Revolutionizing Emergency Medical Services: A Review of Ambulance Technology Advancements and Service Enhancement Strategies

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***Abstract*—This review paper addresses the challenges faced by current emergency ambulance systems, focusing on improving service efficiency and patient outcomes. Analyzing various studies, we explore the demand for emergency services, including factors such as traffic congestion and inappropriate use of ambulances. Additionally, queuing theory models are examined to determine optimal fleet sizes for meeting service standards. The review also highlights advancements in ambulance technologies, emphasizing the potential for enhancing emergency medical services (EMS) effectiveness and efficiency. Through a systematic analysis of ambulance technologies from the past decade, this paper identifies trends, growth patterns, and future directions for EMS technology. The findings underscore the importance of investing in innovative ambulance technologies to improve patient care and survival rates. Recommendations for developing an app-based, 24/7 emergency service connected to hospitals are proposed to address current EMS challenges effectively.**

Keywords—Emergency Medical Services (EMS), Pre-Hospital Emergency Medical Services, Telemedicine, eHealth, Telecommunication Infrastructure, Intelligent Transportation System.

I. INTRODUCTION

Emergency medical services (EMS) are essential in helping people get care right away, when an individual has an medical emergency [1]. These emergencies, ranging from automobile accidents to sudden illnesses, are frequent in urban settings, highlighting the need for efficient EMS systems [2]. A public emergency ambulance system typically handles life-threatening emergencies, while other means manage emergency-like conditions [3]. Understanding and predicting the demand for EMS is crucial for optimal resource allocation. Challenges such as traffic congestion and inappropriate ambulance use persist, but advancements in ambulance technologies offer opportunities for improvement. This study uses information from a public emergency ambulance system to assess the type of demand for emergency services [2].

True medical emergencies are rare for a given household, but they do happen regularly in cities and require professional and timely care [2]. But the EMS system is under pressure from the increasing number of non-life-threatening situations, which calls for a flexible and effective approach. Determining the nature of the need for treating medical emergencies and situations that resemble emergencies is a city's main duty. To best place ambulances and emergency treatment centers, it would be ideal to be able to forecast the kind and frequency of incidents for certain areas [2, 4-6].

Due to rising call numbers and lengthy response times that negatively affect patients, there is a lot of media and public attention focused on the unsustainable demand for emergency ambulance services [3]. Frequent callers, constituting a small minority, pose particular challenges to EMS, with research indicating higher mortality rates [3,8] among this group. Managing strategies for frequent callers is a priority for ambulance services, aiming to provide appropriate care and reduce strain on resources. By analyzing data from an active public emergency ambulance system to estimate the type of service demand, the research attempts to address a portion of this issue [3,9].

The vast majority of emergency-like circumstances, which reflect latent demands on the public system, are managed by alternative means, while the majority of actual medical crises that pose a threat to life or function are treated by the public system. As a result, relatively little modifications to the public system's structure may result in large adjustments to the demand for it. Furthermore, data on potentially significant aspects like weather were not available to the writers. Despite these issues, the authors were nonetheless able to create a model that accounts for almost all of the variation in the demand for publicly dispatched ambulances between census tracts [2].

Advancements in ambulance technologies have the potential to transform EMS delivery. Technologies such as telemedicine, GPS tracking [10], and mobile apps can improve communication, coordination, and efficiency in EMS. For example, a study reviewed ambulance technologies between 2014 and 2024 and identified trends and future directions for EMS technology development [3].

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To boost the survival rate and deliver superior care during the EMS procedure, investing in innovative ambulance technologies is essential.

Thus, this review paper aims to address the challenges faced by current emergency ambulance systems, focusing on improving service efficiency and patient outcomes. Through a systematic analysis of ambulance technologies, this paper identifies trends, growth patterns, and future directions for EMS technology development. The findings underscore the importance of investing in innovative ambulance technologies to improve patient care and survival rates. Recommendations for developing an app-based, 24/7 emergency service connected to hospitals are proposed to address current EMS challenges effectively.

II. Emergency Medical Services

The roots of emergency medical services (EMS) can be traced back to the ancient Knights Templar, who were among the first to attempt resuscitation and life-saving measures [11]. However, modern EMS systems emerged during the Napoleonic Wars, with the primary goal of treating injured soldiers on the battlefield [12]. The concept of civilian ambulances was introduced in 1832 in London, where carriages were used to transport cholera patients [12]. Since then, ambulance technology has continuously evolved to enhance the efficiency and effectiveness of EMS operations [13].

A six steps emergency services care model has been proposed by National Highway Traffic Safety Administration (NHTSA) based in Unites States [13], which outlines six stages of pre-hospital care: detection, alert through notifications, resource allocation, on-site care, en-route care, and transfer to specialized facility. This model provides a standardized framework for discussing and implementing various ambulance technologies throughout the pre-hospital care process [13].

Although the majority of pre-hospital EMS vehicles are ambulances, the definition of an ambulance needs to be modified to take into account the current environment. Dictionary definitions of an ambulance used to state that it was a car meant to take people who were ill or injured to and from hospitals, usually in an emergency [14]. However, the concept of ambulance technology can be expanded to encompass the scientific and engineering knowledge involved in creating and utilizing specialized vehicles and life-saving systems for transporting patients, particularly in emergency situations. To reduce the risk of fatalities or disabilities, it is crucial to transport emergency patients to the nearest hospitals within the "golden hour" (8 minutes).

By analyzing national policies in the United States and Thailand, three main groups of ambulance technologies have been identified based on their applications in pre-hospital EMS [13]:

Group I: Advanced Traffic Management Systems - A vehicle's design, dispatching, access control, position identification, and vehicle-traffic communication technologies are all included in this system. Reaching the eight minute Emergency Medical Services (EMS) response time and lowering mortality are the main objectives, which will be accomplished by facilitating quick patient location identification and transportation to the closest hospitals [15].

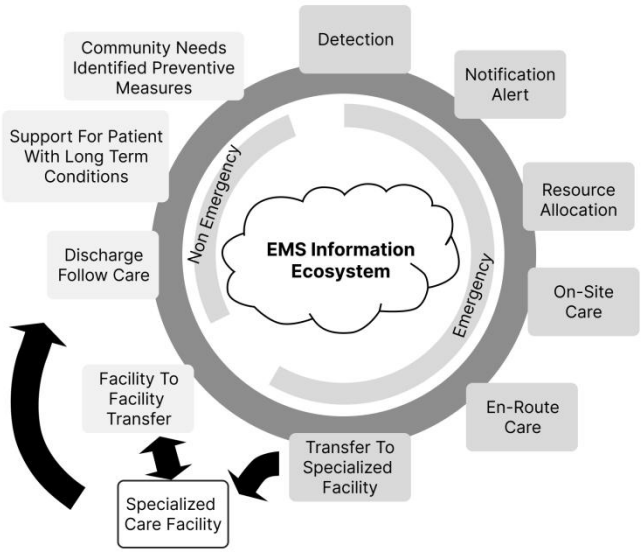

Fig. 1. Six steps in the Journey of Emergency Medical Care (Adapted from [7])

Group II: E-Health - The technologies in this cluster, which include information and communication, can enhance patient health condition management, monitoring, diagnosis, treatment, and preventive [16]. Through the use of telehealth, telemedicine, and E-Health solutions, these technologies facilitate the exchange of vital information between patients in ambulances and medical staff in hospital emergency rooms [17]. This cluster helps emergency physicians get ready for new patients by exchanging critical information that can improve patient survival rate.

Group III: Emergency Response Network - In order to guarantee the quickest possible medical response, a strong communication technology network is essential. This network includes advanced dispatch systems, patient data transmission in real time, and smooth communication between hospitals and emergency responders. Accurately locating patients, enabling quick ambulance deployment, and ultimately saving lives depend on this networked infrastructure.

In summary, ambulance technology will play a crucial role in the future of EMS. However, its definition should be updated to reflect the current research community's needs. Ambulance technology can be categorized into the following main groups: Advanced Traffic Management Systems, E-Health, and Emergency Response Network [7]. The purpose of this paper is to review recent publications in ambulance technology and provide a knowledge base and overview for policy recommendations in pre-hospital EMS.

TABLE I. Three Main Groups Of Ambulance In Pre-hospital Emergency Medical Services (EMS)

Group 1	Advanced Traffic Management Systems
Group 2	E-Health
Group 3	Emergency Response Network

III. Systematic Literature Survey

In this study, the researchers have adapted the Systematic Literature Review (SLR) framework into a 7-step process [19]. This includes organizing the review, defining the research questions, searching the literature, selecting relevant papers, extracting data, analyzing the findings, synthesizing the results, and finally reporting the outcomes, as depicted in Figure 2. These steps are explained below [7]:

Organizing a Review: This first stage is essential to the SLR process as a whole. The goals and parameters of the review must be specified by the researchers, since this aids in defining the parameters and concentration of the literature search. Determining important stakeholders, including decision-makers or subject matter experts, guarantees that their demands are met by the review. Setting up a schedule and project plan gives the review structure and makes it possible to do it quickly. Clearly defined responsibility and coordinated efforts are ensured throughout the process by assigning roles and tasks to the review team.

Defining the Research Questions: The search, selection, and analysis of the literature will be guided by the research questions, which form the cornerstone of the systematic literature review. To make sure the review stays targeted and manageable, these questions need to be clear and succinct. Researchers can create well-structured, thorough questions that address the Population, Intervention, Comparison, and Outcomes of interest. Research topics that are well-defined improve the Systematic Literature Review's overall quality and clarity.

Searching the Literature: Since it establishes the scope and depth of the research that will be included in the review, the literature search is an essential first step. It is imperative for researchers to formulate a comprehensive search approach that leverages a blend of keywords, subject headers, and Boolean operators (such AND, OR, and NOT) to locate the most pertinent studies across many databases and sources. This thorough method lowers the possibility of overlooking significant research by ensuring that the review includes a broad spectrum of pertinent literature. For the search process to be transparent and replicable, detailed documentation is required.

Selecting Relevant Papers: The studies that are most pertinent to the research questions are chosen in this stage after a thorough examination of the search results and the application of preset inclusion and exclusion criteria. This might entail a multi-step screening procedure wherein the complete texts of the remaining papers would be reviewed after the titles and abstracts have been reviewed. To guarantee that the selection procedure is rigorous and impartial, the inclusion and exclusion criteria need to be specified precisely and used consistently. Transparency and review credibility are increased when the selection decisions including the number of studies included and eliminated at each stage are documented.

Data scraping: The methodical collection of relevant data from the selected research is the process of data extraction. To guarantee uniformity and thoroughness in the data gathering procedure, researchers might utilize a standardized data extraction form or template. research characteristics (e.g., authors, publication year, research design), participant data, intervention specifics, outcome measures, and

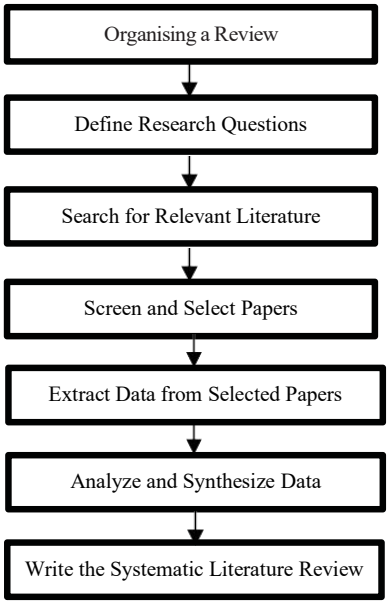

Fig. 2. Steps for a Systematic Literature Review [19]

extracted. The researchers' ability to work with a full and well-organized data set makes the subsequent stages of analysis and synthesis easier when using this structured technique to data extraction.

Analyzing the Findings: Researchers carefully examine the data that was taken out of the chosen studies in this stage. They may use a variety of analytical methodologies, such as descriptive statistics, thematic analysis, or meta-analysis, depending on the type and calibre of the included research. Finding patterns, trends, and connections in the literature as well as evaluating the reliability and quality of the included research are the main objectives. The validity and trustworthiness of the review conclusions are enhanced by this critical assessment of the research' advantages, disadvantages, and possible biases.

Synthesizing the Results: The final step involves synthesizing the findings from the analyzed literature to provide a comprehensive understanding of the research topic. Researchers may use narrative synthesis, where they describe and discuss the key themes, concepts, and relationships emerging from the literature. Alternatively, they may employ quantitative synthesis, such as meta-analysis, to combine and statistically analyze the results of multiple studies. The synthesis should integrate the findings, highlight the key takeaways, and identify any gaps or inconsistencies in the existing literature. The ultimate goal is to present the outcomes of the review, including the conclusions, implications, and recommendations for future research or practice.

The goal is to find and support emerging technology groupings that might support joint research projects and more advancements in this area. Furthermore, the researchers think that implementing new ambulance technology can contribute to raising the standard of pre-hospital emergency medical services (EMS) in general. As a result, the study answers few important research questions:

1. What are some of the groups or categories of recent ambulance technologies being utilized in pre-hospital EMS?

2. What are the connections between these ambulance technologies and the specific products/services associated with each cluster?

3. How do these ambulance technology innovations within the identified categories have the potential to improve emergency response times, resource allocation, and overall effectiveness of pre-hospital EMS?

4. What are the potential future enhancements and updates that could be made to an app-based emergency service platform to further revolutionize and transform pre-hospital emergency medical care?

To answer these questions, the researchers will thoroughly analyze and synthesize the findings from the selected qualified papers. Finally, the study's conclusions will be reported to the intended target audience [20, 21].

IV. Result

The review highlighted the three main categories of ambulance technologies used in pre-hospital emergency medical services (EMS): Advanced Traffic Management Systems, E-Health, and Emergency Response Network.

Technologies like medical drones, intelligent traffic management systems, driverless ambulances [22], and ambulance tracking and navigation systems are all part of the Intelligent Transportation System cluster. The goal of these technologies is to increase ambulance response and transport speed and efficiency. Medical drones and autonomous ambulances seem promising, but there are still some obstacles to be solved in terms of technology, legislation, and public acceptance. The use of Radio Frequency Identification (RFID) [23], Internet of Things (IoT), and Light-Fidelity (Li-Fi) in intelligent traffic control systems is being investigated to provide ambulances priority access through crowded metropolitan areas [24-26].

The technologies that can improve patient monitoring, diagnosis, and treatment within the ambulance are the focus of the e-Health cluster. This includes telestroke services, diagnostic tools, and patient health monitoring devices located in ambulances. More sophisticated on-site medical treatment during patient transport is now possible because to mobile devices, sensors, and telemedicine capabilities [27-29].

During pre-hospital EMS, technologies like cyber security and smooth ubiquitous communications are essential for dependable data transfer and the protection of sensitive patient information. The evolution of smart ambulance technology is anticipated to be significantly facilitated by the switch to 5G networks [30].

Figure 3 depicts the logical procedure for assessing the literature for a research topic. The initial stage is to obtain a total of 183 publications from the database search. Due to duplication or noncompliance with inclusion criteria, 32 publications were eliminated from this collection. Then, the remaining 151 papers' titles and abstracts were utilised to select them. After an additional eighteen articles were discarded through the full-text screening process, 133 papers were selected for analysis. 106 publications made it to the quality evaluation step of the systematic review after 27 of the 133 papers underwent a quality examination [21].

Overall, this review shows how the field of ambulance

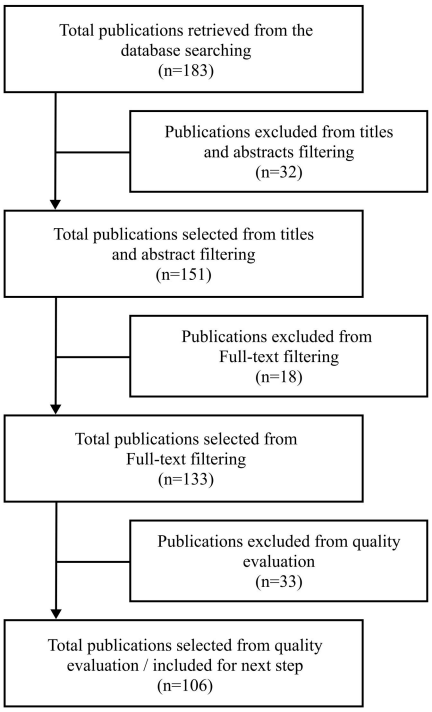

Fig. 3. Flow chart illustrating the procedures for carrying out a thorough literature study [21]

technology research and development is expanding, as seen by the rise in publications between 2014 and 2024. The results offer a body of knowledge and suggestions to help stakeholders and policy makers improve pre-hospital EMS by strategically implementing these cutting-edge technology.

V. Future Scopes

The future of Emergency Medical Services (EMS) is poised for transformation, driven by continuous improvement and adaptation to meet evolving community needs. Building on the insights from this review paper, several innovative enhancements and updates can be envisioned to revolutionize EMS.

Firstly, the app-based emergency service can evolve into a comprehensive platform that not only facilitates emergency transport but also enhances community engagement and involvement [32]. For instance, the platform could enable the creation of a community network where individuals in emergency situations can seek assistance from nearby residents willing to offer their vehicles for transport. This feature would be invaluable in situations where traditional ambulances face challenges in reaching patients promptly, such as during heavy traffic or natural disasters.

Moreover, the platform can be further enhanced to provide real-time updates and notifications to users regarding the availability and location of nearby ambulances [33] or community volunteers offering their vehicles for emergency transport. This would not only improve the efficiency of emergency response but also empower individuals to take proactive measures in assisting those in need within their community. Additionally, the platform can incorporate advanced mapping and navigation technologies to optimize ambulance routes [34], further reducing response times and improving overall service quality [7, 35].

Furthermore, future updates to the platform can focus on expanding its capabilities to provide comprehensive EMS beyond transportation. For example, the platform could integrate telemedicine features [36], allowing Emergency Medical Technicians (EMTs) [37] or paramedics to provide remote medical assistance to patients before they arrive at the hospital. This could help stabilize patients' conditions and improve outcomes during critical situations. Additionally, the platform could incorporate features for remote monitoring of patients' vital signs and medical history, enabling more personalized and effective care. Moreover, in an emergency condition where a patient may be reluctant to go to the hospital, they could receive advice through a chatbot integrated into the system or have a video call with a doctor who can advise them on their medical situation.

In conclusion, the future of the EMS concept is promising, with potential advancements that can revolutionize emergency medical services. By leveraging technology and community engagement, we can create a more efficient, responsive, and inclusive emergency medical system that better serves the needs of individuals in times of crisis. The proposed enhancements and updates to the app-based emergency service represent a significant step towards achieving this vision, paving the way for a more connected, efficient, and compassionate emergency medical system for all.

VI. Potential Outcomes

"In envisioning the future of emergency medical services (EMS), the concept of an "Uber for Ambulances" emerges as a transformative model. This innovative approach leverages technology and community engagement to enhance the efficiency and effectiveness of emergency response systems. By exploring the potential outcomes of implementing such a model, we can glimpse into a future where emergency medical care is more accessible, responsive, and tailored to the needs of communities."

Implementing the "Uber for Ambulances" model could significantly improve emergency response times, potentially saving lives. By utilizing technology to dispatch the nearest available ambulance, the system can reduce the time taken to reach patients in critical conditions. The concept opens up opportunities for community involvement in emergency response, allowing individuals to register their vehicles for emergency services, mobilizing a larger fleet during peak times or in high-demand areas, ensuring quicker access to medical assistance.

Optimizing the allocation of resources by directing ambulances to areas with the highest demand can reduce the strain on traditional EMS systems [38-41]. This ensures that resources are utilized efficiently to meet the needs of the community. By leveraging existing resources, such as private vehicles and community volunteers, the "Uber for Ambulances" model can provide cost-effective solutions for EMS, leading to reduced healthcare costs and more sustainable emergency response systems.

Integrating telemedicine services [42] can allow medical professionals to provide remote assistance to patients before they arrive at the hospital. This can improve the quality of care and outcomes for patients, especially in critical situations [42-44]. Collecting and analyzing data on emergency response times, patient outcomes, and resource utilization can inform decisions about resource allocation, infrastructure development, and policy planning, further enhancing EMS [45-47].

TABLE II. Advantages And Disadvantages

S.No.	Advantages	Disadvantages
1.	Faster emergency response times.	Potential problems with insurance and liability.
2.	Optimum distribution of resources.	The difficulties of organizing and overseeing a large fleet of vehicles.
3.	Affordable options.	Concerns regarding patient information securityand privacy.
4.	Including telemedicine services.	Setup and infrastructure fees at first.
5.	Decision-making based on data.	Reluctance to depart from established emergency medical services (EMS) systems.
6.	Flexibility and scalability.	Reluctance to depart from established EMS systems.
7.	Increased Involvement in theCommunity.	Using private automobiles only might not be thebest option for medical transportation.

The system's scalability and adaptability enable it to be customized to fit various settings and needs. It can be tailored to urban, rural, or underserved areas, ensuring that all communities have access to timely and efficient EMS. Overall, these outcomes suggest a paradigm shift in EMS, with the potential to revolutionize the way healthcare is delivered during emergencies [47, 48].

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