

Índice de Saturación Modificado y Ambulancias (ISMA): Ambulance assignment and remote Emergency Room Bed Reservation

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Abstract

Introduction: In most places all over the world –including our country– services in emergency rooms are oversaturated. This situation frequently forces the continuously arriving ambulances to be redirected to other medical units, delaying the admission of patients moved and thus adversely affecting their physical condition. **Objective:** To introduce an improvement to the Índice de Saturación Modificado computational system, which monitors the degree of saturation of a network of emergency medical services, to include a network of ambulances, enabling in the system: (i) the effective allocation of ambulances to the site of the accident, or severe clinical event, and (ii) the remote booking of beds in the nearest and least saturated emergency room available. **Material and Methods:** The evaluation and connectivity of the computational improvement to the Índice de Saturación Modificado system was carried out with a computational test verifying these two aspects, using only differences in postal codes, for time measuring. **Results:** The verification of its sustainability online showed the new Índice de Saturación Modificado y Ambulancias system (ISMA) has a robust structure capable of being adapted to mobile phones, laptops or tablets, and can efficiently administrate: (i) the quantification of excessive demand in the emergency room services of a hospital network, (ii) the allocation of ambulances attending the site of the event or contingency, and (iii) the allocation of ambulances and patients, in the best distance-time conditions, from the site of the accident or clinical event to the nearest and least saturated emergency room service. **Conclusions:** This administrative management tool is efficient and simple to use, and it optimally relates independent service networks. (Gac Med Mex. 2015;151:293-6)

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Introduction

In most parts of the world, including our country, Medical Emergency Departments are oversaturated. This situation frequently forces for ambulances continuously arriving to the Emergency Department to be

redirected to other medical units, which delays the admission of transported patients and unfavorably impacts on their evolution. For these reasons, this is considered a specific quality indicator of Emergency Departments. One factor that aggravates this situation¹⁻³ is unplanned arrival of ambulances with seriously ill or injured patients. Other phenomenon related to these

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events is the unnecessary arrival of two or more ambulances to the accident site, which results in other seriously ill patients' programmed transportation not to be done on time, or in ambulance services not being available to carry out other planned or urgent transportations.

Since from the clinical point of view, a seriously ill patient can be clinically "stable" or "unstable" (in critical state), ambulances for transportation must have high technology equipment and medical and/or paramedical personnel trained to provide pre-hospital care at the site of the event (accident or serious clinical event) and offer advanced pharmacological and/or electromechanical life support on the way to the hospital.

Although it is impossible for an accident to be predicted, with current telecommunication media, a network to connect and manage services can be built based on two computer-based networks: the ambulance network and the Emergency Medical Services network. This link would enable *in situ*, real-time communication of these networks, thus improving ambulance assignment and increasing the likelihood of first transportation of the patient being final and for the patient to receive medical care opportunely.

To this end, we connected the computer system named ISM⁴, which focuses on the measurement of Emergency Medical Services oversaturation in a network of hospitals, with a network of ambulances. This new system considers bed reservations⁵ at the Medical Emergency Department that is closer to the place of accident or serious clinical event, after automatic designation of the ambulance that must attend the place of accident. We have named this new system ISMA and, similar to the ISM, it is offered for use free of charge.

The ISMA system is basically a manager of services between two computer-based networks: ambulances and Emergency Medical Services. It makes use of the ISM system algorithms for availability of useful beds and authorizes medical and paramedical crew of the assigned ambulance to make a reservation of a useful bed at the nearest and/or least saturated Emergency Department from the very place of accident or catastrophic clinical event. Additionally, it administers the assignment of ambulances to be sent to the zone of the event according to geographic closeness and availability.

The ISMA system is a tool that answers in real time and is available from any computer, or else can be adapted to be consulted from any mobile telephone, laptop or tablet. It doesn't require licences or special software requirements, since its algorithms consider only the difference between the postal codes corresponding to the accident site and ambulance location, as an

approximate measurement for time of arrival estimate. Its simplicity makes it easy to understand and provides a detailed overview on overdemand variables at the appointed Medical Emergency Departments, with the assignment of ambulances for the care of critically ill patients being added, as well as temporary reservation of useful beds at the closest Emergency Departments. The ISMA passed the computational tests successfully.

Material and methods

The ISMA system is a computer-based mathematical method that includes the metrics of the already published ISM system⁴, and that now allows for the management of information on the ambulance network.

The ISMA system

Ambulance assignment

The system selects, within the appointed ambulances network, the available ambulance closest to the site of the event, and assigns it to go to this place. Simultaneously, it calculates the approximate time of arrival of the ambulance from its initial location to the accident site using the following algorithm:

$$\text{Ambulance time of arrival (in minutes)} = \frac{([\text{ambulance location postal code}] - [\text{accident site postal code}]) \times (750 \times 0.002000)}{\text{Where 750 is considered to be the average distance between postal codes and 0.002000 represents the multiplicative inverse of the ambulance average speed (30 km/h) expressed in meters per minute.}}$$

The ambulance assignment is carried out depending on closeness and availability, since the ISMA system assesses with the above algorithm all the ambulances appointed to the network, in order to ultimately assign the ambulance with the lowest estimated time of arrival. Once assigned, it is asked for confirmation to set out towards the accident site.

Reservation at the Emergency Department

The ambulance that has been assigned to the site of accident or serious clinical event is able to reserve a useful bed at the Emergency Department that is closest to the accident site, since the ISMA system calculates the approximate time of arrival of the ambulance from the accident site to the Emergency Department with the following algorithm:

Table 1. Description of the fields the ISMA system shows to the user immediately after each update

no.	Description	Definition
1	Ambulance location Site of accident or serious clinical event	Postal code of the place where the ambulance is located Postal code of the accident site
2	Ambulance	Ambulance ID
3	Condition of the seriously ill/injured patient	Assignment according to colors: [R]ed: unstable [Y]ellow: stable
4	Age	Approximate age of the injured person
5	Gender	Male or female
6	Site of the accident (postal code)	Accident site postal code

$$\text{Time of arrival to the Emergency Department (in minutes)} = \frac{([\text{Emergency Department postal code}] - [\text{accident site postal code}]) \times (750 \times 0.002000)}{750}$$

Where 750 is considered to be the average distance (in meters) between postal codes and 0.002000 represents the multiplicative inverse of the ambulance average speed (30 km/h), expressed in meters per minute.

The ISMA system evaluates all Emergency Departments appointed to the network with this algorithm and recommends that with the shortest time of arrival, while asking the Emergency Department for confirmation accepting or not the ambulance's reservation.

The ISMA system: retrospective analysis

The ISMA system shows the oversaturation variables of the ISM computer-based system in real time³, as well as the following (Table 1):

- Accident or serious clinical event
- Ambulance assigned by the system to go to the accident site and approximate time of arrival to the Emergency Department where a useful bed has been "reserved" by the physicians and/or paramedics of the ambulance.

Since the ISMA system shows only the latest variable variations, all modifications to these variables are stored in a "historical" file to allow for a retrospective analysis to be carried out anytime by means of Time Series. This will allow for time variations by each hospital unit to be observed.

The ISMA system: testing

Verification of the ISMA system was strictly computational and did not include any type of exhaustive or random test. Individual tests focused on two aspects:

- Ambulance assignment.
- Reservation of useful beds at the Emergency Department.

The nature of the changes that gave way to the ISMA system does not, according to the authors' judgement, require other type of tests, since the improvements are strictly computational and in this sense were they verified; this observation is discussed later.

The ISMA system: connectivity

The ISMA system has been developed for a portable computer platform with remote connection via port 22, protected against non-human attacks (from other computers); its time-distance metrics for ambulances and Emergency Departments assignment and reservation are based on postal codes, and the design of the system is of the modular-structured type, so its conversion to mobile telephones, laptops and tablets with Android OS operative system⁶ and location via GPS⁷ is simple, though laborious.

Results

The system did not show any error in the computational tests, which considered: transaction traffic between Emergency Departments, ambulance sites relocation, assignment of ambulances to accidents and reservation of beds at Medical Emergency Departments from the ambulances.

Discussion

Although the multiple and varied factors that determine Medical Emergency Departments oversaturation originate in different parts of the health sector, from the medical and administrative point of view, it is useful to analyze the problem with a functional focus from the

perspective of the Medical Emergency Department itself, since this offers a reference framework that allows for a systematic understanding of the problems we are facing. In this sense, we consider the ISMA system to be a useful complement since it combines two fundamental networks in the care of seriously ill and/or injured patients: ambulances and Emergency Departments. Its versatility allows for the user to decide, according to his/her needs, to use only one of them; if he/she decides to use only the ISM, he/she will be able only to measure oversaturation of his/her Medical Emergency Department, but if the ambulance network is added, it becomes integrated to the system, which will act as a supervisor of the locations of all these units. Even if its use would be intended only to administer accidents or serious clinical events that occur, it would enable, in addition to their recording, an analysis in time and space of accumulation points or occurrence of these incidents.

The ISMA system is a mainly computational improvement and, in this sense, it required *ad hoc* tests that verified the independence between modules, their intercommunication, management of requests coming from ambulances (assignment and reservation), monitoring from the different Emergency Departments and registration of incidents.

To the planning of unexpected incidents (non-programmed events), which are taken care of by the Medical Emergency Services, the fact of working with limited resources has to be added. All of this indicates there is a need to generate local updated and shared information that allows for the occurrence of critical events, such as Medical Emergency Department saturation and the need to redirect ambulances, to be adequately identified, in order to gradually solve the problems with generic applications such as the ISM and the ISMA herein presented. The use of any of both these resources will depend on the needs of each Medical Emergency Department. A more efficient use of available resources is promoted in favor of the users, since by having a "real time" vision of patient flow cycles "alterations", both the physician and administrator will try their best to solve and prevent these events, either by redirecting patient flows, or by modifying processes or correcting anomalies.

With the ISMA, we present an administrative solution intended to prevent or otherwise attenuate the series of problems of redirecting ambulances by means of a program that enables their assignation and at the same time reservation of a bed at the Medical Emergency

Department of the hospital most appropriate to its closeness and degree of saturation.

Conclusions

The addition of the ambulance service to the ISM computer-based system, named ISMA, is a useful device that coadjuvates with organization and administration of the Medical Emergency Department, by allowing for the physician to anticipate the demand of services resulting from programmed and non-programmed (urgent) patient transportation, by assigning ambulances in the best distance-time conditions with regard to the site of accident or serious clinical event and by allowing at the same time for a useful bed to be reserved at the Emergency Department, thus reducing transportation times and the likelihood of ambulance redirection due to oversaturation of the Emergency Department.

Availability

The ISMA system can be used free of charge by request to the e-mail address polanco@unam.mx, for use in personal computers.

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