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Design For An Intelligent Emergency Vehicles Transport System

Pedro Sanchez Caiman[1]*, YessicaVelasquez Castiblanco[2], Raimundo Forradellas[3]

[1]*Faculty of engineering, Industrial Engineering Department, Universidad Militar Nueva Granada, Colombia*
[2]*Faculty of engineering, Industrial Engineering Department, Universidad Militar Nueva Granada, Colombia*
[3]*Faculty of engineering, Universidad Nacional de Cuyo, Argentina*
Corresponding Author: Pedro Sánchez Caiman

ABSTRACT: *Emergency medical services stands for one of the most important worldwide, since it builds up the on-time Incidents resolution. Effective service management enables a complete control over activities and related tasks to life risk scenarios when one or more individuals are involved. On this regard, different sources of information are demanded, in association with incident´s outstanding facts, enabling a real-time decision making.*

This process is tough, since emergencies are associated to dynamic scenarios from a multiple source of variables, where response actions must fit to unforeseen situations or even uncertainty conditions, with harmless to individual lives; with vehicle assignment, available personnel at the highest possible efficiency level. In cities of emergent countries, it´s easy to see 580 daily emergency vehicle transfers approx. On top of that, a Design is advised, which belongs to an Intelligent Emergency Vehicles Transport system, with the aim of improving the transport and transit management, when solving these incidents.

KEYWORDS: *Emergency Medical Services, Information Systems, Intelligent transport system, Logical Subsystem, Emergency Vehicle*

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I. INTRODUCTION

Emergency vehicles management represents one of the most relevant facts in Health Services provisioning, since it constitutes a fraction in reducing mortality and morbidity rate in population. On top of that, since the Incident response time might stand for the difference between ensuring patient´s life or death, as well as potential future consequences. This kind of scenarios have been globally analyzeddue to its high level of complexity in reaching out an adequate resource management, since emergency systems are dynamic.

Well-timed and efficient support to population in urgency situations, emergencies and disasters, constitutes the mission of the so-called urgency and emergency bureau. Based on the influence of the well-timed reaction in patient´s lives. Nevertheless, the overall performance of the cities in regard to those ones with global acknowledgement, thanks to its efficiency, less than a 35 % of coverage can be seen based on the total amount of available ambulances per citizen (Huertas, Barrera, Velasco, & Amaya, 2008).It is considered that, in Latin-American Cities, less than 1 % of total emergency service calls require a true ambulance service; Nevertheless, the 15-min in-place service delivery has not been reached out. In addition, emergency vehicles location is a manual process, with the lack of Information Systems which might enable the resources optimization; considering prioritization levels, as per the healthiness risk of the injured population. Furthermore, relocation process is not consideredfrom an optimization perspective within the entity´s actions.It´s possible to get acquainted that, highest obstacles obey to the resource retention, vehicles fleet, traffic, and transport management, considering the latter as the one with the highest level of saturation of arguments, since it is associated to the wrong zones' distribution, inefficient assignment processes, location and relocation lack of Information Technological tools as well as real-time data.

Intelligent transport systems have been globally deployed, mitigating this kind of issues (ITS - English Acronym), which lately enable electronics tech usage, ensuring the continuous information flow, among vehicles and control centers; Reducing response time in case of accident, by using the traffic enforcement control and validating access paths. (Martínez, Toh, Cano, Calafate, & Manzoni, 2010). In addition, due to the lack of an efficient system for sanitary transport, an adequate design is mandatory to reduce the potential causes formerly described, as well as increasing the coverage rate. The most important goal to increasing the efficiency in associated operations is built on the design of an ITS for emergency vehicles, built upon the conditions and limitations of the cities. In consequence, a design for an Intelligent transport system is required, which enables real-time decisions making, supporting the emergencies management in the city, considering the transport, traffic and available resources. Similarly, an increase in available resource usage efficiency is mandatory, restricted to the infrastructure and the urgency variables. This latter, allowing time saving when reaching out the incident location, as well as the total time of resources usage, increasing the overall coverage level.

II. EMERGENCY MEDICAL SERVICES

It was 1977, when Emergency Medical Services (EMS) started being analyzed, in that year, ambulance location issue arises. Since the event different mathematical models haven been boarded, acting as strategies to increasing the level of efficiency in systems supporting the resolution of emergencies. Emergency management process associated to the transport management consists of five steps to know. Firstly, an emergency call is received, Incident classification is done, and an ambulance is dispatched to the required location if needed. Once the ambulance gets there, first aid is provided, and patient is transported to a Medical Facility if required, ending-up the transport related service delivery.Extensively, in first place, vehicles location and relocation issues are derived, this latter based on the incidents occurred. Later, dispatching and routing is determined as per the service entity policies, followed by the interaction with the National Health Service (other health service systems). Finally, an evaluation or assessment on the effectiveness and efficiency and is required. In addition, an assertive forecast on the demand is needed with the aim of the ensuring the proper management, which will sure enable determining the required resources for an adequate coverage, as well as the workforce needed; considering practitioners, paramedics, and nurses principally on these.(Aringhieri, Bruni, Khodaparasti, & Essen, 2017). Some researchesshowed a set of researches about ambulance dispatching; as well as their location and relocation issues. Through this investigation, several deficiencies and resource over-utilization. In addition, a programming model based on searching algorithm "Tabú" was deployed in software "Xpress Professional". Similarly, Geo-location systems implementation is advised for future deployments, which will enable real-time solutions delivery. (Huertas, Barrera , Velasco, & Amaya, 2008)y(Céspedes, Amaya , & Velasco , 2008)

III. INTELLIGENT TRANSPORT SYSTEM

ITS were born in parallel to the development of Highway systems for intelligent vehicles – IVHS (English Acronym). However, investigators like Kan Chen y Bob Ervin established an expansion for this topic, commonly known as ITS. These refer to a scientific and engineering discipline, focused on reducing at its possible level the total passenger´s transit time as well as the arranged wares in vehicles. In addition, these enable the vehicle to be exactly addressed by its status, plus calculating the shortest and most efficient path. (Ghosh & Lee, 2010)y(Dong & Paty, 2011). In the same way, ITS in Latin America are defined as "A sub-set of technological solutions, Computing and Telco, which gather, store, process and give out information, required to be designed to improving the operation, management and security in transport and transit".The key to successful solutions and complex transport problems in this kind of systems, come out from a global algorithm compression and coordination. Then it supplies relevant and precise information in a timely manner, enabling alternative decisions

The main features which encompasses an ITS are: Capacity to supplying exact information (Precise and updated) as well as ensuring control, coordination and management for available resources. Regarding transmission of information, it is pre-conceived that it is present in large volumes, so a cheap and reliable way must be used. Similarly, ensuring greater efficiency in operations must be ensured by using it in a proper and real-time enabled way. (Ghosh & Lee, 2000)y(Sussman, 2005)There are 6 sub-systems which at the same time belong to system components: Physical (Hardware), logical sub-system (Software), communications, data, human, procedural (Laudon & Laudon, 2012) and (Sousa & Oz, 2017). Logical sub-system (Software), refers to a set of instructions written in a specific language, through which, logical sub-system is warned about the tasks to be done and ensures the interaction between the user and the sub-system. It is classified into two groups. Base and Application. Base software takes care about operating Hardware resources and represents the interface between user and machine. Application Software is separately, in charge of performing tasks which add value to the user. Components for each one of these groups as well as description are related in Table 1.

IV. DESIGN FOR AN INTELLIGENT EMERGENCY VEHICLES TRANSPORT SYSTEM

There is an established relationship between an ITS´s structure and an IS, purchased by the development of the ITS architecture in emergency vehicles, considering the base determined in the Theory Framework in both systems, procurement, storing, and give out of information; as support to making decisions.Additional evidences on this conceptualization are established by Sayeg y Charles (Sayeg& Charles, 2017) by determining that "ITS are essentially a fusion between the Computing development, technological information and telecommunications, united to Expert Automobile sector and transport". Similarly, as formerly stated in the Theory Framework, ITS are known by their flexibility, based on the acquisition of exact and real-time-enabled information, as well as their capacity to communicate and process large amounts of information, aimed to gain better results when performing operations. Due to this, Base structure proposed for ITS is related to ITS, deploying the logical sub-system, part of IS.

Table 1. Software components**(Arjonilla & Medina, 2013)**, **(Laudon & Laudon, 2012)**y **(Sousa & Oz, 2017)**

Group	Component	Details
Base Software	Operating system	Performs basic processes, following elementary routines
	Support software for programming	Transforms Computing programs into a binary language
	Utilities	Programs designed to facilitate interaction between users and programming languages
	Software for communications	Enables communication between machine and the outside
Application Software	Vertical Software	Specialized programs in specific enterprise sectors
	Horizontal Software	General Purpose programs

Information systems must comply with the following requirements (Yokota & Weiland, 2017):

- Compatibility: If a component update, associated to *software* or *hardware* is required, the system will work appropriately
- Expansibility: Sometimes, system adjustments are required, perhaps larger amounts of information will be processed by addition either due to new entities or activities. Compatibility requirements is closely related.
- Interoperability: Observed when two systems can cooperate between them, without interfering in each other´s operations
- Integration: Treated when multiple applications are connected into a single system, enabling savings in require resources like time and money. Nevertheless, since its different components must be strictly harmonized, planning and design activities are more complex.
- Standardization: Systems Architecture standards are mandatory, which enable previous requirements in a faster and more secure way.

Logical sub-system contains different modules (components), where the relationship between different elaborated execution stages can be seen, which will be explained with further details in upcoming pages. In Figure 1, there are conventions applied to the proposed Architecture, considering outcome information (Decision Making Support), data, variables (due to their dynamic condition through time) and parameters.

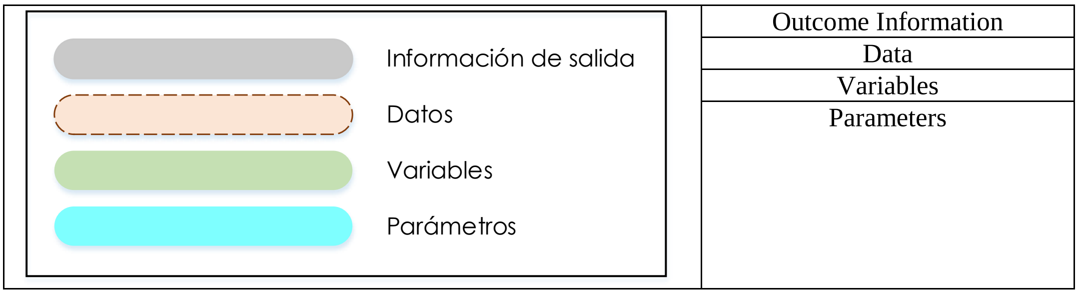


Figure1. ITS Architecture Conventions

Such logical proposed sub-system, defines 6 modules, as stated in Figure 2. These modules have been designed based on the 6 fundamental activities for management and emergency services, which must be programmed with specialized algorithms, according to development requirements, variable interaction and parameters. Each one under the following considerations:

1.1 Location:

The definition for an initial base station which ensures the largest level of coverage within the city, is performed under the consideration of demand points, this is, those geographical points with the highest level of Incidents reported (determined upon previous analysis of the demand); available ambulances and potential location points, associated to potential locations strategically selected.

1.2 Relocation:

Relocation process is not committed if an ambulance is mobilized, based on the associated costs; so, it becomes mandatory a decision to be evaluated either for executing the related relocation or not. This decisionis based upon the relocation cost, penalty coefficient (associated to lack of personnel), work shifts duration and finalization as well as pauses for vehicles crew; since, despite a rapid response is required, human resources can be fatigated, as consequence of the service delivery and the continuous relocation.Just in case a relocation move is allowed, a new base for remaining ambulances is required, so the max number for them is guaranteed. Location and demand points must be considered in this stage, as well as considering the location for every and each ambulance; Once the travel time is calculated based on the traffic conditions and the distance. Having said that, relocation must include contacting the Traffic enforcement Control Centre (It currently operates in the

City), through which a real-time report will be got; as well implementing a GIS, which lately will permit obtaining information by Geographical aid. The current position of the ambulances (as formerly stated), is obtained using a Global Positioning System (GPS) (English Acronym).

4.3 Resource Assignment:

Assignment resource process is initially executed, considering the classification provided by the *Triage*. *Triage* categories are detailed in Table 2. System stores this classification for Incident categories, ensuring a synchronized process just in case a patient requires relocation to a Health Service. On top of that, description and characterization for urgencies and emergencies, *Triage* I and II is known as an emergency status, and III to an urgency. Levels IV and V neither require additional assessment neither nor Hospital Service relocation.

Table 2. *Triage*Categories

Triage	Details
I	Immediate attention is required, once the patient´s clinic condition is in vital risk
II	Patient´s clinic condition might evolve to a rapid degradation or even death. Attention must not go beyond 30 mins.
III	Patient´s clinic condition requires diagnosis and therapy in urgencies.
IV	Patient is in health conditions which neither compromise the overall status nor indicate a life risk.
V	Patient´s clinic condition does not reflect degradation or risk in over status

In addition, Incident´s position must be considered, so the specific ambulance requirements can be met as per the initial service call, and in parallel minimaxing arrival time for the initial assessment, plus, considering current position. Nevertheless, if the Emergency Service is heavy work loaded, queued service calls must be considered, prioritizing the lower category ones previously declared.Ambulance is selected as per availability at certain point in time when assignment is done. This ensures only inactive ambulances to be selected, this is, not in servicing status or under maintenance.If a relocation to a Health Service is required, current capacity and available resources must be assessed. This, having as premise that, according to the Incident, required resources can vary, for instance, specialist doctors, related assessment team,and not all hospitals have spare capacity for specialties.

4.4 Demand Analysis

Demand analysis represents a relevant component within the planning process for emergency service management. To carry out his analysis, historical data associated to date and time of call reception is required, response time, end of call, Incident location, arrival time and exit of the incident, Hospital arrival time, and resource release. With that in hand, demand planning by geographical location is possible, as well as emergency types with the highest system impact, enabling a more accurate work force required. In the same way an averaged travel time can be estimated within the system.

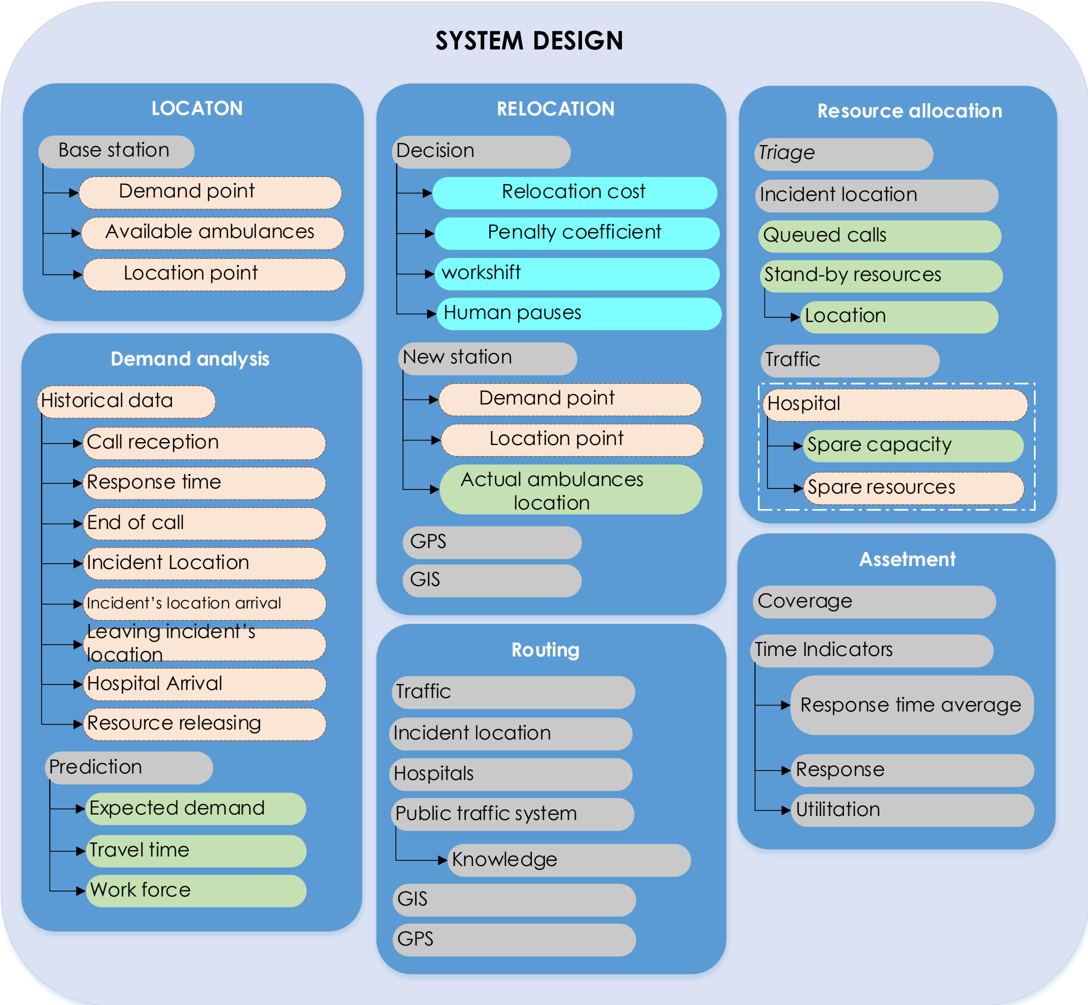
4.5 Routing:

Real-time traffic status is required to determine the ambulance routing, as previously declared, regular communication to the Traffic enforcement control center is required. In contrast, Incident location is needed as well as the Hospital institution, in case a relocation is requested; this constitutes the second stage of the routing process.Considering the chaotic traffic conditions, utilization of exclusive lane of the public transport system is advised as strategy. This option must undergo validation according to the system conditions in Public Transport Service at certain point in time, understanding thatsometimes these lanes show worse traffic conditions than the mixed ones.In the same way, to assign an efficient routing, real-time ambulance position is needed, thanks to the GPS usage and later the GIS.

4.6 Assessment:

This module is intended on the measurement of the emergency system performance, stretched to the service provided by ambulances. For this, level of coverage obtained is needed, as well as time key indicators; this is average in call servicing, response and resource utilization. This assessment can be obtained at the required time, requesting triggering an intelligent report.Strategical decisionsare made at the Control Center using this design architecture, showing two-way data flow to the Traffic enforcement Control Center, ambulances or mobile resources, public transportation operations center, and the patient and allowed hospital institutions for relocation is required.One-way data flow, Control center-bound, comes from the CCTV and floating vehicles, which will report traffic conditions in the City, as well as incidents requiring attention. In reverse way tothe Traffic enforcement Control Center and the ambulances, a data flow will be triggered to the outside, routed to the adaptive semaphore system and hospital institutions, respectively. Ambulances will also get support from the crew and sporadically from the technical team, according to the scheduled maintenance plan per resource.

Figure 2. ITS Logical Sub-system for emergency vehicles



V.

VI. CONCLUSIONS

Emergency medical services – EMS, have been addressed from a variety of qualitative and quantitative models, due to their great impact on securing and saving lives in Incidents, rated as urgencies or emergencies, the latter with greater severity. In addition, these have triggered great motivation in investigators due to their dynamic and complex components. From a generic view, 5 stages have been structured for study, related to location, relocation, dispatching (resources allocation), routing and assessment. Taking into consideration, these 5 stages are supported by the demand analysis and the work force, responsible for delivering outstanding service to patients, since it is the entry point with emergencies management.

Assessment for these systems is established through performance indicators like coverage levels, global average response time, average response time as per the received call category and available resource usage per type.

The proposed architecture for emergency vehicles is associated to IS, which have greatly demonstrated ability treating data and generating information enabling making accurate decisions in certain scenarios. Based on the analogy to the ITS, logical sub-system or *software* architecture was determined. This was characterized according to the identified requirements during the emergency service analysis, mainly focused on transport management and complementary activities; enabling a preliminary solution (considering it is a design) to the problematic faced by large cities in emergent countries.

The integration for this sub-system is extended as a permanent external organization, likewise Traffic enforcement control center. On top of that, the design was elaborated considering the most relevant features of the ITS: compatibility, expansibility, interoperability, integration and standardization.

VII.FUTURE WORKING

As per the initial proposed scope for this work, potential deepening axes have been identified, based on the designed architecture, which are required for its implementation and adequate operation. Nevertheless, it should go further into designing and validating computing algorithms supporting logical processes developed within the proposed architecture. In this way, considering variables, parameters and outcomes of the algorithms, which were determined, it is possible to analyze their structure for location processes, relocation, resource allocation, demand analysis, routing and assessment. It is necessary to highlight that every and each of them deserve an independent study, given the levels of complexity and dynamism.Similarly, determining components and features is required for the remaining 5 sub-systems, ensuring integration between action axes, required to giving solution to the emergency services from the transport perspective.

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