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DETERMINATION OF THE OPTIMAL SOLUTION THROUGH HEURISTICS TO A PROBLEM OF MULTI-LOCATION INSTALLATION LIFEGUARD STATIONS

Bruno Pereira de Oliveira, Wellington Gonçalves and *Rodrigo Randow de Freitas

Department of Engineering and Technology, Centro Universitário Norte do Espírito Santo, Federal University of Espírito Santo, Highway BR 101 North, Km. 60, Litorâneo, Brazil

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ABSTRACT

Occur worldwide annually 372,000 deaths can be prevented, which may be considered as one of the diseases with the greatest impact, both in health and in the world economy. However, it is estimated that the possibility of death by drowning while on a beach protected by lifeguard is 1 in 18 million, thus making the location of the rescue stations an important point connected to response-time. In this context a Facilities Location Problem (FLP) is raised to solve this problem, being studied in Operation Safes Sea (OSS) that happens throughout summer in the resort of Guriri, city of São Mateus, north of the Espírito Santo (Brazil). Finally, the results indicate that the GIS models, PLSC (PL to Set Cover), PLMC (PL Maximum Coverage) and PLp-Med (PLp-median) are the most meaningful to compose a discussion of the issue addressed as a way to aid in decision making. To be held a feedback to rulers of the city of São Mateus (Espírito Santo, Brazil) and the FDES (Fire Department of the Espírito Santo), managers said there is currently a cluttered design of the current rescue stations, and with it, the solutions presented in this work are shown able to propose alternatives to leverage an improvement in service delivery.

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INTRODUCTION

Water is present in almost all aspects of human life and can be considered essential to the maintenance of life (Brasil 2006, Victorino 2007). However, a simple diversion, wherein an individual potentially hazardous situation may become a drowning in fractions of seconds. According to the World Health Organization (WHO 2015) and the United States Saves Lives Association (USLA 2015a) this type of accident can generate epidemiological patterns (Szpilman 2005, Xavier 2011, Sales and Lima 2012) ranging according to the age, the amount of water and the activity involved. It is still pointed out that occur annually 372,000 deaths can be prevented, which may be considered as one of the diseases with the greatest impact on health and the global economy. Among the various types of emergencies are aquatic involving all situations where no body fluid aspiration (input fluid in the airways: trachea, bronchi or lungs) by immersion, characterized by the body being covered with water or other liquid leading to hypothermia victim (below normal body temperature) and immersed in the whole body, including the airway is below the blade of a molten substance as in a drowning (Soar *et al.* 2005). In Brazil, the conditions and climatic characteristics, the extensive river system and the size of the coast are important risk factors for developing this disease, but studies on the subject are scarce (Szpilman 2000, Araújo *et al.* 2008, WHO 2016). In this context, can also be appointed as the second national cause of death for ages 5 and 9 years old, third in the tracks 1-4 years and 10-19 years and fifth leading cause in the track 20-29 years (SOBRASA 2011). According to the Brazilian Society of Aquatic Rescue, about 20 people drown every day in Brazil (SOBRASA 2013). Accidents involving water, immersion or submersion, involve from children to adults, occurring in various environments, such as swimming pools, ponds, reservoirs, rivers, rapids, sea, floods and even household items that allow water. In this sense, emergencies involving submersion (drowning) can be identified as being the most worrying situations to the authorities. Brazil has achieved a rate of 2.71 Deaths Related to Drowning (DRD) for every 100,000 inhabitants in 2012, however, the states of

****Corresponding author:*** **Rodrigo Randow de Freitas**
Department of Engineering and Technology, Centro Universitário Norte do Espírito Santo, Federal University of Espírito Santo, Highway BR 101 North, Km. 60, Litorâneo, Brazil

Amapá with 8.58 DRD, Amazon with 5.82 DRD, Tocantins with 5.64 DRD, and the state of the Espírito Santo with 4.63 DRD lead the top positions with regard to this kind of disease (Brazil, 2013). Thus, transactions involving public safety, such as police and emergency assistance operations are constantly improving their practices, making the search for knowledge a stimulant for developing approaches and perceptions of tactics and strategies that can be included in a planning in terms of collective health (Minayo and Souza, 1999).So, logistics schematic for the implementation of transactions involving public safety, it is key to the use of available resources. Thus, the simulation can offer solutions through scenarios for planning for emergency operations, enabling the interaction between spatial and temporal data, such as the use of techniques and location models of integrated facilities to Geographic Information Systems (GIS) for analysis of alternatives and support decision making (Carver 1991, Gonçalves 2005, Jia *et al.* 2007, Carrara 2007, Paula 2009, Souza *et al.* 2011, Mapa and Lima 2012, SOBRASA 2012). Therefore, as a form of strategy to promote the services and aidoutlined logistics for the implementation of transactions involving public safety, this study aimed to analyze and display solutions, obtained through five simulations for the location of guard posts lifeguards, listing a set of targeted information to support decision-making regarding the logistics of planning for Operation Safes Sea (OSS).

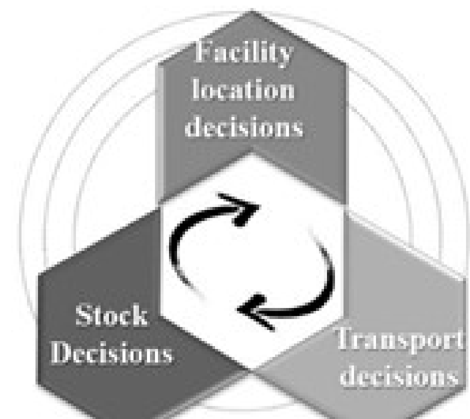
Theoretical Reference

The logistics in the care of drowneds: The care of the drowning victim is seen with a chain of three links (Basic Life Support - BLS, Advanced Life Support - ALS and Reference Hospital), which aims to take all necessary initial steps, called Emergency System Physician (ESP) (Szpilman 2015). According to Szpilman 2015, immediately the occurrence of the event, the SBV is the team qualified to offer the first care (lifeguards), and according to the incident, can vary from acting in a drowning to the basic procedures of Such as injuries (Figure 1), burns, etc. Simultaneously with the BLS team, the medical team or the ambulance with the Advanced Life Support (ALS) must be activated, according to the link, which routines with more complex and specific medical procedures and protocols are developed (AHA 2015). Following this, Szpilman 2015, the reference hospital is the place where care will be given according to the last diagnosis of the ALS, third link, indicating the sector in which the victim will be medicated (basic, intermediate or intensive care unit).

Source: Szpilman 2015.

Figure 1. Sequence of the three-link chain

It is also important to point out that there is a possibility that there is no Medical Emergency System (MES), this can occur when the BLS team does not identify symptoms or associated traumas, such as victims with normal heart rate and breathing, without cold, alert and capable of Walk (Szpilman 2015). The author also explains that in case of doubt, medical help should be contacted to assess the need to train the MES completely. In view of these situations, the logistics of MES training requires elements (initial approach, time of service and location) that lead to the efficiency of this system (AHA 2015). In the emergency scenario, the form of care and speed is summarized in the response time, which according to Szpilman 2000 is the time that the relief takes to reach the victim, being an important variable in prehospital care. Within this context, about 70% of trauma and drowning deaths occur before the victim arrives at the hospital (Szpilman 2015). Contrary to this fact, the USLA (United States Lifesaving Association) points out that the possibility of death by drowning when on a beach protected by life guards is 1 in 18 million (USLA 2015b). Thus, parameters such as the initial approach, the time of service and the location of lifeguards, have a more comprehensive level, this composes the organizational management of the technical and logistical support, which are aimed at the management of health care (CISS 2012). In line with this view, logistics contributes to the planning and management of lifeguards posts by providing the allocation of adequate personnel and material, in the proper place, in a timely manner in the best conditions of efficiency (Paula 2009). However, due to the specific needs that involve each service, the level of service offered to the customer must also meet the lowest possible total cost, seeking to offer alternatives that emphasize flexibility and agility (Greatbatch and Livingstone 2016). The disorderly growth of the urban population has a direct impact on the regional economy, impelling even the search for health services, and this situation is not limited to cities, having an extension to beaches, which therefore require specific planning due to the Variables and constraints (SOBRASA 2011). According to Drezner and Drezner 2016, all logistics planning of location of facilities, whether in the public or private sector, needs to carry out an integrated plan that involves location, inventory and transport (Figure 2). For Verhetsel *et al.* 2015, this plan is necessary because of the complexity and emergence of contemporary issues, which encompasses the logistics of the service sector.



Source: Verhetsel *et al.* 2015.

Figure 1. Logistics elements for facility location planning

In this context, due to gathering logistic elements cited in the literature (Drezner and Drezner 2016, Verhetsel *et al.* 2015), and having demand characteristics (estimated according to pre-established circumstances considering the regional profile) (Szpilman 2000, SOBRASA 2013,Szpilman 2015), the problem of locating lifeguards Can be considered a location of ease (Szpilman 2015, Verhetsel *et al.* 2015).

Problems of the facilities location: As the allocation of resources in a particular scenario or planning to meet a given demand, influences the efficiency of a system in which it is inserted, a Problem of Location of facilities (PL) is raised (Dantrakul *et al.* 2014). In several localization problems, according to Bhattacharya and Shi 2014, elements on demand and service capacity must be combined. According to the literature (Dantrakul *et al.* 2014, Bhattacharya and Shi 2014, Malaguti *et al.* 2016), the objective of the localization models is based on pointing out where to install a facility in order to optimize decision variables. In other words, for Malaguti *et al.* 2016, the problem of location of facilities consists in establishing the solution of a model in function of a spatially distributed set of demand points, which will be attended by facilities located in the vicinity of this. In this way, these PL's are framed in the Models of Mixed Integer Linear Programming (MILP) because they involve problems in which only some of the variables are required to be integers, while other variables may be non-integer to Bhattacharya and Shi 2014, and Malaguti *et al.* 2016. Facility location problems consist of servicing clients by considering a set of potential points where facilities can be located (Drezner and Drezner 2016). In this work, considering the variables present in the location of lifeguards (Szpilman 2000,Soar *et al.* 2005, Macintyre 2014,Szpilman 2015, Greatbatch and Livingstone 2016) and the literature (Dantrakul *et al.* 2014, Bhattacharya and Shi 2014,Malaguti *et al.* 2016), these PL's are classified into four categories, using objective function criteria: (*i*) *p*-medians; (*ii*) *p*-centers; (*iii*) sets of coverage and (*iv*) maximum coverage. In the view of to Bhattacharya and Shi 2014, the purpose of facility location problems is to find a point to allocate an installation in order to minimize the total cost of the facility and transport between customers and facilities. For these reasons, and by determining the location of *p* installations and their assigned clients, in order to minimize the total cost of transport between clients and facilities, is that the *p*-median problem was selected (Dantrakul *et al.* 2014). The problem of location of *p*-Medians (PL*p*-Med) is to locate *p* (or *p*-medians) in order to minimize total cost (Equation 1) (Dantrakul *et al.* 2014). For Albareda-Sambola *et al.* 2015, the cost to meet a demand point is associated with the distance between it and the nearest facility. In specific situations this cost can be weighted using the demand present at the point served (Dantrakul *et al.* 2014 and Albareda-Sambola *et al.* 2015).

$$\mathrm{v(P)} = \min.\sum_{i=1}^{n}\sum_{j=1}^{n} \mathrm{d}_{ij}\mathrm{x}_{ij} \quad (1)$$

Subject to:

$$\sum_{i=1}^{n} y_{ij} = 1 \ \forall j \in j \quad (2)$$

$$\sum_{i=1}^{n} x_{ii} = p \quad (3)$$

$$y_{ij} \le x_i \ \forall i \in I; j \in J \quad (4)$$

$$x_i \in \{0,1\} \ \ \forall i \in I \quad (5)$$

$$y_{ij} \in \{0,1\} \ \ \forall i \in I; j \in J \quad (6)$$

On what: d_{ij} represents the distance between the demand point $j \in J$ and the $i \in I$ facility; p indicates the number of facilities to be located; $y_{ij} = 1$ indicates that the demand point $j \in J$ is served by the $i \in I$ facility, and $y_{ij} = 0$ otherwise; and $x_j = 1$ if a facility is opened in $j \in J$, and $x_j = 0$ otherwise. The restriction equation 2 ensures that each demand point $j \in J$ will be allocated to a $i \in I$ facility, which must be a median, equation 3 determines the exact number of facilities *p*, equation 4 ensures that an allocation will be obtained between a demand point $j \in J$ and a $i \in I$ facility, if a facility is opened at *i*, equation 5 and 6 are associated with the domains of the variables. On the other hand, considering the variables imposed by the characteristics of drownings (SOBRASA 2011), and therefore the possible points for finding lifeguards, the problems of location of *p*-centers (PL*p*-centers) can be employed, because they have a Specific objective function, which allows minimizing the maximum distance between each client and the facility assigned to it (to Bhattacharya and Shi 2014). According to Suzuki and Drezner 1996, PL*p*-centers aims to minimize the maximum distance between clients and a fixed number of service facilities to be determined (Equation 7).

$$\text{Min. Z} \quad (7)$$

Subject to:

$$\sum_{i \in I} y_{ij} = 1 \ \forall j \in J \quad (8)$$

$$\sum_{i \in I} x_i = p \quad (9)$$

$$y_{ij} \le x_i \ \forall i \in I; j \in J \quad (10)$$

$$Z \ge \sum_{i \in I} d_{ij} y_{ij} \ \ \forall j \in J \quad (11)$$

$$x_i \in \{0,1\} \ \ \forall i \in I \quad (12)$$

$$y_{ij} \ge 0 \ \ \forall i \in I; j \in J \quad (13)$$

Where: d_{ij} denotes the distance between the demand point $j \in J$ and the $i \in I$ facility; *p* indicates the number of facilities to be positioned; y_{ij} represents the portion of the $j \in J$ point demand served by the $i \in I$ facility, and Z indicates the maximum distance between a demand side and its nearest facility. In this context, the objective function (Equation 7) minimizes the maximum distance between a demand point and the nearest facility, the constraint equation8 ensures that the demands of the demand points are met by the facilities, equation 9 allows to ensure that exactly *p* facilities will be opened, equation 10 certifies that the $j \in J$ point demand will only be satisfied by the $i \in I$ facility if there is a facility open in *i*. Thus, equation 11 asserts that the maximum distance between a demand point and its nearest facility will be greater than the distance between any other demand point and the facility that meets it, and equations 12 and 13 are associated with the domain of the variables. According to USLA 2015a, SOBRASA 2013 andSzpilman 2015, the occurrence of drownings most often follows a given distribution in terms of locality, allowing with this, to know the sites with the highest incidence. However, these authors point out that due to the probabilistic characteristic of demand behavior, mechanisms are needed that extend the location of lifeguards to meet the occurrences. For these cases, Verhetsel *et al.* 2015 andMalaguti *et al.* 2016, mention that coverage problems are appropriate in these circumstances, because they find the minimum number of facilities to cover all customers, or to maximize the number of customers covered by a certain number of facilities. For Miahet al. 2017, models that address the coverage problem are the most adequate for formulating and indicating solutions for locating service units. According to these authors, the purpose of these models is to define places of "supplies" whose distance to a point of demand until the nearest facility is less than a certain cost. Thus, the demand is considered covered when it is the closest to the critical distance of at least one of the facilities, although these are not available when the service is requested (Verhetsel *et al.* 2015,Malaguti *et al.* 2016, Miah *et al.* 2017).

According to Malaguti *et al.* 2016 and Miah *et al.* 2017, the basic coverage models are divided into two: location model for set coverage and maximum coverage model, in PLSC (PL to Set Cover) models, the objective is to determine the minimum number of facilities required and their locations, so that each demand point is covered by at least one facility,equation 14, (Malaguti *et al.* 2016).

$$\text{Min. } Z = \sum_{j \in J} x_j \tag{14}$$

Subject to:

$$\sum_{j \in N_i} x_j \geq 1 \ \forall i \in I \tag{15}$$

$$x_j \in \{0,1\} \ \forall j \in J \tag{16}$$

Where: I is the set of demand regions, indexed by i, J is the set of candidate sites to receive facilities, indexed by j, N_i is the set of all candidate sites that can cover the demand point i and x_j is the decision variable. The objective function (Equation 14) minimizes the number of localized installations, while the restriction of equation 15 ensures that each demand point is covered by at least one facility, hence equation 16 establishes the decision to install a facility or not. Within this context, and according to Malaguti *et al.* 2016 and Miah *et al.* 2017, the objective of the maximum coverage model is to maximize the number of demand points covered given a fixed number of facilities. For these authors, a point of demand is completely covered if it is within the critical distance of the facility, also known as PLMC (PL Maximum Coverage) (Equation 17).

$$\text{Max. } \sum_{i \in N} h_i z_i \tag{17}$$

Subject to:

$$\sum_{j \in N_i} x_j > z_i, \ \forall i \in I \tag{18}$$

$$\sum_{j \in M} x_j = p \tag{19}$$

$$x_j \in \{0,1\}, \ \forall j \in J \tag{20}$$

$$z_i \in \{0,1\}, \ \forall i \in I \tag{21}$$

Where: I is the set of demand regions, indexed by i, where J is the set of candidate sites to receive facilities indexed by j, the set of all candidate sites that can cover the demand point i is denoted by N_i, a demand at point i is represented by h_i, p is the number of facilities to be located, and $Z_i$is the decision variable, which considers 1 if demand i is covered, and 0 otherwise. The objective function (Equation 17) is directed to maximize the covered demand, and the constraint of equation 18 ensures that a demand point is covered, if and only if at least one installation capable of covering it is opened, equation 19 ensures that at most p facilities are opened, and the constraints equation 20 and 21 guarantee the mastery of the decision variables. The use of facility location models in conjunction with Geographic Information Systems (GIS's) has become an important decision support tool (Höhn *et al.* 2014). These systems have the characteristic of analyzing and comparing a wide range of possibilities, in which the objective is to highlight the best solution that suits the organizational strategy (Mapa and Lima 2012). When submitted to the combined use of this tool, the formulation and obtaining of results of the localization problems is amplified (Mapa and Lima 2012, Höhn *et al.* 2014), because the GIS's allows the visualization of results generated in virtual maps with the layer superposition.

Methods and research techniques

The method adopted for data collection was not probabilistic sampling with accidental or convenience, in which the sample was formed by elements that are circumstantially in the research site, and are described in no particular order until the sample reaches a certain size (Uprichard 2013). Already the PL used as a source of observation to OSS, present throughout summer season in the bathhouse of the Guriri, which has 3 km long, located 12 km from the center of São Mateus (Espírito Santo, Brazil). Data were collected between December 29, 2015 and January 31, 2016, due to tourism this time of year tends to be more pronounced, making the place suitable for operation of a service of aquatic emergencies. Regarding the collection of data, this happened through a documentary survey, since the data sources, records of attendance, come from public agencies of the municipality of São Mateus (Espírito Santo/ Brazil) and the State Fire Department Of Espírito Santo, which are in charge of attending to aquatic emergencies in the bathhouse. Concomitantly was raised the current positioning of rescue stations, through identification of geographical coordinates using a GPS (Global Positioning System) and later in order to plotting and analysis, we used the Google Earth® software. Also, in order to know how many facilities are needed to absorb all demand points, minimizing the distance between demand points and candidate positions, we used the TransCAD® Standard 6.0. Posteriorly we collected data regarding drownings demand at each point that had relationship between events and local geographic positioning of rescue stations. From the collection, was made an issue of the proposed solution, which were integrated into a GIS to assist in understanding the results.

In addition, analyzes were performed comparing the results obtained with the current conditions, generating scenarios with alternative locations. These analyzes are important to understand the logistics of drowning care, and according to (Szpilman 2015), it needs to be based on a MES, based on a system that contains three basic elements (Basic Life Support - BLS, Advanced Life Support - ALS and Reference Hospital). In sequence, the recommendations of the literature (Suzuki and Drezner 1996, Dantrakul *et al.* 2014, Höhn *et al.* 2014,Malaguti *et al.* 2016,Miah *et al.* 2017), which considers the location of facilities and the allocation of customers to these facilities, in order to minimize the sum of the distances for services. Thus, the methodological procedure was established through four phases, described below. The definition of nodes was performed by GPS, by the geographical locations of existing installations. In this case, were considered care centers, however, were also certain customer locations, which should have their demands met by facilities (Demand Centers). Following, there was the creation of candidate points to the location of new facilities (Candidate Location), and their respective locations (Phase 1). Phase 2 addressed to obtain the input data for facility location models as the Distance Matrix, from the definition of network nodes, integrated to a geographically referenced database. Thus, it was possible by means of GIS internal routine, calculate the cost matrix, responsible for storing the distances between all nodes of the network, this information also served as input data for the mathematical Models of Mixed Integer Linear Programming (MILP). From the distance matrix obtained by executing the domestic routine location GIS facilities, the MILP models were run on an optimization solver, IBM ILOG CPLEX Optimization Studio®, through the routines of PL*p*-Med, PLSC, PLMC and PL*p*-centers, featuring Phase 3 (Model GIS and MILP for facilities location). Finally, the solutions achieved were compared by analyzing the results generated by each GIS and MILP model for the simulated scenarios (Phase 4 - Evaluation of the solutions).

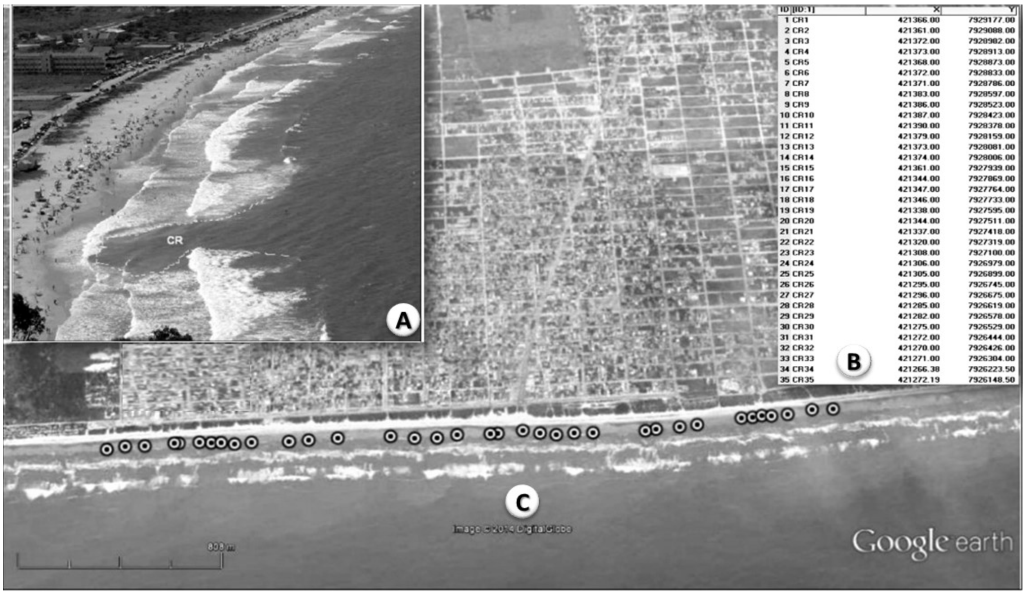
Application and discussion of results

Thus, the geographical locations of existing posts lifeguards (PA) were obtained by GPS and were then processed on Google Earth® software and inserted into the Standard TransCAD software 6.0 (Figure 3). Later, the geographical locations of the points were also acquired by GPS, with the first observation the main sites of emergencies. However, there was an existing relationship between the beach goers and the local Return Currents (RC), also known as “ditches”; for this reason, we considered the locations that had a high drowning rate in the bathhouse. It is noteworthy that the RC’s are responsible for over 75% of drownings (Szpilman 2015); in this sense, the role of lifeguards is to identify the currents and to define their own areas for swimming, working to prevent occurrences. From this point of view, the collection of the main places likely to form return currents was mapped by the criterion of on-site observation and also through interviews with local lifeguards; from the collection of these geographic data, it was possible to put them on a map (Figure 4). It was also established as a parameter, which local candidates should be close to the natural local beach access. In this way, the ALS can access the drowning victims more quickly. However, posts lifeguards should be located close to where beach goers enter and exit the water and should be clearly visible. Further evidence raised from the collection of spatial data was to identify the main entry and exit points of the edge and process a map (Figure 5) in order to cover the maximum amount of candidates. It is worth noting that current posts were also added to the models. For data analysis, the representation of logic covered the principles of induction and deduction (Albareda-Sambola *et al.* 2015). However, the answers to the research originated in the processing of data that fed the various types of GIS layers and the MILP model. Consequently, the data analysis was performed by comparing the results obtained, based on a proposed system related to the current situation of the location of posts lifeguards. Corroborating this, Mapa and Lima 2012 reports that many studies involving GIS have been developed in several areas and focused on the location of facilities, sometimes combined with other mathematical techniques, both in the public sector and the private sector. However, the complexity involved in the processing of a large volume of data and variables present in mathematical formulations involving facility location problems leads to the need to use additional tools that can materialize the visualization of the possible solutions. In this case, GIS’s that can be considered computational tools are georeferenced and presented as an important aid in planning, handling and managing the data and the informations that feeds the mathematical models. When subjected to the use of this tool, the formulation of a facility location problem can best be achieved since GISs allow visualization of the results generated by virtual maps and the superimposition of layers (Höhn *et al.* 2014). For this same purpose, Mapa and Lima 2012, Höhn *et al.* 2014 point out that the GIS tool has many applications in location problems, i.e., for factories, distribution centers, outlets and the public sector, increasing the understanding of experts and users.

To Mapa and Lima 2012, GIS’s multidisciplinary aspect in terms of the evidence can be applied in various fields such as urban planning, geography, agronomy, the environment, forestry, engineering, data processing, operations research, urban architecture, service management, transportation engineering and the deployment of health clinics, among others. GIS can, thus, provide the decision maker with a set of tools for the handling and analysis of spatial informations (Paula 2009). The integration of evaluation through multicriteria techniques with GIS can provide the user with the means to evaluate alternatives based on criteria and multiple objectives, even conflicting objectives. Thus, in view of the data collected, the informations on the OSS was processed by GIS in a database containing the bathhouse of Guriri (city of São Mateus - Brazil) (Espírito Santo 2015). Therefore, a table was preliminarily generated that served as a database containing the coordinates of the 35 applicant points in the RC’s that are marked (Figure 6). From the database generation containing geographical informations related to the demand points and local candidates, we used GIS, which generated a cost matrix (distances). Thus, simulations were performed using TransCAD and CPLEX with the intention to form benchmarks among the current location of posts lifeguards and to provide solutions related to localization techniques (Figure 6B). The routine to run an internal GIS provides a tool for facilities location. It requests as an input parameter the distance matrix where indices between one and 34 correspond to candidate positions, and those between 35 and 46 correspond to current positions. Preliminarily, in order to consolidate the data and the coverage area of the posts lifeguards, some reference informations was necessary. In this sense, reports that a rescue station should be located so that the posts lifeguards travel a maximum distance of 150 meters (m)

Fonte: Google 2018.

Figure 3. Location of current posts lifeguards



Source: Google 2018.

Figure 4. (A) Return current example, the southern end of bathhouse Brava (Itajaí/ Brazil). Source: Silva (2012); (B) Database with the coordinates of return currents (demand). Source: Authors; (C) Walking image of bathhouse Guriri with return currents

Source: Authors 2018.

Figure 5. Main beach access routes and coordinates of the candidate positions

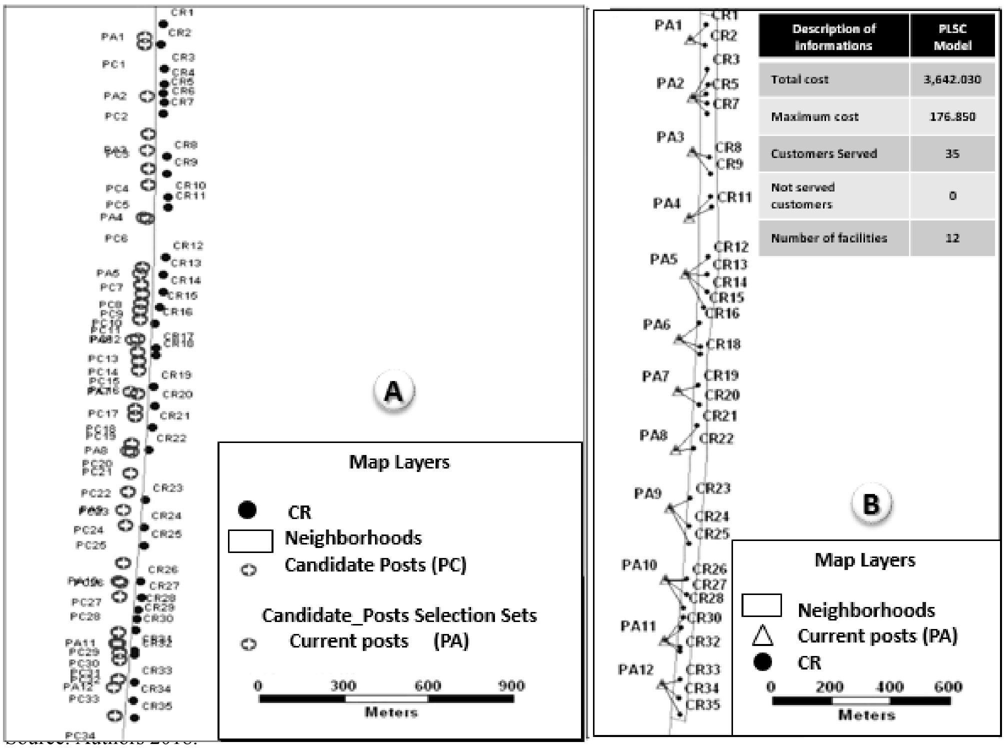
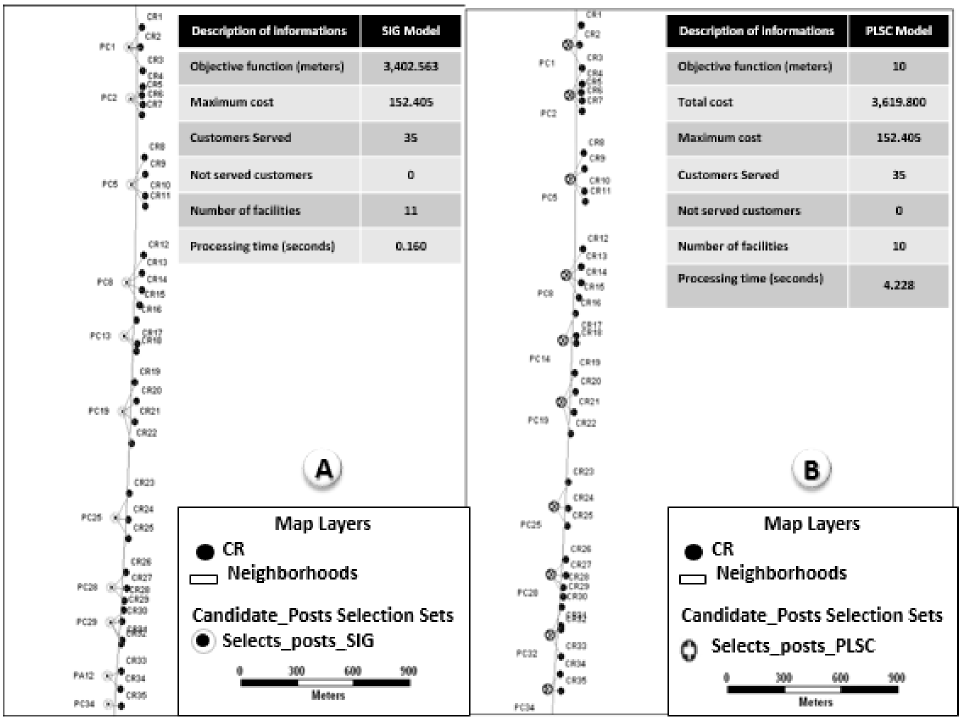


Figure 6. (A) Layer of points containing the RC and the candidate points. (B) Current model of the posts lifeguards



Source: Authors 2018.

Figure 7. (A) Location of new facilities with GIS and model informations; (B) Location of the posts lifeguards using the PLSC and model informations

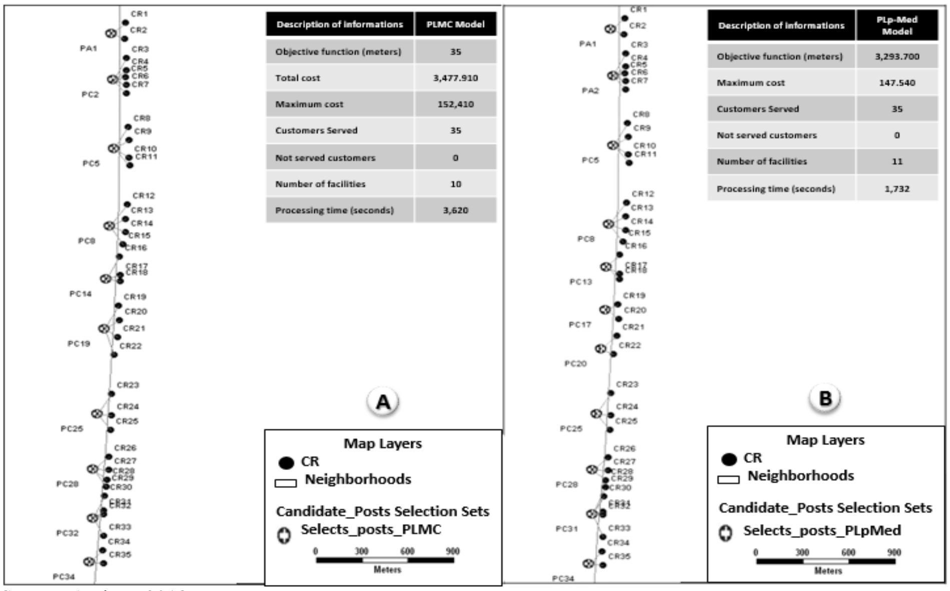
to enter the sea(Szpilman 2015). The author further states that, statistically, this distance is traveled by a lifeguard in a range of 20 second (nd), and the time is based on the victim's resistance with 100% physical effort. Considering the route where the posts lifeguards have to swim to reach a victim, Szpilman 2000 report that a distance of 30 m swimming corresponds to a real situation. The scope of time is around 35 nd. In the United States and Australia, for example, studies show that a victim who cannot swim has between 20 to 60 nd of survival until, in becomes submerged a state of grief and panic, he or she (Szpilman 2000, Szpilman 2015). Thus, as the distance between the posts lifeguards and the demand points feeding the mathematical models was required, we adopted as a basic parameter search the maximum distance of 15.297 m in total, which corresponds to 150 m traveled in 30 m in the sand and water. Thus, the five simulations had the purpose of checking how many facilities are needed to meet the total demand, each being conducted by means of a technique. The first was generated from the resolution of the problem with a service level of 15.297 m; the second had a solution from a PL to a Set Cover (PLSC), and the third used a PL Maximum Coverage (PLMC). However, limiting the number of features offered by the PLSC result, the fourth PL employed a p-Median (PLp-Med), using the number of the GIS proposed facilities with a maximum service level of 15.297 m, and the fifth simulation consisted of executing a PL of the p-Centers (PLp-Centres), also using a maximum service level of 15.297 m with the number of facilities proposed by GIS. It is noteworthy that, for the second through the fifth simulation, we used the CPLEX to solve the PL. Therefore, in order to know how many facilities are needed to absorb all load points, minimizing the distance between the demand points and candidate points (PC's), we obtained the result in figure 7A. However, to perform the routine PLSC, it was necessary to use an assignment matrix in order to meet the maximum distance coverage (Figure 7B). In PLSC, the model realized that the objective function is directed to extract informations concerning the number of necessary facilities to ensure a level of service to beach goers. It points indifferently to the costs, so a demand point can be covered by more than one facility, as what actually occurs in the RC3 point.

In the implementation of routine PLMC, it was also necessary to use the designation matrix, and, after development of the model, the CPLEX generated the results shown in figure 8A; however, in the formulation of PLMC, the goal turned into maximizing the number of demand points covered, given the fixed number of facilities at risk of not having full coverage. However, the result showed that it was possible to cover the entire demand. Also, note that one of the Current Positions, the CP1, has been selected as a host facility. For PLp-Med, the model was implemented in order to locate the 11 facilities previously proposed by GIS in order to verify the quality of the result compared to an exact method (Figure 8B). Considering the PLp-Med applied above, it was to find the ρρ facilities to minimize the total cost, and, in this sense, it is important to note that the cost of care from a demand point can be linked to the distance between this point and the nearest facility, so the idea is to ensure that a demand point is to be served by a facility, unlike in the PLSC and PLMC models. Thus, it can be seen that the current positions CP1 and CP2 were chosen, which does not occur in GIS (Figure 8B). Thus, as with the PLp-Centers, the model was implemented in order to locate the 11 facilities previously proposed by GIS, and, in this model, the objective is to minimize the maximum distance between demand points and a fixed number of facilities to be located. As the concept is to ensure that the maximum distance between a demand point and its nearest facility will be greater than the distance between any point of demand and the suitable facility, it is observed that current post CP6 was selected. CP 11, CP 12 and a demand point should be related to CP 12, a characteristic that does not happen in the previous solutions (Figure 9).

In this way, when analyzing the proposals, it was possible to find solutions by generating a graph comparing the results between the current model and the informations coming from locations of simulations. One can observe the variation in total and maximum costs between the current model and the GIS models, PLSC, PLMC, PLp-Med and PLp-Centers (Figure 10). The simulations indicated possible improvements to the achievement of the coverage target, as in minimizing the amount of facilities, showing that the current location of posts lifeguards that have coverage with a maximum cost for the17.685 does not correspond to that proposed by Szpilman 2015 and USLA 2015a andsurpasses by 13.5% the premised 15.297 m, considering the route on land and water. In this regard, it is noteworthy that the 11 facilities proposed by GIS have a maximum coverage of 14.754 m, being better located than the 12 of the current model. Consequently, it is important to note that the hedging models (PLSC and PLMC) have different goals, providing results that require different interpretations. The PLSC seeks to ensure that all demand is met, ultimately enabling simultaneous coverage due to a demand point being contained in an area spanning two or more facilities. Performing an analogy with the current model, the PLSC indicates the opening of 10 facilities, with a 0.61% variation in relation to the total cost of the current model; however, to reach 15.241 there is an exploration of almost the limit of the maximum distance of coverage established. From this point of view, it became clear that the low variation of the total cost may be related to duplicity and that the exploitation of coverage may be due to the calculations being carried out by the sum of the distances of all arcs to ease customers. As mentioned, the wording of the PLMC model seeks to maximize coverage of the plaintiff points. With the application of the model, it was possible to determine whether the proposed number of facilities has the capacity range of sets of beach goers points. Compared to the current model, the results produced a total cost with a variation of 4.51%; even considering the formulation in order to explore the critical distance, the maximum cost is 15.241.

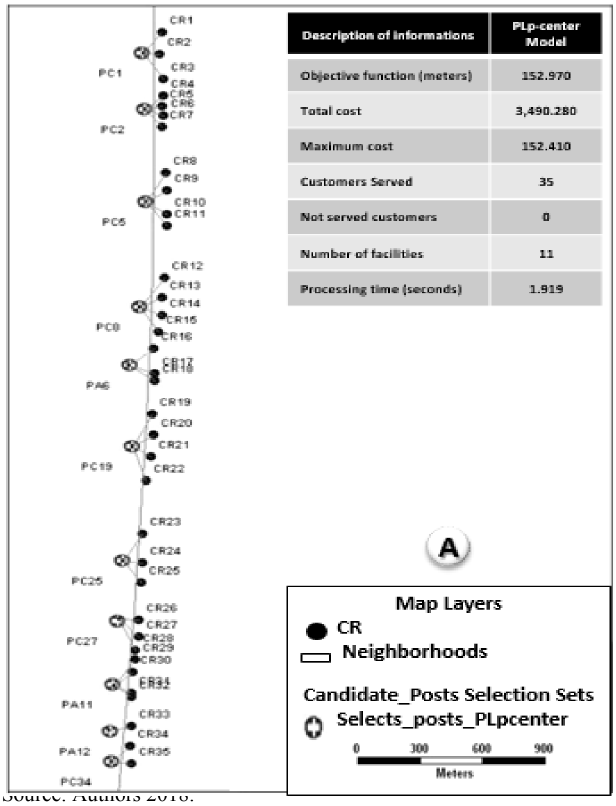
In this context, the GIS models and PLp-Med aim for exclusivity and search for minimizing the distances between the arches while the PLSC and PLMC seek to cover the entire cost of the independent demand, respecting a critical distance established. The he PLp-Centers tend to minimize the maximum distance between demand points and a fixed number of facilities. Thus, it can be seen that, when a simultaneous call for a demand point in hedging models occurs, the total cost may be higher than in the other models. In the GIS model, internal routine facility location is linked to a heuristic modeling; however, due to the MILP model being an accurate method, differences can occur between the solutions obtained. In this sense, the PLp-Med and PLp-Center models were used in order to compare those results with the proposal by GIS. Already, the heuristic implemented through the routine of GIS presented a solution with low variation with PLp-Med, despite being better than the PLp-Center, and can be regarded as good quality in that it converges a solution to the math under the context of minimizing the distance between the demand points and candidate locations with a processing time interval that is less than that in the MILP models, possibly indicating that it is effective.

The PLp-Center model, for example, trying to minimize the maximum distance between the demand points and the nearest facility yielded better results than those of the currently employed model but was less attractive than the GIS and PLp-Med models. From a strategic point of view, the CBMES aims to cover as much as possible the performance area of the emergency services, observing the peculiarities and seasonality of each location. With this, the GIS models, PLSC, PLMC and PLp-Med can be pointed out as the most interesting in discussions on the subject because the solutions offered provide the necessary numbers of facilities distributed along the shore, and still exhibit simulations with the best placements according to the area of the operation of rescue posts lifeguards.



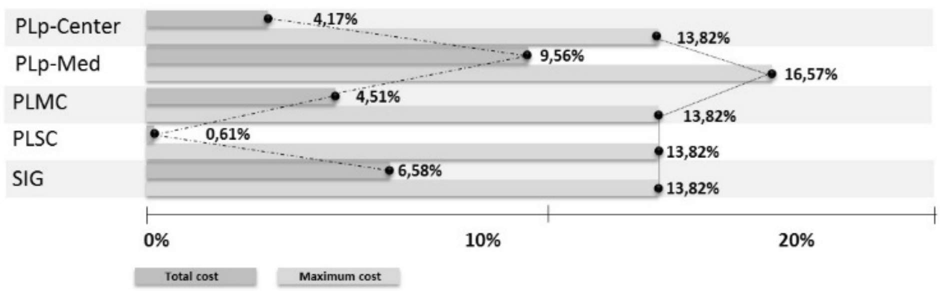
Source: Authors 2018.

Figure 8. (A) Location of the posts lifeguards using the PLMC and model informations. (B) Locations using the PLp-Med and model informations



Source: Authors 2018.

Figure 9. Location of the PLp-Centers of the posts lifeguards.



Source: Authors 2018.

Figure 10. Change in total and maximum costs between the current model and the models

Final Consideration

For the utility industry, the localization strategy of service stations becomes a challenge because the data customarily are fragmented and made available by many organs, requiring methodologies and techniques for integration. As this is a deployment of facilities through arrangements, this work may contribute to aquatic rescue activities, generating solutions that tend to minimize logistics costs related to the location of lifeguard stations. Because of Operation Save Sea happen in the summer period, when the peak of drowning incidents is higher compared to other times of the year, the use of simulation for facility location provided a timely observation, however, important for assistance in care of emergencies related to drowning. Regarding the number of lifeguard stations were given feedback to the rulers of São Mateus (Espírito Santo, Brazil) and the FDES, managers said there is currently a cluttered design of the current rescue stations, and with it, the location is not efficient shows compared the incidence of drowning. In this sense, the solutions presented in this work are shown able to propose alternatives to leverage an improved service offering. Note that the use of the premises of this work in other situations, must take into account the intrinsic characteristics of the site and demand generators poles. In this sense, the strategy of this study was to apply the techniques and methods, with the view to cover all demand points.

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