Preliminary analysis of the economic feasibility of maintenance services for superyachts in Portugal

Nicola San Martino

Instituto Superior Técnico, Universidade de Lisboa, Portugal

ABSTRACT: This paper considers a little explored theme in the literature, namely that of the world of yachts, in particular that of superyachts and the specialized infrastructures used in this sector. The motivation for this research is that Portugal is located in a strategic position for the transit of superyachts between Europe and the Caribbean, both for its proximity to the Strait of Gibraltar and for the islands in the middle of the Atlantic Ocean, and from a preliminary study it was seen that there are not enough and well-developed infrastructures to deal with this business. The specific objectives of this research are to review the scientific and technical literature on yacht maintenance services, wintering practices, repositioning between European regions and across the Atlantic and marina technical developments and define the technical requirements for providing high quality services to yachts in the Portuguese coast. A case study is presented consisting of an economic analysis of the competitiveness of an integrated service proposal for a typical superyacht yearly cycle. The general conclusion is that shipyards and marinas in Portugal lack some characteristics necessary for engaging in this market segment, but that significant savings could be achieved if maintenance and repositioning is carried out based on a hub in Portugal.

1 INTRODUCTION

Yachting world, since its beginning, has been a sector limited to a very small niche of people, but that involves a considerable quantity of money and works around it. Initially, the number and the size of yachts around the world were much smaller than now, and consequently the infrastructures related to them. Marinas and shipyards were very rare and concentrated just around the biggest cities and some touristic locations, just thinking that the first ever marinas built specifically for nautical tourism were realized around 1950.

Year by year, by improving infrastructures with the construction of new marinas (nowadays there are more than 300 marinas just in Italy) and shipyards spread on all the coasts, and especially with the new technologies and materials available for yacht building, this sector has grown, becoming a business of international interest that involves many different sectors with variable degrees of correlation with it. Nowadays, yachting is a business of almost 90 billion USD, increasing every year, despite social and economic contexts not being, at times, favorable. It represents indeed a special form of high value-added tourism, representing a significant income for many countries, mainly in the Mediterranean and Caribbean Islands. In particular, the most relevant subsector is also the most luxurious one: superyachts.

The importance of this market for Portuguese tourism, industries and economy, in general, and the recognition that the yachting world is a valid option to bet on for relaunching the country’s economy, certainly makes this theme an interesting area of study and research. Although this possibility has been around for many years, no studies where found detailing what this hub could specifically be and how feasible from the economic point of view it could be. This paper is a first attempt to provide some light in the path for setting up such a hub in Portugal.

In particular, what was really missing was a complete study about superyachts, that would include their movements and migration during the year, how they move (if by sailing themselves or shipped by a specialized ship) and which routes they use, a description of the ideal superyacht marina and the related facilities needed, as well as a description of state-of-the-art shipyards and which infrastructures and equipment they include, and all the other aspects related to superyachts. The objective is to present an evaluation of the costs involved in a typical yearly cycle for a superyacht in two scenarios: a cycle corresponding to the current situation (yacht based in the Mediterranean) and a cycle corresponding to a situation in which the yacht uses Portuguese shipyards and marinas for repair and maintenance. In any case, the yacht also carries out a transit across the Atlantic in order to allow cruising both in the Mediterranean Sea and the Caribbean Islands

This paper is structured in seven sections and the detailed structure is as follows. Section 1 is the introduction and provides the background for the theme and the objectives of this research. Section 2 provides important information on the typical characteristics of the superyacht fleet in the beginning of the XXI century. Section 3 provides a characterization of the yacht traffic along the Portuguese coast, starting from typical weather conditions, patterns of traffic along the two main transit routes and yacht transportation practices. Section 4 provides a characterization and comparison of the most relevant marinas in three regions: West Mediterranean, Atlantic Northern Europe and Portugal. Main parameters for characterizing these marinas are identified and compared across the three regions. Section 5 provides a characterization and comparison of major shipyards involved in superyacht repair and maintenance in the same West Mediterranean, Atlantic Northern Europe and Portugal. It is important to mention that in the Portuguese case the shipyards included are those which could potentially be used in such activities. Section 6 shows the results of a case study carried out for assessing the economic feasibility of using Portuguese shipyards for carrying out repair and maintenance of a specific superyacht and as a base for transiting across the Atlantic Ocean. Comparison is made with the current cycle which resorts to West Mediterranean marinas and shipyards. Finally, Section 7 includes the final conclusions of the research and recommendations for further work.

2 CHARACTERIZATION OF THE SUPERYACHT FLEET

Yachting is an ever-changing and developing world, in particular the superyacht segment. Despite the importance and the impact of this business on the economy in general and on the many sectors directly involved in particular, it is little-explored and it is not easy to draw a general framework of it.

First of all, there is not a unique and official definition for the various yachts categories, including superyachts. They might be defined by several criteria like minimum price, size, weight, or if it has or not an heliport or a swimming pool (Springer, 2019), but the most scientific and quoted criterion is the length, most of the times length over all (L_{OA}). Broadly speaking, a yacht is a luxury watercraft made for recreational activities (Worth Avenue Yachts , 2019). According to (Springer, 2019), "a superyacht or megayacht is a large, luxurious, professionally crewed motor or sailing yacht, ranging from 24 meters (79 ft.) to more than 180 meters (590 ft.) in length" so it does not make difference between superyacht and megayacht.

(Santos, 2020) concludes that there is not a universal definition for superyachts and megayachts, but generally they are considered to have more than 24 metres or, in some few cases, 30 metres, in length overall. This paper will consider superyachts to comprise large yacht used for pleasure or commercial activity with a length overall equal or greater than 30 metres. Indeed, later in this section it will be shown that the largest part of the yacht fleet comprises vessels between 30 metres and 40 metres. This option is also related to the need of defining marina and shipyard requirements at a high level, suitable for receiving large yachts while performing a high-quality service.

Considering the superyacht characterization indicated above, it is possible to provide a brief analysis of the existing fleet (data could only be found for yachts above 30 m in length overall). In August 2021, there were 5325 superyachts over 30 metres of L_{OA} around all over the world, divided into 4492 motor yachts and 833 sailing yachts. Furthermore, 486 new superyachts over 30 metres of L_{OA} were under building, 450 motor yachts and 36 sailing yachts (Dazert, Herman, Webster, Dowling, & Sabbadin, 2021). This data is more impressive if compared to the ones of the previous years: on 2000 the fleet was made of 1835 units, on 2010 of 3716 units and on 2018 of 4950 units

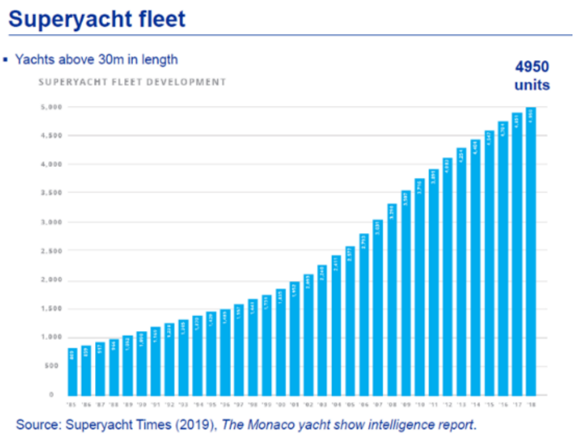

Figure 1 - Superyacht Fleet Development (Santos, 2020).

Apart from size categories, there are also different typologies of yachts: in the first place it is possible to distinguish motor yachts and sailing yachts. Then, motor yachts can be of different types: open, day-cruiser, ribs, off-shore, "classic" motor yachts, sportfish or fisherman, expedition or explorer.

Regarding sailing boats, firstly they can be separated in two categories: monohull and multiple-hull (double hulls are called catamarans, triple hulls are called trimarans). Then, the major sub-segments are: racing-sailing yacht, gullet, motorsailer, cruise sailing yacht.

Yachts can be built using different materials: wood, composites, steel and aluminium. Wood was the first material used in boat construction, and it is still used for some small-medium yachts, in particular marine-ply which is much lighter and more adapt for marine environment and boat construction than classic wood. Wooden yachts require a lot of maintenance and it is not possible to build them in series.

Regarding composites materials, they are surely the most common and used materials on yacht construction up to 35-40 metres, thanks to the relative low cost and for their good strength. The most used fibre is fibre-glass, because it is a good compromise of technical characteristics and price. For particular constructions, mostly for high-performance yachts (offshore, racing-sailing yachts), where it is needed to be as light and as strong as possible, particular fibres could be used, such as Kevlar-fibre and carbon-fibre, that have greater technical characteristics compared to fibre-glass, but much more expensive.

For what concerns metals on yacht building, it is used steel for the hull, which is heavier but strong and more resistant, and aluminium for the superstructures. This helps to obtain a lower centre of gravity and increase the stability, in the first place, and save weight in the second place. There are exceptions of yacht made entirely of aluminium, especially small to medium size yachts, that are very light (almost half of the weight compared to the fibre-glass) and seven times more impact-resistant, but are more expensive and subject to galvanic corrosion (Mondinelli, 2014).

Engines and drives can vary a lot depending on the yacht in question. For small yachts, mostly open, ribs and sometimes off-shore, the most used propulsion system is by outboard engines, which combine engine and drive in a unique block. An alternative to outboards are sterndrives. This type of propulsion has the engine inside the hull, on the engine room, that has to be on the extreme stern of the yacht, and the drive outboard, underwater, fixed on the transom of the yacht. Such setup gives the opportunity to combine the best engine and the best drive, and the power installable it is up to 1200/1500 [hp].

Finally, inboard diesel engines with shaft lines is the most common setup used in medium and large superyachts. It is the same system used on ships, more resistant and simpler compared to all the others, and it has no power limitation as proved engines used for other marine applications are available

3 CHARACTERIZATION OF YACHT TRAFFIC ALONG THE PORTUGUESE COAST THE OFFSHORE SUPPLY

In Portugal, the climate is pleasantly mild, being influenced by the Atlantic Ocean. The climate is cool and rainy in the north, and gradually gets warmer and sunnier as you go south; in the far south, the Algarve has a dry and sunny microclimate. Summer is sunny everywhere, because in this season Portugal is protected by the Azores Anti-cyclone; however, from time to time it can pass the tail of an Atlantic perturbation to the north.

During the rest of the year there is no shortage of rains, which are gradually more frequent and abundant as we proceed northwards. For this reason, the landscape in the north is very green, and gradually becomes more arid going south, until you reach the Algarve which has a fairly dry climate.

Moving deeper into the opened ocean conditions, there are a lot of considerations to take into account when planning the Atlantic crossing. The most important consideration must be about the hurricane season, which is from June to the beginning of December. Leaving the Mediterranean or one of the westernmost islands of Europe (Canarias, Azores...) during this season it's too risky, but since the first days of December yachts can start their voyage, but it's advised to go as south as possible in the early season, maybe even southern than Cape Verde, to avoid any late hurricane that may be still develop.

Another important consideration to do is the position and the intensity of the Azores high, that drives the trade winds. Usually, the Azores high sinks south a little and ridges further west in January giving an increase in wind. This is confirmed by winds measured from satellite which also tend to show an increase in wind speeds as we move through December into January. How far north or south it is situated tends to determine just where the band of the maximum wind is and hence the route while the intensity of the high and the pressure gradient determine the strength of the trades. An alternative option could be to choose anyway the northerly routes that, thanks to stronger winds generated by the depressions, make this crossing quicker and allows yachts to approach Caribbean from a more north position. The risks of following these routes are not limited to the difficulties itself, but are also related to the risks of damage of the yachts, for rough weather conditions, that may reset the advantages of this choice. It's actually possible to say that there are three main routes for an East to West Atlantic Crossing (Heppell, 2018): Northern route which is from Las Palmas to Antigua 2580 [NM], Middle route which goes from Las Palmas to St. Lucia 2800 [NM] and Southern route which is from Las Palmas to Cape Verde 850 [NM] + Cape Verde to Barbados 2000 [NM].

Usually, the first route is mostly chosen by sailing yachts bigger than 20 [m] and by big motor yachts capable of withstanding rough weather conditions, and by those yachts that want to arrive as soon as possible to their destination. The middle route is the most chosen one and well-travelled by any type of yacht able to do the crossing. T represents a compromise of good weather, position and length. The Southern route is preferred by those motor yachts that need to brake the route to fill the fuel tanks, so by smaller motor yachts that don't have the autonomy to complete the Atlantic crossing without stopping (Heppell, 2018).

There are other valid options as an alternative to the three main one. For example, for a yacht coming from the Northern Europe, a possible route would be sailing along the coast until reaching Lisbon, then from Lisbon sailing to the Azores and from there crossing all the way to Bermuda Island: Lisbon to Angra do Heroismo (Azores) 845 [NM] + Angra do Heroismo to Bermuda 1870 [NM]. This route also allows to make the crossing dividing the route into shorter legs compared to the other possibilities, making it attractive to those motor yachts that might have autonomy limitations. In addition, due to the strategic position of the Bermuda, it is the best route for who wants to go to East Coast of the United States, in fact the distance that separates the Bermuda to Savannah (Georgia) is 830 [NM].

Another relevant route is crossing the Atlantic starting from Lagos and going Azores and from there, depending form the final destination, going to the Bermuda (for USA Coast) or to The Settlement (British Virgin Islands (for Caribbean): Lagos to Angra do Heroismo (Azores) 885 [NM] + Angra do Heroismo to Bermuda 1870 [NM], Lagos to Angra do Heroismo (Azores) 885 [NM] + Angra do Heroismo to The Settlement (VG) 2300 [NM]. These other two options, leaving the coast from Lagos instead then Lisbon, might be chosen from those yachts coming from the Mediterranean and after sailed through the Strait of Gibraltar decide to start their Atlantic crossing from the closest port rather than sailing back to Lisbon.

Regarding yacht traffic across the Atlantic, the study related to the traffic and migration of yachts across the Atlantic is a complex and intertwined subject. To better understand it, it is more appropriate to take into account a wider look and have an idea to the situation and the distribution of the yachts around the world. According to the last information publicized by ICOMIA (International Council of Marine Associations), the world association that gathers nautical manufacturers, there are 33 million boats in the world and almost half are located in the United States. Furthermore, the fleet of superyacht at the beginning of 2020 is "just" made of 5520 units. (ICOMIA, 2020). As might be predicted, the distribution of the yachts is not uniform and constant during the year, but it has cyclical peaks and troughs in the Mediterranean and the Caribbean depending on the time of year. This is also applicable to the pattern of superyacht numbers in the rest of the world year-round.

The Mediterranean attracts the majority of the fleet in July and August – the peak summer months – and, simultaneously, this is when numbers in the rest of the world decrease and almost drop off completely in the Caribbean. This supports the fact that, during peak times, the Mediterranean is the most popular region for superyacht visitations worldwide. While the number of yachts in the rest of the world decrees between June and August to concentrate in the Mediterranean, at the other time of the year most of the superyachts emigrate to the rest of the world, sometimes rising over 60 per cent of the fleet between January and April. The Caribbean attracts a much smaller percentage of the fleet, even during the peak months of January and February, which sees between 10 and 18 per cent of the total (Matheison, 2019).

One interesting observation is that while superyacht numbers around the year in the Mediterranean and rest of the world have remained stable over the years, the percentage of yachts visiting the Caribbean during the peak season has dropped significantly. On the last position of the scale there is the west coast of the United States, followed by Australasia and Melanesia, which show a certain level of stability by attracting five per cent of the fleet. South-east Asia has increased a bit in popularity reaching 12 per cent since of the superyacht fleet. The region covering the east coast of the United States and the Bahamas follows a quite stable trend, having peaks during the winter months and dropping off in summer.

Transport by large merchant ships now has a global reach and is constantly expanding, both in terms of the number of ports served and on the size and types of yachts transported, which are increasingly high. Due to the yacht's migration flows already analyzed, it is evident why this market sector is growing so fast and consequently how the services and the options available for yacht owners are better and in continuous development. There are several reasons why an owner would choose to transport his yacht by entrusting it to a company specialized on this kind of business. For example, not all the yachts are able to reach the destination by sailing autonomously.

A motor yacht of about 20 meters that has to go from the Mediterranean to the Caribbean doesn't have the fuel autonomy necessary for such a long voyage (Storgaard, 2019). In addition to the above criteria, an important aspect to consider is the class given by the classification society and the conformity to the European Recreational Craft directive. For example, in order to be able to make the Atlantic crossing, a yacht needs to be classified with the highest of the four classes, which is CE Class A: "A recreational craft given design category A is considered to be designed for winds that may exceed wind force 8 (Beaufort scale) and significant wave heights of 4 [m] and above but excluding abnormal conditions such as storm, violent storm, hurricane, tornado and extreme sea conditions or rogue waves" (Cocheril, 2012).

As regards shipping, the best way is to choose a company that operates a dedicated ship available for the transportation of yachts. Generally, this kind of ships can be of two types: Lo/Lo or a semi-submersible vessel. Lo/Lo ships (Lift-on / Lift-off) are equipped with special cranes able to lift the yachts from the water to the positions on the bridge where they will be secured and tied for the navigation and back into the water when reached the destination.

Figure 2 - Typical Lo/lo Ship.

Semi-submersible vessel (Float-on / Float-off) is for sure the best vessel to transport yachts. They are characterized by the presence of numerous ballast tanks that allow the vessel to be lowered until the main deck is below the surface of the water in order to accommodate large floating loads, in this case yachts, that are able to get into the right place across the deck. The crew prepares the supports (berths), but the yachts reach the correct location by themselves and without the mast (in case of sailing yacht). The load is lifted from the water and stability is ensured by adding water on the ballast tanks. To avoid damage to the ballast water tanks due to over or under pressure, the internal pressure of the tanks and the level are also monitored. This type of ship eliminates the disadvantages of all the other kind of ships about transportation of yachts and due to its innovative system minimizes the chances of damage of this expensive and particular goods.

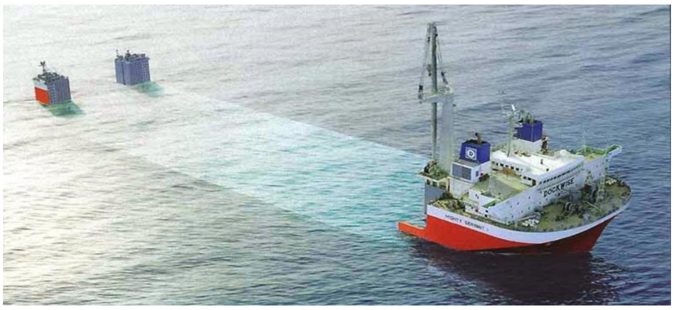

Figure 3 - Typical Float-on / Float-off Ship Ready to be Loaded.

Figure 4 - Typical Float-on / Float-off Ship Fully Loaded.

4 CHARACTERIZATION OF MAJOR SUPERYACHT MARINAS ASSUMPTIONS AND SIMPLIFICATIONS

The word "Marina" usually indicates structures, places, environments very different from each other: it is called "Marina" the touristic port of Belem, which counts around 80 berths, and the touristic port of Marseille, that has a capacity of more than 3000 berths. These marinas are also very different from the point of view of visual impact, organization, available maintenance and services.

A marina, independently from the size and type, is protected from the dominant wind and swell of that region, with the entrance facing the protect side. There always are a sea wall and inner quay, and, depending on the size of the marina, there might be one or more floating docks, even equipped with fingers to make embarkation and disembarkation more comfortable.

About mooring systems, there are several options. The most common is a combination of dead weights, chains and ropes: along the center of the water surface inside the port there are one or more lines of dead weights, not necessary all of the same dimension, designed for the yacht's size usually located on that part of the dock, connected by a main chain line. From the main chain line, connected by marine karabiners, start the secondary chain line, perpendicular to the main one, one for each berth and long around 20m. At the end of each secondary chain line start a rope, that will be fixed at the bow of the yacht. Alternatively, another system could be with wooden poles, fixed on the sea bottom, from where the mooring ropes start. This system is more indicated for those marinas that have no problems in terms of space, because each poles will take some space off from the berth.

Technically speaking, there are several characterization criteria that can be considered for all the Marinas: number of berths, maximum size of yachts that can be hosted (in meters), depth limitation (in meters).

Regarding marinas in Spain, France, Italy, Monte Carlo and Malta, it is possible to say that Spain has an average number of berths close to 700 per marina, with an average maximum length of yachts that can be hosted of 75 [m]. About France, the average number of berths is 820 but the average maximum length of yachts that can be hosted is 42 [m]. Regarding Italy, Monte Carlo and Malta, the average number of berths is almost 600 and the average maximum length of yachts that can be hosted is 72 [m]. Comparing these data, it is possible to say that the country with the grater predisposition for superyachts is Spain, almost on a par with Italy, Monte Carlo and Malta, and followed by France. On the other hand, France has the largest marinas in terms of capacity. This could be due to the fact that France has more channel ports compared to the other countries, and, as already said on the introduction of this section, this type of harbors has strong limitation in terms of size of yachts receivable but are on average larger in capacity. It is important to say that in each country under study there are more than three marinas that can host yachts over 100 [m] except Malta, this means that France, Italy, Spain and Monte Carlo have attractive infrastructures for this type of tourism.

About marinas in the north of Spain, France and England, first of all there is a smaller number of relevant marinas compared to the Mediterranean ones. In addition, the average number of berths in the marinas analyzed is around 700 but the average maximum length of yachts that can be hosted is just 55 [m], including Marina Davila Sport in Vigo (180 [m]) which is the only one exceeding 100 [m]. This means that in the United Kingdom and in the northern coasts of France and Spain there is a less predispositions on receiving superyachts over 50 [m] and consequently the luxury tourism related to them.

About Portugal, it looks clear how different the situation in Portugal is in comparison to the rest of the countries under study. First of all, the average number of berths and of the maximum length of yachts that can be received are the lowest recorded, respectively of ≈ 450 and ≈ 35 [m]. Moreover, the picks of berths and lengths are respectively 825 and 60 [m], both in Marina di Vilamoura in Vilamoura and are way greater compared to the average; in addition, there is just one other marina that can host yachts of 50 [m], which is Marina de Portimão (50 [m]).

Another relevant aspect is the distribution of the major marinas: the bigger ones are in the southern region, Algarve. This region, which is characterized by better weather conditions and it is more protected from waves, tides and currents, is also located close to the connection between the Atlantic Ocean and the Mediterranean, the Strait of Gibraltar, one of the busiest stretches of water in the planet. All these characteristics makes the Algarve really attractive both for nautical tourism and as a logistic springboard for the traffic between Mediterranean and Atlantic Ocean with an incredible potential that can be exploited with an improvement of dedicated and highly specialized infrastructures.

The same potential is also present in the Azores and in the island of Madeira. In keeping with the section 3.1, some of the most important and busy routes between the Mediterranean and the Caribbean and the American continent in general, stop to these islands. The study made shows that the biggest marina in Madeira has just 140 berths and is able to receive yachts up to 30 [m]; for the Azores the highest capacity is of Marina De Ponta Delgada with 640 berths but just for yachts up to 30 [m], and the maximum yacht's size is in Marina da Horta with 35 [m]. It is clear how the marinas present on this territory are not enough developed to cope the intensity of this traffic, such as the dimensions of superyachts that increase year by year.

There are some essential facilities that almost all marinas offer to their clients: first of all, water and electricity supply. Nowadays, the amount and intensity of electricity required from all yachts has increased exponentially due to the increase and improvement of technology onboard, and the necessary adaptation of the existing systems onshore does not always keep pace. This service could be included on the fees of the berths or might be an extra service, regulated by service points [1], equipped with a delivery control system, because, especially for yachts up to 25 [m], the consumption of electricity could be of the same order of magnitude of the price of the berth. Another essential facility is the 24/h surveillance, integrated with a video surveillance system, which is vital to protect precious goods such as port full of multi-millionaire yachts. An important aspect is the equipment need to respect the always new and more restrictive laws about preventing pollution. For example, since 2012 every marina must be equipped with a bilge pumping system, to collect the dirty water mixed with oil and fuel of yachts. For those ports that can receive superyachts, in order to encourage this type of tourism and to fulfil the needs of these boats and clients, there are several essential facilities that almost all of them offer, for example: high speed fuel station, assistance for the bow's rope, heliport.

Usually, the cost of the berth is proportional to the size of the yacht and it is not only depending on the length but also on the beam. In fact, normally boats are moored perpendicularly to the pier, so it is clear how important is to consider the space occupied by the yacht as a rectangular ($L_{OA} * B$) and not only as linear. If a yacht falls into a category for the length but in the upper one for the beam it will pay the upper price, and vice-versa. Another criterion that have an impact to the price of the berth is the time spent in the same marina. Almost all the marinas distinguish at least two types of offers: daily and monthly, but some of them have other options like weekly, yearly and multi-yearly prices. Of course, the highest price is the daily one and way smaller for longer periods of contract. The price is also strongly influenced, on most of the cases, by the period of the year concerned: during summer time and in particularly August, which is the most crowded time of the year for marine traffic, everything is going to be more expensive, including berth fees.

During the stay on the marina, there are other costs to consider that can be entailing significantly the total costs: water and electricity. Sometimes they might be included on the fees of the berth but most commonly they are counted separately: electricity in [EUR/Kwh] and water in [EUR/liter] or [EUR/m^3]. In some cases, this cost could be evaluated as a forfeit. It is highly likely that a superyacht of 35 [m] in length can absorb so many [Kw] in one night to spend more in electricity then in berth fees.

5 CHARACTERIZATION OF INFRASTRUCTURE FOR SUPERYACHT REPAIR AND MAINTENANCE

The shipyards sector, as well as marinas, plays an essential role in the superyacht world. Superyachts are floating luxury mansions and to keep every part fully working and always looking as new, it is necessary a constant and deep maintenance and, when necessary, repair. Due to the complexity of these floating objects, the types of works that must be done during their life vary from mechanical to painting and structural operations. In order to be able to offer all these services, specialized infrastructures are needed. The typical layout of a superyacht repair and maintenance shipyard is composed by:

- Breakwater: which is a structure built on the seaward side of the shipyard for protecting from waves. If the shipyard is located inside a port, it might be not have a dedicated breakwater because it would be protected from the one of the port.
- Waiting dock (mooring berths): inside the breakwater, is where yachts are moored waiting to be lifted and taken over or to be delivered. It might be possible that some works, mostly interior works, can be done while the yacht is on water.
- Open yard: where most of yachts are stored. Some works can be done here like careenage and others that do not need a protected environment.
- Covered space and sheds: it is usually slightly set back in respect to the water and it can be composed by one or more sheds. If it is one it is usually internally divided into different workshops, otherwise there is one shed for the major workshops like painting and resining, carpentry and mechanical works, joinery and systems.
- Internal dry-dock: it is a covered dry-dock where any type of work on superyachts too big to be lifted and moved by any kind of equipment can be made.

Figure 5 - Example of a Perfect Superyacht Repair and Maintenance Shipyard's Layout.

It is relevant to distinguish two different types of shipyards: those inside marinas and those who are not. Sometimes, if the shipyard is a facility of a marina, it is quite small and with the infrastructures and equipment are consequently dimensioned; in addition, in this case the services offered are limited to the basic ones, for examples: cleaning, anti-fouling, small and easy mechanical and electrical works, storage. Other works, if available, are carried out by external resources. Sometimes, if the shipyard is a facility of a marina, it is quite small and with the infrastructures and equipment are consequently dimensioned; in addition, in this case the services offered are limited to the basic ones, for examples: cleaning, anti-fouling, small and easy mechanical and electrical works, storage. Other works, if available, are carried out by external resources. On the other hand, if the shipyard is an independent company, it is probably way larger, the infrastructures and the equipment are more developed and it is capable of carry out almost any type of work by its in-house resources. Of course, this is not a rule and it may occur exceptions.

To have a schematic and scientific approach, for all the shipyards taken into account, the characteristics considered are the following. Yard: surface in $m^2$of the external yard; Covered space: surface in m^2 of covered space; Services: Refitting, painting and composite works, mechanics, metal works, carpentry and joinery, electricity and electronic works, naval engineering and architecture; Waiting docks: number of docks, number of berths, dimension of docks *m*, max length of vessels that can be moored *m;* Drydocks and Slipways: number of drydocks, number of slipways, dimensions in *m;* Travel-Lifts and Syncrolifts: number of travel-lifts, number of syncrolifts, lifting capacity in *t;* other lifting equipment: type of equipment, number of elements per type, lifting capacity in *t*.

Analyzing the data recorded about Spain, France and Italy, it is possible to say that there is a good distribution of superyacht repair and maintenance shipyards along the coasts of these three countries, with a greater intensity around the biggest cities and critical locations. Stand out from the other shipyards Marina Barcelona 92 in Spain, La Ciotat Shipyards and IMS Shipyards in France and Amico & Co and Genova Industrie Navali (GIN) in Italy. These major shipyards, in addition to large outdoor and indoor spaces, are equipped with several lifting systems of different lifting capacity, dedicated infrastructures that make them able to work with several superyachts at the same time and, in case of failures, keep the shipyard working. Furthermore, specialized workshops and engineering studios shall ensure that they are prepared to face any type of refitting work.

Regarding the information obtained about the regions in Atlantic Coasts, on the north of Spain and France the number of relevant shipyards are way less than on the Mediterranean ones. In the United Kingdom, the major shipyard without any doubt is Pendennis in Flamouth, thanks to the two drydocks and 800 [t] travel-lift has an incredible lifting capacity and it is highly specialized on superyacht refitting. About Germany and Netherlands, these countries count a large number of superyacht newbuilding shipyards that could also have a maintenance and refitting section for their superyachts. Noteworthy, Lürssen is probably the biggest and the most important newbuilding superyacht shipyard in the world. From this shipyard came out the largest superyachts ever made: Azzam (180 [m]), Dilbar (156 [m]), Al Saïd (155 [m]) and so on (Barche a Motore).

In what concerns Portugal, the shipyards taken into account are 12. Not all of these shipyards have experience with yachts and, therefore, this section has been entitled simply as concerning Repair Facilities. Indeed, NavalRocha, NavalTagus and Nautiber are involved with other types of ships and boats with only a very limited experience with yachts. In Lisbon there are several shipyards, most of them are small and they are a facility of a marina, like Cascais. Navalrocha and Navaltagus, are large and well-equipped shipyards, but specialized for ship repair and maintenance, this means that they are able to make just a part of works needed on a superyacht, like mechanical, engine and electrical works. They miss that kind of equipments and workshops for the interior works, a painting shed (painting on superyachts is very important compared to ships because the exterior has to be perfect) and some other specialized facilities for superyachts maintenance and repair. Same goes for Estaleiros Navais de Peniche in Peniche. The two shipyards of Sopramar, in Lagos and in Portimão, on the other hand, are made for yachts and superyachts. Comparing the major superyacht shipyards analyzed to the Portuguese ones, there are some differences to highly. First of all, the dimensions: the major shipyards in Italy, Spain and France, are way larger, both in open and covered space, than Sopramar and Navaltgus; the only one with the same order of magnitude is Estaleiros Navais de Peniche. The other major difference is that the other shipyards are thought, designed and built for superyachts, as opposed to the largest Portuguese ones. This causes a substantial difference on the quantity and quality of services offered from the shipyard to superyachts that require, as already said, particular and dedicated infrastructures, equipment and labor.

For the costs, it is hard to create a precise list for repair and maintenance operations. First of all, any type of work it is strongly influenced by the yacht's type, size and year of built. Then another important criterion is if the yacht has been well maintained through the years and if all the previous repairs have been done in the right way. Regarding the maintenance of the engines, which for sure would take a big slice of the costs, it depends on the brand and how much they are used, which means how many hours of work they have done. In addition, shipyards do not share price lists of their operations, due to privacy and to the reasons above, but they usually work with personalized price estimation for each yacht. On the other hand, there are a few exceptions of public price lists for Spanish and Italian shipyards, at least for some basic services and their price criteria, such as: launching and towing by different type of lifting equipment, antifouling, cleaning, cost of staying on the yard and worker labor cost. Regarding Portugal, it was not possible to find any example of prices of yacht shipyards.

However, in order to provide anyway an estimate of the costs of a yacht repair and maintenance shipyard in Portugal it was decided to extrapolate the costs from the ones available. According to ECORYS Research and Consulting (ECORYS SCS Group, 2009), which reports a Eurostat graph of the yearly average labour cost per employee in each country of European Union, the average labour cost per employee in Spain and in Italy is the same and amounts to ≈ 35000 [EUR/Year] gross, in place of the average in Portugal which amounts just to ≈ 19000 [EUR/Year] gross.

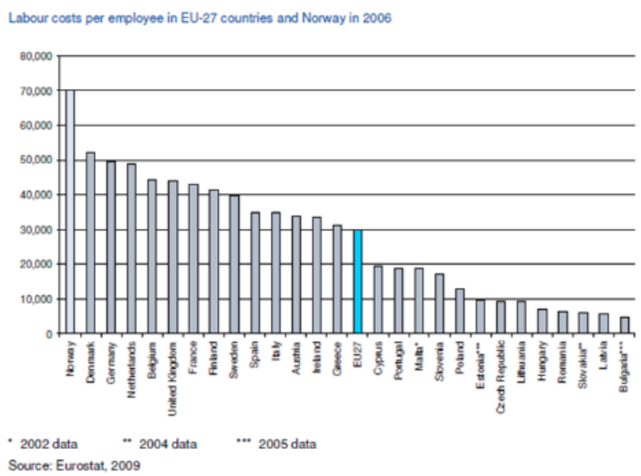

Figure 6 - Yearly Average Labour Cost Per Employee in Each Country of European Union (ECORYS SCS Group, 2009).

Knowing these values, it is possible to make a proportion in order to estimate the man hour cost used by a shipyard in Portugal. In fact, considering Italy where the cost of man hour is 50 [EUR/Hour] and where the yearly average labour cost per employee is 35000 [EUR/Year] and being the average labour cost per employee in Portugal around 19000 [EUR/Year] it can be deduced that the cost of man hour in Portugal amounts to ≈ 27 [EUR/Hour].

Table 1 - Price Lists of a Typical Yearly Maintenance of Port Nautic Castello's Shipyard, in Spain, of Cantiere Nautico Jesus in Italy and Portugal.

Cost of Shipyard for a Typical Yearly Maintenance						
Service	Spain (Port Nautic Castello)		Italy (Cantiere Nautico Jesus)		Portugal	
	Price [EUR]	Units	Price [EUR]	Units	Price [EUR]	Units
Haulage	20	Meter of Lenght	2500	Per Operation	1350	Per Operation
Cleaning and Polishing of the Hull	24	Man Hour	80	m2	50	m2
Revision of Main and Auxiliary Engines	50	Man Hour	50	Man Hour	27	Man Hour
Megger Test and Revision of Electroinical Installation	50	Man Hour	50	Man Hour	27	Man Hour
Revision of Air Conditionig/Ventiliation System	45	Man Hour	50	Man Hour	27	Man Hour
Revision of Watermaker and Sewage Treatment Plant	45	Man Hour	50	Man Hour	27	Man Hour
Repairs in Teak Decks	45	Man Hour	600	m2	350	m2
Revision of Radio and Navigation Equipment	50	Man Hour	50	Man Hour	27	Man Hour
Check of Fire-Extinguishing Equipment	38	Man Hour	50	Man Hour	27	Man Hour
Revision of Life-Saving Aplliance	50	Man Hour	1000	Per Operation	700	Per Operation
Revision of Fire Detection Equipment	50	Man Hour	50	Man Hour	27	Man Hour
Launching	20	Meter of Lenght	2500	Per Operation	1350	Per Operation

6 CASE STUDY FOR SUPERYACHT YEARLY CYCLE

6.1 Characterization of integrated service proposal

The information gathered and presented in the previous sections will now be used to define a typical superyacht cycle and evaluate the total costs implied in the operation of the vessel in a full yearly cycle. On this study it is considered an owner of a motor superyacht of about 40 meters L_{OA}, which spends winter time in the Caribbean, that is the high season of that region, in particular from December to April, and summer time in Cote D'Azur, from May to November, which is the high season for the Mediterranean. Basically, two scenarios are taken into account:

Scenario 1: the yacht is in the Caribbean Islands from middle of December to middle of April. Then it is shipped from Port St. Vincent in US Virgin Islands to Genoa, by a specialized semi-submersible ship, arriving in early May in order to have time to undertake yearly maintenance. After that, the yacht sails to Cannes and spends the summer in Cote D'Azur until the end of November, when it is shipped back to the Caribbean (same port of departure).

Scenario 2: the yacht is in the Caribbean Islands from middle of December to middle of April. Then it is shipped by a specialized semi-submersible ship from Port St. Vincent in US Virgin Islands to Portimão in Portugal, where it arrives at the end of April, for its yearly maintenance. On the second half of May it sails by itself to the port of Cannes in Cote D'Azur, where it spends summer until the second half of October when it sails back to Portimão. The yacht spends there around 1,5 months until middle of December when it is shipped back to Port St. Vincent in US Virgin Islands

The costs of permanence in the Caribbean will not be taken into account on this study because they are constant on the two scenarios, as well as for the costs related to the common permanence in Cote D'Azur. The only costs evaluated are the ones different in the two scenarios. For the first scenario, the shipyard considered is a typical Italian shipyard in Genoa, while regarding the second scenario, the shipyard is a typical Portuguese one, in Portimão. During the time spent in France, the base-marina is the Port de Cannes, while for Portugal is the Marina de Portimão.

6.2 Technical characteristics of the yacht

The motor yacht taken into account for this study is a Majesty 125, 38,40 meters (125-foot) of L_{OA}, built by Gulf Craft's shipyard on 2010, named "Grenadines III". This composite-made superyacht was built using the FRP (Fiber Reinforced Polymers) vacuum infusion technique, that makes the structures lighter and stronger than normal lamination. It is a triple-deck superyacht plus the flybridge, the typical layout for this size and category of superyacht, with a large room to entertain up to 100 guests when moored and 5 double guestrooms for up to 10 guests. The owner's cabin is equipped with a Spa Pool.

The number of crew members is 7, captain included, when in operation. This superyacht is propelled by twin MTU diesel engine of 2400 [hp] each, able to sail at 15 knots at economic-cruise and 23 knots at fast-cruise. This superyacht is also equipped by two diesel generators of 80 [Kw] each, in order to provide to any electrical necessity of the yacht.

Regarding tanks, fuel tanks have a total capacity of 31310 liters, fresh water tanks of 3940 liters, black water tanks of 2800 liters and gray water tanks of 2730 liters. This superyacht, sailing at economic-cruise speed, has a total fuel consumption of around 300 l/h, thus ensuring an autonomy of around 100 hours of sailing equal to 1500 nautical miles at 15 knots (economic-cruise speed). (Charter World, 2021), (212° Yachts, 2021), (Aurora Yachts, 2021). Table 2 shows the technical characteristics of the superyacht understudy.

Table 2 - Technical Characteristics of superyacht Grenadines III (Charter World, 2021), (212° Yachts, 2021), (Aurora Yachts, 2021).

Technical Characteristics Of Grenadines III			
Builder	Gulf Craft	**Engines**	2 x 2400 hp MTU
Type	Majesty 125	**Generators**	2 x 80 [Kw], 50 [Hz]
Year	2010	**Economic-cruise speed**	15 [Kn]
Loa	38,40 [m]	**Fast-cruise speed**	23 [Kn]
Beam	7,55 [m]	**Fuel Consumption (at economic-cruise speed)**	300 [l/h]
Draft	2,11 [m]	**Range (at economi-cruise speed)**	1500 nautical miles
Displacement	210 [t]	**Fuel Capacity**	31310 [l]
Crew	7	**Frash Water Capacity**	3940 [l]
Guests	10	**Black Water Capacity**	2800 [l]
Cabins	5	**Grey Water Capacity**	2730 [l]

6.3 Technical characteristics of the semi-submersible ship

The ship chosen is a semi-submersible ship named "Yacht Express" built by Yantai Raffles Shipyard in China and flying the Netherlands flag. It is owned by the DYT Yacht Transport company.

Table 3 - Technical Characteristics of "Yacht Express" (Yacht Express, Dockwise Yacht Transport, 2021),(Vesselfinder, 2021).

Technical Characteristics Of Yacht Express			
Name	Yacht Express	**GT**	17951 [t]
Type	Semi-submersible/Heavy Lift Vessel	**DWT**	12500 [t]
IMO-Number	9346029	**NT**	5386 [t]
Flag	The Netherlands	**Loa**	208,89 [m]
Port of Registry	Amsterdam	**Lbp**	191,90 [m]
Year of Built	2007	**Breadth**	32,23 [m]
Hull Material	Steel	**Draught**	5,80 [m]
Crew	28	**Depth**	8,50 [m]
Main Engines	Diesel / Electric: 2x Wärtsilä 12V38DE - 4 stroke single acting 12 cylinder combustion engines 8.700 [kW] / 13.860 hp at 600 rpm connected with electric motors each 5.100 [kW]	**Generators**	2x Wärtsilä 6L20 - 4 stroke 6 cylinder 200 x 280 [mm]diesel generatorsets each 1.080 [kW]
Propellers	2 x Azimodal	**Lifting Equipment**	1x Crane - SWL 10 [t]
Bow Thruster	1x 1.640 [kW]	**Max Speed**	18 [Kn]
Deck Space	5115 [m2]	**Deck Lenght**	165 [m]
Carrying Capacity	5000 [t]	**Deck Width**	31 [m]

6.4 Specification of the works during yearly maintenance

The general specification of the works to be undertaken is the following: haulage of the yacht; cleaning and polishing of hull; revision of main and auxiliary engines; megger test and revision of electrical installation; revision of air conditioning/ventilation system; revision of watermaker and sewage treatment plant; repairs in teak decks; revision of radio and navigation equipment (radio survey); check of fire-extinguishing equipment; revision of life-saving appliances; revision of fire detection equipment; costs of annual survey by class and flag.

6.5 Numerical method for calculation of yacht costs sailing in Cannes from Genoa and from Portimão

According to the case study proposal, the superyacht has to sail in both of scenarios: on the first case it will sail from Genoa to Port of Cannes and back, on the second case it will sail from Portimão to Port of Cannes and back. Obviously, the yacht is the same, so all the technical characteristics, will be equal in both cases. The speed taken into account is the economic-cruise speed of the technical datasheet, as well as the fuel consumption. A sea margin of 20% has been considered in order to obtain more realistic results. The cost of the fuel considered, which is a normal diesel, is the average of 2020 in Genoa, equivalent of ≈ 1,6 [EUR/l], for scenario 1, and the average of 2020 in Portimão, equivalent of ≈ 1,5 [EUR/l], for scenario 2 (Global Petrol Price, 2021). The first route, Genoa – Cannes, is just 102 [Miles] long, the second route Portimão – Cannes is 923 [Miles] log. The voyage costs are made of fuel costs and port costs.

Fuel costs are firstly calculated, in terms of the total fuel consumed in liters $Fuel_{Tot}$, by multiplying sailing time [h] $Time_{Sailing}$ and fuel consumption at cruise speed [l/h] $Fuel\ Cons._{cruise\ speed}$ adding the sea margin $Sea\ Margin$:

$$Fuel_{Tot} = Time_{Sailing} * Fuel\ Cons._{cruise\ speed} + \left(0{,}2 * Time_{Sailing} * Fuel\ Cons._{cruise\ speed}\right) \quad (2)$$

Then, the total fuel costs $C_{Total\ Fuel}$ were calculated by multiplying the total fuel consumed times the fuel cost [EUR/l] C_{Fuel}

$$C_{Total\ Fuel} = Fuel_{Tot} * C_{Fuel} \quad (3)$$

Port costs are calculated by multiplying the cost of the marina per night C_{Marina} times the number of nights spent on the marina N_{Nights}

$$C_{Port} = C_{Marina} * N_{Nights} \quad (4)$$

It was considered that the yacht does not make any stop on scenario 1, due to brevity of the leg, and it stops for one night in Valencia, which is almost at half of the voyage, on scenario 2.

Crew cost is negligible because it is constant on the two scenarios. Therefore, for the sake of completeness, it is reasonable to consider 4 crew members while customers or owner are not onboard and 7 crew members, which is the maximum, while they are onboard.

Finally, sailing cost was obtained:

$$C_{Sailing} = C_{Total\ Fuel} + C_{Port} \quad (5)$$

On the following tables are reported the data obtained from the numerical calculations presented above of the two scenarios:

Table 4 - Voyage Costs of the First Leg of Scenario 1

Voyage Costs (Scenario 1)	
Fuel Cost [EUR]	3917
Port Cost [EUR]	0
Total Cost [EUR]	3917

Table 5 - Voyage Costs of the First Leg of Scenario 2

Voyage Costs (Scenario 2)	
Fuel Cost [EUR]	33228
Port Cost [EUR]	210
Total Cost [EUR]	33438

For each scenario, the voyage costs obtained are referred to just one leg, so in order to obtain the total voyage costs for each scenario (roundtrip) it is necessary to double the voyage costs obtained for one leg. The only difference between the two legs is the price of the marina in Valencia (scenario 2), which have two different prices due to the different period of transit (high season in May and low season in October. The price taken into account is the average of the two prices, in order to obtain the total round-trip voyage costs by doubling the one obtained for one leg. Analyzing the results, it is possible to see how the differences of the values obtained depends in the first place on the different lengths of the routes (102 miles for the first scenario and 923 for the second), that influence mainly fuel consumption, and also the port cost which is zero on the first scenario and present on the second, even if it is relatively insignificant, and on the second place on the different cost of the fuel.

6.6 Numerical method for calculation of semi-submersible ship costs in the routes Genoa – Caribbean and Portimão – Caribbean

The calculation method consists on analyzing the costs, with the same criteria, for each leg of both scenarios, that are Scenario 1: first leg is from Port St. Vincent to Genoa, second leg from Genoa to Port St. Vincent; and Scenario 2: first leg is from Port St. Vincent to Portimão, second leg from Portimão to Port St. Vincent. The costs are mainly divided into three parts: operating costs, voyage costs and capital costs. The following formulas and coefficient are taken from (Santos, Economics of Ship Operations, 2019) and (D'Almeida, 2009).

Operating costs (O_c) are calculated using the following formulas and represent all fixed costs related to the maintenance of the ship. It is composed by five different costs: manning (M), stores and consumables (ST), maintenance and repairs (MN), insurance (I) and administration costs (AD):

$$O_c = M + ST + MN + I + AD \quad (6)$$

Manning costs depend on the number of crew members $Crew_{N°}$ and a known coefficient (K) for different types of ships:

$$M = K * Crew_{N°}{}^{0,95} \quad (7)$$

Stores and consumables costs depend on the number of cabins, which are directly related to the number of crew members $Crew_{N°}$, on the quantity of lubricating oil consumed which depends on the power of the main engine P_{ME}, on the cubic number *CN* of the ship, which is the product of length between perpendicular L_{BP} times the breadth *B* times the depth *T*. K_1, K_2, K_3 are given coefficients:

$$ST = K_1 * Crew_{N°} + K_2 * CN^{0,25} + K_3 * P_{ME}{}^{0,7} \quad (8)$$

Maintenance and repair costs include all daily repairs, as well as spare equipment and unexpected mechanical failures. On the following equation, P is the estimated newbuilding price of the ship, K_1 and K_2 are given coefficients and P_{ME}, is the power of the main engines:

$$MN = K_1 * P + K_2 * P_{ME}{}^{0,66} \quad (9)$$

The costs of the insurance can be estimated as following, where K_1 and K_2 are given coefficients, V is the estimated actual value of the ship and GT is the gross tonnage:

$$I = K_1.V + K_2.GT \quad (10)$$

Administrations costs are considered fixed and depend on several aspects, such as registration fee and flag state, show based administrative and management costs, communications costs, etc. In this case, it will be considered as 120.000 [EUR] per year.

Regarding voyage costs, they are made by fuel costs and port costs. The calculation of the total fuel costs $C_{Total\ Fuel}$, is composed by the costs of the fuel consumed by the main engines and by the costs of the fuel consumed by the diesel generators.

In both scenarios, however, for a small part of the routes nearby US Virgin Islands, the ship will sail through a Sulphur Emission Control Area (SECA), where it is necessary to use a Low Sulphur Fuel (LSIFO) which is more expensive than normal fuel burned in open sea, which is IFO 380. This particular was taken into account on the calculation.

Thus, firstly it was calculated the total fuel consumed by the main engines in tons $Fuel_{Tot,ME}$ by multiplying sailing time [Days] $Time_{Sailing}$, fuel consumption of the main engines at cruise speed [g/hp*day] $Fuel\ Cons._{cruise\ speed}$ and the power of the main engines P_{ME}:

$$Fuel_{Tot,ME} = Time_{Sailing} * Fuel\ Cons._{cruise\ speed} * 10^{-6} * P_{ME} \quad (11)$$

Then, the total fuel costs of the main engines $C_{Total\ Fuel,MN}$ were calculated by multiplying the total fuel consumed $Fuel_{Tot,MN}$ times the fuel cost [EUR/t] C_{Fuel}:

$$C_{Total\ Fuel,ME} = Fuel_{Tot,ME} * C_{Fuel} \quad (12)$$

In order to obtain the cost of the fuel consumed by the main engines while sailing in open sea, it was considered 95% of sailing time (and so of the fuel consumed), and the cost of IFO 380:

$$C_{Total\ Fuel;Open\ Sea} = Fuel_{Tot,ME} * 0{,}95 * C_{Fuel,IFO} \quad (13)$$

Therefore, for the cost of the fuel consumed by the main engines while sailing through SECA, it was considered 5% of the sailing time (and so of the fuel consumed), and the cost of LSIFO:

$$C_{Total\ Fuel;SECA} = Fuel_{Tot,ME} * 0{,}05 * C_{Fuel,LSIFO} \quad (14)$$

The same calculations are computed for the diesel generators: firstly it was calculated the total fuel consumed by one the diesel generator in tons $Fuel_{Tot,DG}$ by multiplying sailing time [Days] $Time_{Sailing}$, fuel consumption of the diesel generators [g/hp*day] $Fuel\ Cons_{DG}$, the power of the diesel generators P_{DG} and by 0,65 which represents the fraction of the installed generator power used while sailing:

$$Fuel_{Tot,DG} = Time_{Sailing} * Fuel\ Cons._{DG} * 10^{-6} * P_{DG} * 0{,}65 \quad (15)$$

Then, the total fuel costs of the diesel generators $C_{Total\ Fuel,DG}$ were calculated by multiplying the total fuel consumed $Fuel_{Tot,DG}$ by MGO cost [EUR/t] $C_{Fuel,MGO}$:

$$C_{Total\ Fuel,DG} = Fuel_{Tot,ME} * C_{Fuel,MGO} \quad (16)$$

For what concern port costs, it was considered that both in Port St. Vincent in the Virgin Islands and in Portimão the ship will load and unload outside the port, due to the shallow depth inside the port, so they are not taken into account. In Genoa, on the other hand, the port is big and depth enough to let the semi-submersible ship operates inside it so it is considered. The ship needs 3 days to complete unloading operations and 3 days to complete loading operations N_{Days}, positioning all the yachts and be ready to sail. The total costs of the port of Genova $C_{Port\ Daily}$ for this ship is around 10000 [EUR/Day], so the total port costs $C_{Port\ Tot}$ were calculated:

$$C_{Port\ Tot} = C_{Port\ Daily} * N_{Days} \quad (17)$$

About capital costs, which are made by two components, that is the initial purchase price (newbuilding cost) and periodic cash re-payments to banks or equity of investors, it is the annualized cost divided by 350, considering 15 days of not operation of the ship, and multiplied by the number of days of the voyage. The Newbuilding Cost of the ship considered was $NC = 40000000\ [EUR]$, and the expected life of this type of specialized ship it was estimated $N = 25\ [Years]$; the discount rate considered was $i = 0{,}08$, and a Scrap Price of $SP = 5000000\ [EUR]$. Thus, the Capital Recovery Factor (CRF) was calculated as following:

$$CRF = \frac{i*(1+i)^N}{(1+i)^N - 1} \quad (18)$$

Then, the Annualized Newbuilding Cost (ANC) was obtained by multiplying the Newbuilding Cost times CRF:

$$ANC = CRF * NC \quad (19)$$

After that, the Present Worth Factor was calculated by the following formula:

$$PW = (1+i)^{-N} \quad (20)$$

Thus it was possible to obtain the Present Worth of Scarp Price (PWSC) by multiplying PW times the Scarp Price:

$$PWSC = PW * SP \quad (21)$$

Then, the Annualized Scarp Price (ASP) was calculated by multiplying PWSC times CRF:

$$ASP = PWSC * CRF \quad (22)$$

So the Annuity was calculated by subtracting the ASP from the ANC:

$$Annuity = ANC - ASP \quad (23)$$

Finally, the Daily Cost was calculated dividing the Annuity by 350 days:

$$Daily\ Cost = \frac{Annuity}{350} \quad (24)$$

Once calculated all the costs for each of the voyage, in order to obtain the cost per meter of length of cargo transported, which is the most common unit of measure for this type of goods, it was calculated the total capacity of the ship in linear meters of cargo by analyzing a typical fully loaded voyage of this ship, which counts 480 linear meters of cargo. Then, the total costs of each leg were calculated by making the sum of operating costs, voyage costs and capital costs. Knowing it, assuming a gross income forecast of about 70% the total costs per each leg and knowing the total capacity of the ship in linear meters of cargo and the length of the yacht to be transported, on this case $L_{OA} = 38{,}40$ [m], the costs of each voyage for shipping the superyacht understudy was finally obtained.

Table 6 - Total Costs of First Leg of Scenario 1

Total Cost 1st Leg (Scenario 1) [EUR]	794387
Income Forecast [EUR]	556071
Total Cost 1st Leg (Scenario 1) Per linear Meter of Cargo [EUR]	2813
Total Cost 1st Leg (Scenario 1) For Grenadines III [EUR]	108037

Table 7 - Total Costs of Second Leg of Scenario 1

Total Cost 2nd Leg (Scenario 1) [EUR]	821550
Income Forecast [EUR]	575085
Total Cost 2nd Leg (Scenario 1) Per linear Meter of Cargo [EUR]	2910
Total Cost 2nd Leg (Scenario 1) For Grenadines III [EUR]	111731

Table 8 - Total Costs of First Leg of Scenario 2

Total Cost 1st Leg (Scenario 2) [EUR]	587005
Income Forecast [EUR]	410904
Total Cost 1st Leg (Scenario 2) Per linear Meter of Cargo [EUR]	2079
Total Cost 1st Leg (Scenario 2) For Grenadines III [EUR]	79833

Table 9 - Total Costs of Second Leg of Scenario 2

Total Cost 2nd Leg (Scenario 2) [EUR]	538723
Income Forecast [EUR]	377106
Total Cost 2nd Leg (Scenario 2) Per linear Meter of Cargo [EUR]	1908
Total Cost 2nd Leg (Scenario 2) For Grenadines III [EUR]	73266

Analyzing the results obtained, it looks evident how the first scenario is the most expensive, due mostly for the grater length of the route. In addition, second leg of scenario 1 appears the most expensive of the four understudy. The results obtain and shown on the tables above are a bit lower than the data found on the literature, which are ≈ 3500 – 4000 [EUR/m] for the two bigger yachts (similar to the one taken into account) and ≈ 1300 [EUR/m] for the smallest one. This is probably caused by the fact that the costs of shipping a yacht is not just a function of length and, in addition, the revenue it might be greater than what has been assumed.

6.7 Numerical method for calculation of marina costs and shipyard costs

In this section marina costs and shipyard costs were calculated for both scenarios. On scenario 1, it was considered that the superyacht will spend all its permanence in Cannes, until leaving to Genoa. On this case, the pricelist of Port De Cannes was taken into account and, the only option available was the daily price, including water and electricity. Thus, the daily price was extrapolated for the right yacht category and right period understudy. Once knowing it, in order to calculate the total marina cost, it was multiplied the daily price by the number of days of permanence in the marina. On the second scenario, it was considered that the yacht, during both voyages from Portugal to France and back, will spend a night in the port of Valencia Mar, in Valencia. In addition, it will spend around 50 days in Marina De Portimão before being shipped back to the Caribbean. In Marina De Portimão, weekly price and monthly price were considered, both including water and electricity supply, in order to evaluate the total cost of the marina, being these two more convenient then the daily price.

Regarding shipyard costs, a pricelist of all the works to be undertaken was obtained for both scenarios, respectively of a typical Italian shipyard for scenario 1 and of a typical Portuguese shipyard for scenario 2. The pricelist of the Portuguese shipyard was obtained with the same method described on section 5 and shown on Table 1. Even if for some types of works there are different types of unit of measures for the prices, it looks evident how, looking at the man-hour costs, second scenario would be more convenient than the first one. In addition, it is important to say that the cost of spares and materials is just an estimation, that can vary a lot depending on drawback, suppliers, etc.

6.8 Summary of results obtained for the yearly cycles

Analyzing the results obtained it looks evident how the second scenario appears more convenient than the first one for almost every aspect considered, economically speaking.

Firstly, the shorter voyage from US Virgin Islands to Portugal, which counts 3210 miles against the 4180 miles of US Virgin Islands to Italy, plays an important rule on the different costs of the two scenarios. In fact, all the costs related to the shipping are reduced, form the costs of the fuel to the capital costs and the operating costs, due to the less voyage days. In addition, the prices of the fuels in Portimão are lower than in Genoa, this implies an additional save of money. At the end, the results obtained are 2813 [EUR/m] and 2910 [EUR/m] for scenario 1 against 2079 [EUR/m] and 1908 [EUR/m] for scenario 2, which is a significant difference. In fact, the total costs for the superyacht understudy to be shipped amounts to ≈ 108000 [EUR] and ≈ 112000 [EUR] for scenario 1 and to ≈ 80000 [EUR] and ≈ 73000 [EUR] for the second scenario.

The costs related to the voyage of the yacht from Portimão to Cannes of scenario 2, on the other hand, which obviously is way longer than the voyage from Genoa to Cannes of scenario 1 and requires also one stop per each leg, does not compensate the saving of money of the shipping but reduce significantly the differences. Therefore, the voyage costs are ≈ 4000 [EUR] per each leg of scenario 1 and ≈ 33000 [EUR] per each leg of scenario 2, including the price of the marina in Spain. So, the total voyage costs per each leg (shipping + sailing) amounts to ≈ 112000 [EUR] and ≈ 116000 [EUR] for the first scenario and to ≈ 113000 [EUR] and ≈ 107000 [EUR] for the second scenario.

Regarding marina costs, the difference between the two scenarios is again an advantage to the second scenario, with ≈ 5000 [EUR] of scenario 1 against ≈ 3000 [EUR] of scenario 2, even if these costs do not influence a lot the total costs of the scenarios.

Table 10 - Summary of Shipping Costs Calculation and Voyage Costs of the Superyacht

Summary of Shipping Costs Calculation & Voyage Costs of the Superyacht				
Shipping				
Type of Costs	**Scenario 1**		**Scenario 2**	
	Leg 1	**Leg 2**	**Leg 1**	**Leg 2**
Voyage Costs [EUR]	543376	570539	394243	345961
Operating Costs [EUR]	135114	135114	103760	103760
Capital Costs [EUR]	115897	115897	89002	89002
Gross Income Forecast [EUR]	575085	575085	410904	377106
Shipping Costs for Case Study [EUR/m]	2813	2910	2079	1908
Shipping Costs for Case Study [EUR]	108037	111731	79833	73266
Voyage of the Superyacht				
Fuel Costs [EUR]	3917	3917	33228	33228
Port Costs [EUR]	0	0	210	210
Total Costs [EUR]	3917	3917	33438	33438
Shipping + Voyage				
Total Costs [EUR]	111953	115648	113271	106704

Finally, shipyard costs are once again lower in the second scenario: ≈ 264000 [EUR] for scenario 1 and ≈ 197000 [EUR] for scenario 2. This consistent difference of costs, on equal terms, is attributable to the different costs of the grunt work, both specialized and not, which influence also the operation like haulage and launching. In addition, a difference on the costs of spares and materials would be reasonable, to the benefit of scenario 2, due to the different GNP and economy of Portugal and Italy but, on a first phase of calculation it was decided to not take it into account.

At the end, considering all the costs taken into account of the two scenarios, the costs obtained are the following and reported on Table 11. Total costs of scenario 1: 496687 [EUR] ≈ 500000 [EUR]; Total costs of scenario 2: 420389 [EUR] ≈ 420000 [EUR]

Table 11 - Total Costs per Scenario

Total Costs of Each Scenario		
Type of Costs	**Scenario 1**	**Scenario 2**
Shipping [EUR]	219767	153099
Voyage of the Superyacht [EUR]	7834	66876
Marinas [EUR]	5085	3474
Shipyard [EUR]	264000	196940
Total Costs [EUR]	496686	420389

The total savings amounts to 80000 [EUR] which is a significant result consistent with what it was expected to obtain after the previous studies already done.

7 CONCLUSIONS

After reviewing the literature about the superyacht market segment, it was understood how this sector has undergone an incredible development throughout the years, in particular in the recent past. Due to the increase of the superyacht fleet and to the huge economic impact of this business, a study about the migration and repositioning of superyachts has been undertaken, analyzing the most common routes, the criteria from which they are chosen, the influence of weather forecast and the limits of the yachts.

For those yachts that are not able to sail across the Atlantic Ocean, in order to have an alternative way to cross the Ocean, shipping options have been analyzed regarding the type of ships used, the average costs and routes. The potential of Portugal in this business was explained, in particular due to its geographical position, which makes it a strategic point and a perfect hub for superyacht traffic, not only for the superyachts crossing by themselves, but also for the traffic between North Sea and Mediterranean. The operation of shipping companies carrying yachts all over the world was also described.

After that, a database of the major marinas and shipyards in the Mediterranean and North Sea was presented, in order to be able to understand the distribution of these infrastructures along the coasts and to compare the level of development between the countries under study. In addition, the characteristics of these infrastructures have been analyzed and collected, in order to be able to understand which are the most important specifications of these shipyards and marinas. It was concluded that Portugal is the country with the lower number of both marinas and shipyards specialized on superyachts, which require very particular characteristic for these infrastructures. This explains why, despite the potential, Portugal is behind compared to Spain, France and Italy in the yachting world. Regarding costs, Italy, Spain and France are more or less in line as regards marina costs, while Portugal reveals itself cheaper. For what concerns shipyard costs, France is the most expensive, due to the greater labour costs, followed by Italy and Spain, which are at the same level; once more, Portugal is the cheapest option analyzed, which is another point in favor to this country.

Finally, using all the information collected, a case study for a superyacht yearly cycle has been developed, analyzing and comparing two scenarios: an existing typical scenario, in which a certain superyacht is shipped to Italy, makes there the yearly maintenance and repairs, then sails to Cote D’Azur and then it is shipped back from Genoa to the Caribbean; a new scenario in which the same superyacht is shipped to Portugal and takes there the yearly maintenance and repairs, then it sails to Cote D’Azur and sails back to Portugal where it spends a short period before be shipped back.

Comparing these two scenarios, the information, data and conclusions collected were confirmed, with the results obtained being consistent with what was expected. In fact, comparing the costs of the two scenarios, the second one turns out to be the most convenient. Firstly, the shorter voyage of the ship to deliver the superyacht in Portugal rather than in Italy causes a consistent reduction of the costs, which are, however, almost compensated by the difference of the costs of sailing from Portugal to France rather than from Italy to France. Also as expected, reduced costs of marina was obtained for the second scenario compared to the costs of marina in the first scenario. But the most significant difference between the two cases, which is also the greater saving in costs, is the different costs of the shipyard. In fact, assuming to undertake the same works on the same superyacht, the difference of the costs calculated amounts to around 25% from scenario 1 to scenario 2, with a saving of around 65000 [EUR] for the case understudy. At the end, comparing the total costs of the two scenarios under study, it was obtained a difference of almost 80000 [EUR] from the existing scenario to the new scenario. Such a consistent difference, to the advantage of the second scenario, demonstrate that, even in a preliminary study like the one developed in this paper, there is a definite saving on choosing Portugal as a hub for superyachts.

The general conclusion of this work is that Portugal could play a significant role in the future of superyachts, becoming a hub for those superyachts that transit between the Mediterranean and the Caribbean and the North Sea. It was also demonstrated that a consistent improvement of the infrastructures, marinas and shipyards is needed along all the Portuguese coast, in order to be ready to manage the flux of these luxury vessels, and that already, economically speaking, Portugal is a valid option for those superyachts that can be managed by the existing infrastructures.

As recommendation for further work, it is suggested to focus on the feasibility study, both economic and technical, for the construction of modern superyacht marinas and shipyards, located in some strategic position in Portugal. It will also be important to take into account the issues related to the weather conditions, swell, wave motions and typical current, as well as the economical sustainability of these investments considering a reasonable amortization and future investments.

REFERENCES

212° Yachts (2021). *Grenadines III*. https://www.212-yachts.com/yacht-charter/luxury-yacht-charter-cannes-grenadines-iii/

Aurora Yachts (2021). *Majesty Yachts, Majesty 125*. https://www.aurorayachts.net/listings/majesty-125/#1468238791521-8e8c0611-a354

Barchemgazine (2020). *Majesty 175 di Gulf Craft, lo yacht in composito più grande del mondo*. https://www.barchemagazine.com/majesty-175-di-gulf-craft-lo-yacht-in-composito-piu-grande-del-mondo/

Bees, N. (2020). *Yachting Pages Media Group*. https://yachting-pages.com/articles/what-is-a-superyacht.html (June 12th)

Bottero, S. (2002). *Nautica Alta Marea* . https://www.nauticaltamarea.it/rinnovo-certificato-di-sicurezza/ (December 27th)

Bunting, E. (2019). How to cross the Atlantic from the Caribbean to Europe: Everything you need to know, https://www.yachtingworld.com/sailing-across-atlantic/eastward-caribbean-europe-120203 (April 9th)

Carrier, J. (2013). *Cruising World* . (February 5th)

Ceglia, V.D. (2021). *La Repubblica*. https://www.repubblica.it/dossier/economia/i-gioielli-del-made-in-italy/2021/06/22/news/la_nautica_batte_il_covid-19_italia_in_vetta_nei_superyacht-307219060/ (June 22th)

Charter World (2021). *Grenadines III, Majesty 125*. https://www.charterworld.com/index.html?sub=yacht-charter&charter=mygrenadines-iii-6119

Chauvin, O. (2020). *BOAT OSMOSIS*. https://blog.bandofboats.com/en/boat-osmosis-how-to-prevent-it (April 22th)

Cione, C. (2021). *Daily marine magazine*. https://marinecue.it/yacht-azzam-lusso-record-500-milioni-2021/29725/ (July 17th)

Clima e Viaggi (s.d.). Guida ai climi nel mondo: https://www.climieviaggi.it/clima/portogallo

Colombo, A. (2020). *Tipi di barche a vela*. https://www.inautia.it/blog/vela/tipi-barche-vela/#megayacht (November 13th)

Complete Marine Freight. (2021). Making your adventures happen. http://www.completemarinefreight.com. (September 14th)

D'Almeida, J. (2009). *Arquitectura Naval - o Dimensionamento do Navio.* Lisboa: PrimeBooks.

Dazert, R., Herman, A., Webster, F., Dowling, K., & Sabbadin, C. (2021). *Monaco Yacht Show Market Report 2021 by SuperYacht Times.* Amsterdam: SuperYacht Times.

Dockwise Yacht Transport (2021). Yacht Express, https://www.ship-technology.com/projects/yachtexpress/.

DYT (s.d.). Super Yacht Transport. https://www.yacht-transport.com/

ECORYS SCS Group (2009). *Study on Competitiveness of the European Shipbuilding.* Rotterdam: Directorate-General Enterprise & Industry.

Global Petrol Price (2021). *Global Petrol Price*. https://www.globalpetrolprices.com/gasoline_prices/

ICOMIA (2021). SMALL CRAFT STANDARDS BULLETIN 2021 - EDITION 15: https://www.icomia.org/content/icomia-small-craft-standards-bulletin-2021-edition-15 (August 19th)

ICOMIA (2020). *International Council of Marine Associations*. https://www.icomia.org/ (September 5th)

Marina Barcelona 92 (s.d.). *Marina Barcelona 92*. https://mb92.com/barcelona/shiplift

Marina di Porto Cervo. (2021). Marina di Porto Cervo. https://www.marinadiportocervo.com/wp-content/uploads/2021/04/NEW-PORT-2021.pdf (May 1st)

Marine Traffic (2019). *The Yacht and Superyacht Migration.*

Matheison, W. (2019). *Superyacht Migration Report 2015-2019.* Rory Jackson.

Mondinelli, A. (2014). *Boat Magazine* . https://www.boatmag.it/3701-cesare-cancelli-alluminio-superyacht/ (May 7th)

Moretti, P. (2015). *Boat International.* https://www.boatinternational.com/yachts/luxury-yacht-advice/yacht-classification-definitions--587 (January 21st)

Redazione. (2021, Jenuary 7). *Quanto Costa Un Superyacht, Tutte Le Spese Da Considerare*. https://sailbiz.it/quanto-costa-un-superyacht-tutte-le-spese-da-considerare/ (January 7th)

Santos, T. A. (2019). Economics of Ship Operations. Lecture Notes of TMPI, Lisbon, Lisbon, Portugal.

Santos, T. A. (2020). Superyacht Market Segment. Lecture Notes of TMPII, Lisbon, Portugal.

Springer, B. (2019). What Makes A Superyacht A Superyacht?: https://www.forbes.com/sites/billspringer/2019/08/07/what-makes-a-superyacht-a-superyacht/?sh=69179c0e71c6 (August 7th)

Superyachts (2020). *World is not Enough*. https://www.superyachts.com/fleet/world-is-not-enough-4077/ (October 4th)

Tamara Hardingham-Gill (2021). *CNN Travel.* https://edition.cnn.com/travel/article/hidden-costs-of-owning-a-superyacht/index.html (June 1st)

Vesselfinder (2021). *Vesselfinder*. https://www.vesselfinder.com/it/vessels/YACHT-EXPRESS-IMO-9346029-MMSI-244870311