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Geolocation Of Ambulance Centers Using Tabu Search Algorithm

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Abstract

This article presents a literature review of the studies conducted on problems of location and relocation of Emergency Medical Services (EMS) vehicles. A detailed analysis is made of the components that influence the development of the problem, the information extracted from the referenced articles, for the development of this paper were: the implemented methodologies, the variables involved in the system, performance measures, computer technology tools (software) implemented for the development of these methodologies, mathematical models, simulation models and others, found in the literature review, each item classified according to its function. Finally, an analysis of new technologies in the development of the subject is made and a proposal is made to address this problem with industries 4.0.

Keywords: Ambulances, Logistics, Location, Relocation, , Medical Emergency System (MES).

Introduction

Emergency medical systems (EMS) are state organizations in charge of providing out-of-hospital medical assistance quickly to possible emergency events. In the modern health system they are considered as fundamental and even critical elements, since they fulfill the function of providing the service to people by means of a fleet of vehicles trained to attend to possible eventualities. This organization exists worldwide and each country has or should have its own EMS. Some countries may have a much more developed system than others.

In Colombia, the SEM is attached to the Ministry of Health, which states that the Medical Emergency System - SEM, as stated in Resolution 926 of 2017, is a general integrated model that seeks the articulation of the different actors of the General System of Social Security in Health, to ensure timely response to victims of disease, traffic accidents, trauma or cardiorespiratory arrest. As a premise of the System it is established that "to take the right patient to the right hospital at the right time", which is associated with the reduction of mortality and disability due to situations derived from medical emergencies, Ministry of Health (2022).

There is a regulatory center for emergencies and emergencies, at national and departmental level, designated by the acronym CRUE, which the Ministry of Health defines as the non-assistance operational units responsible for coordinating and regulating in their jurisdictions, access to emergency services and health care for the affected population in emergency or disaster situations. These entities are under the regulation of resolution 1220 of 2010, which seeks departmental coordination and standardization of the care process.

The United States has a generally well-organized system for responding to health needs, with small-scale disasters being handled by local authorities Parmar,et al;(2013). Almost all systems use a coverage level performance measure where the proportion of high priority patients reached within a fixed time frame (usually within nine minutes of receiving the call) is reflected [4]. On the other hand, Japan's national disaster medical system, which is part of the department of health and human services, has disaster medical assistance teams (DMATs), which are responsible for response in case of mortuary operations and disaster. These DMAT teams have approximately four to five members, including a doctor, a nurse, and logistical support staff, all of whom are trained in disaster response.

Based on the statements compiled from the different countries mentioned above, it is evident that with respect to the purpose of EMS, the organization's policies are maintained at the international level; another case that reaffirms this is Mexico, it is offered to sick or injured people who are outside an institution where they can be provided with the medical service they require, its primary objective is to attend and transfer the injured person to the corresponding hospital and be assisted in the shortest possible time, thus contributing to a decrease in the mortality rate and reducing the sequelae that may leave some malfunction of organs of patients Perez,et al;(2014).

In the case of Brazil, which has a government program that fulfills similar functions to the entities mentioned above. This program is called as Emergency Medical Care Service (SAMU), which aims to provide emergency medical assistance to people and ensure the quality of care in urban centers, these systems are characterized by uncertainties in terms of availability, location and service time of servers, as well as in terms of user demand and response time for care De Souza,et al;(2013).

One of the main concerns of the users is the efficiency in the attention and solution of the emergency, and the response time of these vehicles. Normally there is a certain waiting and response time before the vehicle arrives to the place of the event, in many other occasions different factors influence in which these times are affected, and can exceed the average, which can generate complications for the patient's health depending on the criticality of the case. Some studies have revealed that the time of care and response is directly proportional with the mortality rate of the population, in cases of greater severity the response time comes to be the crucial element that can circumstantially affect the health and recovery of the patient Ferrari,et al;(2018). In this case it is affirmed that the more prompt the response and attention of such vehicles, the more it tends to decrease the mortality rate in people.

When talking about EMS and emergency response vehicle logistics, we automatically talk about localization and relocation. Localization, taken from a strategic point of view, contemplates finding base points where ambulances are located at a given time of the day, taking into account measures that evaluate the performance of the decision. Tactics from an operational point of view are aimed at finding dynamic solutions that adapt easily to changes in the characteristics of the environment. On the other hand, relocation allows evaluating whether some ambulances that were not assigned to incidents should make a base change with the objective of having lower response times and increasing the demand coverage that could have been affected by the departure of ambulances during the assignment process

Zapata,et al;(2018).

EMS operations can be segmented into two steps: central and external operations. The first is to provide telephone support to the patient and define the most appropriate response to the call. The second is to provide pre-hospital care to patients. The operations center, which provides telephone support to the person requiring emergency services and defines the most appropriate response to the call, is a fixed facility where the profile of incoming calls is analyzed. If the dispatcher believes that it is not necessary to send a team, the call is terminated, ending the service. However, when the decision is to dispatch a team, the dispatcher determines the appropriate rescue team, according to the default dispatch rule, which takes into account the severity of the incoming call and the nearest idle ambulance. The external operation begins when a rescue team is notified to perform a service. Subsequently, the vehicle, already prepared with the necessary materials, moves to the scene of occurrence. When the team arrives at the scene, the victim stabilization process begins with the application of the appropriate techniques. Transport to the hospital unit is the next procedure, if further medical care is necessary.

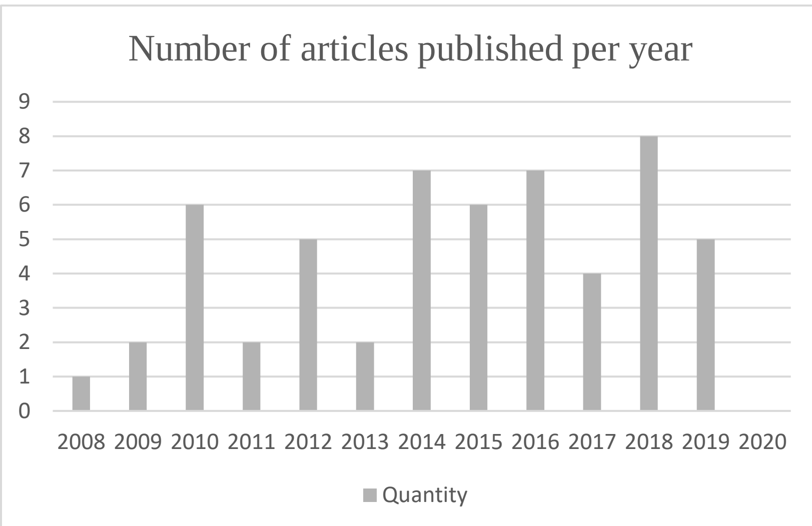
Based on the findings of a research conducted in the city of Bogota, it is stated that the location of ambulances as a method of high impact on the time of care. This is because a correct distribution of these throughout the city can allow a faster and more efficient response; without the need to invest in new vehicles, the ambulance dispatch phase can be improved Garcia,et al;(2019).

The following research conducted a literature review based on the thematic of localization and relocation in ambulance bases, In the use of mathematical models there are important limitations to solve problems, which show that they often fail to fully characterize the dynamics of ambulance dispatch and event care Rodriguez,et al;(2016). On the other hand, Parra makes the following contribution, Representing a grouping of research conducted in the last forty years, in order to Transfer knowledge about this type of models towards their implementation in emergency care systems Ortega,O;(2013). Finally, the following contribution is taken as a reference, where a classification of literature studies is made in three classes: static, probabilistic and dynamic, according to their objectives and their resolution methods. In addition to this, it presents recent researches that integrate the geo-information system in their simulation models. As a result, such a classification allows analyzing the historical progress of model coverage and improvement of emergency medical response Benabdouallah & Bojji;(2018) . Unlike the previously related contributions as a reference for the development of this article, a review of the state of the art in thematic of localization and relocation in ambulance bases is performed taking into account a wide time window of the last ten (10) years, considering this as the trend and the vanguard in the developments made in the proposed thematic.

In the development of this article, an update on the review of the state of the art and literature on localization and relocation in ambulance and emergency medical service vehicle bases is proposed. The methods, variables involved, performance measures, tools and software for the solution of the problem and new technologies are integrated.

Method

The methodology implemented for the development of this article resorted to the search of articles in the different scientific databases provided by the university (Scielo, Sciencedirect, Google Scholar, Scopus) with similarity to the topic of study. Conference proceedings were taken into account with 3.57%, undergraduate theses with 8.93% of which 1.78% corresponded to undergraduate theses, and 7.15% to master's theses. The articles with a percentage of 87.50%, the most representative databases from which the findings were made for the development of the article are EBSCO host with 53.57% and in a lower percentage Google academic with 26.76%, also databases such as Scielo 8.93%, Science Direct 3.57% and Scopus 1.79% were consulted. Another aspect that was taken into account was the location where the research was carried out, where the American continent predominates with 50%, of which 12.50% (7 cases) are geographically located in North America (United States - Canada), 33.93% (19 cases) are located in South America, the remaining is distributed in the collaborations between North America with the Asian continent 1.79% (1 case), likewise North America with the European continent 1.79% (1 case). followed by the European continent with 23.21%, with a lower percentage, the Asian continent with 19.64% and finally the African continent with 3.57%. The language in which the articles were written was also taken into account, where English predominated with 73.21%, followed by Spanish with 23.21% and, to a lesser extent, Portuguese with 3.57%. The inclusion criteria for this article are: articles indexed or approved in scientific journals, time of publication no longer than 10 years, with a very low exception. Degree works not exceeding 10% of the total number of references. Finally, a list of the time period of publication of these articles can be seen in Figure 1.



Number of articles published per year

From the above Graph it is observed that the year with the highest flow of publications (8publications) was made in 2018, for a percentage of 14.5% followed by 2016 and 2014 with 7 publications each, for a percentage of 12.7%, then there is 2015 and 2010 with 6 publications each, for a percentage of 10.90% respectively, followed is 2019 and 2012 with 5 publications each, for a percentage of 9,1% , followed by 2017 with 4 publications, for a percentage of 7.27%, followed by 2013,2011,2009 with 2 publications each, for a percentage of 3.64% respectively and lastly 2008 , which together with 2009 are exceptions of the range established for the selection of articles, such that they represent an almost insignificant percentage 1.81% and the current year with no publications 0%.

Results

In this chapter, the components that are considered relevant in the development and solution of the problem of localization and relocation in ambulance bases and ambulances are presented. In order to determine the approach proposed in this article, first, an exhaustive research on the subject is carried out. In this research, it was decided to carry out a comparative analysis with other articles of the same type, in order to determine the contribution to be made. Among the findings are: Alma K. rodríguez [10]takes into account nine (9) factors in the study, in which she describes the process, factors that influence the design of the proposed models, solution methods, performance measures, aspects related to data collection, verification techniques and validation of the models and relocation policies. On the other hand, Oscar Para presents an approach based on ESVS (emergency service vehicle system), where he describes the operation and modeling of ESVS, details some implementation models, performs an approach based on queuing theory, mentions some heuristic techniques and simulation models, and performs a literature review of other articles. Meryam Benabdouallah, makes a classification of hedging models into 3 classes, and presents several relevant parameters for the simulation of hedging models. Based on these findings, the focus of this article is determined, which presents a differentiating factor with each of the previously mentioned. A time window no longer than the last 10 years is established in order to generate a current and valid contribution to the literature. The development of this article is divided into 5 sections that have a relevant influence on Emergency Medical Systems; the following components are analyzed: development methodologies used in the different projects (section 3.1), variables involved in these methodologies (section 3.2), performance measures (section 3.3), tools and software implemented for development (section 3.4) and new technologies implemented (section 3.5).

3.1 Development Methodologies. For the study and development of localization and relocation of ambulance and ambulance bases, many methodologies proposed by different authors have been implemented, many of them agree on the use of some of them, others differ from the previous ones and agree among others, and others decide to propose and design their own methodology for the development of the problem in question. Within these methodologies we find the application of heuristics, meta heuristics, algorithms of different types, mathematical models, simulation models, even statistical methodologies as support for the development, or otherwise the mixture of several of the above mentioned to find a better optimization solution in the proposed events. By means of the exhaustive review of the literature, it is possible to identify the most concurrent methodologies among the consulted authors, next, each one of them will be detailed in a brief and complete way.

Simulation. According to H. maisel and G. Gnugnoli, it is a numerical technique for performing experiments on a digital computer. These experiments involve certain types of mathematical and logical models that describe the behavior of business, economic, social, biological, physical or chemical systems over long periods of time. The most appropriate definition for the context is selected. This methodology was the common denominator in many of the references in this article.

Local search algorithm. When speaking of the local search algorithm, reference is made to a basic heuristic methodology that allows the optimization of the processes to be developed by means of mathematical modeling. It basically consists of searching for the best solution within its neighborhood, and repeating the process until the search process can no longer be continued, which means that the best possible solution has been found. This methodology has also been one of the common denominators in the references in this article.

Maximum Expected Covering Location Problem (MEXCLP). Maximum Expected Coverage Problem, according to Daskin, is an optimization model that allows maximizing the covered demand weighted by the availability of the service. This is calculated through the global estimation of the average occupancy level for each ambulance.

Set Covering Location Problem (SCLP). Set Covering Location Problem, as in the previous model. (MEXCLP), is an optimization model that allows the development of the subject under discussion, since its purpose, according to toregas, is to minimize the number of servers needed to fully cover the demand in a given region.

These aforementioned methodologies were the common denominator and the most common in the literature consulted. The categorization of each and every one of the methodologies used for the development of this article is shown below (**Table 1)**.

Table 1. Summary table of grouping of implemented methodologies.

METHODOLOGY	TYPE	OBJECTIVE
Simulation	Discrete Events validate performance measures	
	Monte Carlo discrete events	generate random variables according to the corresponding probability distribution.
Heuristics	Dispatch algorithm	ambulance assignment
	artificial bee colony (ABC) algorithm	optimizing the location of the mobile ambulance station and vehicle repositioning
	Clustering algorithm	Assign medical emergency calls to network nodes.
Meta heuristics	local search algorithms	locate and identify neighborhoods
	exchange algorithm	complement the search algorithm
	Genetic Algorithm	generate high quality solutions to optimize
	Ant Colony Optimization (ACO)	solve computational problems that can search for the best paths or routes in graphs.
	Variable Neighborhood Search (VNS)	Generate solutions to combinatorial optimization problems.
	Tabu Search (TS)	Improves the local search algorithm by using a memory to record the recently examined solution.
Optimization models or methods	maximum expected coverage location models (MEXCLP).	maximizes the covered demand weighted by the availability of the service.
	set covering location problem (SCLP)	searches among the possible optimal MEXCLP alternatives for the one that uses the fewest number of ambulance dispatch bases. And determines the location of the bases.
	p-median model.	optimize the location of the APH system ambulances in the calls for admission to the UNAM.
	integer linear programming (ILP)	evaluate the performance of the chosen solution.
	mixed linear programming	locate heterogeneous fleet vehicles
	mixed integer nonlinear programming (MINLP)	Considering continuous variables and nonlinear problems
	programming algorithm	Decision-making for patient transfer transfer of a patient
	modified double standard (DMS)	maximize covered demand points
	Free distribution model	stochastic ambulance location
	Approximate dynamic programming (ADP)	Solve the markov type problem posed
	Spatial Queuing Theory (Hypercube Model)	analyzing and planning EDCs
	Enumerative algorithm	determines the optimum reliability in terms of base placement
	Tandem Equipment Allocation Model (TEAM)	considers two extra variables for vehicle types.

METHODOLOGY	TYPE	OBJECTIVE
	Facility Location Equipment Emplalcement Technique (FLEET)	select the location of the stations, together with the selection of the vehicles to be assigned in the defined facilities.
	dynamic vehicle routing with time window (DVRPTW)	maximize the satisfaction of dynamic requirements within established lead times
	Diamond covering	Ensure coverage that does not exceed the maximum time allowed.
	P-centers	minimize the distance between the demand point and the service point
	MALP (I-II)	maximize population coverage within one available ambulance
	upper-bound unavailability location (UBUL)	Extension to complement the LSCP model
	Dynamic Relocation Problem (DRPt)	maximize demand points and minimize vehicle relocation costs.
	Maximum Expected Performance Location Problem for Heterogeneous Regions (MEPLPHR)	Determine the location of ambulance stations and the assignment of ambulances to stations.
	Strategic and Tactical Integrated Model (STIM)	provide a tool for combining strategic and tactical location planning
	Minimum P-envy location problem (MPELP)	balance customers' perceptions of fairness.
	dynamic available coverage location model (DACL)	determine the minimum number of vehicles required to ensure coverage of each demand area
	Maximal Expected Coverage Relocation Problem (MECRP)	maximize covered demand through dynamic relocation for vehicle waiting sites.
	Maximal Coverage Location Model (MCLM)	maximizing the population or the number of demand nodes covered with a limited number of stations
	Backup Double Covering Model (BDCM)	propose a backup station to provide another alternative where the ambulance closest to the nodes is busy.
	Maximum Service Restricted Set Covering Location Model (MSRSCLM)	Improved version of the MCLM model
	Centralized Final Ratio Model (CFRM)	ensure as far as possible that the number of times a node is covered is proportional to the population of each demand point.
statistics and probabilistics	Analysis of variance (ANOVA)	test the equality of service times.
	SMDP (semi , markov desicion problem)	Discrete event modeling
	Kolmorov-Smirnov test	determines the goodness of fit of two probability distributions to each other.
	wilkoxon test	examine the mean or median of a single

METHODOLOGY	TYPE	OBJECTIVE
		population
	Mann-Whitney-Wilcoxon test	examining non-normal distributions
	Bootstrapping	compare estimated standard errors, confidence intervals and hypothesis testing
	Pareto Domain	analyze the relationship between two conflicting objectives.
	shapiro wilk	test the normality of a data set (null hypothesis).

As can be seen in the result of the review of the state of the art, it is identified that several authors resorted to several specific methodologies, in turn it is also observed that although authors agree on certain methodologies, the complete development of each one may vary according to the approach. This allows concluding that for the development of a problem of localization, relocation, or optimization in the emergency medical systems of any country, the use or implementation of a single methodology is not a restriction, much less a particular set of the same, since this depends on the approach or need of the researcher. Given the opportunity to solve problems from different criteria, an advantage is identified because it allows critical or strategic decision makers to have several alternatives to evaluate, before making any decision that generates a great impact, either in the service or in the investment costs of the entity providing the service.

It should be clarified that the methodologies classified in **Table 1** as statistical, do not solve the problem of localization and relocation, they play an important and complementary role, their function is the analysis of data, and such data are input parameters for the implementation of another methodology, so they are considered relevant for inclusion and classification.

3.2 Variables involved in the development methodologies. In this section a classification is made of the variables considered in the methodologies presented above; the great majority are based on mathematical models, mathematical programming, and mathematical modeling for the simulation of discrete events; which means that all or most of them have a scientific-mathematical process involved. For this reason it is considered important to determine these variables since they are the ones that allow providing a solution to the proposed problem situation, and are the ones that determine whether the project objective is met, is not met, is feasible or not feasible, whether or not there was an optimization in the development of the selected methodology. Next, the variables are mentioned and defined in detail, according to the approach given throughout the literature review.

Zone of demands or bases. This variable refers directly to the location and location of the ambulance bases, where the exact location is estimated to be determined. It is called demand zone because it will be the specific location of the base to meet the demand of a given area.

Number of ambulances per base. This variable is directly related to the demand zone or base; they complement each other to fulfill the purpose of the objective function. The former determines the exact optimal location of the ambulance bases to meet the demand, and the latter determines the number of vehicles required to meet the demand in the previously determined area, according to the location point.

Types of ambulance. This variable is limited to certain investigations where it has been considered. It is established as an important variable in the literature review, because its use makes the mathematical model a little more complex and at the same time more precise, since its use suggests the existence of several types of ambulance that, according to the need of the event, determines which one can optimally cover the situation.

The variables mentioned above are not all those considered within the development models and methodologies; their relevance is considered at the discretion of the authors. The following is a list of the variables found in the review of the state of the art for the references included in this document. **Table 2.**

3.3 Performance Measures. This section analyzes the performance measures, which are the product or object of optimization in the system. Performance indicators are instruments that provide quantitative information on the performance and achievements of an institution, program, activity or project in favor of the population or object of its intervention, within the framework of its strategic objectives and mission. Performance indicators establish a relationship between two or more variables, which, when compared with previous periods, similar products or established goals, allow inferences to be made about the progress and achievements of the institutions and/or programs.

In emergency medical systems, performance measures must be very accurate and as optimal as possible. This statement is made based on the literature reviewed, since the vast majority of these performance measures or indicators are based on patient care, directly or indirectly the objective is to provide the best possible service, decrease the mortality rate, increase the number of calls attended, increase coverage, decrease response times, among others. A more complete and detailed analysis of the performance measures that the authors considered in their research.

Table 2. Summary table of grouping of Variables

Variables
Demand zones or bases
Number of bases
Number of ambulances in the system
Number of ambulances per base
Distance between demand point and location
Ambulance types
Availability of ambulances
Ambulance status
Patient's condition
Ambulance location
Total service time
Service capacity
Travel time from location to demand or response time
Ambulance speed
Travel time from demand to hospital or evacuation time
Vehicle dwell time at the event or scene time
Attendance time
Ambulance relocation
Vehicle relocation time

From this detailed analysis of the literature according to the variables that interfere in the systems, models and methodologies, it can be seen that there are many more variables that are taken into consideration when solving the problem. Several of these variables complement each other forming a set of variables with which we can obtain a performance measure. Some of these can be quickly identified when talking about location and relocation, such as base locations, number of bases, number of vehicles and more; at the same time, there are uncommon variables, such as patient condition, ambulance condition, and ambulance speed. The latter is usually confused with an input parameter in the models, but from the approach of the authors proposed, it is understood that it is directly related to the response time and to the decrease in the mortality rate, which is the performance measure.

It can be seen that unlike the previous tables the performance measures are not so variable, this is because the purpose of the service will always be optimization, regardless of the methodology used, the variables that interfere, and tools that are chosen. Based on this statement, it is illustrated and deduced that approximately 48% (Mortality rate 16% + response time 32%), both indicators are added together since, as mentioned above and reaffirmed by the above, the response time is the same for both indicators. [7] reaffirms it, response time and mortality rate are directly proportional related. In the authors' opinion, this is one of the most important indicators, or even the most relevant, since it is presented as a function of life in human beings.

3.4 Computational tools (software) implemented. This section presents the computational tools or software found in the literature review, currently considered important and necessary for the development of a problem in question that requires mathematical models. This is due, according to the complexity of many of the models or methodologies established in **Table 1**, and the amount of variables **table 2** that influence these models, bringing with it a range of advantages in its use and implementation such as: it *offers an optimal solution, the execution times are much lower than without these tools, it has a fairly high effectiveness.* They are considered relevant for the development of this article, since it allows to make a contribution to the literature by biasing the search for software according to the need or focus of the methodology to be implemented, making it clearer and more specific. The following is the list of software according to their function. This result can be seen in **Table 4.**

3.5 Implementation of New Technologies. This section identifies and analyzes the new technologies implemented in the development of the projects investigated. After the respective literature review, quite interesting technologies were found, which deserve to be highlighted and suggested for future works. Considering the concept of new technologies refers to tools (software and hardware) that are part of the forefront in technology, among the findings we can find the development of new applications based on other existing applications such as the wide range of options offered by Google for developers. Next, these technologies are mentioned and highlighted and finally a contribution exposing a case of a current project in the Middle East.

Among the particular cases found is the case of García M, where two tools mentioned in **Table 4** (Visual Basic + Google APIS) are used to program a complementary application to determine the distance parameters and travel times between the parking nodes (or service dispatch) and the medical emergency demand nodes.

Another particular case is Roa J, where he uses software and hardware for the implementation of his project. Among the tools used are Garmin devices for each vehicle, GPS devices with sim card and data for geolocation. Different application cases are presented to verify the operation of the tools and the implemented programming. It is evident that the results obtained do not differ significantly from the expected results.

Finally emphasizing these findings of the technological implementation (software, hardware), for the development of the problem of localization and relocation. It is suggested for future works to make use of such tools, in order to use real time data for the solution of the different models implemented. In the authors' opinion, it is important to standardize the use of these tools, aiming at the improvement of medical systems, taking advantage of the technological revolution 4.0, this technological development is already being developed in Middle Eastern countries, a clear example is Abu Dhabi, in the United Arab Emirates, where the first steps are being planned and taken for the development of the project called "Smart cities". This basically consists of the technification of a complete city, including different entities (banks, hospitals, schools, traffic) and others, providing real-time data on vehicular traffic, traffic (queue) in the different entities mentioned above, for the more specific case of location and relocation, the targeting of Smart cities, would complement the medical assistance service, reducing care times, dispatch times (leaving the patient at the hospital), even determining whether the hospital to which the patient intends to go, is the appropriate one according to the emergency queue at the time of the event, thus being able to determine a second option, all this in favor of reducing mortality in patients, as a result of lost time in transfer, or delay in arrival at the point of demand.

Table 3. Summary table of software grouping and classification

SOFTWARE	USO	% OF PARTICIPATION
ARENA	discrete event simulation	6,25%
ServiceModel-promodel		0,89%
Visual Basic for Excel		4,46%
flexim expertfit		0,89%
Simul8		0,89%
Stochastic simulation in java (SSJ)		0,89%
RngStream		0,89%
BARTSIM		0,89%
IBM ILOG CPLEX Optimization Studio	optimization tool	15,18%
FICO Xpress Optimizer		3,57%
Ampl		1,78%
LINGO optimizer		1,78%
Matlab		4,46%
Excel		3,57%
gusek application		0,89%
solver Gurobi		2,68%
General algebraic modeling system (GAMS)		0,89%
Sim OPT		0,89%
LAPACK		0,89%
Counterpart Robust (CR)		0,89%
java	programming language	8,03%
Python		3,57%
C++		5,35%
Pascal		0,89%
Unified Modeling (UML)		0,89%
C#		0,89%
Mosel		0,89%
ArcGIS	geographic information system (GIS)	6,25%
Google Maps version 3		5,35%
Google Earth		2,68%
google APIS		0,89%
Baidu API		1,78%
TransCAD 5.0		0,89%
Universal Transverse Mercator (UTM)		0,89%

SOFTWARE	USO	% OF PARTICIPATION
SAS	Statistical data analysis	0,89%
BestFit		1,78%
R		2,68%
SPSS		1,78%
SOS2		0,89%

In this table we can see a consolidation of the software used for the development of the different projects, categorized according to their application. According to the data obtained, simulation software has a 16.05% of use, optimization software or tools have a 37.47% of use, highlighting CPLEX software as the most used with 15.18%, in the programming languages category it obtained a 20.51% of participation, being JAVA the most representative, Geographic information systems have a 19.62% share, and finally, statistical tools, which in the same way that statistical methodologies serve as support for data collection and analysis within the process, have an 8.02% share. It is suggested for future work to increase the percentage of participation in geographic information systems.

Discussion

The results obtained in the review of the literature proposed for this article determine that for the study of location and relocation of ambulances it is essential, in terms of resources, to resort to the literature and scientific application, through the different methodologies mentioned here. In these findings it is determined that 59.20% alludes to the optimization models (see table 1) for the solution of this problem, on the other hand, the main variables that are determined for the location and relocation of ambulances, are the location of the bases, the number of vehicles per base, and the type of vehicle, with a percentage of participation of 17.42%, 14.20%, 9.70% respectively, which reiterates again that these are the main concerns when working on this issue. The performance measures, in relation to other research, it is evident that the objective is the same, to optimize to the greatest degree the emergency medical service, reducing response times, the mortality rate, and increasing the response to the demand, even this statement is not only reiterated in the articles cited, but in all the literature consulted.

Among the findings found in the literature review, Table 4 shows software and technological tools to support the development of these models implemented throughout the research. It agrees and at the same time it differs with the other review articles, since for the present one a restriction of the last 10 years is handled, which allows us to identify that the other authors have covered a wider time window, but nevertheless it is evidenced at the same time that the tools used do not present such a wide variation.

Finally, as a contribution of this article, chapter 3.5 implementation of new technologies is presented, as its name indicates, it analyzes the implementation of different or innovative technologies in the development of these projects, in the literature review it is found that a minimum percentage presents this feature, so they are highlighted and shown in detail in their respective chapter. Based on these findings, it is determined that it is a differentiating factor for the research and an interesting contribution in the literature, since, with the technological advances in the world, including the fourth technological revolution (industries 4.0), within which technology 4.0 is part of, it is important to go into the subject little by little, and go addressing related research, in order to determine how technology 4.0, and industries 4.0 can be coupled to the optimization of medical emergency service at national and international level.

Conclusions

This article reviews the literature related to the topic of optimization in the emergency medical service (EMS) through the location and relocation of ambulance bases and ambulances. Initially, a review of the literature acquired for the development of this paper is carried out in order to identify the points discussed in them, and subsequently determine through an analysis of the relevant points of the process and the possible methods of solution and all its components.

This work identifies the development methodologies, the required mathematical models and the variables that compose them. At the same time, the performance measures are taken into account, these three points are common denominator in the researches consulted. In addition to this, it was decided to include technological tools required to carry out the development and new technologies implemented.

As a result of the literature study, Table 1 consolidation matrix of methodologies, Table 2 consolidation matrix of intervening variables, Table 3 consolidation matrix of performance measures, and Table 4 consolidation matrix of software used are obtained. Each table yields its corresponding data reading, but in general the research concludes that each system must be considered as unique and different, that there is no standard methodology to solve the problems of localization and relocation, this can be verified in table 1, since a large number of different methodologies are shown for the particular development of the problem, in X city. Although many of the authors agree on the use of the methodology, the complete development is not the same, since it is taken into account that the methodologies can complement each other according to the objective or need of the researcher. What for one system is apparently positive, for another may be counterproductive, depending on the current state of the problem.

This review allows us to identify the main objective of most of the studies, which is to maximize the covered demand, in other words, to increase the response capacity or the number of events successfully attended. Another of the models found for the same purpose is the Modified Double Standard Model (DMS), whose objective is to maximize the number of covered demand points.

Among the development methodologies is the simulation of discrete events presented in 17 of 55 referenced cases, which is equivalent to 31% of participation, at the same time they resort to Meta heuristics such as local search algorithms, which are used for localization, are presented in 7 of 55 referenced cases, which is equivalent to 12.73% of participation and finally the statistical methodologies, as mentioned above, these methodologies do not solve the problem of localization and relocation, but are a complement and support for data analysis, which when complemented with another methodology, become input parameters, the most representative is the Analysis Of Variance (ANOVA), which is presented in 6 of 55 referenced cases, equivalent to 11% of participation.

The performance measures identified and included in this article are not as variable depending on the number of methodologies available. Since the objective of the emergency medical system is to optimize the process and the service, in terms of the users, the most relevant performance measure is response times, in terms of the service providers, the performance measure is costs, and in terms of both entities, the performance measure is the mortality rate, which in the authors' opinion is the most relevant.

This review allows identifying the optimization computational tools to develop the methods and mathematical models proposed throughout each project, in which Table 4 is obtained as a product, where we can observe the categorization of the different software implemented according to their function, it is evident and it is concluded that the software, as well as the methodology, is variable, and is defined according to the need and criteria of the researcher, is variable, and is defined according to the need and criteria of the researcher, however, some are more common than others, for example for simulation ARENA and visual Basic, as optimization tools, the most notable is CPLEX, as JAVA programming language, statistical tools are included as support in the data analysis, the most significant was R. Last but not least, GIS and GPS, geographic information systems, with a participation of 16 out of 55 referenced cases with a percentage of 29.01%, the most representative being ArcGIS and Google Maps.

Finally, it is recommended for future research to increase the percentage of participation of geographic information tools (GIS, GPS), since they allow obtaining data in real time, such as distances traveled, travel speed, travel time, among others, which are input parameters for the realization of a mathematical model, which makes it more accurate. Its use also allows technological progress in the system, and not lagging behind in the new technological revolution (4.0 technologies).

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