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OPERATIONAL REQUIREMENTS FOR A CABINED MARINE RESCUE VESSEL

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Abstract. *Rescue boats lack laws, protocols, rules, and ordinances that delimit their characteristics. Therefore, the available boats do not meet the operators' minimum requirements. This work is premised on understanding the operation of a rescue vessel, what its needs are, what minimum characteristics should be considered in the preliminary design stage to provide the designer with more information so that all needs and requirements are met, and more lives are saved more safely. For this determination to be possible, laws, protocols, rules, and guidelines for rescue vessels will be identified and the analysis of the rescue vessel will be carried out. At first, all ordinances and laws for existing rescue boats will be presented, followed by the legal obligation to be able to carry out search and rescue missions and the need to carry out these missions as quickly as possible. With this scenario in mind, the remaining steps will be taken to identify the factors needed to achieve these goals. The Regate 1 rescue boat will be analyzed. Finally, improvements are needed, based on the findings of the work, so that vessels can be used more efficiently and effectively to save lives. As well as the lack of guidelines in laws and protocols, they can be circumvented once the data mentioned here are considered.*

Keywords: *rescue boat, operational requirements, rescue boat needs.*

1. INTRODUCTION

Rescue and medical assistance vehicles are important for any city. According to its geography and topology, a specific type of vehicle is necessary, which are divided into 3 macro categories: land, water, or air. Although this is routinely handled in the triple split above; international conventions, national laws and regulations widen the division so that the appropriate resource for each situation is used, providing both the victim and rescuer with all the necessary assistance and equipment.

In relation to rescue vessels, this division, however, is not possible to be applied. The wide possibility of arrangements means that the requirements cannot be met, and according to Xavier (2021), “the requirements are conditions or capabilities that must be met”, in other words, today there are projects that make the operation of the final product inefficient, which can cause serious risks to the victim and the crew and eventually cause death.

Given the complexity of urban mobility, and the remote locations, adequate rescue vessels can be the solution for a more efficient emergency service and, eventually, more agile searches and rescues.

Rescue vessels work in situations of drowning, accidents of any nature (inertial, environmental, clinical) on other vessels, diving accidents, rescue of crews whose vessels sank or were left adrift, animal attacks and even surveillance and prevention.

In a general overview, the survey of necessary requirements for a rescue vessel will guide the designer in such a way that resources and needs for an efficient and safe search and rescue operation are present in the final product design. As a result, the response time and the number of vehicles involved are reduced, safety and efficiency increase and, most importantly, the victim is assisted in the right way immediately after being located with all the resources that are required.

From a different perspective, an oversized vessel or equipment would reduce efficiency and occupy a space that could be better used for service.

From the design point of view, according to Araújo (2016) “the shipbuilding process has a sequence of steps, which includes the definition of the main characteristics of the vessel in order to balance [...] conflicting performance attributes [...]”. According to the product development model proposed by Rozenfeld et al. (2006), among the numerous stages, the informational project aims to define the project specifications, being primarily captured the needs of the customers and the project requirements related to the use of the product (ROZENFELD et al., 2006, apud ARAÚJO, 2016). Part of the requirements are derived from laws and regulations, standards, and part from the operator.

The laws and regulations of these vehicles do not clearly specify the requirements of these vessels. Ordinance 2048 (BRASIL, 2002) defines that “this waterway motor vehicle, intended for transport by sea or river, may be equipped as indicated for Type A, B, or D Ambulances, depending on the type of assistance to be provided”. That is, a rescue vessel can be characterized as a transport ambulance (type A), with very little life support equipment, basic support ambulance

(type B), with some more advanced equipment compared to type A, or advanced support ambulance (type D), with advanced equipment and possibility of performing procedures.

The main objective of this work is to restrict the range of rescue vessel options listing relevant characteristics for a search and rescue operation (SAR - Search and Rescue), meeting the operational needs of users, increasing the safety of the victim and respecting laws, rules, and regulations.

The rules, conventions, laws, regulations of response agencies (such as the Mobile Emergency Care Service - SAMU and the Fire Department) and regulations of health-related councils, such as the Regional Council of Medicine of Santa Catarina (CRM-SC) will be analyzed to restrict this range.

2. PROBLEM HISTORY AND BASIC LEGISLATION

Unlike land services, when there is a situation of maritime search and rescue, it is not possible to see the displacement of vehicles in such a common way, so there is no real dimension of the number of occurrences. However, between 2006 and 2015 the country recorded almost 1,300 deaths in accidents between vessels.

With so many accidents, it is necessary to have a fleet capable of carrying out the operations according to the demands, regardless of the weather conditions and the type of occurrence. In figure 1, it is possible to observe the increase in the number of accidents per year between 2000 and January 2021 based on the number of rescue calls registered by the Brazilian Navy transparency portal.

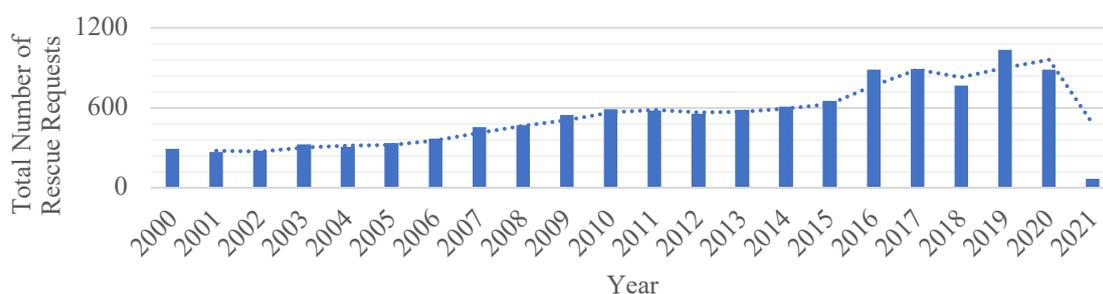


Figure 1. Total number of redemption requests.

Despite the growing number of cases, search and rescue vessels still do not meet the operational needs of first responders. However, as described below, they do not lack laws, rules and regulations regarding their construction and use. As well as the obligation to have aquatic rescue vehicles to carry out the requested rescues and assistance.

2.1 Ordinance 2048 - Ambulance Legislation

Ordinance 2048 (2002) regulates urgent and emergency services, from types of health units to vehicles, crew, and equipment. Regarding maritime rescue, the ordinance addresses operational aspects.

Chapter IV, item 1.2.3.3, discusses the need for the captain of the vessel to be qualified to conduct the vessel in accordance with maritime laws and regulations and its technical capacity to assist the team during an occurrence, this includes knowing the equipment and its locations.

Also in chapter IV, item 2.1, there is the definition of type F ambulance. "Medical transport vessel: waterway motor vehicle, intended for transport by sea or river. It must have the necessary medical equipment to care for patients according to their severity" (Ordinance 2048, BRASIL, 2002).

Item 3.6 defines the equipment and medications required for a type F transport vehicle. "This waterway motor vehicle, intended for transport by sea or river, may be equipped as indicated for Type A, B, or D, depending on the type of assistance to be provided" (Ordinance 2048, BRASIL, 2002).

The type A, B and D are respectively defined at Ordinance 2048 (BRASIL, 2002) chapter IV, item 2.1, as "a vehicle intended for transporting patients who are not life-threatening in the horizontal position, for simple and elective removals", "vehicle intended for the interhospital transport of patients at known risk of life and pre-hospital care of patients with unknown risk of life, not classified as potentially requiring medical intervention on site and/or during transport until the destination service" and "a vehicle for the care and transport of high-risk patients in pre-hospital emergencies and/or inter-hospital transport who need intensive medical care. You must have the necessary medical equipment for this function."

It is noteworthy that type A, B and D ambulances differ significantly in terms of the need for equipment and medicines, making a differentiation between types A, B and D not a simple bag of equipment, but rather the installation of systems and life support machines.

2.2 National Health Surveillance Agency - ANVISA

ANVISA's reference protocol number 7 (BRASIL, 2011) addresses the adequacy of vehicles for transporting sick travelers. In summary, the approach is extremely similar, identical in some cases, to Ordinance 2048.

2.3 United Nations Convention on the Law of the Sea (UNCLOS)

The United Nations Convention on Maritime Rights, UNCLOS, regarding rescue, salvage, search, and rescue at sea, only refers to article 98 of part VII, in its second paragraph, regarding the duty to provide assistance. For UNCLOS (1982), "every coastal country should promote the establishment, maintenance and operation of an effective search and rescue service capable of promoting safety at sea and that, when circumstances demand, enter into mutual regional cooperation agreements with neighboring states to this end".

2.4 Regional Council of Medicine of the State of Santa Catarina - CREMESC

Resolution No. 027/97, of March 13, 1997, deals with the regulation of ambulances and other vehicles for transport, removal, and assistance to victims. Its dealings in many points are like Ordinance 2048, however, this does not define vessels. There is nothing in the text that refers to the type of maritime transport, although it defines ambulances as being "any and every vehicle (including aircraft) intended exclusively for the transport of the sick" (BRASIL, 1997)

2.5 International Convention on Maritime Search and Rescue (SAR Convention)

This convention addresses several points related to search and rescue, from the need for cooperation between different rescue centers to the search and rescue stages, naming each of the steps, actions to be taken and information to be sought.

In terms of preparatory measures, the SAR Convention, in its chapter 4, item 4.1.2, recommends that each rescue coordination center and its respective sub-centers have easy access to information on all vessels within its operating range, this information would be the speed, heading, position and way of contacting it.

Also in chapter 4, in items 4.2.3 and 4.2.4, it informs the obligation of, once there is reason to believe that a person or vessel is in a state of emergency, inform the rescue coordination center which must immediately establish the emergency phase and the scale of the necessary operations.

Item 4.8.1 advises that the search must continue until all reasonable hope of redeeming the survivors has been lost.

2.6 NBR 14561 - Vehicles for Assistance to Medical Emergencies and Rescues

The NBR 14561 (BRASIL, 1997) is geared only to land vehicles, not covering aircraft or vessels. However, from an operational point of view, there are definitions of the standard that can be applied to vessels from the point of view of a future design, the main one being the provision of internal space as needed.

Other definitions that can be used are internal lighting in the patient allocation environment, examination lighting, dimensions of the marine model stretcher, dimensional parameters of the patient compartment, door dimensions, location of medical instruments, waste disposal for materials cutters, lashing points and anchorage points (from the rescuer and from the stretcher).

2.7 Maritime Authority Standards (NORMAM)

NORMAM-16/DPC (2003) addresses the general concepts of salvage, says it is necessary to constitute a legal entity to carry out operations and the need to follow laws that govern the need and obligation to carry out searches.

Within the set of standards called NORMAM, there are also rules on construction procedures, bulkhead needs and other project requirements that naturally should (and are) considered by the designer.

Nothing within NORMAM-16/DPC (2003) deals with the operation itself and operational requirements.

3. VIABILITY ANALYSIS

At an early stage of understanding, analyzing the viability of a rescue vessel can be crucial for following up on other studies. However, for purposes of understanding and comparison, the analysis will be done by comparing the water and land mode, or a land ambulance and a rescue vessel.

Travel time from the beginning of the call until the victim is in the operating room, the financial cost of the operation and allocation of funds and the possibility of using the waterway mode will be analyzed and compared.

3.1 Analysis of time of travel between the call and the victim entering the surgical center

Although a vessel has a lower maximum speed than a land ambulance, this does not represent a longer time between the team's dispatch and the victim entering the operating room.

The North American Coast Guard rescue vessel, RBM – Response Boat- Medium, designed for this purpose, reaches a maximum speed of 42.5 knots, or 78 km/h approximately, and has a range of 250 nautical miles, 463 km, at a cruising speed of 30 knots, or approximately 55 km/h (NORTH AMERICAN COAST GUARD, 2015).

The Santa Catarina SAMU land ambulance has its maximum speed allowed at 90 km/h, with an autonomy of 600 km, with its 90-liter tank full (TRENTINI, 2019).

However, it is important to emphasize that in the case of a land displacement, traffic must be considered and the variation in distance as well. Rescue boats, if there is a depth, follow a straight line, taking the shortest path, with no traffic. Land ambulances follow the traces of the lanes, reducing on traffic lights, facing traffic.

It is also worth noting that the maximum speeds mentioned above may not be reached in both modes depending on the sea condition in the case of the vessel and traffic, traffic lights, crosswalks, closed streets and other impediments, in the case of the land ambulance.

In practical terms, for a better assessment, a hypothetical victim will be considered at Praia do Sambaqui. On a normal day, for an ambulance to travel 15.8 km at a constant speed of 90 km/h and then remove it to Cmt Lara Ribas hospital, 19.1 km away from the incident (route in blue in figure 2, adapted from google maps), would take about 24 minutes. Added to this time must be the service time and a correction factor given to traffic, traffic lights and blocked lanes.

As for a rescue vessel, to respond to the same call, the displacement distances are 14 km to the place of occurrence, 10.4 km from the place of occurrence to the pier where there can be a modal transition (route in red in figure 2, adapted from google maps), either to the air or to the terrestrial, and finally, 4.1 km to the Hospital Cmt Lara Ribas. Considering the maximum speeds described, there is a time of 19 minutes of displacement of the vessel (as per Navionics calculations, figure 3) and 3 minutes of land displacement, totaling 22 minutes. It is noteworthy that, under this time, the service time (even for the land ambulance), modal transition time and correction factor for the final stretch by land caused by traffic must be added.

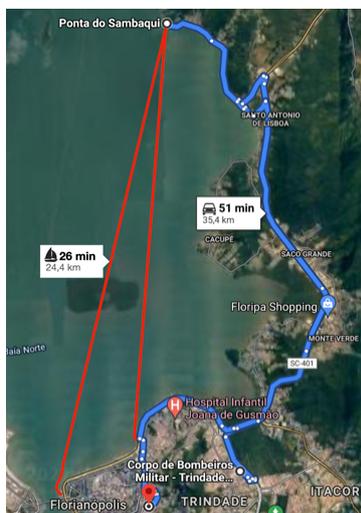


Figure 2. Routes by sea and land.

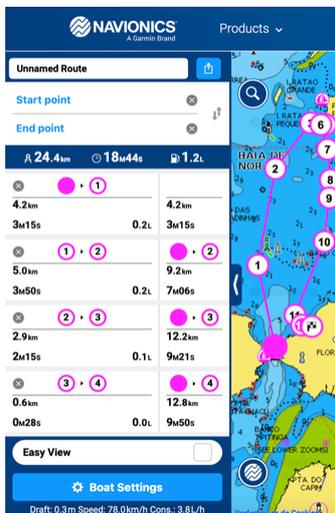


Figure 3. Route at full speed.

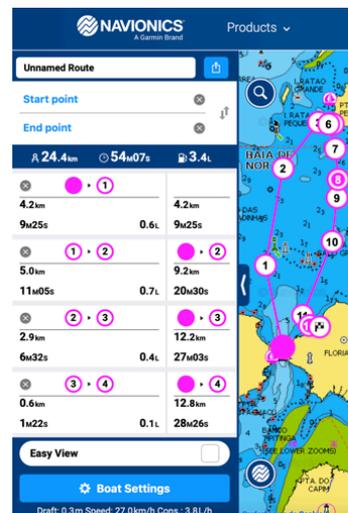


Figure 4. Route 50% cruising speed.

The results are similar, however, when considering times with speed variations, the standard displacement time for the ground ambulance can reach 51 minutes (as shown in Figure 2), while for the vessel, at a speed 50% lower than the speed standard vessel, that is, very slowly, the vessel would take 54 minutes (figure 4, as calculated by Navionics). Seasonal traffic should also be considered, for example, during the summer, the time between the phone call and the victim's arrival at the hospital can be significantly longer if there is no support from a boat. A different scenario from the others occurs when there is a technical complexity involved in the rescue, such as rescues on cliffs, deserted beaches, distant beaches.

For this type of occurrence, in addition to the vehicle travel time, there is the team travel time to the point necessary to start the work, the equipment assembly time (when necessary), arrival to the victim and finally, the removal of the victim to the vehicle.

There is also the possibility of the occurrence taking place on an island, vessel or even at sea, such as the fall of an aircraft or a drowning victim. In these cases, there are only two alternatives: rescue by aircraft or rescue by vessel.

The aircraft has an even shorter time compared to the vessel, but it is not always possible to get its support, since the weather conditions need to be favorable, and autonomy is reduced when compared to a vessel. The number of victims and rescuers that the vessel can transport is also significantly higher.

3.2 Analysis Of Financial Costs To Carry Out The Rescue

The cost scenario is a little more delicate to deal with. There are acquisition costs, maintenance, fuel, number of first responders and drivers needed. This study does not aim to analyze the acquisition since it is a bidding process that varies according to manufacturer, model, and quantity, therefore, only the costs after the acquisition will be considered.

The vessel works most of the time at a constant speed since it has no traffic, intersections, traffic lights and other situations that require it to reduce. For this reason, for identical engines, with constant rotation, their efficiency is higher and their fuel consumption lower.

According to the manufacturer of the engine model used by the North American Coast Guard, MTU (2006), diesel consumption is 163.8 liters per hour of operation at full power or 0.47 km/l given the capacities and speeds. Also based on the North American coast guard vessel, the fuel tank is 1874 liters (VIGOR, 2020).

As for SAMU's ground ambulances, given the operational capacity and the tank, consumption of 6.6 km/l is reached for a 90-liter tank. However, it is important analyze that such consumption takes place in an ideal situation (at constant speed). To better compare it is necessary to use the concept of stopped delay and running delay (PIETRANTONIO, 2018). This concept is because there is a time when the land vehicle will be stationary, and there is also a time when it must accelerate until reaching speed.

The non-linear variation in speed causes consumption to increase, 6.6 km/l represents a situation in which a lower than maximum speed is valued with a balance of time and fuel consumption. The real average will certainly be even smaller given the variations between stopped time and time at maximum speed, that is, the acceleration of the land vehicle. It is noteworthy that this variation does not occur on vessels, except when the displacement starts or in atypical situations along the route.

4. FEATURES OF A RESCUE VESSEL

Each type of rescue vehicle - air, land, or water - has its crucial peculiarities for basic operation, regardless of punctual and specific needs of the rescuer.

A great particularity of vessels that clashes with other modes are the number of forces involved in different degrees of freedom and the impossibility of reducing vessel oscillation with the use of a spring-damper system as in land vehicles.

The great complexity of a service on vessels is the unpredictability of movements. Without knowing the next move, it is up to rescuers to try to maintain balance during care. Furthermore, processes such as intravenous access or intubation are not possible with the slightest presence of waves, considering that the vessel has a professional qualified to perform such procedures and equipment.

The forces in a vessel's 6 degrees of freedom (heave, roll, pitch, surge, sway and yaw) come from the vessel's motion caused by engine-driven displacement, waves, wind and mass displacement a board. As it is a random process resulting from waves in numerous directions, it is not possible to predict the movement, just be prepared for it.

It is in this scenario where dangerous situations arise that must be taken into consideration, for example slamming.

It is important that a rescue vessel not only withstands these impacts but also has safety features, so rescuers do not have to worry about impacts during a rescue operation.

Among the existing vessels, there are two alternatives: hulls with hydraulic suspension or damping on the vessel's seats.

Another big difference between a rescue vessel and a ground ambulance is that the vessel must be able to perform searches.

Searches involve a long time at sea, a way to always communicate with the base, and specific systems for searches. In addition to the systems, it is also necessary to meet the rescuers' physiological needs, such as water, food, protection from rain and wind.

5. OPERATIONAL DEMANDS OF AN ONBOARD RESIDENTIALIST

Despite all the data that already exists, it is not rare that operational needs are not met. The complexity, the long period required for data collection, the high demand for projects is just some of the factors that may come to interfere in this regard.

The operator's need can be divided in terms of equipment, service, searches, types of use, logistical issues, among countless other factors.

For study purposes, the vessel will be analyzed from the inside out, starting with the requirements of assistance to the victim after its location and boarding, followed by the need to carry out searches and rescues and operations in general, seeking to locate the victim and embark. there.

5.1 Victim Service

The basic difference between SAV (advanced life support) and SBV (basic life support), in operational terms, according to the Central-North Regional Head of the Joinville Volunteer Fire Department, consists of, in the case of advanced support, a doctor be on board the vehicle and invasive procedures are performed, these situations being simultaneous (ANZINI, 2021).

The need to have a doctor on board for an SAV unit does not match the current Brazilian reality. The Joinville Volunteer Fire Department, for example, works only with land ambulances of the USB type (Basic Support Unit, considered SBV). Also based on the CBVJ, when necessary, the doctor and the necessary equipment are shipped, converting a basic unit into an advanced unit relatively simply and quickly.

For both SAV and SBV the internal layout will be similar, so it is possible to maintain a single layout in both situations.

For land vehicles, NBR 14561 (BRASIL, 1997) formalizes the need that, regardless of the type of vehicle, there is a place for the allocation of a primary patient on an articulated stretcher on wheels and a secondary patient on a folding/portable stretcher on the seat of the crew being able to accommodate 3 seated patients.

In a vessel, given the differentiated internal layout, it is understood that the three victims seated could be allocated in different seats of the vessel. In addition, the stretcher to be used differs from the one mentioned in NBR 14561 (articulated stretcher on wheels).

It is understood by Brazil (1997) that the volume of the victim's compartment must be of at least $9.2m^3$, excluding $1m^3$ of storage cabinets for medicines, rescue devices and equipment. Dividing this volume into linear dimensions makes it better measurable.

Some details become crucial when analyzing the chaotic scenario given the multiple degrees of freedom mentioned above, such as the need for an appropriate place to dispose of infecting sharps and biological waste, the need for support points for the rescuer and the fixation of the stretcher predicting movement in multiple degrees of freedom.

As for lighting, based on NBR 14561 (BRASIL, 1997), the light in the patient compartment, measured at floor level without obstruction, should not be less than 50 cd/m and on the primary stretcher, in fact minus 90% of it the incidence of white light must be at least 115 cd/m.

The lighting electrical system must not be connected to the circuit powered by the battery and inverter of the care equipment.

For safety purposes, for both the victim and the rescuer, immobilization of the victim is important. The NBR 14561 (BRASIL, 1997) requires three immobilization points along the body, one on the chest, one on the pelvis and one on the ankle and a fourth point on the head with pads. The four points are intended to prevent the patient, either by reflex or by a characteristic linked to the condition, from interfering with the rescuer's care and to ensure that the patient is safe in case of sudden decelerations, turning movements - in the case of a ground ambulance an overturning, and in the case of a vessel an overturning or simple rolling motion.

In addition to immobilizing the victim, the stretcher must also be secured to prevent movement and ensure that the victim and rescuer are safe.

It is necessary to make an additional observation that, depending on the victim's situation, it will not be possible to immobilize him due to basic life support maneuvers. Anyway, having the immobilization systems is essential in a vessel.

According to protocols and routine knowledge, the immobilization of the patient must always be evaluated and performed (ANZINI, 2021).

It is up to the rescuer to evaluate the best method to perform the immobilization (using or not a hypothermic package, for example), however, the high risk of hypothermia should always be considered, especially when the victim is in shock or unconscious.

5.2 Search And Rescue Operation

According to item 3.1. time analysis of the present work, the autonomy of US Coast Guard vessels is about 463 km (or 250 nautical miles) and for SAMU's ground ambulances, 600 km. When analyzing the vessel Rescue 1 of the Military Fire Department of Santa Catarina, there is a similar autonomy, according to the manufacturer, two trips to the island of Florianopolis are possible safely.

The autonomy of a vessel being less than the autonomy of a land ambulance is understandable since the vessel will operate in straight lines, without the need to follow a predetermined path through an asphalt (track, highway, street). In addition, it is worth noting that, as there is no traffic, the operating speed tends to be more constant for a period that is too prolonged when compared to a ground ambulance.

Finally, the vessel's autonomy must consider a search area starting the displacement from its base and the return after the operation.

Being able to operate in a storm becomes crucial. It is in this type of weather situation where the greatest number of accidents occur and, the displacement of aircraft without instrument flight capability is impossible during storms. Even those aircraft with instrument flight capability tend not to operate given the high risk, thus leaving the vessel.

A good way to delimit performances is with the use of the Beaufort Scale of wind strength, in addition to providing approximate wind speed and wave height based on visual observation, it can also be used as a determining factor for use or not of aircraft or joint operations.

For a vessel to operate in adverse situations, it is necessary to consider abrupt inclinations beyond the traditional limits imposed by classification societies.

It is also necessary to provide for the use of systems that assist in search and rescue in such conditions, such as windshield wipers, non-slip floors, support points for rescuers and on-board systems for location, communication, and displacement.

For New Zealand Coast Guard First Aider Chris Young, proper operating and rescue lighting is imperative. “As a rescue boat, we need to be available to work 24 hours a day, 7 days a week. Many of our calls take place at night and it is crucial that in addition to the embedded systems we also have excellent search and operation lighting. Lighting is important when we are looking for people on the water, for boats, when we are approaching unfamiliar bays and shores, when we are approaching the surf line, when we are looking for victims on the coast. We operate with 4 light bars forward, a long-distance spotlight for about 300m, we have 2 smaller light bars on the sides, a small spotlight for rescuer handling. On the sides we also have two other bars to assist in the lateral approach of other vessels and the pier (it has the capacity to light between 50 and 100 meters). At the stern we have a combination of lights including red light bars so that our ability to see in low light is not affected – referring to pupil dilation – but we also have white when we already have our target and need better lighting.” (YOUNG, 2019).

In addition to search lights, Brazilian legislation requires signal lights so that the vessel can be easily seen during low light moments.

As with land and aeronautical vehicles, seatbelts on boats are required. In addition to the traditional seat belt, anchorage points on the outside can be very well used by rescuers when they need to stay in these areas.

Communication between the center and the rescue team takes place through the resources available at the time, such as radio, call, WhatsApp, Spot. The purpose of the initial communication is to inform the team about the occurrence, transmit all available information and dispatch them to the location. During the search stage, communication will help the teams draw strategies, request support, and share new data. Once the victim(s) have been treated, communication will be necessary for medical regulation.

The regulation consists of the support of a central doctor regarding procedures and when to the destination hospital, based on the mechanism of injury, the victim's needs, and the availability of nearby hospitals. According to ANZINI (2021), based on the Joinville Volunteer Fire Department, every occurrence is regulated.

Given the vessel's needs to operate in stormy sea situations, having watertightness, at least in the victim's compartment, is crucial.

It is assumed, for easy understanding, a sea situation with high waves relative to the height of the vessel, if the vessel capsizes, even if it is able to return to the initial equilibrium position, it cannot enter water where the victim is. The ingress of water would interfere with care and could drown the victim – a small, but sudden amount of water hitting the face of the victim who is unaware, or unconscious can cause this – aggravating the problem even further.

Equipment on a rescue vessel makes it possible for the rescuer to access the victim. Buoys, ropes, diving suits, oxygen cylinders for diving, diving masks, food and drink for the teams and for the victim, backpacks for first aid off the vessel, life jackets, helmets, gloves are used.

It is up to the designer to analyze the best place to store them so as not to leave them loose, which could cause accidents or damage.

For study purposes, there is an example of a rescue vehicle used by firefighters in Orlando, United States, to transport the vessel to the water launch site. It is in this vehicle where the equipment is and the teams can pick up, at the time of the launch, whatever they deem necessary and store in the correct places on the vessel. This structure allows for a reduction in weight and greater flexibility for each scenario.

5.3 Specific Embedded Systems

In search or even displacement situations, some equipment's are necessary to enable the driver to guide the vessel towards the correct destination, minimizing time, but avoiding places that are too shallow or with rough seas beyond.

Therefore, radar, sonar, radios, GPS system, security cameras are needed.

5.4 Fire Fighting Capacity

In terms of need, between 2000 and 2021, registered by the Directorate of Ports and Coasts - Navy of Brazil (2021), there were 158 explosions on vessels and 762 fires. Thus, the ability to firefighting is necessary. The need for extinguishes the fire in rescue situations is always needed, even if the primary objective is to rescue, it may be necessary to fight a focus to safely carry out the victim. In terms of procedures, all rescuers are instructed to only carry out the rescue after ensuring their safety, their team, and possible spectators, and in the event of a fire, this primarily involves extinguishing it.

There is also no need for a water tank, which takes up too large a space. The water itself from the river, lake, lake, or sea can be used in firefighting.

5.5 Need For Beaching Capacity

The stranding capacity is related to the need to care for victims on beaches, sand banks and even a quick modal transition in case of rough seas and strong waves. Such capability involves both structural aspects and possible impacts on the propulsion and steering system during project design.

Structural impacts are linked to the vessel's weight and performance/distribution of hull weights. While immersed in water, the pressure along the hull will be distributed proportionally to geometry and depth, having a slightly larger contact surface than when the vessel runs aground. When on the beach, similarly to what happens during transport in trucks, efforts are much more concentrated (a smaller contact surface).

The steering system (rudder) and the propulsion system must be designed with stranding capacity in mind. None of these may be below the vessel's keel line, the keel must be the lowest point on the vessel.

In the case of jet engines (similar to jet-ski engines) a form of debris prevention must be provided, so it is guaranteed that no stones, rubbish, sand or any object or debris other than those necessary for the propulsion entered the jet.

In the case of propellers, the propeller cannot touch the ground. A good solution for this point is the use of a tunnel system, that is a deliberate bend in the hull to raise the height of the propeller in relation to the bottom.

In addition to the entire structure, of which the hull is also a part, the plating or hull wall (in non-metallic boats) must be able to withstand impacts from stones or debris that may collide with the vessel during stranding, as per example a tree trunk.

After stranding, it is necessary to place the vessel in a transport truck or take it back to the water. Therefore, it is necessary to develop a parallel tool capable of performing this task.

For a perfect relationship between machines, the vessel will need anchorage points for cables or specific tools for this purpose.

RNLI has a solution that has proven itself capable of meeting the needs. A tractor attached to a trailer capable of tilting the platform and towing the vessel upwards.

5.6 Floor And Deck Coatings

Vessels, in general, have their floors covered with non-slip material, however, in rescue vessels, this care must be redoubled.

In addition to having to operate in different scenarios, rescuers need to move according to demand, not being able to wait for a better time to move to a certain location inside the vessel.

In some cases, placing a platform that allows water to drain under the rescuer's foot may be an alternative.

5.7 Board The Victim

The rescue, when the victim is in the water, consists in bringing him on board so that, later, the assistance can be done.

To lift a victim, the lower the freeboard is, the easier it is. In contrast, the higher the freeboard is, the greater the significant wave height the vessel will be able to face with minimal water loading on deck.

Another possible solution is the use of specific nets for this purpose. With the use of this system, if the victim is awake, it can be used as a ladder, if unconscious, it is possible to board it having points to hold and pull safer and more ergonomic than the victim's clothing.

A third option, which is the most suitable for victims with suspected spinal cord trauma, consists of placing the victim on the stretcher while still in the water and then loading the victim onto the stretcher, being hoisted by ropes and eventually with the support of a ladder or board (enabling the stretcher to slide).

6. ANALYSIS OF CBMSC RESGATE 1 VESSEL

The vessel Resgate 1 (figure 4) of the Military Fire Department of Santa Catarina was developed by Rhino Tech Defense. According to the manufacturer (Redação Itajaí Naval, 2020) its length of 11 meters allows 12 people on board (including rescuers and victims), and even fully loaded it can reach a speed of 46 knots. Also, according to the manufacturer the two fuel tanks of 330 liters each allow an autonomy of 10 hours of uninterrupted operation, enough to take 2 turns around the island of Florianópolis, for example.

The Rescue 1 vessel is designed for safe navigation up to 20 miles from the coast. For this reason, it is equipped with windshield wipers, non-slip floor, larger fuel tanks. However, his project also contemplates the possibility of navigation in rivers, lakes, dams, in addition to the coastal navigation previously mentioned According to the manufacturer, Rhino Defense.



Figure 4. Resgate 1 from Santa Catarina Military Fire Department (photo from CBMSC).

Based on the needs raised in the previous chapters, the authors visited the vessel *in loco* and it was possible to evaluate the vessel. The internal space (figure 5) is restricted, there is no proper place to care for victims, to store rescue and care equipment. However, the presence of rescuer support bars throughout the vessel calls for the attention. On the aft deck there is a non-slip material with space for water to run under the rescuer's feet, further reducing the chance of slipping.



Figure 5. Resgate 1 Interior (photo from the author).

The object of analysis has crucial characteristics for a search and rescue situation, such as the possibility of walking around the vessel through the access and passage decks, places for storing oxygen cylinders, systems of GPS, radar, sonar and radio. However, it lacks search and operation lights, as well as safety belts, safety, damping systems, proper place to serve, cabinets or shelves to accommodate diving equipment or suits.

One of the first responders' needs that this model has and is essential is the rebound in the freeboard for a casualty to be loaded. This rebounds, in addition to helping rescuers, ensures greater safety for everyone, including the victim.

Also, Resgate 1 does not have any type of firefighting equipment.

Once built, the solution to adapt the vessel to all needs involves intense renovation and adaptations, however, the ideal is that all points are considered in the design process by the engineer.

7. CONCLUSIONS

Given the lack of specific laws, protocols and standards addressing the requirements of the rescuer on a vessel and such comprehensiveness of these, vessels have been adapted and provided to the response agencies. Therefore, compiling such requirements and analyzing them results in practicality for a designer when starting a new project and more efficiency and security for the rescue teams.

In addition to the facility, once determined, such requirements can be included in laws and ordinances, as in the case of land ambulances and aircraft. In this way, it is guaranteed that all vessels will have adequate characteristics so that the victim is assisted in the shortest time, the rescuer is not in danger and can work with greater concentration and safety, and the number of lives saved is greater.

In summary, the requirements identified in this work allow any naval engineer, through the standards and procedures of this engineering, to design a rescue vessel that meets the minimum operational needs. Some of them are need for communication and geolocation systems, lighting for operation and searches, cabin tightness, non-slip floor, seat belt, windshield wipers, firefighting capability, environment suitable for care, ability to navigate rough waters, system to board the victim, beaching capacity.

Although the research was entirely focused on a vessel to be designed, it is suggested that in future work, the possibility of adaptations to existing vessels is also analyzed, since the acquisition of new ones will take place through a process that is too bureaucratic, even if the requirements discussed here are not fully met. Or, in the continuation of the development of the project until obtaining it in full.

The possibility of having multi-mission vessels is also an attraction that can be studied in the future, as well as the use of different materials with a focus on efficiency and rigidity.

Finally, this work makes it possible for engineers to have a knowledge of the operation of a rescue vessel so that future projects can fully meet the rescuer's needs, ensuring faster, safer rescues and more lives saved.

8. REFERENCES

- ANZINI, Jackson Aurélio. Interview given verbally to Igor Carrijo Ramos (in Portuguese). Joinville, Feb 23 2021.
- ARAÚJO, I. Project of a firefighters vessel for salvage. TCC (Graduation in Naval Engineering) – Naval Engineering, (in Portuguese) Federal University of Santa Catarina. Santa Catarina, p. 94. 2016.
- BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. NBR 14561: Vehicles for medical emergencies and rescue (in Portuguese). Rio de Janeiro, 2000.
- BRAZIL. ANVISA. Reference Protocol No. 07, of June 11, 2011. Adequacy of vehicles used to transport sick or suspect travelers (in Portuguese). Available at: <<http://portal.anvisa.gov.br/documents/375992/4011173/Adequacao+de+veiculos+para+transp+orte+de+enfermos.pdf/3e7d1597-564c-4f3a-8f6c-329641aa7464>>. Accessed on: June 12 2019.
- BRAZIL. Regional Council of Medicine of the State of Santa Catarina. Resolution No. 027/97, of March 13, 1997. Regulates the activities of transport, removal and care of patients by ambulance and other vehicles (in Portuguese). Available at: <https://www.google.com.br/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjvxEL5teTiAhVBH7kGHd_fB4YQFjAAegQIARAC&url=http%3A%2F%2Fneu.br%2Findex.php%2Flegislacao%2Flegislacao-Santa+Catarina%3Fdownload%3D41%3Aresolucao-cremesc-027-97&usq=AOvVaw0XyaPM9r2zMbEaD-2kMTSG>. Accessed on: June 12 2019.
- BRAZIL. Ministry of Health. Minister's Office. Ordinance No. 2048, of November 5, 2002. Regulates the technique of state urgent and emergency systems (in Portuguese). Official Gazette of the Union, Brasília, 12 nov. 2002, p. 50.
- BRAZIL. Ministry of Health. Minister's Office. Ordinance No. 1010, of May 21, 2012. Redefines the guidelines for the implementation of the Mobile Emergency Care Service (SAMU 192) and its Emergency Regulation Center, a component of the Network of Attention to emergencies (in Portuguese). Official Gazette of the Union, Brasília, DF, May 21 2012. Available at: <<http://www.saude.sc.gov.br/index.php/documentos/legislacao-principal/redes-de-atencao-a-saude-3/rede-de-urgency-e-emergencia-1/samuleg-1/13126-en-1010-21-05-2012-redefines-guidelines-samu/file>>. Accessed on: 13 Oct. 2020.
- Itajaí Naval Newsroom. Meet the main vessel of the Military Firemen of SC (in Portuguese). Portal Itajaí Naval, 30 Aug. 2020. Available at: <<https://www.itajainaval.com.br/conheca-a-principal-embarcacao-dos-firemen-militares-de-sc/>>. Accessed on: 2 mar. 2021.
- MTU. Diesel Engines S60: for marine main propulsion high performance ratings. 2006. Available at: <https://www.transdiesel.com/app_docs/mtu%20series%2060%20marine%20625-825.pdf>. Accessed on: Nov. 20 2020.
- MARITIME AUTHORITY RULE. NORMAM-16: Rules of the maritime authority to establish conditions and requirements for granting and delegating assistance and rescue activities for a vessel, thing or good, in danger at sea, in ports and inland waterways (in Portuguese). 1st ed. Rio de Janeiro: Directorate of Ports and Coasts, 2003.
- Navigation Accidents. Directorate of Ports and Coasts – Brazilian Navy (in Portuguese), 2021. Available at: <<https://www.marinha.mil.br/dpc/acidentes-de-navegacao2>>. Accessed on: Feb 24 2021.
- PIETRANTONIO, Hugo. INTRODUCTION TO THE THEORY OF TRAFFIC FLOW (in Portuguese). São Paulo: Polytechnic School - University of São Paulo, 2018. 56 slides, B&W. Available at: <<http://sites.poli.usp.br/d/ptr5803/et2-teoria.pdf>>. Accessed on: Nov. 19 2020.
- ROZENFELD, H. FORCELLINI, F.A. AMARAL, D.C. TOLEDO, J.C. SILVA, SL ALLIPRANDINI, D.H. SCALICE, R.K. Product Development Management: a reference for process improvement. São Paulo: Saraiva, 2006.
- TRENTINI, Natalia. A day in the life of an ambulance driver in Jaraguá do Sul (in Portuguese). By Acaso, Jaraguá do Sul, July 25, 2019. Available at: <<https://poracaso.ocp.news/pessoas/profissao-motorista-ambulancia-samu-jaragua-do-sul/>>. Accessed on: Nov. 20 2020.
- UNITED STATES COAST GUARD. Response Boat-Medium, 2015. Available at: <<https://www.dcms.uscg.mil/Our-Organization/Assistant-Commandant-for-Acquisitions-CG-9/Programs/Surface-Programs/Response-Boat-Medium/RBM-Profile-Copy/>>. Accessed on: Nov. 20 2020.
- VIGOR. USCG Response Boat - Medium. Available at: <<https://vigor.net/projects/uscg-response-boat-medium>>. Accessed on: Nov. 19 2020.
- Xavier, Carlos Magno da Silva. How to collect requirements in projects (in Portuguese). Available at: <<https://beware.com.br/academia/artigos/coletar-requisitos/>>. Accessed on: August 16. 2021.
- Young, Chris. Hella marine supply LED lighting for Coastguard Howick boat. Interview granted to Hella Marine. April 4 2019. Available at: <<https://www.youtube.com/watch?v=k1T5zJCxaRM>>. Accessed on: Feb 27 2021.

9. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.