



PREHOSPITAL RESOURCE ALLOCATION: EXAMINING THE ROLE OF EMERGENCY MEDICAL DISPATCH SYSTEMS

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Abstract

Emergency services globally are under rising cost pressures that may restrict their current resources. Emergency services in several nations have the problem of insufficient personnel, which poses additional difficulties and limitations, particularly during critical periods like the COVID-19 epidemic. Additionally, the need to cover extensive distances to reach thinly inhabited regions leads to prolonged response times. In order to address these challenges and potentially mitigate the impact of daily medical emergencies, a number of countries, including Sweden, Germany, and the Netherlands, have implemented initiatives that involve the utilization of novel human resources and equipment that were not previously integrated into their existing emergency systems. These resources are used in medical emergency situations if they can reach prior to emergency medical services (EMS). Several studies have examined the use of these novel resources in EMS systems, focusing on medical, technological, and logistical aspects as major areas of investigation. There are other review studies in the literature that specifically examine one or more of these new sorts of resources. As far as we know, there is currently no thorough review study that examines all the new kinds of resources in emergency medical response systems. In order to address this deficiency, we aim to provide a comprehensive literature review of research that examine various novel resources used prior to the introduction of EMS. The aim of our study is to provide a comprehensive and systematic summary of these publications, with a focus on their practical applications and methodologies. Our goal is to give valuable insights into this significant topic and raise awareness among scholars, emergency managers, and administrators.

Keywords: Emergency service, review, emergency medical services (EMS), resources.

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1. Introduction

According to Quarantelli (1995), daily or everyday crises are common occurrences that have a relatively little impact. These crises may be broadly classified into two categories: urgent and non-urgent. In the context of medical crises, urgent cases refer to situations that pose an immediate risk to life. Examples of life-threatening emergencies include out-of-hospital cardiac arrest (OHCA) and stroke, when time is of utmost importance. For patients experiencing a stroke, it is essential to get them to the hospital promptly in order to increase their chances of survival. However, for patients with out-of-hospital cardiac arrest (OHCA), receiving rapid care at the scene is vital (Herlitz et al., 2005, 2003; Fothergill et al., 2013).

Several nations possess highly developed and well equipped emergency medical services (EMS) systems, which dispatch proficient paramedics or emergency medical assistants to the location of crises. Nevertheless, almost all emergency medical services (EMS) systems globally confront a growing financial strain, often coupled with a dearth of personnel and essential resources, as well as the challenge of covering vast distances in thinly inhabited regions (Weinholt 2015; Yousefi Mojir and Pilemalm 2016). The COVID-19 epidemic has worsened the problem of staff scarcity in several nations, highlighting the crucial need to use all existing resources with maximum efficiency. Ensuring timely and sufficient response times for all patients, around the clock and in all areas, during both regular and emergency situations, is challenging and may even be unattainable.

There are several planning choices for routine EMS that focus on lowering response times while considering the required and available resources. For a comprehensive understanding of EMS logistics, including the planning challenges and current strategies, as well as a typical EMS system, refer to the works of Reuter-Oppermann et al. (2017) or Bélanger et al. (2019). In order to address the challenges encountered by the EMS and mitigate the impact of everyday medical crises, a number of nations such as Sweden, Germany, the UK, and the Netherlands have implemented programs that make use of innovative resources, including both personnel and equipment. Several programs dispatch first responders or volunteers to emergency sites to provide assistance to patients prior to the arrival of the EMS.

Some individuals make use of automated external defibrillators (AEDs) found in public establishments or drones capable of delivering essential supplies to an emergency site. The exploitation of these human resources and equipment, referred to as "pre-EMS services" in this research, has the potential to help to saving the lives of patients before the arrival of EMS. Thus, they might be characterized as services that provide assistance to patients until the EMS arrives at the location. Although these services may enhance response times, they do not serve as a substitute for the traditional system.

This study provides a comprehensive assessment of research that specifically examine pre-EMS services. The objective is to provide valuable insights to both academics and practitioners in this sector. Despite being a relatively new area of study, there are several existing studies that have examined the use of pre-EMS services in medical emergency systems. These studies have approached the topic from various viewpoints, including medical, technological, and logistical. This research specifically examines pre-EMS services, which may be divided into two primary categories: (1) human resources, such as first responders and volunteers, and (2) equipment, including AEDs (Automated External Defibrillators) and drones. In order to provide a thorough analysis of the existing literature on pre-EMS services, we examine their use in the treatment of everyday medical crises. These services may also be used in the event of larger-scale situations, such as catastrophes. Nevertheless, this study specifically focuses on everyday medical crises and deliberately omits other sorts of occurrences, such as catastrophes or mass casualty tragedies.

As far as we know, this is the first evaluation focusing on pre-EMS services. Instead of examining individual publications and their specific contributions to the area, our objective is to provide a comprehensive and systematic review of these studies, focusing on their practical applications. Our purpose is to offer valuable insights into this topic and raise awareness among scholars, emergency managers, and administrators. We accept articles that include both quantitative and qualitative methodologies from all publications in the fields of operations research / operations management (OM) and medicine, including journals and conference proceedings.

2. Scheme for selecting and categorizing

The oldest documented research on everyday medical crises relied on one of the newly discovered resources, dating back to 1982. We restricted the temporal scope of our literature evaluation to include just the period until the conclusion of 2020. We used Scopus as the primary search engine and Google Scholar as the supplementary one, including articles from all journals and conference proceedings. We conducted a search using the term "emergency medical services" together with each of the following terms individually: "first responders", "automated external defibrillator", "drone", "unmanned aerial vehicle", and "volunteer". Furthermore, there was an individual search for "stop the bleed".

After many rounds of selection from the original pool of 2127 publications, which included duplicates, we have chosen 258 research papers for inclusion in this review. In addition to eliminating duplicate publications, we specifically rejected studies that focused on non-medical daily crises and catastrophes, as well as those that explored the use of new resources in contexts outside of daily medical emergencies (such as doctors volunteering for research done in a hospital). We specifically omitted publications that examined the well-being, such as mental health, of emerging human resources or technological components of equipment, such as the technical design of drones or AEDs. Additionally, we removed papers that primarily focused on EMS rather than pre-EMS services. In the medical context, we rejected articles that primarily focused on medical outcomes without specifically emphasizing pre-EMS services and their implementation in the examined medical emergencies.

3. The conventional emergency response procedure

The conventional emergency response procedure starts with the arrival of the call (e.g., Reuter-Opfermann et al. (2017); Aringhieri et al.

(2017)). As seen in Figure 1, pre-EMS services may be provided at the location of an emergency while waiting for an ambulance to arrive during the EMS response time. If there are spectators present at the site, pre-EMS services may commence before to the initiation of the emergency call. The allocation of resources such as volunteers or drones by the coordination center is only beneficial if they arrive much earlier than the ambulance.

Figure 1 depicts the individuals involved in emergency management, including human resources (referred to as actors) and the equipment they use. The focal point of this diagram illustrates the emergency management life cycle, a concept often discussed in literature on catastrophe management, such as the works of Coppola (2006) and Nikbakhsh and Farahani (2011). Nevertheless, this cycle may also be used to the management of everyday crises (Matinrad 2019). The emergency management life cycle has four distinct phases: mitigation, readiness, response, and recovery, as shown in this image. Professional emergency management entities such as ambulances, call centers, fire and rescue services (FRS), and police are involved to varying degrees in all four phases. However, new types of entities such as community first responders, laypersons and bystanders, semi-professionals, and volunteers are primarily involved in the response phase. The human resources need additional equipment for their reaction activities. This figure presents the equipment used for medical crises, which may be categorized into two groups: medical equipment (specifically, first-aid kits and AEDs) and transport equipment (including drones and cars). These devices are used in both the readiness and reaction stages. It is important to mention that the medical equipment shown in this image pertains only to the new sorts of performers. The arrows originating from outside the border of the emergency management life cycle link each resource category to the phase(s) in which they are engaged.

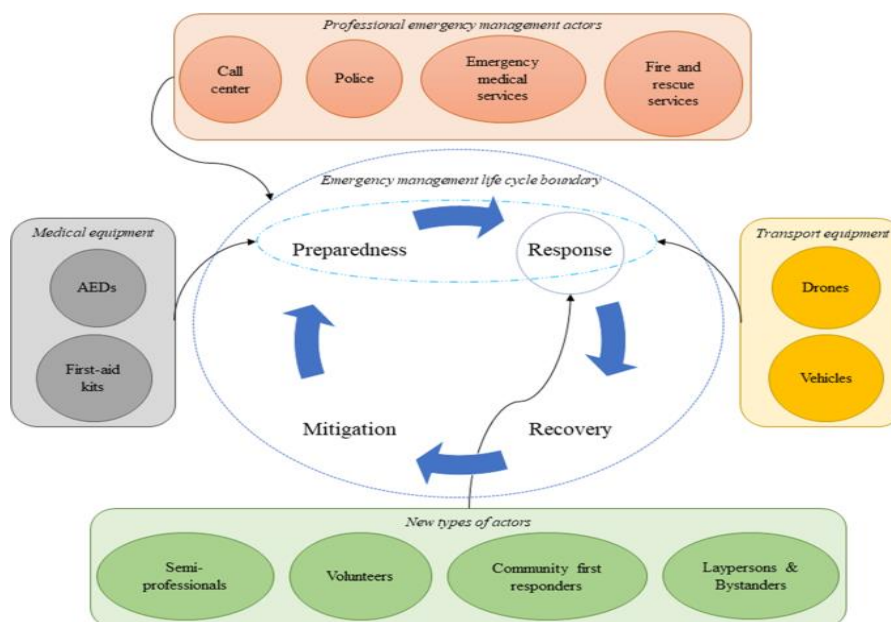


Figure 1. The actors and equipment that are part of the emergency management life cycle.

1. Studies about the use of numerical data to analyze and evaluate pre-EMS services

Most models have used a deterministic approach for strategic site planning, disregarding the uncertainties that arise in emergency situations. These uncertainties are to factors such as trip durations, the accessibility of personnel, or the operational effectiveness of equipment. Consequently, a deterministic model may have limited capacity to accurately represent reality, and thus, be less practical. Stochastic, probabilistic, or resilient optimization techniques that account for these uncertainties have been seldom used. Only a total of six studies have specifically focused on the operational planning level, and none of these papers have examined a planning challenge at the tactical level.

The majority of the models have used coverage maximization as the primary goal function. Given that the majority of these studies have focused on the positioning of AEDs, it is logical to include coverage as the objective function. Given that pre-EMS services are used in reaction to medical crises, it is advantageous to take into account the survival probability of patients in the modeling process. Survivability has been the goal function in just four out of the 41 publications. Erkut et al. (2008) demonstrated that the survival probability may be included in the ambulance locating issue as an objective function. Thirteen studies have used other goal functions, such as quantifying the time saved by drone usage or AED placement in comparison to EMS arrival, or lowering travel and reaction times in general.

The predominant location model used by academics is the maximum coverage location problem (MCLP), particularly for the positioning

of automated external defibrillators (AEDs). Another option to consider instead of this modeling approach is the maximum survival location problem (MSLP) as proposed by Erkut et al. in 2008. This strategy prioritizes the survival of patients above their coverage.

2. Conclusion

This study examines the research on pre-EMS services that has been published in OR/OM or medical publications, as well as conference proceedings, up to the end of 2020. Our research primarily concentrated on everyday medical crises and provided a macro-level study of the current literature in this area, rather than delving into a comprehensive micro-level examination of a select few particular publications. We anticipate that the findings of this analysis will appeal to new researchers and provide significant insights and guidance for future research to both academics and medical emergency management.

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