Simulation Modelling Practice and Theory 47 (2014) 46–59

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

A simulation study to improve the performance of an emergency medical service: Application to the French Val-de-Marne department

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A R T I C L E   I N F O

Article history:
Received 4 December 2013
Received in revised form 30 April 2014
Accepted 18 May 2014

Keywords:
Emergency medical services
Discrete event simulation
Decision support for healthcare
Service operations management

A B S T R A C T

The French Emergency Medical services, which are known as SAMU (the acronym of Urgent Medical Aid Services in French), are public safety systems responsible for the coordination of pre-hospital care under emergency conditions throughout a particular geographic region. The goal of these systems is to respond in a timely and adequate manner to population calls, to provide first- aid services and to transfer patients to the appropriate care facility when needed. The current study aims to develop the process of the Val-de-Marne department's SAMU system (SAMU 94) in an efficient manner that meets the population's needs using limited resources. For this purpose, we propose a discrete event simulation (DES) model implemented in the ARENA software to analyze possible changes in the SAMU 94 processes that would lead to enhanced operational efficiency for coverage performance (i.e., the percentage of calls for which the patient wait time before a SAMU 94 rescue team arrives does not exceed a specific target time). Hence, the model enables to test five categories of scenarios that are mainly related to the level of resources used as well as the location of rescue teams throughout the service area. Among other results, we found that repositioning a portion of the existing teams into potential bases increased the 20-min coverage performance up to 4.5% in average. Furthermore, this improvement in coverage can reach 7.3% when the whole fleet is relocated based on the multi-period redeployment plan obtained from simulation optimization.

1. Introduction

Emergency medical services (EMS) are public safety systems that coordinate the delivery of pre-hospital care to patients under medical emergency conditions. The pre-hospital care includes the stabilization of the patient's condition and the transport of the patient to an appropriate care facility. In France, the EMS system is known as SAMU, which stands for "Urgent Medical Aid Service" in French. SAMU was established in 1968 to coordinate the activity of the "Mobile Emergency and Resuscitation Services", or SMUR, which are mobile response vehicles that are staffed with qualified personnel and are operated by public hospitals. French law defines the SAMU mission as "hospital-based services that provide permanent

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http://dx.doi.org/10.1016/j.simpat.2014.05.007
1569-190X/

phone support and that choose and dispatch the proper response for a phone call request". A unique feature of the French SAMU system in comparison with other EMS systems worldwide is that physicians are involved in the medical evaluation of emergency calls and in the realization of rescue missions. The objective is to guarantee efficient assistance and high advance care to victims either on the phone or at the scene of accidents. However, a higher quality of service involves extended time to process calls and to perform on-scene treatments.

The SAMU system is managed at the department level (i.e., a French administrative division corresponding to a median area and population of approximately 6000 km^2 and 510,000 inhabitants, respectively) and provides 24-h service for each department. In this study, we focus on SAMU 94, which covers the Val-de-Marne department. The Val-de-Marne department is a small department that spans 245 km^2, has a large population (approximately 1,300,000 inhabitants) and is located in the southeast portion of the city of Paris in the Ile de France region.

The current study, funded by the French National Research Agency (*Agence Nationale de Recherche*), proposes a discrete event simulation (DES) model implemented in the ARENA software to analyze possible changes in SAMU 94 processes that are expected to provide enhanced system performance. Hence, the proposed DES model tests five strategies that are mainly related to the level of resources used as well as the position of rescue teams throughout the service area. Two performance measures are used to evaluate each scenario: (i) coverage, which is defined as the percentage of calls for which the response time (i.e., the period between the incident reporting and the arrival of a rescue team at the scene of accident) does not exceed a specific target time, and (ii) the human resources utilization rate, which is defined as the total workload divided by the total operating time. These two metrics are of critical importance because they are related to the primary objective of the SAMU systems, which is saving lives while limiting the cost of operations. The association between high coverage and the high survival rate of patients has been noted by several authors in the literature especially in the case of life-threatening emergencies [1–5]. For instance, the likelihood of survival from cardiac arrest decreases by 7–10% for each minute of delay in response time [6]. For acute myocardial infarction, the risk of 1-year mortality increases by 7.5% for each 30-min delay in response time [7]. Therefore, SAMU 94 aims to increase the coverage performance within a target time set to 20 min to reduce patient mortality and to improve the patient's chance of recovery.

The paper is structured as follows: Section 2 outlines literature related to the use of DES models in EMS operations. Sections 3 and 4 present the detailed methodology used to build the SAMU 94 DES model, including the process description, data collection, simulation model design and validation steps. Sections 5 and 6 provide comparisons for the proposed scenarios and include the results and discussion. Finally, Section 7 reports some concluding remarks and the directions for future research.

2. Literature review

This section reviews the existing literature for the application of DES models to EMS systems. Existing papers are classified based on the type of decision they address, such as the dimensioning of human resources and potential bases location, deployment and redeployment, shift scheduling, dispatching and destination hospital selection.

The dimensioning of human resources consists of determining the skills and the aggregate number of human resources to hire, while potential bases location refers to the identification of the location and the capacity of waiting positions in which rescue teams (i.e., emergency vehicles staffed by one or several physician(s), nurse(s) and/or emergency medical technician(s)) are placed between rescues to adequately cover the service area. Several DES studies have explored the possibility of adding/removing rescue teams and potential bases concurrently to compare the cost and quality performance of these two alternatives [8–11].

Deployment is the most studied problem in EMS design and operation. It consists of determining the number of rescue teams required at each potential base to reach patients promptly and to achieve a particular service level objective. In EMS literature, deployment scenarios are usually evaluated jointly with the scenario of adding bases to assess the allocation of rescue teams to both existing and new waiting points. One category of papers evaluates deployment strategies that are selected heuristically to improve the service performance based on criteria such as proximity to areas of high demand [12–14]. Another category of deployment scenarios, which is more prevalent in the literature, is a combined approach that involves the use of an analytical technique to determine sets of optimal locations based on the set of feasible locations and then the use of a more realistic and detailed simulation model to estimate system performance under the resulting deployment plan. The analytical techniques proposed in this approach include deterministic mathematical programming models [15,16], probabilistic mathematical programming models [17] and queuing theory [18].

More recently, a dynamic version of deployment, known as redeployment, has been addressed in the EMS simulation literature. Redeployment considers the assignment of rescue teams to bases that is adjusted to adequately cover changes in the temporal and geographical demand pattern during a time period (known as multi-period redeployment) or in the real-time availability of rescue teams following the allocation or release of a team (known as dynamic redeployment). Similar to the static deployment problem, the redeployment literature has focused on both the relocation scenarios that are heuristically selected [10,19] or are obtained from analytical models [20,21].

Compared with the scenarios described above, shift scheduling, dispatching and destination hospital selection remain less studied problems in the literature. The shift scheduling problem consists of determining the working hours and location for both vehicles and crews. Scenarios that are developed to estimate the impact of improved shift scheduling are proposed by Trudeau et al. [18] and Ingolfsson et al. [10]. The dispatching problem refers to the assignment of the best rescue team to