	40	40	2.0	0.0	3.8	8.00E+01	0.00E+00	1.52E+02
Engine hatch cover	2	200	400	13.0	0.0	3.8	5.20E+03	0.00E+00	1.52E+03
Shore connections	2	20	40	18.0	0.0	4.0	7.20E+02	0.00E+00	1.60E+02
Steering gear hatch cover	1	20	20	3.0	-3.5	3.8	6.00E+01	-7.00E+01	7.60E+01
Ballast hatch cover	4	20	80	7.5	0.0	3.8	6.00E+02	0.00E+00	3.04E+02
Mooring Capstan	2	300	600	1.5	0.0	4.0	9.00E+02	0.00E+00	2.40E+03
Bollards	4	100	400	1.2	0.0	4.0	4.80E+02	0.00E+00	1.60E+03
Polypropylene hawsers	2	43	86	1.5	0.0	4.0	1.29E+02	0.00E+00	3.44E+02
Panama chocks	4	80	320	1.5	0.0	4.0	4.80E+02	0.00E+00	1.28E+03
Stairs	2	80	160	18.0	0.0	4.0	2.88E+03	0.00E+00	6.40E+02
Total cargo deck			**2962**	**6.43**	**-0.02**	**3.98**	**1.90E+04**	**-7.00E+01**	**1.18E+04**

Items	Qty	Weight items	Total weight	LCG	TCG	VCG	Long. Moment	Trans. Moment	Vert. Moment
		kg	kg	m	m	m	kg.m	kg.m	kg.m
INTERIOR PASSENGER DECK									
General									
Floor	1	655	655	28.0	0.0	5.8	1.83E+04	0.00E+00	3.80E+03
Roof	1	262	262	28.0	0.0	8.1	7.34E+03	0.00E+00	2.12E+03
Inside walls and doors	2	1812	3624	28.0	0.0	7.0	1.01E+05	0.00E+00	2.54E+04
Life jackets	50	5	250	28.0	0.0	6.2	7.00E+03	0.00E+00	1.55E+03
Extinguishers	4	20	80	28.0	0.0	6.2	2.24E+03	0.00E+00	4.96E+02
Lighting equipment	34	2	68	28.0	0.0	8.1	1.90E+03	0.00E+00	5.51E+02
Infirmery									
Bed	1	40	40	18.7	-2.9	6.2	7.48E+02	-1.16E+02	2.48E+02
Wardrobe	1	30	30	18.6	-0.7	6.7	5.58E+02	-2.10E+01	2.01E+02
Full medical shelf (medicins, tools,…)	1	100	100	22.0	-3.7	6.2	2.20E+03	-3.70E+02	6.20E+02
Water closet	1	20	20	22.2	-0.5	6.2	4.44E+02	-1.00E+01	1.24E+02
Sink	1	20	20	20.8	-0.5	5.8	4.16E+02	-1.00E+01	1.16E+02
Shower	1	20	20	21.8	-1.4	6.2	4.36E+02	-2.80E+01	1.24E+02
Disabled fourniture	1	50	50	21.5	-1.1	6.3	1.08E+03	-5.50E+01	3.15E+02
Economical bathroom									
Water closet	2	20	40	20.1	3.7	6.3	8.04E+02	1.48E+02	2.52E+02
Sinks	2	20	40	21.3	2.1	6.6	8.52E+02	8.40E+01	2.64E+02
Shower	2	21	42	21.3	3.7	5.9	8.95E+02	1.55E+02	2.48E+02
Economical salon									

Seat left wings	6	20	120	23.9	-3.4	6.6	2.87E+03	-4.08E+02	7.92E+02
Seats center left	9	20	180	23.9	-1.4	6.6	4.30E+03	-2.52E+02	1.19E+03
Seats center right	6	20	120	23.9	1.7	6.6	2.87E+03	2.04E+02	7.92E+02
Seat right wings	6	20	120	23.9	3.4	6.6	2.87E+03	4.08E+02	7.92E+02
Electrical plugs	27	1	27	23.9	0.0	6.6	6.45E+02	0.00E+00	1.78E+02
Economical lounge			0						
Table	1	60	60	26.8	-2.4	6.6	1.61E+03	-1.44E+02	3.96E+02
Bar stools	6	5	30	26.7	-2.4	6.3	8.01E+02	-7.20E+01	1.89E+02
Self vending machine	1	80	80	27.8	-1.1	6.8	2.22E+03	-8.80E+01	5.44E+02
Lounge first									
Bar	1	200	200	28.9	2.0	6.6	5.78E+03	4.00E+02	1.32E+03
Bar equipment's	1	100	100	28.9	2.2	6.6	2.89E+03	2.20E+02	6.60E+02
Lift	1	50	50	28.6	2.4	6.3	1.43E+03	1.20E+02	3.15E+02
Bar stool	4	5	20	29.4	2.3	6.3	5.88E+02	4.60E+01	1.26E+02
Arm chairs	3	20	60	31.2	2.7	6.3	1.87E+03	1.62E+02	3.78E+02
Round table	1	25	25	30.7	2.4	6.3	7.68E+02	6.00E+01	1.58E+02
First class bathroom									
Sink	2	20	40	29.2	-1.1	6.6	1.17E+03	-4.40E+01	2.64E+02
Water closet	2	20	40	30.5	-3.6	6.3	1.22E+03	-1.44E+02	2.52E+02
Shower	2	20	40	29.4	-3.6	5.9	1.18E+03	-1.44E+02	2.36E+02
First class salon									
Seats	14	20	280	33.6	0.0	6.6	9.41E+03	0.00E+00	1.85E+03
Electrical plug	14	1	14	33.6	0.0	6.6	4.70E+02	0.00E+00	9.24E+01
TOTAL INTERIOR PASSENGER DECK			**6947**	**27.59**	**0.01**	**6.75**	**1.92E+05**	**1.01E+02**	**4.69E+04**

Items	Qty	Weightitems	Total weight	LCG	TCG	VCG	Long. Moment	Trans. Moment	Vert. Moment
		kg	*kg*	*m*	*m*	*m*	*kg.m*	*kg.m*	*kg.m*
FORECASTLE DECK									
3 anchors + 2 chains	1	4559	4559.2	39.0	0.0	2.0	1.78E+05	0.00E+00	9.12E+03
Polyproplyene hawsers	2	43	86	39.0	0.0	5.8	3.35E+03	0.00E+00	4.99E+02
Towline	1	180	180	39.0	0.0	5.8	7.02E+03	0.00E+00	1.04E+03
Anchor capstan with gipsy	2	1200	2400	38.5	0.0	5.8	9.24E+04	0.00E+00	1.39E+04
Bollards	4	100	400	39.0	0.0	5.8	1.56E+04	0.00E+00	2.32E+03
Panama chocks	4	80	320	39.7	0.0	5.9	6.35E+03	0.00E+00	9.44E+02
Mooring capstans	2	400	800	37.0	0.0	6.3	2.59E+04	0.00E+00	4.41E+03
Hatch cover chain locker	1	50	50	39.00	0.00	5.80	2.59E+04	0.00E+00	4.41E+03
TOTAL FORECASTLE DECK			**8795.2**	**40.29**	**0.00**	**4.17**	**3.54E+05**	**0.00E+00**	**3.67E+04**

Items	Qty	Weightitems	Total weight	LCG	TCG	VCG	Long. Moment	Trans. Moment	Vert. Moment
		kg	*kg*	*m*	*m*	*m*	*kg.m*	*kg.m*	*kg.m*
CREW DECK									
General									
Floor	1	706	706	27.0	0.0	3.6	1.91E+04	0.00E+00	2.51E+03
Roof	1	283	283	27.0	0.0	5.6	7.64E+03	0.00E+00	1.58E+03

Inside walls and doors	1	3055	3055	27.0	0.0	3.6	8.25E+04	0.00E+00	1.10E+04
Extinguishers	4	10	40	27.0	0.0	4.0	1.08E+03	0.00E+00	1.60E+02
Stairs	1	200	200	27.0	0.0	3.6	5.40E+03	0.00E+00	7.20E+02
Aft rooms (Captain and C/E rooms)									
Bed	2	60	120	19.1	0.0	4.2	2.29E+03	0.00E+00	4.99E+02
Bed shelf	2	10	20	18.3	0.0	4.1	3.66E+02	0.00E+00	8.12E+01
Office shelf	2	60	120	21.2	0.0	4.6	2.54E+03	0.00E+00	5.47E+02
Office armchair	2	10	20	21.8	0.0	4.1	4.36E+02	0.00E+00	8.12E+01
Desk	2	30	60	21.7	0.0	4.4	1.30E+03	0.00E+00	2.61E+02
Chairs	2	5	10	20.8	0.0	4.1	2.08E+02	0.00E+00	4.06E+01
Wardrobe	2	30	60	19.4	0.0	4.6	1.16E+03	0.00E+00	2.73E+02
Sink	2	20	40	18.7	0.0	4.2	7.48E+02	0.00E+00	1.66E+02
Water closet	2	20	40	19.7	0.0	4.0	7.88E+02	0.00E+00	1.58E+02
Shower	2	20	40	20.9	0.0	3.7	8.36E+02	0.00E+00	1.46E+02
1st Deck Officer room									
Bed	1	35	35	25.0	3.0	4.2	8.75E+02	1.05E+02	1.46E+02
Bed shelf	1	5	5	24.3	3.7	4.1	1.22E+02	1.85E+01	2.03E+01
Armchair	1	20	20	23.0	3.4	4.1	4.60E+02	6.80E+01	8.12E+01
Wardrobe	1	30	30	23.9	1.0	4.6	7.17E+02	2.85E+01	1.37E+02
Sink	1	15	15	22.7	2.3	4.2	3.41E+02	3.45E+01	6.24E+01
Water closet	1	20	20	22.7	1.7	4.0	4.54E+02	3.40E+01	7.92E+01
Shower	1	20	20	23.0	1.0	3.7	4.60E+02	2.00E+01	7.32E+01
2nd Engineer Officer room			0						
Bed	1	35	35	22.5	-2.9	4.2	7.88E+02	-1.02E+02	1.46E+02
Bed shelf	1	5	5	23.7	-3.8	4.1	1.19E+02	-1.88E+01	2.03E+01
Armchair	1	20	20	25.0	-3.4	4.1	5.00E+02	-6.80E+01	8.12E+01
Wardrobe	1	30	30	24.2	-1.0	4.6	7.26E+02	-2.85E+01	1.37E+02
Sink	1	15	15	25.3	-2.4	4.2	3.80E+02	-3.53E+01	6.24E+01
Water closet	1	20	20	25.4	-1.8	4.0	5.08E+02	-3.50E+01	7.92E+01
Shower	1	20	20	25.0	-1.0	3.7	5.00E+02	-2.00E+01	7.32E+01
2nd Deck Officer room									
Bed	1	35	35	28.6	-2.9	4.2	1.00E+03	-1.02E+02	1.46E+02
Bed shelf	1	5	5	27.4	-3.8	4.1	1.37E+02	-1.88E+01	2.03E+01
Armchair	1	20	20	26.0	-3.4	4.1	5.20E+02	-6.80E+01	8.12E+01
Wardrobe	1	30	30	27.0	-1.0	4.6	8.10E+02	-2.85E+01	1.37E+02
Sink	1	15	15	25.8	-2.4	4.2	3.87E+02	-3.53E+01	6.24E+01
Water closet	1	20	20	25.7	-1.8	4.0	5.14E+02	-3.50E+01	7.92E+01
Shower	1	20	20	26.0	-1.0	3.7	5.20E+02	-2.00E+01	7.32E+01
1st Ratings room									
Bed	1	100	100	29.1	-2.9	4.6	2.91E+03	-2.90E+02	4.56E+02
Bed shelf	2	5	10	28.7	-2.1	4.4	2.87E+02	-2.10E+01	4.36E+01
Wardrobe	2	20	40	30.4	-3.4	4.6	1.22E+03	-1.36E+02	1.82E+02
Sink	1	15	15	28.8	-1.6	4.2	4.32E+02	-2.40E+01	6.24E+01
2nd Ratings room			0						
Bed	1	100	100	31.2	-2.8	4.6	3.12E+03	-2.80E+02	4.56E+02
Bed shelf	2	5	10	30.8	-1.9	4.4	3.08E+02	-1.90E+01	4.36E+01
Wardrobe	2	20	40	32.5	-3.1	4.6	1.30E+03	-1.24E+02	1.82E+02

Sink	1	15	15	31.0	-1.5	4.2	4.65E+02	-2.25E+01	6.24E+01
3rd Ratings room									
Bed	1	100	100	33.2	-2.4	4.6	3.32E+03	-2.40E+02	4.60E+02
Bed shelf	2	5	10	32.9	-1.5	4.4	3.29E+02	-1.50E+01	4.40E+01
Wardrobe	2	20	40	34.6	-2.6	4.6	1.38E+03	-1.04E+02	1.84E+02
Sink	1	15	15	33.0	-1.1	4.2	4.95E+02	-1.65E+01	6.30E+01
Rating bathroom			0						
Sink	1	15	15	35.7	1.1	4.2	5.36E+02	1.65E+01	6.30E+01
Water closet	1	20	20	35.7	1.7	4.0	7.14E+02	3.40E+01	8.00E+01
Shower	1	20	20	35.3	2.4	3.9	7.06E+02	4.80E+01	7.80E+01
Mess									
Table 1	1	50	50	33.6	2.6	4.3	1.68E+03	1.30E+02	2.15E+02
Seat table 1	4	5	20	33.6	2.6	4.0	6.72E+02	5.20E+01	8.00E+01
Table 2	1	30	30	35.9	1.2	4.3	1.08E+03	3.60E+01	1.29E+02
Seats table 2	6	5	30	35.9	1.2	4.0	1.08E+03	3.60E+01	1.20E+02
Galley									
Working deck	1	200	200	32.0	2.0	4.4	6.40E+03	4.00E+02	8.80E+02
Lift	1	50	50	28.1	2.4	4.4	1.41E+03	1.20E+02	2.20E+02
Galley equipment's (fridge, oven,…)	1	500	500	32.0	2.0	4.2	1.60E+04	1.00E+03	2.10E+03
Light galley furniture	1	100	100	32.0	2.0	4.2	3.20E+03	2.00E+02	4.20E+02
TOTAL CREW DECK			**6779**	**27.47**	**0.07**	**3.93**	**1.86E+05**	**4.75E+02**	**2.66E+04**

Items	Qty	Weight items	Total weight	LCG	TCG	VCG	Long. Moment	Trans. Moment	Vert. Moment
		kg	*kg*	*m*	*m*	*m*	*kg.m*	*kg.m*	*kg.m*
				ENGINE DECK					
General									
Corridor walls + doors	2	713	1426	26.2	0.0	2.5	3.74E+04	0.00E+00	3.50E+03
Front wall spare parts room	1	135	135	25.5	2.1	2.5	3.43E+03	2.83E+02	3.30E+02
Inside walls of the staire case	1	92	92	26.7	1.7	2.5	2.47E+03	1.57E+02	2.27E+02
Front wall of the stair case	1	114	114	27.7	1.9	2.5	3.17E+03	2.17E+02	2.81E+02
Technical local aft wall	1	132	132	34.3	0.0	2.5	4.53E+03	0.00E+00	3.24E+02
Front workshop wall	1	132	132	26.2	-2.1	2.5	3.46E+03	-2.77E+02	3.24E+02
Front pantry wall	1	101	101	29.2	-1.7	2.5	2.96E+03	-1.72E+02	2.48E+02
Stair	1	100	100	27.0	0.0	1.3	2.70E+03	0.00E+00	1.30E+02
Paint floor	1	220	220	28.0	0.0	1.3	6.15E+03	0.00E+00	2.85E+02
Fire extinguishers	4	10	40	28.0	0.0	1.6	1.12E+03	0.00E+00	6.40E+01
Pantry									
Equipments	1	100	100	28.0	-2.0	1.8	2.80E+03	-2.00E+02	1.80E+02
Washing machine	2	84	168	27.0	-2.0	1.8	4.54E+03	-3.36E+02	3.02E+02
Dryer	2	80	160	26.5	-2.0	1.8	4.24E+03	-3.20E+02	2.88E+02
Cold room									
Shelf	1	200	200	32.0	-1.5	1.7	6.40E+03	-3.00E+02	3.40E+02
Cold room equipment's	1	40	40	33.0	-0.6	1.7	1.32E+03	-2.40E+01	6.80E+01
Food store									
Shelfs	1	200	200	32.0	1.5	1.7	6.40E+03	3.00E+02	3.40E+02
Spare parts room									

Spare parts	1	3700	3700	24.0	2.0	1.7	8.88E+04	7.40E+03	6.29E+03
Workshop									
Equipment	1	2500	2500	22.0	-2.0	1.7	5.50E+04	-5.00E+03	4.25E+03
Technical local									
Equipment	1	1000	1000	37.0	0.0	1.7	3.70E+04	0.00E+00	1.70E+03
Bow thruster	1	2000	2000	37.0	0.0	1.0	7.40E+04	0.00E+00	2.00E+03
Engine room									
Diesel engine Wartsila 6L20	2	9300	18600	13.0	0.0	1.2	2.42E+05	0.00E+00	2.23E+04
Starting batteries DE	2	40	80	15.0	0.0	1.0	1.20E+03	0.00E+00	8.00E+01
Gearbox	2	1450	2900	12.0	0.0	1.2	3.48E+04	0.00E+00	3.48E+03
Generator 40kW	3	1090	3270	16.0	0.0	1.2	5.23E+04	0.00E+00	3.92E+03
Starting batteries generators	3	30	90	13.5	0.0	1.0	1.22E+03	0.00E+00	9.00E+01
Shafts diameter dia=7.6cm; L=7m	2	260	520	7.0	0.0	0.7	3.64E+03	0.00E+00	3.64E+02
Propellers dia=1250mm	2	192	384	3.0	0.0	0.7	1.15E+03	0.00E+00	2.69E+02
Electrical panel	1	60	60	17.8	-1.5	0.8	1.07E+03	-9.00E+01	4.80E+01
Engine room insulation	1	1796	1796	14.0	0.0	2.8	2.51E+04	0.00E+00	5.03E+03
LO Circulating pump	2	10	20	10.0	0.0	0.8	2.00E+02	0.00E+00	1.60E+01
DO circulating pump	4	13	52	17.0	0.0	0.8	8.84E+02	0.00E+00	4.16E+01
Seawater pump	2	71	142	16.0	0.0	1.5	2.27E+03	0.00E+00	2.13E+02
Sewage pump	2	20	40	17.0	1.0	0.8	6.80E+02	4.00E+01	3.20E+01
FW pump	2	10	20	17.0	1.5	0.8	3.40E+02	3.00E+01	1.60E+01
Bilge pump	1	30	30	16.0	-1.0	0.8	4.80E+02	-3.00E+01	2.40E+01
Ventilations blowers	3	100	300	18.0	-2.0	1.5	5.40E+03	-6.00E+02	4.50E+02
Fresh water system plant	1	700	700	15.0	-1.5	1.5	1.05E+04	-1.05E+03	1.05E+03
Ballast pump	1	200	200	17.0	2.0	0.8	3.40E+03	4.00E+02	1.60E+02
CO2 fire fighting system ER	1	200	200	11.0	-3.0	1.5	2.20E+03	-6.00E+02	3.00E+02
Steering gear compartment									
Rudders	2	80	160	2.0	0.0	1.0	3.20E+02	0.00E+00	1.60E+02
Steering systems & rams	1	150	150	2.0	0.0	2.0	3.00E+02	0.00E+00	3.00E+02
Steering gear and hydraulic piping	1	100	100	2.0	0.0	2.0	2.00E+02	0.00E+00	2.00E+02
Auxiliary steering gear	1	50	50	2.0	0.0	2.0	1.00E+02	0.00E+00	1.00E+02
Tanks									
Ballast water tanks	1	2723	2723	6.0	0.0	2.0	1.63E+04	0.00E+00	5.45E+03
Servide Diesel Oil tanks	1	189	189	15.0	0.0	1.5	2.84E+03	0.00E+00	2.84E+02
Storage Diesel Oil tanks	1	996	996	19.4	0.0	2.3	1.93E+04	0.00E+00	2.29E+03
LO tanks	1	155	155	8.8	0.0	1.0	1.36E+03	0.00E+00	1.55E+02
Grey water tanks	1	117	117	19.4	0.0	1.0	2.27E+03	0.00E+00	1.17E+02
Black water tanks	1	47	47	18.5	0.0	1.0	8.70E+02	0.00E+00	4.70E+01
Fresh water tanks	1	143	143	18.8	0.0	1.0	2.69E+03	0.00E+00	1.43E+02
Sludge tanks	1	96	96	10.4	0.0	1.0	9.98E+02	0.00E+00	9.60E+01
Hydraulic tanks	1	20	20	3.5	0.0	2.0	7.00E+01	0.00E+00	4.00E+01
TOTAL ENGINE DECK			**46910**	**16.717**	**-0.004**	**1.466**	**7.84E+05**	**-1.72E+02**	**6.88E+04**

Items	**Qty**	**Weight items**	**Total weight**	**LCG**	**TCG**	**VCG**	**Long. Moment**	**Trans. Moment**	**Vert. Moment**
		kg	***kg***	***m***	***m***	***m***	***kg.m***	***kg.m***	***kg.m***

BRIDGE DECK									
Inside Bridge Deck									
Floor	1	243	243	29.0	0.0	8.2	7.05E+03	0.00E+00	1.99E+03
Roof	1	97.2	97.2	29.0	0.0	10.4	2.82E+03	0.00E+00	1.01E+03
Walls	1	126.72	126.72	29.0	0.0	9.3	3.67E+03	0.00E+00	1.18E+03
Pilot chairs	2	50	100	29.0	0.0	8.8	2.90E+03	0.00E+00	8.80E+02
Navigation desk with equipment's	1	500	500	31.0	0.0	9.0	1.55E+04	0.00E+00	4.50E+03
Shelf (and contents)	1	120	120	28.0	0.0	9.0	3.36E+03	0.00E+00	1.08E+03
PC	1	10	10	29.0	0.0	8.8	2.90E+02	0.00E+00	8.80E+01
Normal/Emergency lights	1	20	20	29.0	0.0	10.4	5.80E+02	0.00E+00	2.08E+02
Safety equipment	1	50	50	29.0	0.0	9.0	1.45E+03	0.00E+00	4.50E+02
Emergency battery system	1	1000	1000	34.0	0.0	9.0	3.40E+04	0.00E+00	9.00E+03
Outside Bridge Deck									
Diesel oil tank vents	6	20	120	22.0	0.0	11.0	2.64E+03	0.00E+00	1.32E+03
Grey/black water tank vents	4	20	80	22.0	0.0	11.0	1.76E+03	0.00E+00	8.80E+02
FW tank vents	2	20	40	22.0	0.0	11.0	8.80E+02	0.00E+00	4.40E+02
Exhhaust ventilation	3	20	60	21.0	0.0	11.0	1.26E+03	0.00E+00	6.60E+02
Intake Ventilation	3	20	60	20.0		12.0	1.20E+03	0.00E+00	7.20E+02
Engine Exhausts	2	100	200	19.0	0.0	12.0	3.80E+03	0.00E+00	2.40E+03
Life raft 28 pax	2	100	200	25.0	0.0	11.0	5.00E+03	0.00E+00	2.20E+03
Monkey bridge									
Mast	1	200	200	28.0	0.0	12.0	5.60E+03	0.00E+00	2.40E+03
GPS Antenna	2	20	40	28.0	0.0	11.0	1.12E+03	0.00E+00	4.40E+02
Radarr antenna	2	150	300	28.0	0.0	11.0	8.40E+03	0.00E+00	3.30E+03
AIS antenna	2	20	40	28.0	0.0	11.0	1.12E+03	0.00E+00	4.40E+02
VHF antenna	2	20	40	28.0	0.0	11.0	1.12E+03	0.00E+00	4.40E+02
Searchlight	1	30	30	28.0	0.0	11.0	8.40E+02	0.00E+00	3.30E+02
Navigation lights	10	10	100	28.0	0.0	11.0	2.80E+03	0.00E+00	1.10E+03
Whistle	1	10	10	28.0	0.0	11.0	2.80E+02	0.00E+00	1.10E+02
TOTAL BRIDGE DECK			**3786.9**	**28.90**	**0.00**	**9.92**	**1.09E+05**	**0.00E+00**	**3.76E+04**

Items	Qty	Weight items	Total weight	LCG	TCG	VCG	Long. Moment	Trans. Moment	Vert. Moment
		kg	*kg*	*m*	*m*	*m*	*kg.m*	*kg.m*	*kg.m*
PAINT									
Underwater paint (with extra-fouling)	1	606	606	19.0	0.0	1.8	1.15E+04	0.00E+00	1.09E+03

Overwater paint	1	844	844	24.0	0.0	5.0	2.03E+04	0.00E+00	4.22E+03
TOTAL PAINT			**1450**	**21.9 1**	**0.00**	**3.6 6**	**3.18E+04**	**0.00E+00**	**5.31E+03**

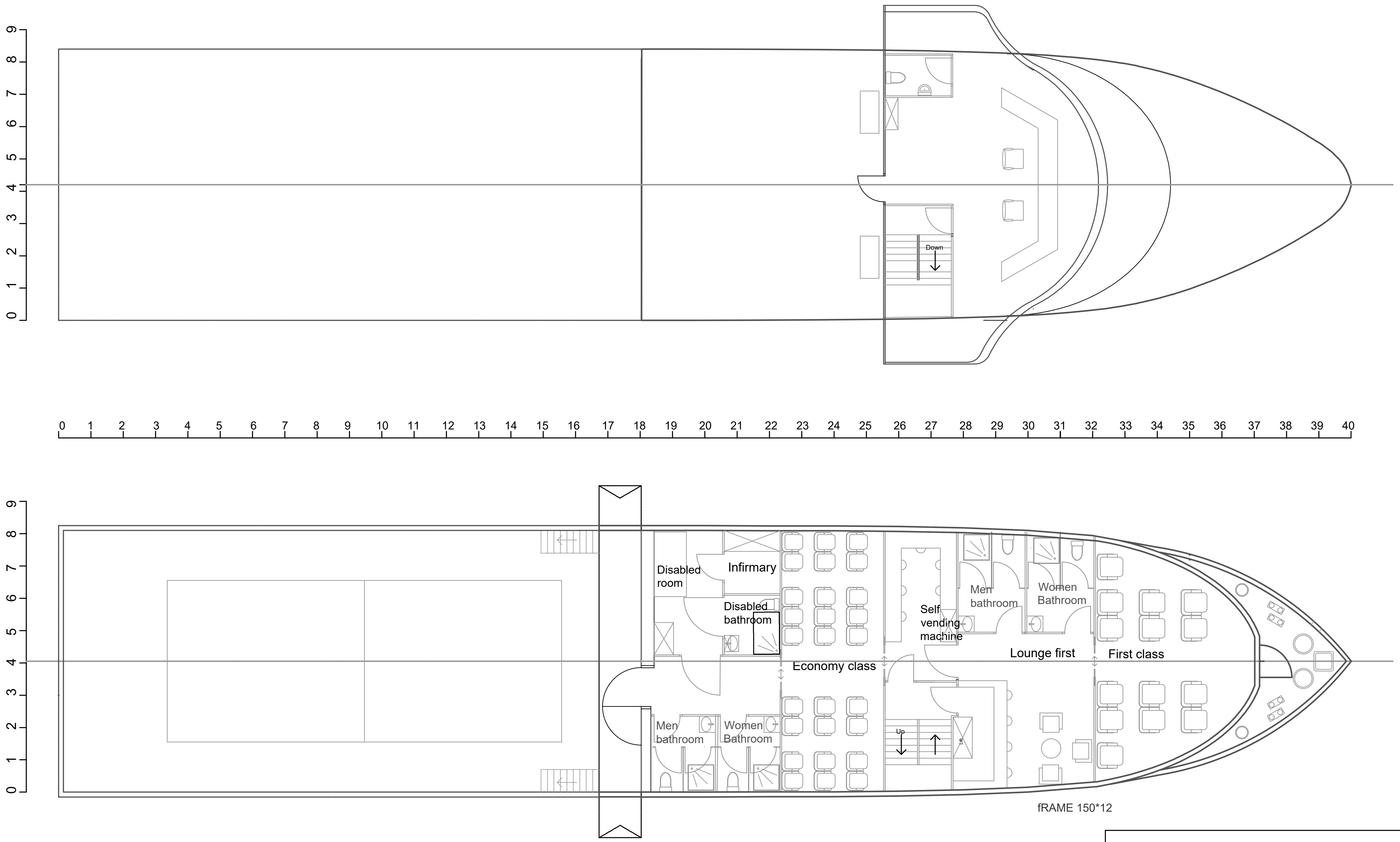
18.6 Annex 6: Electrical Balance Analysis

							Harbour		Manoeuvring		Sailing		Emergency	
	Consumer	**Units**	**Rated load**	**Load factor**	**Used load**	**Max. load**	**% Max**	**Load**	**%Max**	**Load**	**%Max**	**Load**	**%Max**	**Load**
			kW		*kW*	*kW*		*kW*		*kW*		*kW*		*kW*
No	**Propulsion auxiliairies**													
1	Starting and control Air compressor	2	3	0.8	2.4	4.8	25%	1.2	50%	2.4	25%	1.2	50%	2.4
2	MDO Circulating pump	4	0.6	0.8	0.48	1.92	10%	0.192	50%	0.96	100%	1.92	0%	0
3	LO pump	2	0.5	0.8	0.4	0.8	10%	0.08	100%	0.8	100%	0.8	0%	0
4	Seawater pump	2	4.2	0.8	3.36	6.72	10%	0.672	100%	6.72	100%	6.72	0%	0
5	Freshwater pump	3	0.2	0.6	0.12	0.36	25%	0.09	100%	0.36	100%	0.36	50%	0.18
6	Black/grey water pump	2	0.6	0.8	0.48	0.96	80%	0.768	0%	0	0%	0	0%	0
7	Bilge pump	2	1.8	0.8	1.44	2.88	0%	0	0%	0	10%	0.288	100%	2.88
8	Battery charger/monitoring equipment	1	5	0.8	4	4	100%	4	10%	0.4	10%	0.4	0%	0
9	Hydraulic pump	1	0.5	0.8	0.4	0.4	25%	0.1	25%	0.1	25%	0.1	0%	0
10	Emergency fire fighting pump	1	0.75	1	0.75	0.75	0%	0	0%	0	0%	0	100%	0.75
	Total Propulsion Auxiliaries							**7.10**		**11.74**		**11.79**		**6.21**
	Ship service auxiliaries													
1	Anchor/mooring windlass forepeak	2	22	0.7	15.4	30.8	25%	7.7	50%	15.4	0%	0	0%	0
2	Refrigerated container	1	7	0.8	5.6	5.6	20%	1.12	100%	5.6	100%	5.6	0%	0
3	Mooring windlass aft peak	2	15	0.8	12	24	25%	6	100%	24	0%	0	0%	0
4	Water boiler	1	5	0.8	4	4	50%	2	50%	2	100%	4	0%	0
5	Steering gear pump	1	3	0.8	2.4	2.4	0%	0	100%	2.4	100%	2.4	0%	0
6	Auxiliary steering gear pump	1	1.5	0.8	1.2	1.2	0%	0	0%	0	0%	0	0%	0
7	Bow thruster	1	10	0.8	8	8	0%	0	75%	6	0%	0	0%	0
	Total ship service auxiliaries							**16.82**		**55.40**		**12.00**		**0.00**

	HVAC Equipment													
1	Ventilation Engine room	3	3.5	0.8	2.8	8.4	50%	4.2	100%	8.4	100%	8.4	0%	0
2	Ventilation Accomodation	2	4	0.9	3.6	7.2	100%	7.2	100%	7.2	100%	7.2	0%	0
3	Air conditioning Crew deck	1	5	0.8	4	4	25%	1	100%	4	100%	4	0%	0
4	Air conditioning Passenger deck	1	7	0.8	5.6	5.6	100%	5.6	100%	5.6	100%	5.6	0%	0
5	Air conditioning Bridge deck	1	3	0.8	2.4	2.4	50%	1.2	100%	2.4	100%	2.4	0%	0
	Total HVAC Equipment							**19.20**		**27.60**		**27.60**		**0.00**
	Passenger deck													
1	Normal lighting	34	0.05	0.8	0.04	1.36	10%	0.136	75%	1.02	85%	1.156	0%	0
2	Emergency lighting	15	0.01	1	0.01	0.15	0%	0	0%	0	0%	0	100%	0.15
3	Electrical plug	50	0.07	0.8	0.056	2.8	0%	0	50%	1.4	75%	2.1	0%	0
	Total passenger deck							**0.14**		**2.42**		**3.26**		**0.15**
	Crew deck													
1	Normal lighting	40	0.05	0.8	0.04	1.6	50%	0.8	50%	0.8	50%	0.8	0%	0
2	Emergency lighting	20	0.01	1	0.01	0.2	0%	0	0%	0	0%	0	100%	0.2
3	Electrical plug	40	0.07	0.8	0.056	2.24	50%	1.12	50%	1.12	50%	1.12	0%	0
4	Computer	2	0.1	0.8	0.08	0.16	100%	0.16	100%	0.16	100%	0.16	0%	0
	Total crew deck							**2.08**		**2.08**		**2.08**		**0.20**
	Engine deck													
1	Normal lighting	40	0.05	0.8	0.04	1.6	100%	1.6	100%	1.6	100%	1.6	0%	0
2	Emergency lighting	20	0.01	1	0.01	0.2	0%	0	0%	0	0%	0	100%	0.2
3	Washing machine	2	1.82	0.8	1.456	2.912	50%	1.456	0%	0	0%	0	0%	0
4	Dryer	2	1.95	0.8	1.56	3.12	50%	1.56	0%	0	0%	0	0%	0
5	Refrigeration system cold room	1	4	0.8	3.2	3.2	100%	3.2	100%	3.2	100%	3.2	0%	0
6	Oven	1	3.4	0.8	2.72	2.72	25%	0.68	50%	1.36	50%	1.36	0%	0
7	Microwave	1	0.8	0.8	0.64	0.64	25%	0.16	50%	0.32	50%	0.32	0%	0
8	Refrigerator	1	0.01	0.8	0.008	0.008	100%	0.008	100%	0.008	100%	0.008	0%	0

9	Computer	1	0.1	0.8	0.08	0.08	100%	0.08	50%	0.04	50%	0.04	0%	0
10	Specific equipment's	1	0.5	0.8	0.4	0.4	25%	0.1	25%	0.1	25%	0.1	0%	0
	Total Engine deck							**8.84**		**6.63**		**6.63**		**0.20**
	Bridge deck													
1	Battery charger general service	1	1.2	0.8	0.96	0.96	10%	0.096	100%	0.96	100%	0.96	50%	0.48
2	Normal lighting	10	0.05	0.8	0.04	0.4	50%	0.2	30%	0.12	30%	0.12	0%	0
3	Emergency lighting	5	0.01	1	0.01	0.05	0%	0	0%	0	0%	0	100%	0.05
4	Alarm and monitoring installation	1	3	0.8	2.4	2.4	25%	0.6	100%	2.4	100%	2.4	100%	2.4
5	Navigation lighting	1	1	0.8	0.8	0.8	50%	0.4	100%	0.8	100%	0.8	100%	0.8
5	Nav. & Communication equipment	1	3.5	0.8	2.8	2.8	25%	0.7	100%	2.8	100%	2.8	25%	0.7
6	Search light	1	0.5	0.8	0.4	0.4	0%	0	0%	0	0%	0	0%	0
	Total bridge deck							**2.00**		**7.08**		**7.08**		**4.43**
	Total							**56.18**		**112.95**		**70.43**		**11.19**

18.7 Annex 7: Technical drawings



STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: PASSENGER AND BRIDGE DECK

SCALE: 1:125

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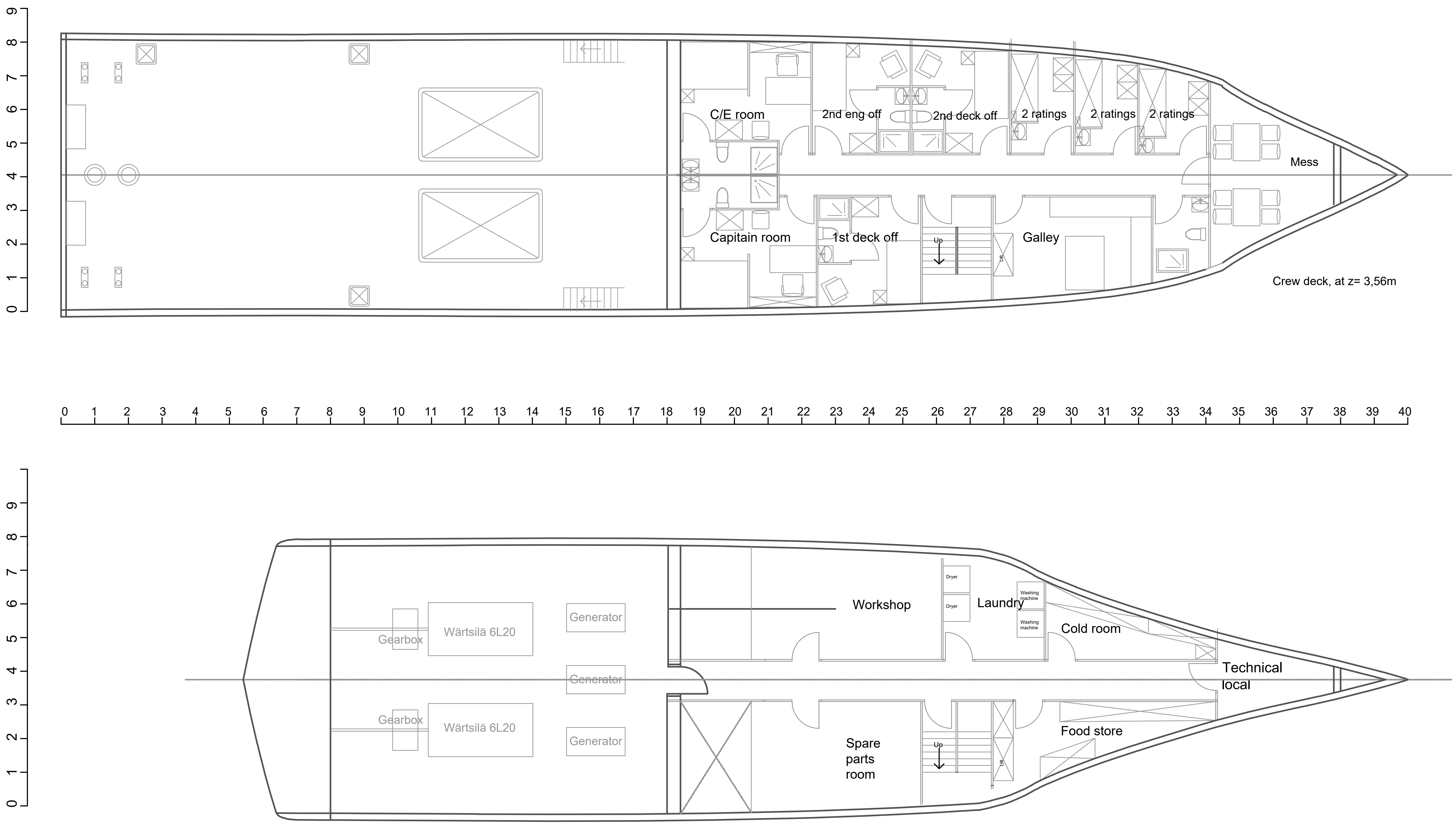

STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: ENGINE AND CREW/CARGO DECK

SCALE: 1:125

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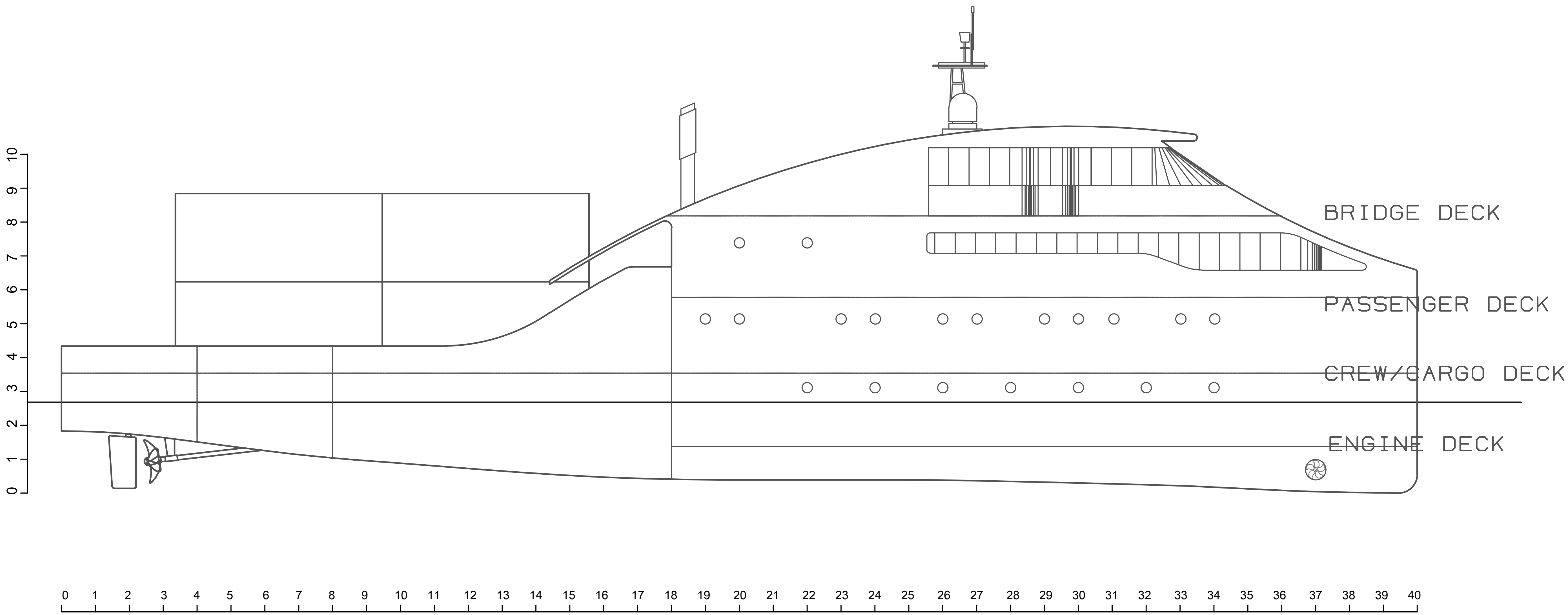

STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: LONGITUDINAL VIEW

SCALE: 1:125

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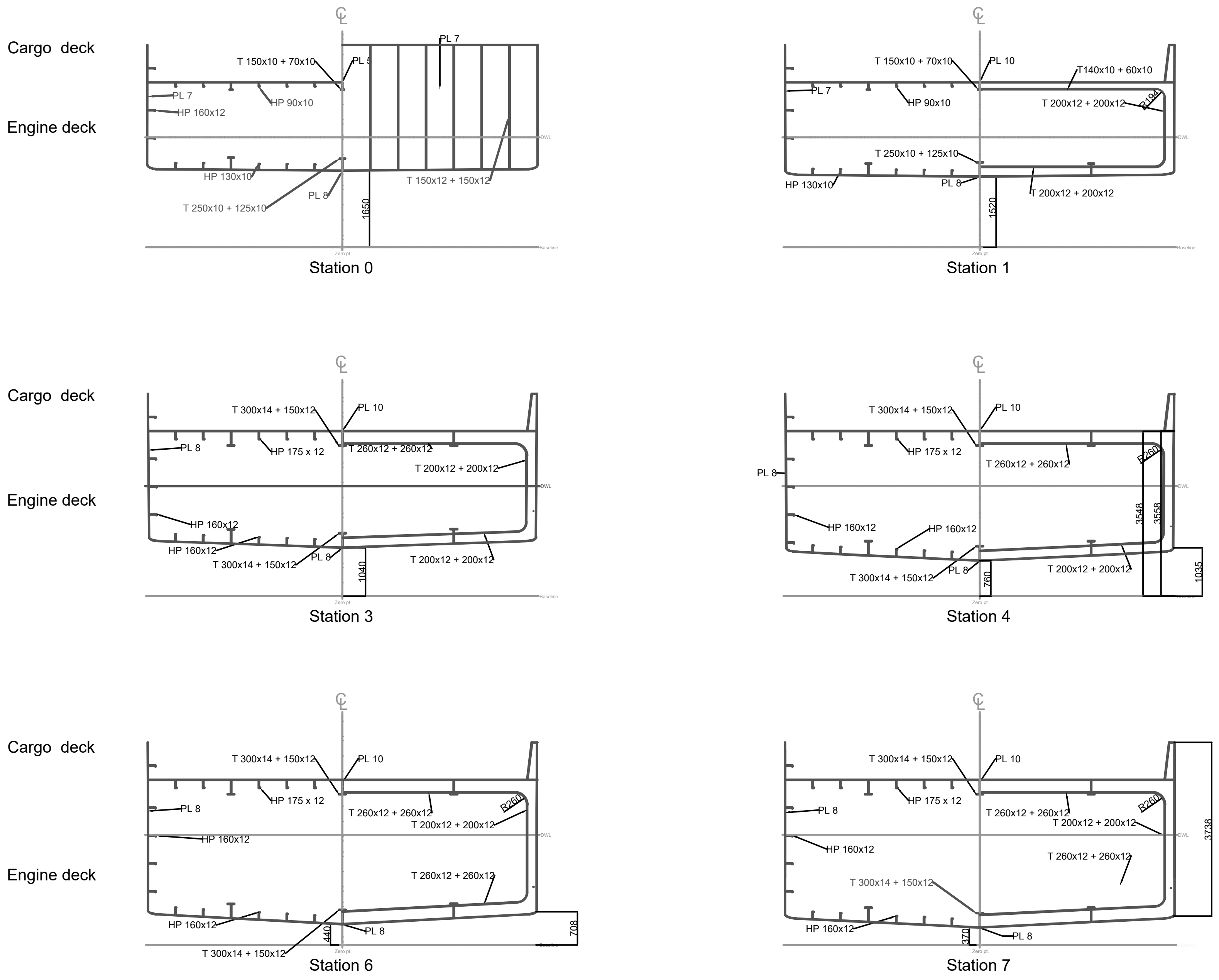

STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: FRAME DRAWINGS

SCALE: 1:125

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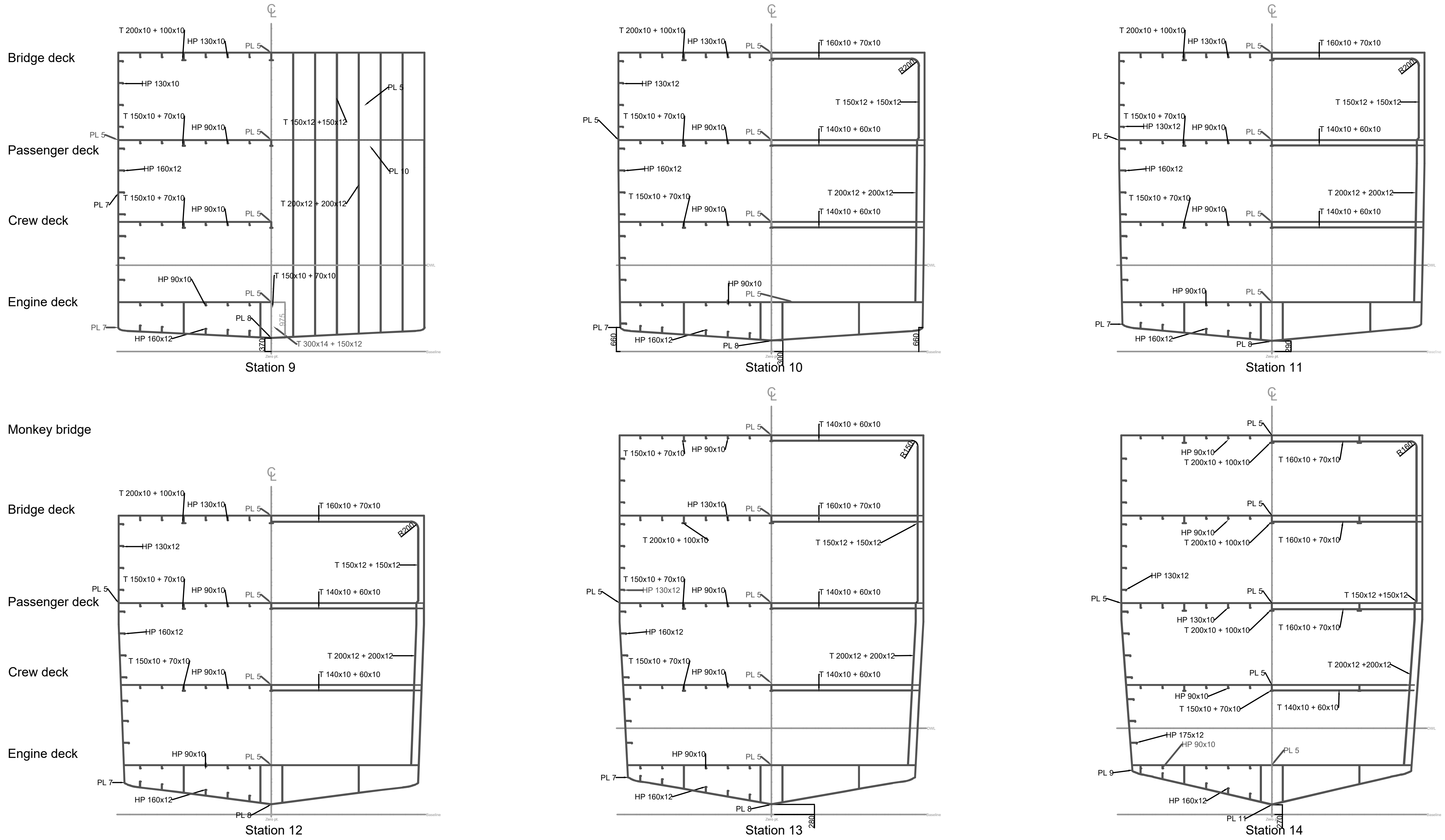

STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: FRAME DRAWINGS

SCALE: 1:125

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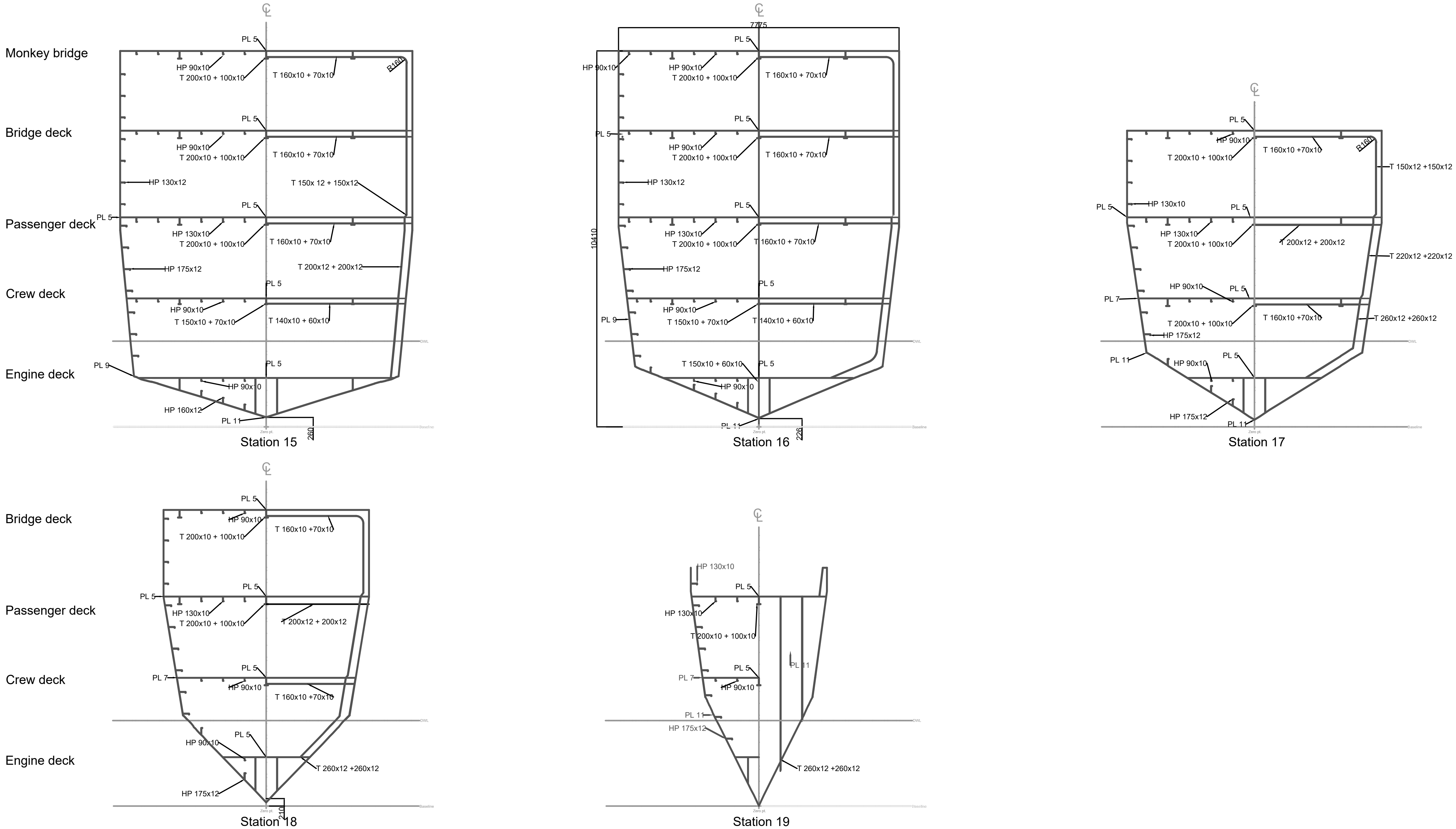

STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: FRAME DRAWINGS

SCALE: 1:125

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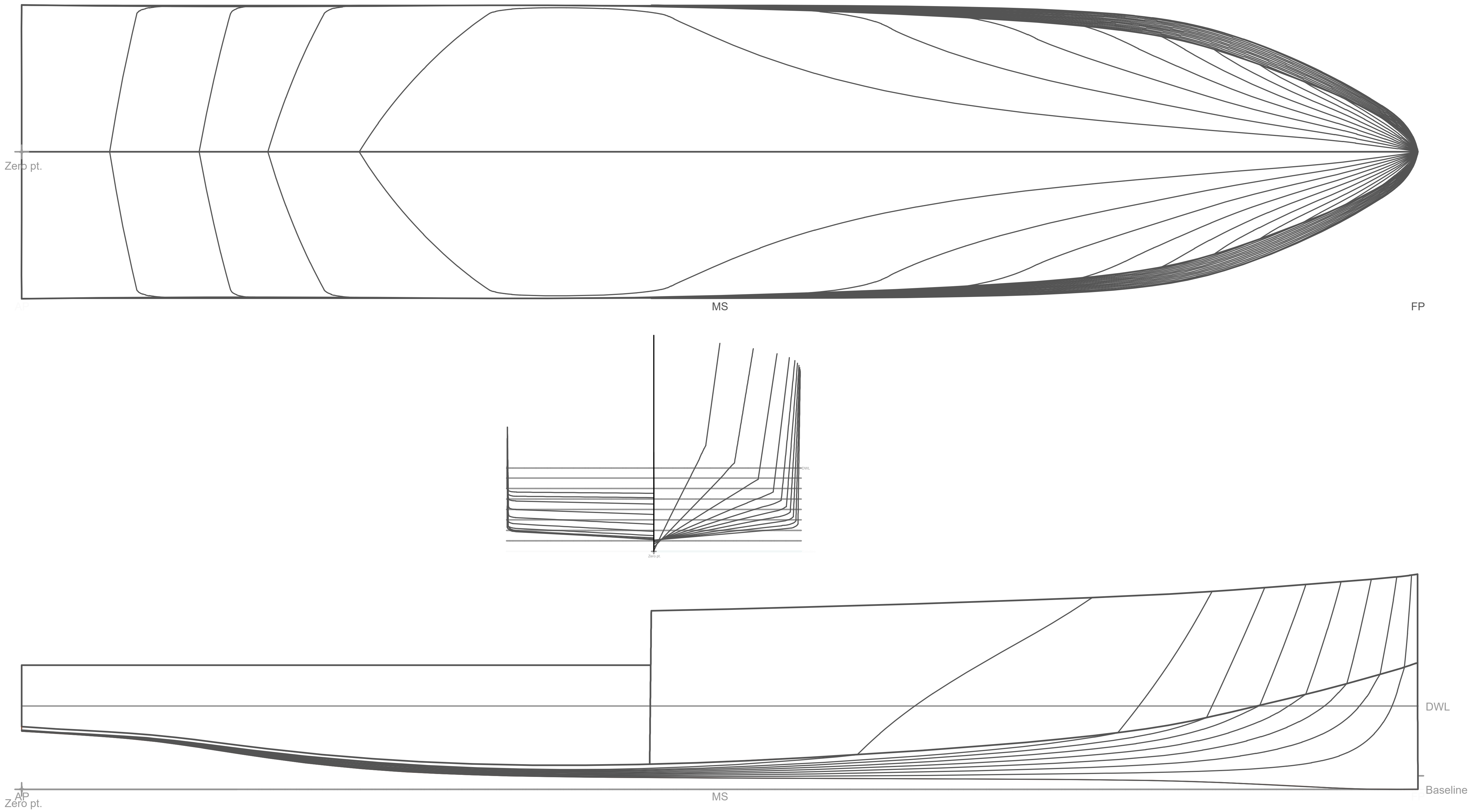

STUDENT NAME: THOMAS OLIVRY

MASTER THESIS: "THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WALLIS AND FUTUNA ISLANDS AND THE MARITIME TRANSPORT SYSTEM"

PLAN: HULL LINES PLAN

SCALE: 1:125

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