ACSIS: An Intelligent Medical System for Improving the Pre-hospital Healthcare Process

Petros Valacheas[1](✉), Sarandis Mitropoulos[2], and Christos Douligeris[1]

[1] University of Piraeus, Piraeus, Greece
petros.valacheas@gmail.com, cdoulig@unipi.gr
[2] Ionian University, Lefkada, Greece
sarandis@unipi.gr

Abstract. The purpose of this research article is to present an online intelligent pilot medical system designed to support the existing Greek pre-hospital medical care system. The proposed system effectively dispatches the available ambulances when an incident occurs and provides high quality medical services to the patients as well as transportation to the appropriate hospital. The evaluation of the proposed system, benchmarked via the paired t-test statistical tests and using the TIBCO business studio, shows a significant performance improvement on both the overall time to respond and the associated costs.

Keywords: Pre-hospital Care · Healthcare · Mobile Applications · intelligent medical systems · web IS · Business Information Systems

1 Introduction

Pre-hospital care has developed rapidly over the last decades and is now a necessary part of patient medical care [1]. An initial diagnosis in the ambulance can improve the patient's handling on arrival at the hospital [3]. Telemedicine solutions are increasingly used to speed up the process of diagnosis and care of the patient during transport to the hospital. The aim is to analyze and evaluate the health condition of a patient before the hospitalization phase. Electronic diagnostics, video conferencing and medical data analysis technologies are the main methods used [4].

Historically, the pre-hospital medical systems provided health care to patients without considering their clinical/medical condition. The most common approach was to refer them to the nearest health center or hospital. This approach resulted in considerable delays in the process of diagnosis and medical care. Too often, transporting patients to the appropriate hospital or health center for medical care was not the best possible as there was incomplete information about their condition [5].

Modern pre-hospital medical care systems have increased their ability to assess and diagnose the patient's health status, providing high quality medical care. They can also manage a fairly large number of patients who previously could not be assisted due to

L. A. Maglaras and C. Douligeris (Eds.): WiCON 2023, LNICST 527, pp. 63–81, 2024.
https://doi.org/10.1007/978-3-031-58053-6_5

insufficient equipment and know-how. The effective transport of the injured or patient to the appropriate hospital has been fully integrated into the functions of pre-hospital medical care and has ceased to be part of hospital medical care [6].

Various commercial telemedicine systems that feature state-of-the-art software are extremely bulky and expensive. Thus, they are used by very few health centers or hospitals. The rapid progress made in the field of Information and Telecommunications Technology (ICT) in recent years, enables us to design and develop quality telemedicine services for the pre-hospital health system that are accessible to all [7].

Emergency Medical Systems (EMS), as they support the first aid at the incident scene, provide some fundamental benefits to the overall healthcare services offered to the patients, as can be seen in Table 1 [3]. The Mobile Data Terminals (MDTs)[1] and the Medical Priority Dispatch Systems (MPDs)[2] are dispatching systems that help to determine the appropriate ambulance to be sent to the scene of the incident [8]. TrackerAssist, ManDown, and ePCR3[3] are remote sensing emergency care systems that can identify some critical health metrics of the patient and then notify the call center for incident reporting [9]. STREMS uses wearable sensing technology to capture the important medical data of the patient and provide a list of them for the efficient in-hospital medical care [22]. E-911 is used only for incident reporting as it cannot dispatch the appropriate ambulance [10].

The proposed ACSIS (Ambulance Consulting Services Information System) is an advanced ambulance dispatching and health care provision system which incorporates "On-time Incident Reporting", "On-time Arrival at the incident", "On-site Care", "Medical Care during Transportation", and "Transportation to the Health Center". ACSIS can be viewed as a mix of the E-911 computer aided system, MDTS and STREMS giving valuable benefits to the existing EMS systems. For example, Tracker Assist is likely a system that can track the location of individuals or assets in real-time. This can be useful for various purposes, including monitoring the movement of personnel, vehicles, or valuable items. It might have the capability to send emergency alerts or notifications when predefined conditions are met. For example, it could send an alert when a person enters or leaves a designated area. TrackerAssist may provide reporting features to generate historical location data, helping organizations analyze trends and make informed decisions. In addition, ManDown systems are typically designed to enhance the safety of personnel, especially in hazardous environments or high-risk occupations. They can detect unusual movements or conditions that may indicate a person is in distress or has fallen. ManDown systems often include fall detection features, automatically triggering alerts if someone falls or becomes immobile. These systems can send alerts to designated contacts or monitoring centers in case of a distress signal, allowing for a rapid response to emergencies. ePCR is used by emergency medical services (EMS) personnel to electronically document patient information and medical assessments during emergency incidents. It helps ensure the accuracy and legibility of patient records,

[1] https://thorcom.uk/products/mobilize/mobilize-mdt/ (accessed 02/12/2022).

[2] https://prioritydispatch.net/marketing-resource/ASSETS/PDFS/MPDSCatalog140114_English.pdf (accessed 02/12/2022).

[3] https://www.ems1.com/ems-products/epcr-electronic-patient-care-reporting/ (accessed 02/12/2022).

reducing errors in medical reporting. ePCR systems streamline the documentation process, allowing EMS personnel to focus on patient care. They often include templates and drop-down menus for quick data entry. ePCR systems may integrate with hospital electronic health records (EHRs) and other healthcare systems, enabling seamless sharing of patient information (Table 1) [3].

Table 1. The Respective Emergency Medical Systems per Performance criterion.

Performance Criterion	EMS Systems that support the Criterion
Timely Incident Perception	TrackerAssist, ManDown, ePCR
On-time Incident Reporting	E-911, TrackerAssist, ManDown, ePCR, eEKAB, ACSIS
On-time Arrival at the Incident	CAD, GIS, MDTs, MPDs, eEKAB, ACSIS
On-site Care (Extra operation from the e-Ekab EMS)	STREMS, ACSIS
Medical Care during Transportation (Extra operation from the e-Ekab EMS)	STREMS, ACSIS
Transfer to the Health Center	MDTs, eEKAB, ACSIS

ACSIS bridges the pre-hospital and the in-hospital health care by providing efficient and effective healthcare services to the patients. It is an add-on information system that could play a crucial role before the patient arrives at the hospital, providing inputs to the triage systems which will then take over [22].

This study aims to address the following research question: How can the Ambulance Consulting Services Information System (ACSIS) enhance pre-hospital care by incorporating advanced features such as 'On-time Incident Reporting,' 'On-time Arrival at the incident,' 'On-site Care,' 'Medical Care during Transportation,' and 'Transportation to the Health Center'? Additionally, what benefits does ACSIS offer compared to existing EMS systems, such as E-911, MDTS, and STREMS?" It explicitly outlines the research question and sets the stage for the subsequent sections to discuss the proposed ACSIS and its potential contributions to pre-hospital care.

2 Analysis and Design of ACSIS

Upon arrival of an emergency call in the call center, a process is launched for the effective selection of an ambulance to be sent to the scene of the incident. The call center operator, knowing, through the mapping application, the exact location of the available ambulances, can choose precisely the one which will be immediately dispatched. In fact, the call center can send notifications to all the available ambulances using the Firebase Cloud Messaging platform, a free notifications service provided by Google. The ambulance, after receiving the corresponding notification with the exact location, follows the route determined via Google Maps for its effective routing to the point.

At the incident location, medical care to the patient is provided in parallel with the appropriate cardiac pulse and respiration rate measurements. The nursing staff inside the ambulance is given the opportunity to make phone calls to find out the on-duty hospitals and pharmacies. A patient diagnostic functionality at the ambulance is provided to interpret the patient's symptoms. Finally, the nursing and the medical staff of the ambulance select the appropriate hospital center to which the patient will be transported. The destination is displayed on a map and the ambulance is navigated using Maps.

The ambulance taking notice (Notification) of the location of the emergency can go to it as soon as possible. GeoFire allows real-time data update, which is a very useful tool which performs "smart" calculations to retrieve selected data in specific locations. It is a key part of designing the ambulance application as it manages to update the base in real time data for the location of each vehicle. This allows the call center to be updated constantly with the current location of each ambulance, which is a crucial element for the proper dispatch of an ambulance to the emergency location [13][4].

The software development methodology that was used to plan, organize, prioritize, and proceed with the design and the implementation of the application was the Agile Scrum. For implementing ACSIS, each sprint, i.e. The smallest block of scrum which has a small team that works on an assigned task, lasted for 2 weeks [11].

The software system implemented to support and enhance the pre-hospital medical system consists of two independent applications, which are directly interconnected, of the web-based application which is the interface point with the call center operators, and of the mobile (Android) application that is handled by the ambulances. The two applications are connected on a common database located in Firebase, where the data are stored and retrieved. Their communication takes place through Firebase Cloud Messaging (FCM), which gives the capability of easy, reliable, and secure sending of messages. The mobile device sends its location via GeoFire, allowing the call center to visualize the above information in real time. The system architecture follows the Server-Client model. The server communicates with all its clients, serving requests via the HTTP protocol. Each client can be an ambulance or a call center application user. The server communicates with the database through Firebase to manage all the appropriate data for its operation (Fig. 1) [12].

The web-based application simulates the call center of the pre-hospital health system. The system has the following screens:

- Home Page (medical instructions for providing medical care to the patient)
- Display screen of the hospital centers on a map.
- HelpLine screen (incl. a table with the hospitals in which the patient can be transferred)
- Display and selection of available ambulances on a map in real time.

The screens that have been implemented for the mobile application are the following:

- Start Activity
- Login and Register Activities
- Main Activity with the following screens:
- Display and navigation to the available hospitals.

[4] The UML sequence diagram of ACSIS is provided in the following link: https://bit.ly/3rxfsue.

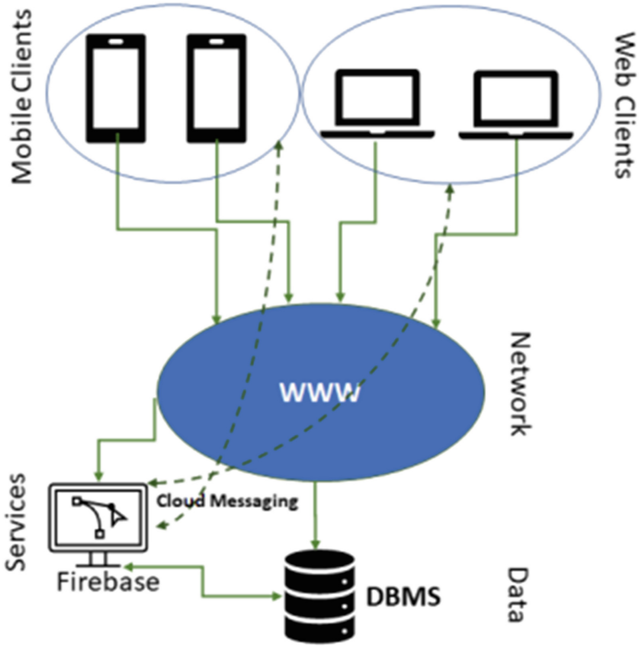

Fig. 1. ACSIS Client-Server Communication and the overall Architecture. Mobile and Web Clients communicate via the Firebase Messaging Service.

- Emergency: The nursing staff can be informed about the appropriate medical services to be offered to the patient.
- Patient Diagnosis.
- Patient's Heart Rate.
- Patient's breathing Rate Activity.

3 Demonstration of Applications' Operation

When launching the application, the user is prompted to connect to the ambulance application. Firebase adds the user details to the system and redirects the user to the main page of the application. Thus, the nursing and medical staff of the ambulance can provide medical services to the patient for immediate and timely treatment to the patient[5].

3.1 "Hospitals" Operation in Mobile Application

By clicking the Hospitals button at the top of the screen, a new application page appears with the nearest hospitals and health center's locations, where the patient can be transported - searching is possible using free text. By selecting one of the displayed hospitals,

[5] The image "Interface of the mobile application" is provided in the following link: https://bit.ly/3LJCnt9.

the user can use Google Maps to get directions, and estimated travel times. To display the nearest hospitals based on the specific location, the user should click on the blue icon symbolizing "Hospitals" at the bottom of the map. Then, the user of the ambulance can calculate the distance between the current location and the location to be reached, as well as the time needed to reach it. This is an extremely useful service that makes each ambulance independent of the call center. As a result, the user can determine, the available options through Google Maps[6]. Beyond the graphical representation of the available hospital centers on the map, the user in an ambulance can see their exact address on the map. This helps the user to verify the location of the hospital to which he has decided to transfer the patient.

To suppress severe symptoms, a list of actions has been documented to be followed by the ambulance nursing staff in an emergency. Pressing the "Information" button leads to the list of the available incidents. The nursing and medical staff of the ambulance can make phone calls to receive information about the on-call hospitals, to request blood from the National Blood Donation Centre, as well as to contact, if needed, the Poison Centre. By pressing the EMERGENCY CALLS button, which is located on the main screen, one can switch to a new screen to make emergency calls. The ambulance staff can also get in touch with various medical centers. The nursing and medical staff need to have direct access to information that concerns the best medical care of the patient. Using phone calls, the ambulance staff can request blood in case the patient is bleeding, search for medical advice if it is a poison incident or be informed about the on-duty hospitals. All the above operations prevent some critical medical conditions when transporting the patient to the hospital.

By pressing the MEDICAL DIAGNOSIS button, a user is led to a new page where he can select the exact symptoms of the patient, complete the year of his birth and his gender[7]. By selecting Heart Rate in the menu, located on the top-right of the application, the patient's heart rate is measured using the mobile phone camera. After 30 s the result of the measurement is displayed on the screen. This operation allows the ambulance medical and nursing staff to examine whether the pulses of the patient's heart are within or outside the normal range. The timely notification of the patient's heart rate is an important step for the effective provision of medical care in the ambulance. Using the located light sensors in the camera, the amount of blood in the body is detected at the given moment[8].

3.2 ACSIS Web Application

The ACSIS web application is used by the staff in the ambulances operating centre. By launching the web application, the location of the Call Centre and the available hospitals are shown on a map. Selecting the "Hospitals" button in the left bar, the hospitals' and

[6] The image "Hospital locations and route for reaching the patient" is provided in the following link: https://bit.ly/46AB5Jf.

[7] The image "Medical diagnosis button" is provided in the following link: https://bit.ly/3Q0HUhL.

[8] The image "Screens for Heart Rate and Respiration Rate" is provided in the following link: https://bit.ly/46a8cnn.

the health centers' locations are displayed on the map. This functionality helps the call centre employee perceive the geographical zoning on the map and correlate the location of the hospital centers to the ambulance's one. This operation makes the ambulance selection for emergency handling effective.

In the past, the lack of depicting hospitals and health centers on the map often prohibited the call center from providing effective information for both the citizens and the ambulances. The "Show Hospitals" button displays the hospitals and the health centers that are located at a distance that can be used by the available ambulances. The digital display on a map of the respective locations, modernizes and speeds up the decision-making process and saves valuable time.

The call center upon arrival of an emergency is responsible for selecting and dispatching an ambulance to the scene. The need of the call center to have the full picture of the location for each ambulance led to the development of this functionality. By constantly monitoring the location of ambulances, the call center manages to efficiently optimize the available resources at its disposal and at the same time to provide the best possible medical care treatment for the patient[9].

The call center can fill in the emergency address of the patient and send a Notification to the ambulance. This feature enables the call center to speed up the dispatching of an ambulance to the scene of the incident. The traditional wireless communication with the ambulance has been recently replaced by modern cloud messaging technology. The call center can send medical assistance to the patient at no time. The Notification is sent to the mobile application of the ambulance, which undertakes to handle the part of the patient's medical care and the transport to the hospital. By clicking on Notification, the ambulance user is led to the map of the application to rush to the address of the incident. The Notification includes the exact address of the emergency incident to which the ambulance needs to be transported. The ambulance driver, by selecting the corresponding address on the map provided by Google Maps, navigates at the point knowing the estimated time it takes, the mileage and the traffic that will be encountered on the road. One primary consideration is the encryption and secure transmission of patient data. The system must employ robust encryption protocols to protect data during transmission from ambulances to healthcare centers and during any remote consultations. Discussing the specific encryption methods employed, adherence to industry standards, and strategies for preventing unauthorized access can enhance the transparency of ACSIS's security infrastructure.

4 Evaluation

4.1 Empirical Results from Cross-Sectional Research

In this section, a thorough evaluation analysis is provided regarding the performance of the EMS before and after the integration of ACSIS. The paired t-test statistical test was used to compare the corresponding results. The statistical model was applied through a survey via assumptions, which was conducted online using 30 ambulance drivers and 30 ambulance crew rescuers. Moreover, evidence regarding the health benefits in the

[9] The survey data are provided in the following link: https://bit.ly/3REfgUI.

adoption of ACSIS, feedback for the effective provision of in-hospital medical care of the patient and the better resource allocation of the ACSIS EMS system was achieved concerning the Cross-Sectional research.

The ambulance drivers and the ambulance rescue crew downloaded the mobile application, created their free account and used it to provide emergency medical care to the patients. The ambulance drivers received a notification via the ACSIS application and observed if they could arrive at the incident location on time. The ambulance rescue crew monitored if they could provide a quick and effective medical diagnosis of the patient's health within the ambulance. Having used the application at least once, they had to complete a questionnaire to express their satisfaction or displeasure[10].

30% of the rescuers mentioned that the ACSIS application offer benefits concerning the timely retrieval of information while 18,33% of the rescuers emphasize on the reduced costs after using ACSIS[11]. 83,33% agree that the patients were transported on time at the proper hospital to receive effective medical health care services after using the ACSIS[12]. 85% of the respondents agree that resource (ambulances, clinics, ambulance crew, time) management was improved after using ACSIS[13]. 88.33% of the ambulance drivers and ambulance crew acknowledged that the ambulance reached the spot between 3-to-5-time units. Specifically, the majority (43,33%) verified that the ambulance arrived in 4-time units. The time unit values are used to figure out the general time frame of this emergency medical care activity rather than to precisely calculate this timing value16[14]. 48.33% of the ambulance drivers and ambulance crew highlighted that the ambulance reached the spot in 1 time unit. They expressed their satisfaction on the quick arrival of the ambulance in the corresponding location and acknowledged the performance improvement using ACSIS on providing effective and on time medical services on the spot[15]. 90% of the responders agree that the traditional diagnostic procedure does not effectively assess the patient health condition on the way to the hospital[16]. 88,33% noticed an evaluation improvement on the diagnostic procedure that takes place within the ambulance. Most of the ambulance and ambulance crew highlighted that the ACSIS emergency system provides immediate medical diagnosis for the patient on the way to the hospital[17].

Specifically, there is a statistically significant difference in the arrival time of the ambulance after using ACSIS compared to the time needed before ($t = 13{,}501$, $p =$

[10] The image "The health benefit from the adoption of ACSIS between Ambulance drivers/Rescuers" is provided in the following link: https://bit.ly/3EZVbAK.

[11] The image "On time transportation and effective provision of medical care" is provided in the following link: https://bit.ly/3LHCLIG.

[12] The image "Efficient resource allocation after ACSIS" is provided in the following link: https://bit.ly/45dErQY.

[13] The image "The arrival of the ambulance times at the scene of the incident before ACSIS" is provided in the following link: https://bit.ly/46ADcwF.

[14] The image "The arrival of the ambulance at the scene of the incident after ACSIS" is provided in the following link: https://bit.ly/46vtsn9.

[15] The image "The provision of immediate diagnostics before ACSIS" is provided in the following link: https://bit.ly/3ZEBCHI.

[16] The image "The provision of immediate diagnostics after ACSIS" is provided in the following link: https://bit.ly/3PKS7xw.

[17] The statistical results are displayed in the following link: https://bit.ly/468IuQb.

0,000). Similarly, there is a statistically significant difference in the immediacy of the patient's diagnostic procedure with the use of ACSIS compared to its absence (t = -20,433, p = 0,00). In practice, this means that the use of the application contributed significantly to the timely and immediate transportation of the patient to the hospital. Also, the automation of the procedure for the diagnosis based on the patient's symptoms with the use of ACSIS increased the possibility of correctly assessing the pathological condition[18].

In Table 2, the mean values of two emergency medical care services are compared before and after ACSIS via the paired t-test statistical test. Pair 1 is related to the arrival of the ambulance at the scene of the incident. Footnotes 16–17 show the results that were formed based on the survey. The statistical method showed that the mean value for the time units needed after ACSIS is half of the time units needed before. Also, based on the pair analysis, the diagnostic procedure has improved significantly after ACSIS. More specifically, the candidates expressed that it is almost twice more effective than the existing one. A paired t-test was employed to assess the statistical significance of the difference between the time taken for an ambulance to reach an incident location before the implementation of the ACSIS and the time taken after ACSIS adoption. Specifically, this statistical test was utilized to determine whether there was a statistically significant change in ambulance response times associated with the introduction of ACSIS. The null hypothesis (H0) posited that there would be no significant difference in the time it takes for an ambulance to reach the scene before and after ACSIS was implemented. The alternative hypothesis (H1), on the other hand, suggested that there would be a significant difference in response times before and after ACSIS adoption. Data on response times for a sample of ambulance dispatches were collected both prior to and following the implementation of ACSIS. These response times were then paired according to the specific incidents, where each pair represented the time taken before and after ACSIS utilization for the same incident location. The paired t-test was chosen for this analysis because it is appropriate for assessing the mean difference between two related groups (in this case, response times before and after ACSIS) when the data are continuous, and the assumption of normality is met. Additionally, it takes into account the dependence between the two sets of response times for the same incident locations. The results of the paired t-test indicated whether the observed difference in response times was statistically significant, which, if significant, would provide evidence for or against the effectiveness of ACSIS in reducing ambulance response times. The level of significance (alpha) chosen for the test determined the threshold for statistical significance. Overall, the paired t-test was a suitable statistical method to evaluate whether the implementation of ACSIS had a significant impact on ambulance response times and to provide valuable insights for emergency response system improvements. The results of the paired t-test provided insights into whether the observed difference in the immediacy of diagnostic procedures was statistically significant. A significant result would suggest that the implementation of ACSIS had a notable impact on expediting diagnostic assessments during ambulance transport, potentially leading to more timely and informed patient care decisions.

[18] The diagram "The ambulance Consulting Services application's process before ACSIS" is provided in the following link: https://bit.ly/3ZCJ0TW.

Table 2. Pairs Samples before and after ACSIS. The first question of each Pair concerns the "Before" ACSIS while the second one concerns the "After" ACSIS enforcement.

	Mean	N	Std. Deviation	p-value
How many minutes does it take for the ambulance to reach the spot before ACSIS?	4,02	60	0,965	<0.05
How many minutes does it take for the ambulance to reach the spot after ACSIS?	2,00	60	0,611	
Is diagnostic procedure immediate for assessing the patient's condition on the way to the hospital by ambulance before ACSIS?	1,73	60	0,634	<0.05
Is diagnostic procedure immediate for assessing the patient's condition on the way to the hospital by ambulance after ACSIS?	4,32	60	0,676	

4.2 ACSIS Simulation Evaluation

ACSIS was evaluated using the Tibco Business Studio, which allows the design of the components of the process to be evaluated and the simulation of the respective parameters and weights to perform a cost-effectiveness analysis [14]. To draw conclusions about the evaluation of the efficiency of ACSIS, the analysis focused on both the cost and on the time reduction through the emergency medical lifecycle. Each process consists of a logical sequence of steps which has a beginning and an end [15]. The diagram in "the ambulance Consulting Services application's process before ACSIS"[19] shows the processes that are performed to complete the transport of the patient to the hospital without the integration of ACSIS, while Fig. 3 the corresponding automated processes [14]. The first step is the initial step where an emergency incident is reported to a call center, typically through a 911 or emergency hotline. The call center operators receive information about the nature and location of the incident. Once the call center operators have gathered the necessary information, they determine the appropriate level of emergency response required. They then dispatch the nearest available ambulance or emergency response vehicle to the incident location. The ambulance is equipped with a navigation system, often using tools like Google Maps, to find the quickest and safest route to the incident location. This helps reduce response time, especially in critical situations. The ambulance arrives at the scene of the emergency, and the paramedics assess the situation and provide immediate medical attention to the patient [25]. This may involve stabilizing the patient, administering first aid, or other life-saving measures. The paramedics continue to provide medical care to the patient as needed. This care can range from basic first aid to advanced life support, depending on the severity of the situation. Based on the patient's condition and the hospital's availability, the system automatically selects the most suitable hospital for the patient. The ambulance's navigation system guides the crew to the chosen hospital using tools like Google Maps. During transport to the hospital, paramedics and nursing staff may have access to medical guidance

[19] The image "Available Ambulances" is provided in the following link: https://bit.ly/3terCJ0.

or protocols via digital devices or communication with a medical control center. This ensures that the patient receives appropriate care end route to the hospital. Paramedics continue to assess the patient's condition during transport, updating the patient's status and vital signs. This information is vital for the hospital staff to prepare for the patient's arrival.

The ambulance arrives at the selected hospital, and the patient is transferred to the hospital's care. The hospital staff takes over the patient's treatment and may perform further diagnostic tests and medical procedures. The described process for handling emergency incidents, from the arrival of the incident in the call center to the patient's arrival at the hospital, is highly useful for several reasons, like rapid response, efficient resource allocation, efficient navigation and ambulance routing, medical guidance, automatic appropriate hospital selection, effective coordination and communication, patient data management, quality assurance, reduced human error and, enhanced accountability.

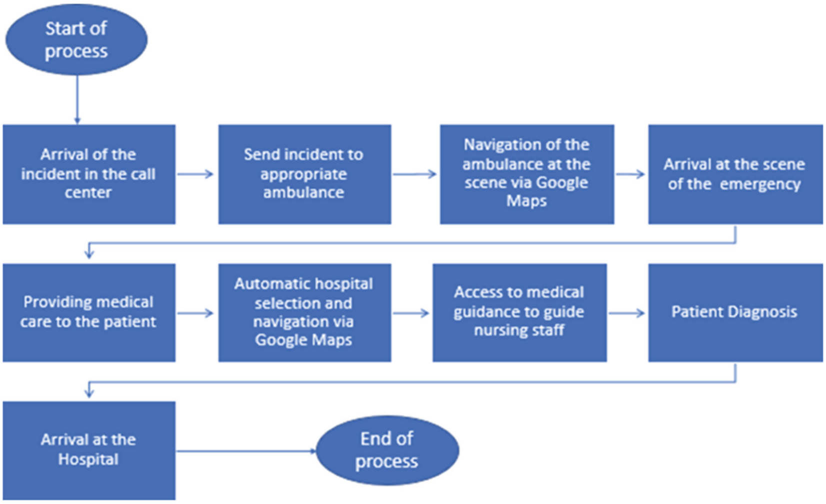

Fig. 3. The ambulance Consulting Services application's process after ACSIS enforcement.

The quality management approach requires to clearly understand the requirements, create a value-add process, and improve the overall process. The ASCIS evaluation presented hereby follows the ISO 9001:2015 qualified process approach, which involves the Plan-Do-Check-Act (PDCA) cycle and risk-based thinking [16]. The methodology for assigning time and cost parameters to the EMS simulated Tibco processes is conceptually supported by the Pairs Sample Statistical test as described previously. The cross-sectional statistical method that was used to compare the differences in the mean values before and after ACSIS, proved that it can enhance the EMS activity by 2 or 3 times. Particularly, the arrival time of the ambulance at the scene of the incident decreased by 50% compared with the time needed before ACSIS. Moreover, the ambulance drivers and the ambulance crew clearly expressed their satisfaction for the improved diagnostic procedure of the patient within the ambulance. They expressed that the medical diagnosis of the patient after ACSIS is almost 3 times more immediate. We assume that the automated emergency medical services will follow the same statistical flow and as a result they will improve 2 or 3 times compared to the emergency medical services offered before ACSIS.

To be more specific, the emergency processes that take place and handle the arrival of the ambulance on the spot are estimated to be twice as fast after ACSIS. The provision of medical care processes is estimated to be three times more efficient after ACSIS. In addition, we assume that the cost of the Tibco simulation will remain the same before/after ACSIS as the resources (ambulances, hospitals, ambulance crew and call center employees) will stay unchanged. In terms of the cost parameter for both simulations, we consider 12 call centers and 40 call center employees with a labor cost per day of 30 Euros. We also presume to have 1200 ambulances with an hourly cost of 160 Euros each. Therefore, we consider 1200 Euros for operating the call center and 200.000 Euros as an estimated cost for the ambulances.

The evaluation process of the parameters for the cost - time estimation of the ACSIS system using Tibco includes two stages. At first, we estimated the parameters based on the simulation of the processes performed by pre-hospital care systems without the ACSIS services and at second, these parameters were estimated using the ACSIS services.

4.3 Simulation Evaluation Results

Tibco calculated the minimum, average, and maximum values of the execution time, and of the cost of the process before the use of ACSIS. Cost and cycle time measurements are displayed in minutes in Fig. 4.

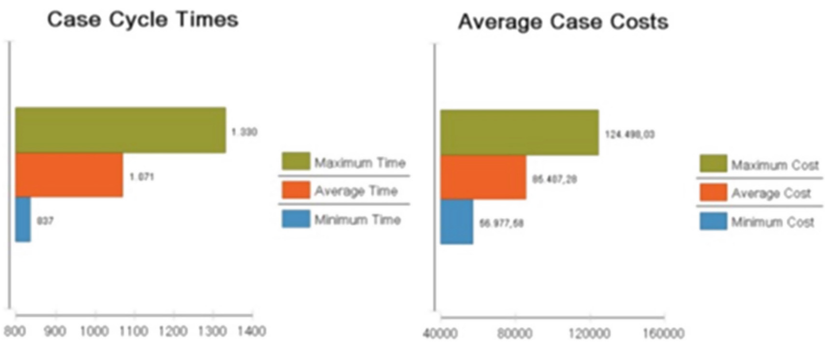

Fig. 4. Average Case Cycle Times and Case Costs after ACSIS enforcement.

It is obvious that the use of ACSIS has decreased spectacularly the total cost required for the response to an incident. In Fig. 5, it appears that before integrating applications the average cost relative with the average time of completion of the processes is estimated at 220,000 euros for 1100 min. After integrating the applications, the average cost in relation to the completion time of processes is set at 85,000 euros with an average time of 880 min.

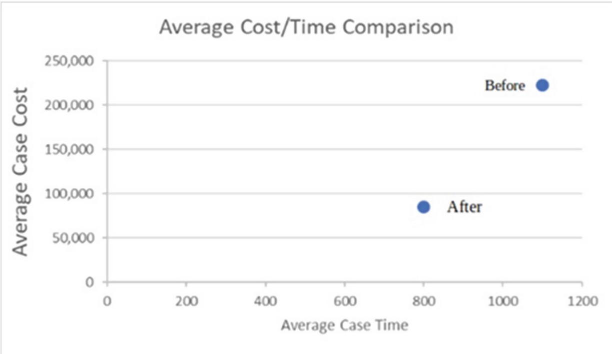

Fig. 5. Average Cost/Time comparison of before and after ACSIS enforcements.

5 Discussion and Future Work

The ambulance is transformed into a modern independent medical care unit that is an integral part of the pre-hospital health system. The ambulances are not any more fully dependent on the call center directions regarding the fast and reliable dispatch in the scene of the incident and the transportation of the patient to the nearest hospital. The medical diagnosis of the patient within the ambulance, the heart and respiration rate measurements in the ambulance play a vital role in assessing the patient's medical condition and helping to provide the optimal health services by the ambulance team. There are also some research limitations that we need to highlight. The proposed system does not thoroughly examine economic feasibility, despite acknowledging a reduction in accompanying costs. The lack of a comprehensive analysis of staffing and training needs, especially for non-medical personnel, raises concerns about the long-term sustainability and practicality of implementing the system on a broader scale. The low accessibility to networks in rural and barren areas can be an obstacle for the efficient operation of ACSIS. Moreover, poor ambulance availability can limit the effective provision of pre-hospital emergency care in these areas. It is also vital to ensure the protection of the patient's data concerning both the medical and location-based information [22].

While ACSIS presents a promising advancement in pre-hospital care, it is crucial to acknowledge and address potential limitations and challenges that may arise during its implementation across diverse healthcare contexts. One key consideration is the variability in healthcare infrastructures and resources among different regions. The effectiveness of ACSIS may be influenced by the level of technological infrastructure available in a particular area, potentially posing challenges in areas with limited access to advanced technologies. Moreover, cultural and regulatory differences across healthcare systems may impact the seamless integration of ACSIS. Adhering to diverse medical protocols, privacy regulations, and data security standards is essential. Ensuring compliance with these requirements is imperative for the successful adoption and sustained use of ACSIS in various healthcare settings. Another potential challenge lies in the adaptability of ACSIS to different emergency scenarios. The system's performance may vary based on the nature of incidents, geographical locations, and the specific healthcare needs of the population. It is crucial to explore the customization capabilities of ACSIS to cater to the unique demands of each healthcare context. Furthermore, the financial implications of implementing ACSIS need careful consideration. While the system aims to be a cost-effective alternative to existing telemedicine solutions, the initial setup costs, training programs for healthcare professionals, and ongoing maintenance expenses should be thoroughly evaluated. This economic aspect becomes particularly important when introducing ACSIS in healthcare systems with limited financial resources. Additionally, user acceptance and training play a pivotal role in the successful implementation of any healthcare technology. The readiness of healthcare professionals, emergency responders, and other stakeholders to embrace and effectively use ACSIS must be assessed. Addressing potential resistance to change and ensuring comprehensive training programs will be essential for the smooth integration of ACSIS into daily pre-hospital care practices. In conclusion, a thoughtful examination of these potential limitations and challenges will contribute to a more nuanced understanding of the practical implications of ACSIS in diverse healthcare contexts. By proactively addressing these issues, stakeholders can work towards maximizing the benefits of ACSIS and fostering its successful integration into pre-hospital care systems worldwide [23]. While our study provides valuable insights into the potential benefits of ACSIS within the Greek healthcare system, it is essential to acknowledge the potential limitations in generalizability to other healthcare systems with distinct operational dynamics. The Greek healthcare system has its unique characteristics, including specific regulatory frameworks, infrastructure, and patient demographics, which may differ significantly from other global healthcare contexts. The operational dynamics of pre-hospital care can vary widely between countries due to differences in healthcare policies, emergency response systems, and technological infrastructures. Therefore, the successful implementation of ACSIS in the Greek healthcare system does not automatically guarantee its seamless integration into other healthcare systems. Cultural and regulatory differences also play a crucial role in the generalizability of ACSIS. Compliance with local privacy laws, medical protocols, and ethical standards is paramount. The degree to which ACSIS can accommodate these variations without compromising its functionality and effectiveness should be explored in future research. To enhance the external validity of our findings, future studies could consider multi-country comparisons, taking into account a diverse range of healthcare systems. Such comparative analyses would provide a more comprehensive understanding of how ACSIS performs across different contexts and could identify specific challenges and opportunities unique to each setting. For instance, a comparative study could explore the implementation of ACSIS alongside similar ambulance dispatching and healthcare provision systems in countries with varying healthcare infrastructures, regulatory frameworks, and technological landscapes. By evaluating the experiences of these systems, we can draw meaningful comparisons that highlight the specific strengths and challenges of ACSIS in relation to its counterparts. Such a comparative approach allows for the identification of best practices, lessons learned, and potential areas of improvement. It also facilitates a more comprehensive understanding of the factors influencing the success or challenges faced by telemedicine solutions in different global settings. Additionally, it provides a basis for developing recommendations that are not only tailored to the Greek healthcare system but are also informed by a broader international perspective [12].

Various areas can certainly be improved. One area where the system could be extended, is the creation or updating of the electronic Medical Record of the patient within the ambulance. The medical diagnosis of the patient could be recorded and used to analyze and evaluate the health progress of the patient in the hospital. This operation could improve the medical services that are provided to the patient when at the hospital [20]. Another area where the system can be improved is security. The need to connect ambulances remotely to a wireless communication network (VPN) which would allow them to stay connected for the duration of providing emergency services, is an important feature for its effective operation. VPN offers a complete encryption and secure service over the network.

Finally, ACSIS could expand the clinical Triage systems and improve the overall health care services offered to the patients [21, 22]. The basic idea is that a Triage system can start cooperating with ACSIS still from the ambulance stage. In recent years, a key aspect of societal progress has centered around the availability of healthcare facilities [23]. Consequently, the strategic placement of ambulance stations and dispatching methods has gained significant importance. One widely adopted approach is the Emergency Medical System (EMS), which aims to optimize the allocation of a limited number of ambulances across emergency stations to effectively serve areas with the highest demand. Moreover, the challenge has grown more complex due to escalating medical expenses, surging demand, and urban traffic congestion [24]. These variables exert an influence on ambulance response times and should be taken into account when determining their optimal locations [25]. Regrettably, the prevalent technologies and methods employed by the majority of EMS agencies could impede this shift, as they continue to rely on outdated and less effective EMS approaches that were in use during the 1990s. As an example, numerous ambulances still utilize radio communication to connect with hospitals [26]. This research offers several noteworthy contributions. Initially, it delves into the organizational framework of regional medical unions. Within these unions, specialists collaborate with general practitioners to formulate treatment strategies and assume a central role in the treatment process [27]. Further research proposals could include the following: (1) investigating the management of identified system weaknesses, particularly addressing the omission of personnel-related cost analysis, to enhance the overall reliability and practicality of the research; (2) exploring the impact of the system on real-world healthcare practices; (3) investigating the most effective way to manage patients' digital data in terms of security and confidentiality compliance.

Acknowledgment. This work has been co-financed by Greece and the European Union (European Regional Development Fund-ERDF) through the Regional Operational Program "Attiki" 2014–2020.

Appendix

(See Tables 3 and 4).

Table 3. The simulation of the ACSIS process.

	Activity	Property values
1	Emergency call in the call center.	The duration of the procedure follows the normal distribution with an average value of 5 and a deviation of 2.
2	Ambulance information from the call center.	The duration of the procedure follows the normal distribution with an average value of 10 and a deviation of 2.
3	Send the route that the ambulance must follow to reach the point of the incident.	The duration of the procedure follows the normal distribution with an average value of 20 and deviation 2.
4	Arrival of the ambulance at the scene of the emergency.	The duration of the procedure follows the normal distribution with an average value of 4 and a deviation of 2.
5	Providing medical care to the patient at the scene.	The duration of the procedure follows the normal distribution with an average value of 15 and a deviation of 2.
6	Selection of the hospital center for the transfer of the patient.	The duration of the procedure follows the normal distribution with an average value of 10 and a deviation of 2.
7	Phone communication of the ambulance staff with the specialized medical staff of the hospital to suppress the patient's symptoms.	The duration of the procedure follows the normal distribution with an average value of 15 and a deviation of 2.
8	Assess the patient's health to determine its severity incident.	The duration of the procedure follows the normal distribution with an average value of 10 and a deviation of 2.
9	Arrival of the patient in the hospital.	The duration of the process follows the normal distribution with an average value of 10 and a deviation of 2.

Table 4. The second simulation case using ACSIS

	Activity	Property values
1	Emergency at the call center.	The duration of the procedure follows the normal distribution with an average value of 5 and a deviation of 2.
2	Automated procedure for sending the incident to the appropriate ambulance.	The duration of the procedure follows the normal distribution with an average value of 1 and a deviation of 1.
3	Automated ambulance navigation process at the emergency incident via a route specified by Google Maps.	The duration of the procedure follows the normal distribution with an average value of 4 and a deviation of 1.
4	Ambulance arrival at the scene.	The duration of the procedure follows normal distribution with mean value 2 and deviation 1.
5	Automated process of providing medical care to the patient on the spot incident.	The duration of the procedure follows the normal distribution with an average value of 3 and deviation 1.
6	Automated hospital selection process for patient transfer.	The duration of the procedure follows the normal distribution with an average value of 3 and a deviation of 1.
7	Automated process of providing medical advice to the nurse ambulance staff.	The duration of the procedure follows the normal mean distribution value 4 and deviation 1.
8	Automated diagnostic process of the patient based on the symptoms.	The duration of the procedure follows the normal distribution with an average value of 3 and a deviation of 1.
9	Automated process of patient arrival at the hospital.	The duration of the procedure follows the normal distribution with an average value of 5 and a deviation of 1

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