



Emergency Department Management in Lazio, Italy[☆]



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ABSTRACT

The assignment of service requests to emergency departments is of paramount importance both from a life-threatening and an economical viewpoints. In the process of a more general project that aims at defining optimal allocation policies of patients to regional hospital network facilities (together with the potential reorganization of the facilities), the Department of Epidemiology of the Regional Health Service of Lazio, Italy, was interested in obtaining a completely offline picture of the effect of an optimal assignment of requests to emergency departments. This is in the spirit of evaluating the so-called *Price of Anarchy*, where the fully centralized (admittedly unrealistic) allocation is used as a reference for both the state-of-the-art completely decentralized approach and future reorganization ideas.

We have implemented and tested with real-world data of all service requests of 2012 a mixed-integer programming model that computes such an optimal request allocation by minimizing travel and waiting times and penalizing workload unbalance among emergency departments in the region. Within the development process we have studied special cases and relaxations of the complete model showing interesting mathematical properties that are, in turn, useful from a practical viewpoint, for example, in obtaining a real-time version of the approach.

The present study is an important, quantitative step in the evaluation of centralized allocation strategies like remote triage that could have a remarkable impact in making the allocation process much more efficient and effective. More precisely, the developed methodology as well as the software tools are currently used by the DEP-Lazio for the reorganization of the regional networks of emergency healthcare.

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1. Introduction

The Department of Epidemiology of the Regional Health Service of Lazio, Italy (DEP-Lazio in the following), a regional center for Health monitoring and management, is currently involved in a project that aims at defining optimal allocation policies of patients to regional hospital network facilities. The reorganization of health centers in order to deliver services in an effective way by taking into account economic sustainability is a topic of increasing importance for Regional Health Services in Italy. In recent years several inputs have been given, through financial laws, to reorganize hospitals infrastructure in order to increase efficiency. Reorganization policies can be considered, from a strategic point of view, as composed by two main decision elements: the definition of the subset of hospital facilities that should be active within the regional territory and the

allocation of demand of services to active facilities. Because the reorganization of a regional health system in terms of facility location and service allocation is a task of great complexity regional managers decided to start by focusing their attention on emergency departments (ED). Indeed, EDs are a crucial access point to hospital network facilities and as a consequence their management is a critical factor in order to improve system effectiveness and efficiency. In Italy it is possible to state that the role of EDs is even more important than in other European countries because, in addition to real emergency and urgency services, they have to face a set of demands that should instead be managed by Primary care units or by General Practitioners. This is due to historical reasons associated with the development of the system and, recently, to the increase of (often illegal) immigration. The 2013–2015 operational programs of the Lazio region require the activation of new clinical care pathways for emergencies, with a special priority for life-threatening diseases, such as acute coronary syndrome, stroke and trauma. For these situations, a timely medical intervention, performed in facilities with the necessary equipment, can save the patient's life and significantly improve the prognosis. For example, with respect to patients suffering from ST Elevation Myocardial Infarction (STEMI), it is suggested to perform a percutaneous coronary intervention (PCI) in hospitals with high volume of activity, equipped with

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catheterization laboratory and highly qualified teams. Moreover, according to clinical guidelines, it is strongly recommended to perform PCI within 90 min from the onset of the early symptoms. Therefore, it is essential that STEMI patients can immediately be transferred to a specialized hospital. Unfortunately, preliminary analyses showed that the current emergency networks are not able to provide an appropriate and timely healthcare assistance to all residents, especially in areas far from the city of Rome, generally characterized by a lower socioeconomic status.

Emergency department characteristics. An emergency department can be defined as a health facility that is dedicated to the management of emergency and urgency treatments, that is to say to that spontaneous or traumatic pathological conditions that need to be treated within a short period of time. Emergency activities are, for their own nature, nonelective and patients can reach ED facilities both by their own (walk-ins) or with the support of an emergency vehicle. Due to the impossibility of planning patients arrival, EDs have to provide an initial treatment for a wide number of diseases some of which can be life-threatening. Because the set of patients that ask for treatments is heterogeneous from the pathological point of view, the admission of patients is driven by a priority-based policy. The stochastic nature of arrival times and of pathological conditions can have a strong impact on workload and as a consequence on patient waiting times and quality of care. It is then fundamental that the priority assignment is properly managed in order to meet patients' needs according to their critical condition. The process of assigning priorities to patients is defined as *triage* and it is usually coded at a regional or national level. Triage is a set of procedures that ensure, in the best possible way, that patients with a more critical condition are admitted before the others. The priority level is usually represented by a color code (white, green, yellow and red) that defines the increasing need of care. For each patient the priority is usually defined just after the arrival by a dedicated operator. The definition of triage procedures is then fundamental to guarantee an immediate care for the patient, to identify the priority level and the medical area that may treat him and, ranking lower priority patients, to reduce waiting times. Triage activities can directly address the patient to the most appropriate hospital ward in case of complex treatments, for less serious ones the patient can be directly treated by emergency department physicians and discharged. It is then important for health managers to plan EDs so as to meet a set of objectives that can be in some cases conflicting. At first it is fundamental to guarantee quality of care that is composed by treatment timeliness, according to the patient health condition, and appropriateness, according to the patient pathological condition. On the other hand the cost sustained to provide services has to be reduced as much as possible by taking into account a minimum standard of care.

Paper contribution. As already discussed, triage is currently the first activity that is performed when a patient reaches the ED. This means that ED triage is only in charge of determining the care pathway within the hospital structure. In other words, the possibility that a better quality of care and/or a shorter waiting time could have been reached if the patient would have been sent to another ED is not considered.

The objective of the present study is to develop an hybrid model that considers both ED workload and service allocation, evaluating what could be the impact of a remote triage management that, anticipating the patient classification, can address population requests to the first-aid structure, thus assuring the best possible service level. In particular, the final allocation policy for emergency department requests needs to maximize quality of care and service timeliness. In order to develop a regional allocation approach we must suppose that all requests can be filtered at a regional level. That is to say that walk-in or ambulance referral that have not been screened by the triage management center are not accepted. Clearly, this is only an

hypothetical scenario that is, however, potentially useful to define a reference solution (as well as a reference methodology) in terms of service quality (to be defined below), so as to evaluate, in comparison, new and more sophisticated allocation policies. In other words, the current case-study establishes a benchmark solution with respect to which the cost of a completely decentralized and loosely planned allocation is computed. In this sense we somehow follow the so-called price-of-anarchy viewpoint [23] although the techniques applied here do not exploit game theory in the computation of an equilibrium. Instead, we have implemented and tested with real-world data of all service requests of 2012 a mixed-integer programming model that computes such an optimal request allocation by minimizing travel and waiting times and penalizing workload unbalance among emergency departments in the region. Within the development process we have studied special cases and relaxations of the complete model showing interesting mathematical properties that are, in turn, useful from a practical viewpoint. Finally, one of those special cases allowed us to devise a real-time version of the first-aid requests allocation approach, which can be used as a Decision Support System for the Triage Center daily operations.

The present study is an important, quantitative step in the evaluation of centralized allocation strategies like remote triage that could have a remarkable impact in making the allocation process much more efficient and effective. More precisely, the developed methodology as well as the software tools are currently used by the DEP-Lazio for the reorganization of the regional networks of emergency healthcare. Our findings will be shared with the Regional Directorate for health and social-health integration and the Regional Healthcare Emergency Unit, which operatively manages the first aid requests in Lazio. The joint analysis of the results by those who plan emergency healthcare programs and by those who operationally run them in the territory are expected to be helpful to develop and quantitatively evaluate strategies to: (a) improve health assistance for the population living in disadvantaged areas, (b) reduce waiting times in emergency departments and (c) balance workload among EDs of the Lazio region. More generally, considering that the technical equipment is known for each hospital, this type of optimization (possibly coupled with simulation) techniques can be effectively used to reorganize the emergency networks in accordance with the hierarchical levels of the hospitals equipment complexity. This is likely to result in optimization of the current "Hub and Spoke" model, based on the distinction of the emergency departments in basic EDs, first level EDs and second level EDs, depending on the provided intensity of care and on the dimension of the hospital catchment area. Basic or primary care hospitals are characterized by a catchment area of 80,000–150,000 inhabitants and have a limited number of active medical specialization departments. First level hospitals have a catchment area of 150,000–300,000 inhabitants and radiology and ultrasound with X-ray CT as well as laboratory and blood transfusion services should be available 24 h per day. Second level hospitals have a catchment area of 600,000–1,200,000 inhabitants and are equipped with all medical specialization departments. Those facilities are supplied with the most advanced technological devices in order to properly treat complex patients. Note that the current model does not take into account ambulance availability, routing and dispatching, which are important resource constraints. Future work plans involving those resource constraints are discussed in the last part of the paper.

Paper organization. In Section 1.1 we review the literature reporting ED and emergency medical services (EMS) management approaches. In Section 2 we discuss the details of the problem and we introduce the required notation and definitions. In Section 3 a mixed-integer linear programming (MIP) approach is proposed and several properties and relaxations are discussed. In Section 4 we extensively discuss computational experiments performed by solving the MIP model on real-world instances provided by DEP-Lazio. In Section 5 we propose a real-time algorithm for first-aid

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