Assessment of the Stability of Passenger Ships in Coastal Navigation in Case of Lacking Ship Geometry Data

Kristofor Lapa

Ships should ensure safe navigation by meeting the stability norms defined by the International Maritime Organization (IMO) and determined by national maritime administrations. The fulfillment of these norms is becoming increasingly important, especially for passenger ships used for tourist excursions. Recently, the development of maritime tourism has greatly increased the demand for these ships most of which are converted fishing vessels. The situation described in this paper pertains to Albania and most probably differs in other countries in the region and the wider area. Ships rarely have adequate technical documentation. The Albanian Register of Shipping requires the performance of stability tests, the results of which are entered in the amended stability book to ensure the vessels’ compliance with the norms following modifications undergone and guarantee safe navigation for tourists. An examination of a variety of ship design papers helped us identify various methods and methodologies for determining approximate geometric ship elements with an acceptable degree of reliability. However, their use should be limited and reliability proven by calculating parameters such as lightship VCG, number of passengers per m², assessing the possible range and area of navigation and weather conditions (mainly wind speed and wave forces). The calculations based on stability testing and the use of highly reliable software such as MaxSurf - Integrated Naval Architecture Software, Napa - Naval Architectural Package, Autoship - Systems Operation, Orca3D – Naval Architecture Software delivered fast and reliable stability assessment results and verified conformance with the norms prescribed by the Albanian Register of Shipping.

1. INTRODUCTION

Recently, maritime tourism in the bay of Vlora saw rapid development and the consequently increasing demand for passenger ships, especially those suitable for one day excursions (Rexhepaj, 2019).

Field observations and contacts with the Albanian port authorities and maritime administration suggest that these ships have major safety standard and service issues. Tourist boats operate mainly in the bays of Vlora and Saranda, at short distances (1-2 hours) and inland, such as on Koman and Vau i Dejes lakes on the Drin River or artificial lakes such as Belsh lake in Elbasan. The problems faced by the owners of these ships are associated with the coastal infrastructure required for periodic and instantaneous technical repair and maintenance. The only repair shipyard is the Pashaliman Shipyard, which is still under the jurisdiction of the Ministry of Defense, but lacks the tools and specialists needed to meet all ship repair, maintenance and construction requirements. In these conditions, lacking the required safety-related technical data, these ships fail to meet the safety standards applicable at sea and geometric and stability calculations are not made. As the Albanian Register of Shipping...
the effect of free surfaces on the stability of tanks containing liquids must be determined;
• a diagram of cross curves of stability indicating the height of the assumed axis from which the righting levers are measured and the trim assumed must be drawn up;
• superstructures, deckhouses, hatchway structures on or above the freeboard deck may be taken into account in the curves;
• the diagram and statements are required to be provided separately for the light, ballast and service loaded conditions at departure and upon arrival, provided that consumables are reduced to 10% of their capacity. A statement indicating lightweight, deadweight, displacement, their center of gravity, metacenter and metacentric height (GM). The curve of Righting Levers (GZ). These are corrected for a liquid free surface.
• The inclining test and appropriate lightship calculations must be made.

3. SHIP HULL 3D-CAD MODELLING

The physically measured point coordinates were used to obtain hull lines and surfaces. Then, the faired model of the hull was developed by interpolation and optimization processes. The hull was reconstructed using the Maxsurf software. All surfaces were checked to ensure the observance of the geometric boundary conditions and recreate surfaces belonging to any of the three main groups: the bow, the stern and the central regions (C, 2006).

The following steps need to be taken to reconstruct a 3D ship hull model based on physically measured point coordinates (al X. B., 2008):
• Necessary measurements of keel line, extreme parts of the hull and its sections were taken. Based on the condition of a particular ship and international guidelines, we intended to measure as many sections as we could. Although it is generally recommended to measure physical frames every 50 cm, that depends on the length of a given ship. In this case, ship length was sixteen (16) meters. A total of 20 measurements were taken.

### Table 1.
Number and transport capacity of ships in the bay of Vlora.

<table>
<thead>
<tr>
<th>Year</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ships</td>
<td>3</td>
<td>4</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Daily transport capacity</td>
<td>295</td>
<td>342</td>
<td>1198</td>
<td>1350</td>
</tr>
<tr>
<td>Number of pax</td>
<td>9150</td>
<td>14546</td>
<td>30843</td>
<td>51815</td>
</tr>
</tbody>
</table>

(ARS) (AMA, 2009) set a series of safety norms that must be taken into consideration, we attempted to conduct an in-depth analysis of IMO norms and requirements implemented by other European registers having similar coastal conditions with respect to tourist services, mainly of the Croatian Register of Shipping (Shipping, 2002).

We consulted several bibliographies because:
• these ships are rather old and have been in operation for a great number of years;
• these ships underwent structural modifications, in the course of which they were examined for potential damage that may have occurred during the provision of technical support;
• some ships have undergone structural modifications without the supervision of a specialist or an engineer.

Most ships have been completely repurposed and converted from service ships into one-day passenger transport ships. Thus, to meet the prescribed requirements and norms, these ships must first meet some other preconditions.

As almost no ship has the requisite documentation, such as technical documentation, general layout and structural drawings, the development of a ship lines plan requires their size and respective structural elements to be physically measured.

### 2. THE TRIM AND STABILITY BOOKLET

All relevant calculations for ships in lightweight and other loading conditions should be made both at departure and upon arrival to determine their displacement and coordinates of their center of gravity. Hydrostatic data facilitate the identification of the vertical center of the metacenter, KM. Hydrostatic and dynamic stability curves are then calculated and designed by drawing up stability booklets (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003), (IMO, Resolution MSC.267(85) - International Code on Intact Stability, 2008) containing calculations and stability curves for anticipated loading conditions.

The following ship stability rules have been set in accordance with the safe navigation norms (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003), (IMO, Resolution MSC.267(85) - International Code on Intact Stability, 2008):
• ship name, number in the register, harbor of registry, gross/net tonnage, ship dimensions, number of passengers and draft must be indicated;
• general layout with all compartments, tanks, storage, crew and passenger accommodation and amidships positions must be indicated;
• capacity and center of gravity (longitudinal and particularly vertical) of each load such as fuel, stores, fresh or ballast water, vertical center of gravity of vehicles must be calculated;
• weight of passengers and crew, their effects and centers of gravity must be calculated. The hydrostatic data of the ship, the heights of the transverse metacenter and the time to change the trim by one centimeter;
• the effect of free surfaces on the stability of tanks containing liquids must be determined;
• a diagram of cross curves of stability indicating the height of the assumed axis from which the righting levers are measured and the trim assumed must be drawn up;
• superstructures, deckhouses, hatchway structures on or above the freeboard deck may be taken into account in the curves;
• the diagram and statements are required to be provided separately for the light, ballast and service loaded conditions at departure and upon arrival, provided that consumables are reduced to 10% of their capacity. A statement indicating lightweight, deadweight, displacement, their center of gravity, metacenter and metacentric height (GM). The curve of Righting Levers (GZ). These are corrected for a liquid free surface.
• The inclining test and appropriate lightship calculations must be made.
Surfaces were built individually for each part of the hull (bow, stern, central body).

Individual surfaces were assembled and the hull assumed its preliminary form.

The hull was double checked. Initially based on previously designed geometric data and subsequently on physical measurement. This approach was adopted to avoid systematic and chance errors.

The surface of the CAD model was smoothed until the required level of compliance with hydrostatic characteristics was achieved.

The drawing of the CAD model of the modelled hull was carried out. (al K. L., 2016)

Since measurements are highly important and have a significant effect on the viewing of ship stability assessment results, they deserve special attention.

Traditional measuring requires simple measuring tools such as: plumb line, measuring tape and digital meter, batten, 90 degree measuring tool, spirit level, marker, and tensioned rope. Using the data obtained, the lines were initially modeled in AutoCAD, potential measurement errors were corrected and the lines plan for the ship drawn up.

There are two problems:

- The ship is on the ground. In this case the positioning of the ship against the horizontal and diametric plane must be well-controlled, and some corrections may be required.
- The ship is in the water. In this case the measurements should be made directly on and inside the ship, beginning with the physical frames and proceeding to the lines plan.

Other digital methods using 3D scanning of the hull surface are not applicable, as they take longer and do not have very high measurement accuracy requirements.

The following example illustrates traditional vessel positioning and measurement:

- putting the vessel in the right position, just as it would be free in the water;
- positioning two horizontal tensioned ropes to determine the middle line plane;
- determining the main dimensions of the vessel (LOA and BOA);
- choosing an external reference system for the vessel;
- choosing half-breath along which the transverse sections (De_Ruyter, 2012) will be drawn.

### 4. THE NUMBER OF PASSENGERS PERMITTED AND THEIR ACCOMMODATION

Ship owners seek to increase the number of passengers onboard tourist vessels operating in Albanian bays, sometimes even beyond the norms or requirements of the International Convention for the Safety of Life at Sea (SOLAS, 1974/1980), which is detrimental to vessel stability and passenger safety. We have issued some recommendations in response to the norms (Shipping, 2002):

- For passenger ships not engaged on international voyages, passenger cabins must not be located in front of the fore nor behind the aft collision bulkhead, nor where clear headroom is less than 2.0 m;

### 4.1. Permitted Number of Passengers on Exposed Parts of the Deck

In case of day trips, the number of passengers allowed to stay on the exposed deck during transportation is determined by dividing the free space available to passengers by 0.7. In no case should the number of passengers exceed the number of the seats provided.

### 4.2. Seats Dimensions Should Be as Follows

The seats should be at least 0.45 m wide, seats on the deck should be 400-480 mm high. Rear seat backrest must be at least 400 mm high. When the seats are grouped in transverse or longitudinal rows, the crossings between these groups must be at least 0.75 m wide. The distance between two adjacent rows must not be less than 0.80 m.
5. PRELIMINARY DETERMINATION OF LIGHTSHIP AND VCG

Lightship (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003) is the weight of an empty ship (hull, outfit, and weights of machinery including liquids in various systems). The concept of marginal weight, which should be slightly higher, is used to identify inaccuracies in lightship assessment in naval architecture. R – reserve (tolerance/margin of uncertainty) is 2–3% (up to 6% according to Schneekluth) to compensate for potentially inaccurate weight group estimates.

Lightship weight (WL) approximately corresponds to the weight of the ship upon its delivery from the shipyard to the ship owner.

It is defined as:

\[ W_L = W_H + W_M + R \]  

(1)

where:

\[ W_H = W_{st} + W_{ot} \]

- weight of hull

\[ W_{st} \] - weight of steel structure

\[ W_{ot} \] - weight of outfitting

\[ W_M = W_{mm} + W_{ms} + W_{mr} \]

- weight of machinery

\[ W_{mm} \] - weight of main machinery

\[ W_{ms} \] - weight of shaft and propeller

\[ W_{mr} \] - weight of remaining machinery

\[ R \] - reserve (tolerance/margin of uncertainty) is 2–3% (up to 6% according to Schneekluth) to compensate for potentially inaccurate weight group estimates.

As for the initial estimation of the VCG of a fully loaded ship, the relationship between KG and depth D is illustrated as:

\[ KG = C \cdot D_s \]  

(2)

where modified depth \( D_s \) is defined as:

\[ D_s = D + \frac{V_{ss}}{(L_{pp} \cdot B)} \]  

(3)

and \( V_{ss} \) – volume of superstructures and deckhouses.

Coefficient C is taken from Dudszus and Danckwardt (1982) as in the following table.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Weight Items</th>
<th>Weight (t)</th>
<th>VCG of weights Zi (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lightship</td>
<td>32,00</td>
<td>1,27</td>
</tr>
<tr>
<td>2</td>
<td>Passenger and crew members</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Main deck (33 = 30+3)</td>
<td>2,64</td>
<td>3,30</td>
</tr>
<tr>
<td>3</td>
<td>Passenger on upper deck (50)</td>
<td>4,00</td>
<td>5,30</td>
</tr>
<tr>
<td>4</td>
<td>Fuel</td>
<td>5,00</td>
<td>0,35</td>
</tr>
<tr>
<td>5</td>
<td>Water</td>
<td>2,00</td>
<td>0,35</td>
</tr>
<tr>
<td>6</td>
<td>Other</td>
<td>3,00</td>
<td>1,35</td>
</tr>
<tr>
<td></td>
<td>Total Weight</td>
<td>48,64</td>
<td>1,58</td>
</tr>
</tbody>
</table>

Based on the Estimation of Ship Weights study, page 177 Papanikolaou, A. (2014), Ship Design (pp. 268, 262-263), the vertical position of the weight center of R was assumed to be located 20% higher than the estimated KG of the vessel.

5.1. Evaluation of Vertical Center of Gravity

In our case study, based on the above recommendations, the vertical center of gravity of the ship with 30 passengers on main deck and 50 passengers on upper deck was calculated as shown in Table 4 based on the following assumptions:

- that the maximum number of crew was 3 people on board.
- the average weight of each individual was estimated at 75 kg,
- that the center of gravity of a seated passenger was 0.3 m above the seat and the center of gravity of a standing passenger 1 m,
- that the lightweight is determined based on real measurement of the draft. The measured draft of the vessel was 1.10 m and the hydrostatic data indicated that the ship’s lightweight was 32 tons,
- the vertical center of “Other” group weight was taken \(0,5*(\text{Depth of Ship})\).

<table>
<thead>
<tr>
<th>Nr</th>
<th>Weight Items</th>
<th>Weight (t)</th>
<th>VCG of weights Zi (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passengers</td>
<td>6.7</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>Fishing vessels</td>
<td>6.66-0.75</td>
<td></td>
</tr>
</tbody>
</table>
The vessel's vertical center of gravity:

\[ KG = \frac{\Sigma_2}{\Sigma_1} = \frac{76.89}{48.64} = 1.58 \text{ m} \]  

\[ T_{ROLL} \propto \frac{B}{(GM)^{1/2}} \]  

where \( T_{ROLL} \) is the natural roll period of the ship.

\[ \text{GM} \geq 0.30-0.35 \text{ m is recommended upon departure and in design loading condition. (Papanikolaou, Typical Values of Metacentric Height, 2014).} \]

\[ M_r = 0.200 \cdot \frac{V_o^2}{L_{WL}} \cdot \Delta \cdot (KG - \frac{d}{2}) \]

where:

- \( M_r \) = heeling moment (kN·m) 
- \( V_o \) = service speed (m/s) 
- \( L_{WL} \) = waterline length (m) 
- \( \Delta \) = displacement (t) 
- \( D \) = mean draught (m) 
- \( KG \) = height of center of gravity above baseline (m).

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### Table 5.
Data on ships for tourist transport in Albania.

<table>
<thead>
<tr>
<th>Name</th>
<th>Year of construction/reconstruction</th>
<th>Built in</th>
<th>GT</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAGOBIA, Koman</td>
<td>1982/2013</td>
<td>Durres</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>BERISHA 01, Koman</td>
<td>N/A/2015</td>
<td>Koman</td>
<td>57</td>
<td>18</td>
</tr>
<tr>
<td>BERISHA 03, Koman</td>
<td>N/A/2015</td>
<td>Koman</td>
<td>64</td>
<td>19</td>
</tr>
<tr>
<td>TEUTA</td>
<td>1976/2015</td>
<td>Italy</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Black Pearl</td>
<td>2012/2015</td>
<td>Marmaris, Turkey</td>
<td>99</td>
<td>53</td>
</tr>
<tr>
<td>Teuta I</td>
<td>1980/2018</td>
<td>Italy</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>SARDA, Vau i Dejes</td>
<td>N/A/2015</td>
<td>N/A</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>JULKA UNIQUE</td>
<td>2018/N/A</td>
<td>Vlore</td>
<td>142</td>
<td>64</td>
</tr>
<tr>
<td>TINA TOURIST</td>
<td>1984/2018</td>
<td>Greece</td>
<td>44</td>
<td>26</td>
</tr>
<tr>
<td>ESPERANZA</td>
<td>1990/2018</td>
<td>SCILLA RC, Italy</td>
<td>43</td>
<td>13</td>
</tr>
<tr>
<td>ROZAYA</td>
<td>N/A/2018</td>
<td>N/A</td>
<td>42</td>
<td>23</td>
</tr>
<tr>
<td>AQUAMARINE</td>
<td>1997/N/A</td>
<td>Marmaris, Turkey</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>DELFINI 23</td>
<td>1980/N/A</td>
<td>Kalymnos, Greece</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>LIBURNA</td>
<td>1963/2019</td>
<td>Greece</td>
<td>77</td>
<td>34</td>
</tr>
<tr>
<td>SEASTAR</td>
<td>2017/N/A</td>
<td>Italy</td>
<td>7</td>
<td>2.1</td>
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<tr>
<td>AVVENTURA II</td>
<td>1991/N/A</td>
<td>Peschici FG, Italy</td>
<td>7.27</td>
<td>4.94</td>
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<tr>
<td>ANNA ST</td>
<td>1984/2019</td>
<td>Durres, Alb</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>MOGILA</td>
<td>1955/2002/2019</td>
<td>Montenegro</td>
<td>132</td>
<td>40</td>
</tr>
<tr>
<td>PADAJ</td>
<td>1989/2020</td>
<td>Bellaria, Italy</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of passengers</th>
<th>Lightship</th>
<th>VCG Lightship</th>
<th>VCG Fully loaded</th>
<th>LOA</th>
<th>B</th>
<th>D</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAGOBIA, Koman</td>
<td>46 pax</td>
<td>22.40</td>
<td>1.27</td>
<td>1.45</td>
<td>12.90</td>
<td>4.50</td>
<td>1.85</td>
<td>1.25</td>
</tr>
<tr>
<td>BERISHA 01, Koman</td>
<td>80 pax + 10 cars</td>
<td>32.8</td>
<td>1.20</td>
<td>1.588</td>
<td>24.60</td>
<td>6.40</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>BERISHA 03, Koman</td>
<td>100 pax + 12 cars</td>
<td>49.81</td>
<td>1.20</td>
<td>1.55</td>
<td>29.80</td>
<td>7.40</td>
<td>1.30</td>
<td>0.65</td>
</tr>
<tr>
<td>TEUTA</td>
<td>30 pax</td>
<td>8.99</td>
<td>0.88</td>
<td>1.175</td>
<td>12.75</td>
<td>3.70</td>
<td>1.90</td>
<td>1.20</td>
</tr>
<tr>
<td>Black Pearl</td>
<td>180 pax</td>
<td>91.31</td>
<td>1.75</td>
<td>2.088</td>
<td>21.35</td>
<td>6.90</td>
<td>2.75</td>
<td>1.43</td>
</tr>
<tr>
<td>Teuta I</td>
<td>50 pax</td>
<td>9.58</td>
<td>0.82</td>
<td>1.31</td>
<td>13.60</td>
<td>3.80</td>
<td>1.50</td>
<td>0.92</td>
</tr>
<tr>
<td>SARDA, Vau i Dejes</td>
<td>40 pax</td>
<td>N/A</td>
<td>N/A</td>
<td>0.96</td>
<td>14.50</td>
<td>4.00</td>
<td>1.60</td>
<td>1.00</td>
</tr>
<tr>
<td>JULKA UNIQUE</td>
<td>200 pax</td>
<td>31</td>
<td>2.66</td>
<td>3.12</td>
<td>24.00</td>
<td>9.00</td>
<td>1.65</td>
<td>0.98</td>
</tr>
<tr>
<td>TINA TOURIST</td>
<td>150 pax</td>
<td>30.5</td>
<td>1.49</td>
<td>1.648</td>
<td>22.50</td>
<td>4.80</td>
<td>2.85</td>
<td>1.255</td>
</tr>
<tr>
<td>ESPERANZA</td>
<td>80 pax</td>
<td>32</td>
<td>1.27</td>
<td>1.58</td>
<td>16.60</td>
<td>4.60</td>
<td>2.45</td>
<td>1.46</td>
</tr>
<tr>
<td>ROZAYA</td>
<td>30 pax + 10 cars</td>
<td>29.6</td>
<td>0.99</td>
<td>1.7</td>
<td>20.40</td>
<td>7.40</td>
<td>1.80</td>
<td>1.33</td>
</tr>
<tr>
<td>AQUAMARINE</td>
<td>225 pax</td>
<td>127.8</td>
<td>1.67</td>
<td>2.09</td>
<td>30.50</td>
<td>8.00</td>
<td>3.50</td>
<td>2.10</td>
</tr>
<tr>
<td>DELFINI 23</td>
<td>48 pax</td>
<td>12.19</td>
<td>1.54</td>
<td>1.52</td>
<td>11.90</td>
<td>3.30</td>
<td>1.28</td>
<td>0.79</td>
</tr>
<tr>
<td>LIBURNA</td>
<td>120 pax</td>
<td>145.74</td>
<td>2.06</td>
<td>2.21</td>
<td>23.75</td>
<td>6.25</td>
<td>3.40</td>
<td>2.40</td>
</tr>
<tr>
<td>SEASTAR</td>
<td>50 pax</td>
<td>2.97</td>
<td>1.13</td>
<td>1.67</td>
<td>12.00</td>
<td>5.00</td>
<td>1.70</td>
<td>0.40</td>
</tr>
<tr>
<td>AVVENTURA II</td>
<td>45 pax</td>
<td>11.45</td>
<td>1.2</td>
<td>1.3</td>
<td>11.96</td>
<td>2.72</td>
<td>2.00</td>
<td>0.95</td>
</tr>
<tr>
<td>ANNA ST</td>
<td>33 pax</td>
<td>18</td>
<td>1.056</td>
<td>1.30</td>
<td>13.22</td>
<td>3.58</td>
<td>1.90</td>
<td>1.26</td>
</tr>
<tr>
<td>MOGILA</td>
<td>286 pax</td>
<td>159.7</td>
<td>1.69</td>
<td>1.79</td>
<td>25.50</td>
<td>13.70</td>
<td>2.15</td>
<td>1.142</td>
</tr>
<tr>
<td>PADAJ</td>
<td>20 pax</td>
<td>12.35</td>
<td>0.82</td>
<td>1.02</td>
<td>11.00</td>
<td>2.82</td>
<td>1.50</td>
<td>1.00</td>
</tr>
</tbody>
</table>
9.1. Basic Steps to Model the Ship Hull of the “Esperanza”

The development of a 3D-CAD model of a real ship requires the obtainment of vessel hull dimensions. The main dimensions of the vessel are shown in Table 2 and general layout in Figure 2. The measurement process was carried out on physical bulkheads and on 10 or 20 theoretical ordinates of the ship. Following measurement completion and the obtainment of ordinates, profile line and extreme parts required to draw up a database in MS Excel, the set up of the half-breaths of the model to be built was created (al X. B., 2008).

Table 6.
Main dimensions of the ship “Esperanza”.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length overall</td>
<td>LOA</td>
</tr>
<tr>
<td></td>
<td>16.60 m</td>
</tr>
<tr>
<td>Length between perpendiculars</td>
<td>LBP</td>
</tr>
<tr>
<td></td>
<td>15.60 m</td>
</tr>
<tr>
<td>Breadth overall</td>
<td>BOA</td>
</tr>
<tr>
<td></td>
<td>4.60 m</td>
</tr>
<tr>
<td>Depth</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>2.45 m</td>
</tr>
<tr>
<td>Draft</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>1.46 m</td>
</tr>
<tr>
<td>Passengers + Crew</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80+3</td>
</tr>
<tr>
<td>Main engine:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2x177 HP</td>
</tr>
<tr>
<td>Construction material:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wood</td>
</tr>
<tr>
<td>Year of reconstruction:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1990</td>
</tr>
<tr>
<td>Place of construction:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Italy</td>
</tr>
</tbody>
</table>

Figure 3.
General layout of tourist ship “ESPERANZA”.

<table>
<thead>
<tr>
<th>MV ESPERANZA - MAIN DECK</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 seats</td>
</tr>
<tr>
<td>22 seats</td>
</tr>
<tr>
<td>10 seats</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MV ESPERANZA - UPPER DECK</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 seats</td>
</tr>
</tbody>
</table>
After database creation in MS Excel, the 3D model of the vessel was created using the MaxSurf software. The hull surface design process was conducted in three stages:

1. Modelling of initial hull curves
2. Building of the hull surface
3. Smoothing of the hull surface

After visualization, potential errors occurring during coordinate insertion were corrected, appropriate modifications were made and record file containing all coordinates of the points needed to generate the hull were created (Systems, 2009).

### 9.2. Generation of Hydrostatic Curves

Hydrostatic curves were calculated (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003) (Figure 3) using the Hydromax Software. Table 2 presents data for the fully loaded vessel, corresponding to waterline DLW=1.46m.

<table>
<thead>
<tr>
<th>Draft Amidsh. M (m)</th>
<th>DWL=1.46</th>
<th>Block Coeff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement tonne</td>
<td>48.5</td>
<td>0.78</td>
</tr>
<tr>
<td>Draft at FP m</td>
<td>1.46</td>
<td>0.82</td>
</tr>
<tr>
<td>Draft at AP m</td>
<td>1.46</td>
<td>8.36</td>
</tr>
<tr>
<td>Draft at LCF m</td>
<td>1.46</td>
<td>7.95</td>
</tr>
<tr>
<td>WL Length m</td>
<td>15.6</td>
<td>0.90</td>
</tr>
<tr>
<td>WL Beam m</td>
<td>4.20</td>
<td>1.23</td>
</tr>
<tr>
<td>AWL (m2)</td>
<td>51</td>
<td>0.515</td>
</tr>
<tr>
<td>Prismatic Coeff.</td>
<td>0.68</td>
<td>0.51</td>
</tr>
</tbody>
</table>

### 9.3. Stability Data Calculations

Stability data were calculated using the MAXSURF Naval Architecture Software (Hydromax).

The following diagram shows the static stability curve of the vessel.

![Figure 5. GZ diagram vs heeling angle.](image-url)
Table 8.
Stability data according to Hydromax Software calculations.

<table>
<thead>
<tr>
<th>Heel to starboard (degrees)</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>GZ (m)</td>
<td>0,15</td>
<td>0,30</td>
<td>0,43</td>
<td>0,47</td>
<td>0,45</td>
<td>0,40</td>
<td>0,32</td>
<td>0,22</td>
<td>0,12</td>
</tr>
<tr>
<td>Displacement (mt)</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
<td>48,40</td>
</tr>
<tr>
<td>Wetted area (m²)</td>
<td>69,58</td>
<td>70,38</td>
<td>74,50</td>
<td>77,60</td>
<td>79,47</td>
<td>80,68</td>
<td>81,47</td>
<td>81,81</td>
<td>81,39</td>
</tr>
<tr>
<td>Water plane area (m²)</td>
<td>51,36</td>
<td>53,05</td>
<td>47,91</td>
<td>41,27</td>
<td>36,93</td>
<td>34,23</td>
<td>32,80</td>
<td>32,49</td>
<td>32,23</td>
</tr>
<tr>
<td>Prismatic coefficient</td>
<td>0,68</td>
<td>0,68</td>
<td>0,70</td>
<td>0,71</td>
<td>0,72</td>
<td>0,73</td>
<td>0,74</td>
<td>0,75</td>
<td>0,75</td>
</tr>
<tr>
<td>Block coefficient</td>
<td>0,53</td>
<td>0,50</td>
<td>0,53</td>
<td>0,59</td>
<td>0,63</td>
<td>0,66</td>
<td>0,68</td>
<td>0,68</td>
<td>0,63</td>
</tr>
</tbody>
</table>

9.4. Criteria for Righting Lever Curve Properties

The assessment of the level to which the IMO stability criteria (IMO resolution A.167) have been met is conducted using the stability curve for the main loading condition/s in respect of the vessel's operation.

Table 9.
Verification of IMO stability criteria.

<table>
<thead>
<tr>
<th>Code</th>
<th>Criteria</th>
<th>Value</th>
<th>Units</th>
<th>Actual</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.749(18) Ch3</td>
<td>3.1.2.1: Area 00 to 300</td>
<td>3.151</td>
<td>m.rad</td>
<td>6.65</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>3.1.2.1: Area 00 to 400</td>
<td>5.157</td>
<td>m.rad</td>
<td>11.25</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>3.1.2.1: Area 300 to 400</td>
<td>1.719</td>
<td>m.rad</td>
<td>4.60</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>3.1.2.2: Max GZ at 300 or greater</td>
<td>0.200</td>
<td>m</td>
<td>0.47</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>3.1.2.3: Angle of maximum GZ</td>
<td>25</td>
<td>degree</td>
<td>40.9</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>3.1.2.4: Initial GMt</td>
<td>0.150</td>
<td>m</td>
<td>0.82</td>
<td>Pass</td>
</tr>
</tbody>
</table>

9.5. Weather Criteria (Wind and Rolling Criterion)

The ability of a vessel to withstand the combined effects of beam wind and rolling was demonstrated by reference to Figure 9 (al L. k., 2005).

Under these circumstances, area b is equal to or greater than area a, as indicated in the following table.
Table 10.
Verification of weather criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
<th>Units</th>
<th>Actual</th>
<th>Status</th>
<th>Margin%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.749(18) Ch3 - 3.2.2: Severe wind and rolling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle of steady heel is not greater than</td>
<td>16.0</td>
<td>deg</td>
<td>4.6</td>
<td>Pass</td>
<td>+60</td>
</tr>
<tr>
<td>Angle of steady heel / Deck edge immersion angle is not greater than</td>
<td>80.000</td>
<td>%</td>
<td>28.59</td>
<td>Pass</td>
<td>+64</td>
</tr>
<tr>
<td>Area1 (b) / Area2(a) is not less than</td>
<td>100.000</td>
<td>%</td>
<td>231.14</td>
<td>Pass</td>
<td>+131</td>
</tr>
<tr>
<td>Area1 (under GZ), from 6.2 to 50.0 deg.</td>
<td></td>
<td>m.deg</td>
<td>15.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1 (under HA), from 6.2 to 50.0 deg.</td>
<td></td>
<td>m.deg</td>
<td>5.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1(b), from 6.2 to 50.0 deg.</td>
<td></td>
<td>m.deg</td>
<td>9.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2 (under GZ), from -16.4 to 9.5 deg.</td>
<td></td>
<td>m.deg</td>
<td>-0.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2 (under HA), from -16.4 to 6.2 deg.</td>
<td></td>
<td>m.deg</td>
<td>3.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2(a), from -16.4 to 6.2 deg.</td>
<td></td>
<td>m.deg</td>
<td>4.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. CONCLUSIONS

The purpose of this study was to present the necessary stability procedure required by the Albanian Register of Shipping, which is of paramount importance for the safety of short distance passenger transport activities.

Consulting various authors and literature on ship design, methods and methodologies for preliminary determination or empirical formulas for calculating various technical elements of vessels, such as vertical center of gravity for lightship, minimum values for metacentric heights GM or others parameters, helped us create an excellent inventory to be used in ship calculations required to fill out the trim and stability booklet as described above.

Some technical recommendations with respect to the maximum number of passengers allowed were given to ensure safe navigation. The application of these recommendations to ship stability assessment required by the Albanian Register of Shipping was described. The procedure followed by actual measurement is helpful for 3D modelling of ship hulls and useful for creating models in similar cases.

The use of the naval computer package significantly contributed to the obtainment of improved hull surface and facilitated extremely tedious manual work.

The fulfillment of the stability criteria was verified in accordance with the criteria stipulated in the IMO stability code and the norms prescribed by Resolution MSC.267 (85).

REFERENCES


IMO. (n.d.). International Convention for the Safety of Life at Sea (SOLAS) - Chapter II-1 - Construction - Subdivision and stability, machinery and electrical installations.


Rexhepaj, L., 2019. Data on the number of vessels, capacity and number of passengers in the period, 2016-2019, Harbor of Vlora - Vlora Port Administration.