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Emergency Medical Service Information System: the ARES 118 experience

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Parole chiave: *Servizio Sanitario Emergenza, Sistema Informativo, Data Warehouse, Business Intelligence, Cubo*

Abstract

Background. *In this paper we describe ARES 118, the prehospital Emergency Medical Service of the Region Lazio, Italy, focusing on its data system used to populate a data warehouse and to create ad hoc reports. ARES 118 is a regional public mono-specialized health company, established in 2004, that manages the emergency care throughout the Region Lazio.*

Methods. *Being a peculiar company in its kind, and being the first experience of this kind in Italy, ARES 118 has begun to equip itself, in an autonomous way, with a corporate information system, starting from what already existed as data collection from the individual provincial operating Centers and then by activating a unique information system at a regional and company level by deploying a data warehouse. All operations were carried out using open source software.*

Results. *Currently, ARES 118 is equipped with a business information system that enables data collection with its storage, management and processing of the same in fairly and easy way. The system allows the production of specific reports and measures modulated on the user requests in order to highlight the different aspects of the activity.*

Conclusions. *The production of ad hoc reports, with the possibility of developing specific indicators, allows the identification and analysis of critical areas/processes in order to implement any corrective actions and monitor the effectiveness of the same.*

Introduction

In Italy the prehospital Emergency Medical Service is organized in specific regional models, despite the same national reference laws. The common objective to be pursued is the realization of a medical aid system, in emergency-urgency, effective, efficient and closely integrated with the hospital network, in order to guarantee citizen the continuity of care.

The Regional Service for Health Emergency 118 (ARES 118), established in 2004 in Latium Region, was the first national experience of a single regional service, versus other regional realities where the service was entrusted to multiple healthcare local organizations, sometimes employing

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hospital staff. ARES means "Regional Company for Emergency Service" and 118 is the free phone number to call the service.

ARES 118' aims are to ensure the following performances throughout the region:

- management and coordination of the prehospital emergency: alarm phase and local treatment phase, including secondary transport related to first management (the patient, according to his critical medical conditions, is first transported to the closest emergency room for the clinical stabilization, and then to the most appropriate hospital);
- management of health-related transportation activity for transplants;
- management of planned inter-hospital transfers.

The Context

Ares 118 operates in the Latium Region, divided in the five provinces of Rome (RM), Frosinone (FR), Latina (LT), Rieti (RI) and Viterbo (VT). The Region counts 378 municipalities, an area of about 17,232 sqkm, 54% of which are hilly areas, 26% mountainous and the remaining 20% plains (1). The municipality of Rome is the largest, counting 1,287.4 sqkm, and equalling the 0.4% of the entire national territory (2).

Rome hosts the Fiumicino International Airport "Leonardo da Vinci" (40.2 million travellers per year), which is classified as the first national and the seventh Europe's largest airport. Along with Rome's second airport "Giovanni Battista Pastine" in Ciampino (5.8 million travellers per year) it forms Rome's airport system, counting a total of 46 million passengers per year (2015 data) (3).

Furthermore, the Latium Region has three major harbours, Civitavecchia and Fiumicino in the province of Rome, and Gaeta-Formia in the province of Latina. In 2014 the Civitavecchia harbour was classified as the first in Mediterranean cruise activity, counting almost 2.3 million passengers per year (4).

The Latium Region has circa 5,880,000 inhabitants. To this value, people moving across the Region, tourists visiting Rome, students of the six universities in Rome, government employees, central state organs and diplomatic representatives determine a daily additional transitory population of circa 155,000 persons.

ARES 118 operates with four Operation Centres: Rome Metropolitan City (RM), Rieti (RI) along with Viterbo (VT), Latina (LT) and Frosinone (FR). It has a helicopter rescue service and a specific Service for the management of maxi-emergencies, catastrophes and of the planned major events (National and Vatican celebrations).

The emergency phone number in the majority of the Italian territory is 118. Only in Rome's district, as of 19 November 2015, the phone number 112 ("Unique European Emergency Number") became effective. ARES 118, counting 1,815 employees of various professional qualifications, coordinates 154 rescue stations located throughout the region, 223 emergency vehicles: ambulances, cars for EMS (Emergency Medical Service, non transporting patients), off-road vehicles and helicopters, all with sanitary staff, nurse or nurse + physician).

The helicopter rescue service operates from 3 bases, Rome, Latina and Viterbo, with three helicopters. The Latium territory has large mountainous areas that constitute a hostile environment for emergency on the road équipes. Hence, Ares 118 collaborates with the National Corps for Mountain Rescue - Delegation of Latium (CNSAS - SASL), for joined rescue operations with helicopters in mountain areas, underground or otherwise inaccessible areas.

Each of the five provinces has an Emergency Medical Communications Centre (EMCC). It is composed of nurses plus a referring physician for more complex issues. The EMCC handles territorial emergencies receiving the help request calls,

defining levels of urgency, and directing the required emergency vehicles.

Upon arrival, the healthcare staff evaluates the patient/s conditions and confirms or modifies the gravity phone code assigned by the EMCC, performs first aid treatments on site and, if necessary, transports the patient/s to the nearest emergency hospital department or, if clinical conditions allow it, to the more suitable hospital for the specific clinical condition or disease.

EMCC interacts via telephone with target hospitals to pre-alert arrivals of patients in critical clinical conditions or with specific diseases ("golden hour disease").

ARES 118 monitors the availability of beds in critical units (intensive care, coronary care, specialist post-operative care) in the Region's hospitals, and the connection between the hospitals requiring/accepting the transfer of patients in critical conditions. It also manages the Continuity Care Listening Centre (CCLC) of Rome's territory, providing first aid guidance to citizens that require care when primary physicians are not on duty (during the night, on weekends, etc.) and activating physicians in charge for the continuity of care in different Local Public Health Units.

ARES - Activity data

In 2015, ARES 118 EMCCs received 2,555,042 calls; of these, 1,506,979 were made by citizens requiring health aid, resulting in about 255 calls per 1,000 inhabitants.

Emergencies calls were followed by 447,472 missions, resulting in 76 missions per 1,000 inhabitants and 1 intervention every 3.9 calls.

Emergency calls were managed: 62.8% by the EMCC of Rome, 9.1% by the EMCC of Frosinone, 12.6% by the EMCC of Latina, 15.5% by the EMCC of Rieti and Viterbo, while missions were distributed 73% for Rome and province, 8% for the province of Frosinone, 11% for the province of Latina, and 9% for the provinces of Rieti and Viterbo.

Relieved patients were male in 49.7% and females in 50.3% of cases; 1.9% of cases were children under 10 years of age, and 54.4% of cases were patients over 60 years of age, with a significant proportion of octogenarians, accounting for 27.8% of the total.

In 67.5% of cases the code assigned on the phone by EMCC staff was "yellow", 18.4% "green", 13.6% "red", only <1% of the cases were "white". The "house" and "street" were the most frequent event places, respectively 58.3% and 21.7%. The on site treatments concerned for 24.6% traumas, for 13.5% cardiovascular diseases, for 9.6% respiratory diseases and for 8.1% neurological diseases.

In 2015 the helicopter rescue service was activated 2,138 times for a total of 1,536 flight hours, with a prevalence of interventions for traumatic pathology. The severity code on arrival on site was "red" for 54.3% of rescue cases, "yellow" for 22.1%, "green" for 2.5%, "white" for < 1%.

Information system

The health information systems allow the collection of the data necessary to measure and to evaluate the health activities, making it a useful tool for health planning and for the improvement of the quality of care (5, 6).

While for the hospitals, in Italy, there's a national specifically encoded and consolidated information flow, the EMS information flow was only very recently established (2008) and not yet consolidated, also because of the regional peculiarities and the type of provided service.

ARES 118 considered it necessary to establish a specific data stream that controls the peculiar health activities and the supporting enterprise-wide activities. ARES 118 developed a system based on specific

needs, thought entirely within the company without any external companies' support. In this context, ARES 118 has developed a specific tool: The Cube.

Database

The main tool intended to store and to elaborate data is the Database (DB) server. The Operational Unit Information System needed an open-source, highly performing DB server. The choice fell on MySQL by Oracle.

The open-source software is available as it is; it requires a dedicated staff to perform the *ad-hoc* development, installations, configurations, monitoring, updates, etc. This needed a period of development and testing before the software could become operational. The maintenance of this software, in fact, must be continuous. This instrument was necessarily developed step by step, always following specific requirements about data processing and Key Performance Indicators (KPI).

The evolution has mainly involved two aspects: the DB and the analysis-reporting system.

The software architecture of the EMCCs of Latium, from the technological/ software point of view, currently counts five independent computer systems, one for each Center. Each system contains the necessary information for the software application used in the EMCC to support the 'on site' health assistance (run-time data), and information related to closed events (historical data).

The first step of the development of the system was the concentration in a single server of a copy of the many tables of the relational historicized DBs existing in each EMCC, on a monthly basis (Fig. 1). This DB, decentralized from the servers used by the Stations, contains the key data of each individual health intervention, such as response time, severity codes and details about the alleged pathologies, geographical information, details on the activities of the EMCC and rescue vehicles, details on the clinical conditions of the patients, the destination hospitals, etc.

This allowed us to perform complex analytical processing in our offices, without any negative impact on the computer systems of the EMCCs. Our DB server was entirely an open-source Linux-based operating system.

At the same time an integrated environment of applications, which facilitated the reading and querying of the DBs, was developed, also open-source, again on a Linux system. The first used applications allowed the access to DB exclusively by means of queries written in SQL (Structured Query Language). SQL is a very powerful but difficult language and not within the reach of every user. Alongside this application, an office environment was integrated (eg. electronic spreadsheet). It was used to work on the data extracted from the DB to produce the final reports. A limit of this architecture was the need to repeat the queries for each DB of EMCC, to integrate the results, and finally to format them in reporting documents.

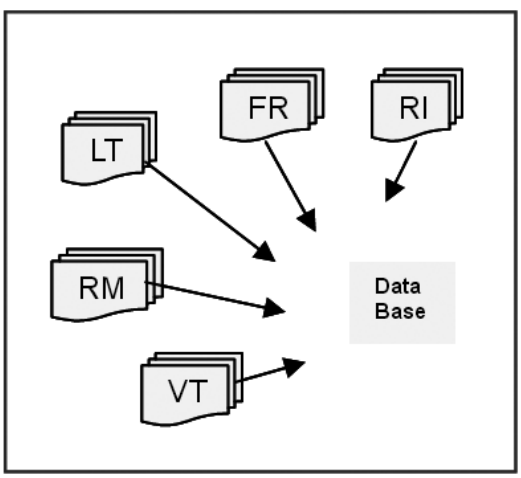


Fig. 1 – The Data Base of each Emergency Operation Center (RM-Roma, FR-Frosinone, LT-Latina, RI-Rieti, VT-Viterbo) has been duplicated in a single Data Base Server to permit centralized analyses and report generation

Data Warehouse

To remedy the first critical issues that emerged, including the rapid growth in the size of DB and consequently the long delays in query processing, the server was upgraded (the DB has been stored on 2 SSD disks, Sata III, RAID-0) and, in order to allow the processing of all EMCC data at the same time, a data warehouse (DWH) was designed and implemented - i.e. a single multi-dimensional relational DB that concentrates all EMCC data in a few tables linked together.

Through an application with ETL functions (Extract, Transform, Load - Talend Data Integration) a daily automatic loading system of historical data from the EMCCs was implemented, surpassing the monthly manual loading method (Fig. 2).

The DWH has been enriched with metadata that increase its functionality and has been reorganized with the aim of enabling the production of easier, faster and more sophisticated analyses and the necessary decision-making reports.

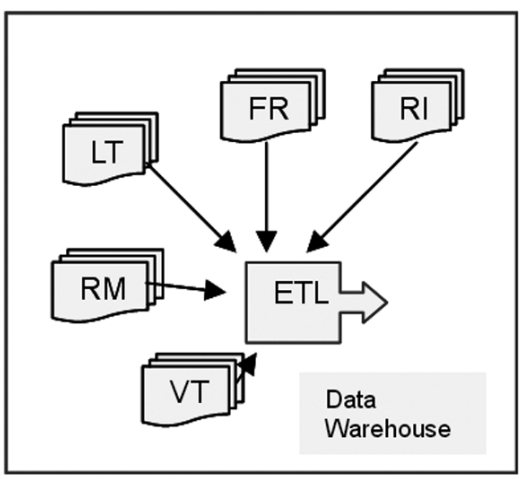


Fig. 2 – Data Warehouse - The Data Base of each Emergency Operation Center (RM-Roma, FR-Frosinone, LT-Latina, RI-Rieti, VT-Viterbo) has been duplicated and aggregated in a single Data Warehouse through an ETL program (ETL: Extract, Transform and Load) to store all significant data on a more structured Data Base to permit faster, centralized analyses and report generation involving the whole regional activity

Business Intelligence

In order to extend the use of the system to non-technical users, a selection of so-called Business Intelligence (BI) tools was performed.

With the term BI we can usually refer to:

1. a set of business processes to collect data and analyze information of strategic relevance;
2. the technology used to realize these processes;
3. the information obtained as a result of these processes.

The business intelligence tools, that are open-source, were selected evaluating the computing power, completeness of functions, processing speed, expandability and possibility of integration with other informatic systems. The choice fell on the JasperSoft server that collects all the mentioned features.

In summary, the BI server implements a web portal that provides access to multiple users simultaneously, arranged and grouped by Operational Units. Access is based on the login credentials. Users are confined to distinct areas of the portal that are specifically dedicated to them. In these areas there are reports and data analysis tools related to their profile.

The server makes available to end-users a type of pre-packaged reports, designed by technical professionals, producing as a final output documents in PDF format, spreadsheets, graphs, tables etc. The reports can also be parameterized, indicating, for example, a range of dates or a provincial area, a type of vehicle, etc.

It also allows users to draw some sophisticated analyses using the simple interface of the OLAP Cubes (On-Line Analytical Processing).

On-Line Analytical Processing

The most important innovation brought to the system was the implementation of OLAP Cubes.

These tools are similar to the most famous pivot tables of electronic spreadsheet, acting on multiple tables simultaneously. One feature that makes them particularly effective is that they allow to cross-reference any information contained in the data warehouse (e.g. health interventions per year; health interventions per pathology code, etc.), without limits of complexity.

The OLAP system designates a set of software techniques for interactive and fast analysis of large amounts of data, that can be examined in complex modes.

Typically, the system is based on a main table (the fact table-FACT), linked with a series of tables that define how data are grouped (dimensions-DIM, and attributes-ATR), in a structure called snow-flake (Fig. 3).

The OLAP Cube can be thought as an extension of a two-dimensional spreadsheet, on which calculations crossing rows and columns (pivot tables) can be performed. The OLAP Cube has from two to an arbitrary number of analysis tables. It is called Cube because, schematically, it is easier to represent the product of an OLAP query as the product of the intersection of tables stacked in a three-dimensional (Fig. 4) or multi-dimensional structure (hypercube).

The programming process of the Cube entailed an analysis of the available data and reporting requirements. This has had an impact on the building of the Data Warehouse in terms of development time.

The benefit obtained, however, is that through today's Cubes we can perform the analysis with an impressive speed, even with very large DBs. For example, the Data Warehouse today includes about 14 million records spread across 40 tables and represents the data of health activity and administrative

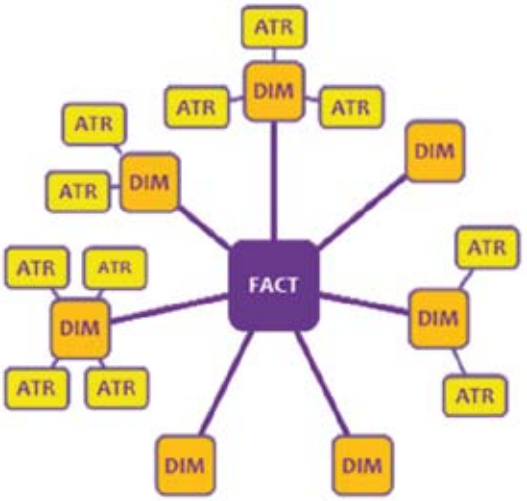
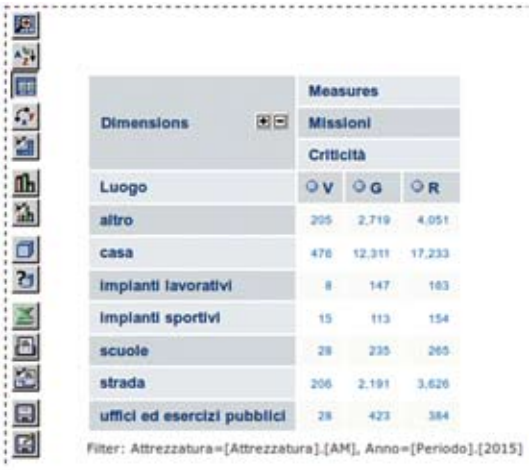


Fig. 3 – Snow-flake schema – The FACT table of the Data Warehouse stores the significant data related to the emergency activity. This table is connected (joined) with other tables (DIM) representing aggregation sources, such as time period, hospital networks, pathology classes, each with attributes (ATR) able to specialize the analysis, such as time quarter, care level of the hospital, emergency activity for trauma. This logical structure is the basis for the On Line Analytical Processing (OLAP).

Fig. 4 - OLAP (On Line Analytical Processing) Cube graphical representation: inside the red circle, a single measure is selected as a result of the calculation (B joined to C2 joined to Aug).



Dimensions	Measures		
	Missioni		
	Criticità		
Luogo	V	G	R
altro	205	2,719	4,051
casa	476	12,311	17,233
impianti lavorativi	8	147	183
impianti sportivi	15	113	154
scuole	28	235	265
strada	206	2,191	3,626
uffici ed esercizi pubblici	28	423	384

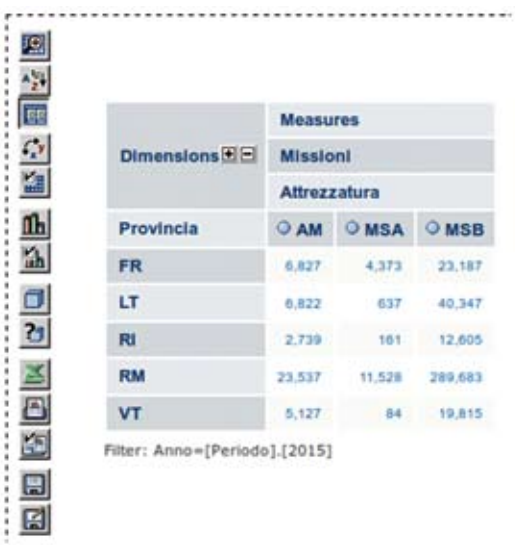
Filter: Attrezzatura=[Attrezzatura].[AM], Anno=[Periodo].[2015]

Figura 5 – Cube example: number of missions (Missioni) made by medical rapid response vehicles (AM) in 2015 per severity code (Criticità) cross-joined with the type of place of the intervention (Luogo).

data of ARES 118 in the past five years. The elaborations, even the most complex, take a few seconds (Fig. 5 and 6).

Given the ease of use, versatility and power of this system, it has also been extended to other services. The data stream of helicopter activity was added to the system. The health information was integrated also with administrative information (payroll, attendance etc.), for integrated analyses using the common key represented by Cost Centers codes.

Actually, many Offices use these tools, mostly the OLAP Cube, for their analysis, monitoring and reports.



Dimensions	Measures		
	Missioni		
	Attrezzatura		
Provincia	AM	MSA	MSB
FR	6,827	4,373	23,187
LT	6,822	637	40,347
RI	2,739	161	12,605
RM	23,537	11,528	289,683
VT	5,127	84	19,815

Filter: Anno=[Periodo].[2015]

Figura 6 Cube example: number of missions (Missioni) of emergency vehicles (AM, MSA, MSB) cross-joined with the Operation Centers (Provincia) in 2015 (Filter)

Reporting System and Key Performance Indicators

Next to the OLAP system for on-line data analysis, a set of very useful tools for the above-mentioned BI consists of report-generating engines. The BIRT and Jasper Report tools were chosen for their power and versatility.

Through these tools, we can compose and lay out some very sophisticated documents in printable format (PDF) or further editable documents (electronic spreadsheets, text documents etc.).

The documents are produced by querying the data warehouse with *ad hoc* requests (queries), also parametric (eg. Date range), the result of which will fill the tables and will draw the graphics that compose the document.

Through this tool the report is programmed only once, but can be replicated and reproduced at every need modifying, if necessary, the input parameters.

For example, a report that describes the activities of each individual rescue station in a given time interval has been edited, showing every related information.

The example, in Figure 7, is actually a very partial representation of what can be achieved with this tool. The same report, when generated for the activities of all rescue stations in the Region, consists of a PDF document of about 300 pages, produced in about 5 minutes of processing. Without

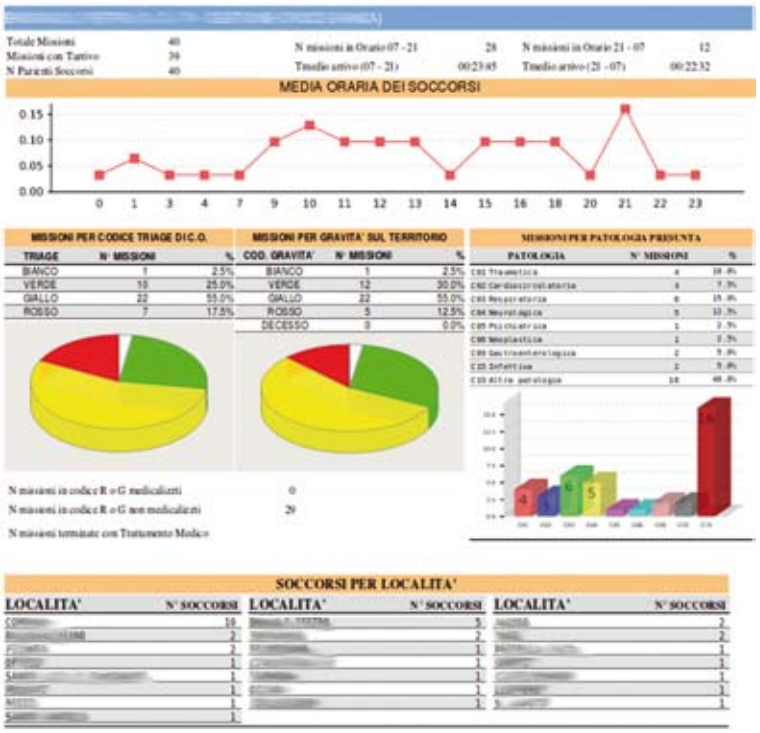


Fig. 7 - A page of a PDF report graphically representing a focus on the activity of a single ambulance in a time interval of one month. It is possible to report any indicator or variable value in a tabular or graphical representation inserted into a single PDF document (Some information was intentionally blurred).

this reporting system it would be virtually impossible to obtain the same result in an acceptable time.

With the same BI engine, we designed and put into production many types of reports, some describing the services and others containing all sorts of KPI (alarm-target time, time spent in the hospital emergency department, distribution of ambulances in hospitals, response times of the rescue stations to the target, daily trend of the rescue etc.).

Some of these reports are now generated without any intervention by the operator: the same business intelligence system, at predetermined intervals, produces the reports with updated data and sends them to the users in PDF format by e-mail.

Cartography

A further line of development of the information system is to link health data to the geographical mapping system. A major step forward in the analysis was the opportunity to map the emergency vehicle activity directly represented on a geographical system.

The chosen mapping system, also open-source (QGis), integrates maps provided by commonly used internet services (google maps, open street map, etc.). The maps can be overlaid with various information layers, representing the locations of the 118 local stations, hospitals, border areas of the municipalities, neighborhoods, town districts, health districts etc. The system then allows us to draw geographical coordinates

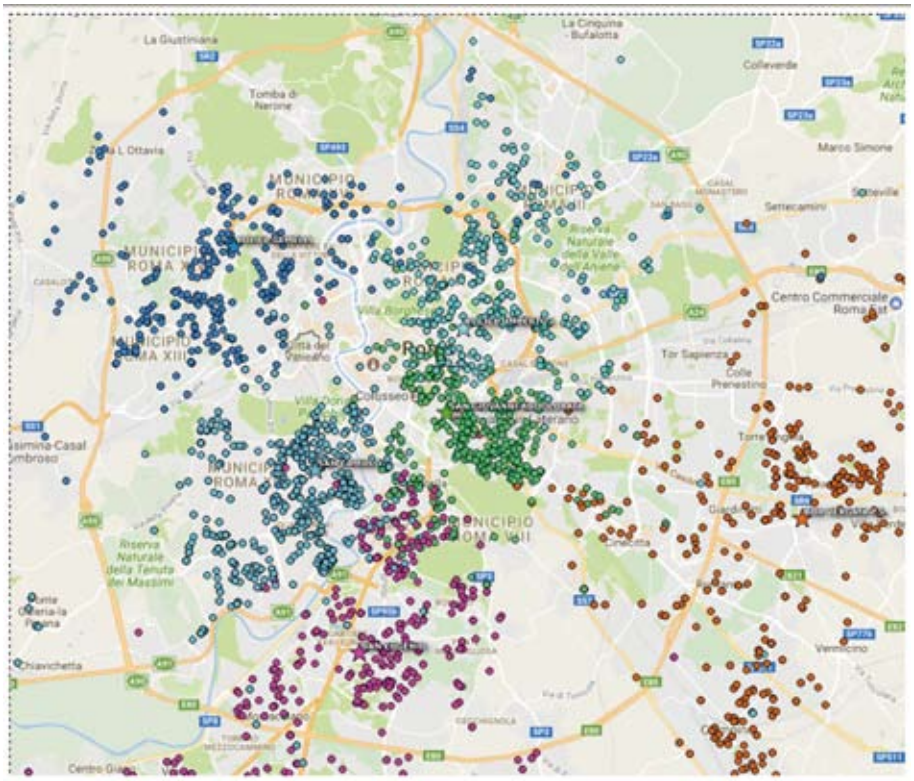


Fig. 8 – Emergency interventions for Red code for cardiological pathology (spots) – Hospital of patient delivery (star shaped spots). Each spot has the same color of the hospital's star where the relieved patient has been left by the ambulance

or addresses of the rescue sites carried out from the Data Warehouse, filtering them in every possible way (by disease severity code, type of vehicle used, response times, hospital destination etc.), representing various information on the geographical map, from a single point representative of the rescue intervention to the density of interventions by area, etc. (Fig. 8 and 9).

We have only begun to explore the possibilities of the representation of the data mapping, but what has been achieved has already proven to be very interesting on several occasions (eg. patient distribution to hospitals, highest density rescue interventions areas, time-dependent diseases networks, etc.).

Discussion and conclusions

With this work we intended to describe the ARES 118 Company, with its complexities and peculiarities, and what has been done internally to prepare an *ad hoc* information system to support the management.

All work, as described hitherto, has been carried out customized on the Company's needs. This was necessary as there are no other similar companies in Italy, therefore there is no software product on the Italian market that fits the specific needs of ARES 118 (7, 8).

The need for new systems of analysis and representation of data and KPIs has always come from within, in response to specific requirements from the management

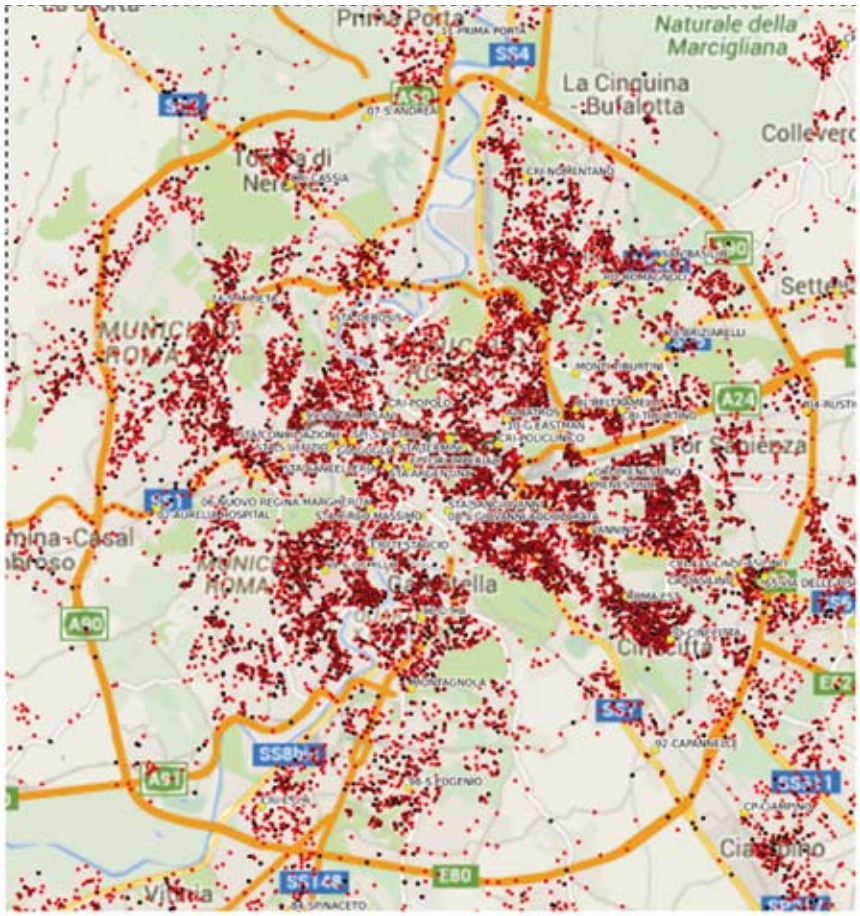


Fig. 9 – Emergency interventions for red code – density of occurrences (red spots) vs geographical position of the expecting ambulances (yellow spots)

corporate Units, and from the Latium Region Government.

The production of reports on specifically developed KPIs has allowed us to identify and report some critical issues and to improve the effectiveness and efficiency of the system.

With the same open-source tools we are planning to implement a real-time dashboard based on real-time data showing additional performance and qualitative indicators, available for decision makers and, eventually, for the operators themselves.

We also intend to confirm that a DWH and a business-intelligence systems based entirely on open-source software can be built by using internal personnel, saving significant economic resources.

Our System is perfectly adherent to the requirements of the Company, having been packaged and continually re-modulated on the basis of the specific information needs. This would not be possible using commercial products.

Each implementation of every new software module, in fact, has been preceded by a period of analysis of internal needs, analysis of the products in the open-source world and analysis of the opinion of other users to choose the most appropriate one. Then it needed analysis of technical manuals,

practice in a testing area to learn how to use it, and, finally, a testing and checking period to evidence any issue and making corrections (debugging).

By the use of our information systems we have discovered, thanks to the analysis of the specific reports, that the quality of the data was not always optimal. This allowed us to start a virtuous cycle of improving the quality and completeness of the information collected.

We hope that, by creating an internal know-how about the use of this set of tools, the path of improvement and efficiency of information system can continue uninterrupted even in the future and that the whole organization can benefit of its extended use.

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Special thanks to Margherita Trani M.D., for her precious contribution to the translation of this text.

Riassunto

Il Sistema Informativo nel Servizio di Emergenza-Urgenza Sanitaria: l'esperienza dell'ARES 118.

Contesto. In questo articolo viene descritta l'Azienda Regionale per l'Emergenza sanitaria 118 (ARES118) della regione Lazio, in Italia, focalizzando l'attenzione sul data warehouse aziendale, contornato dai singoli applicativi utilizzati per la gestione dell'attività, con la creazione di reportistica *ad hoc*. ARES 118 è una azienda sanitaria pubblica, costituita nel 2004, monospecialistica, che gestisce il soccorso sanitario pre-ospedaliero, in emergenza-urgenza, di tutta la regione Lazio.

Metodi. Per le sue peculiarità, ed essendo la prima esperienza italiana di Azienda Sanitaria regionale dedicata al soccorso sanitario, ARES 118 si è dotata, in modo autonomo, di un sistema informativo aziendale. Tale sistema si è evoluto, dai singoli sistemi di Centrale Operativa Provinciale, in un sistema informativo unico a livello aziendale, fino alla costituzione di un data warehouse. Tutte le diverse fasi di sviluppo sono state effettuate utilizzando applicativi gratuiti.

Risultati. Attualmente, ARES 118 è dotata di un data warehouse abilitato alla raccolta dei dati, alla loro conservazione ed elaborazione con modalità semplificate e trasparenti. Il sistema permette la produzione di specifici report ed indicatori modulati sul bisogno degli utenti in ordine ad analizzare i diversi aspetti dell'attività.

Conclusioni. La produzione di report *ad hoc*, con la possibilità di sviluppare specifici indicatori, permette l'individuazione e l'analisi di aree/processi critici al fine di implementare eventuali interventi correttivi e monitorare l'efficacia degli stessi.

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