OPTIMIZATION FRAMEWORK FOR OPTIMIZING AIR AMBULANCE LOCATIONS

HOW AMBULANCE DELIVERY SYSTEMS MARGINALIZE LOW-INCOME AND RURAL COMMUNITIES

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

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November 24, 2020

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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In the last few years, healthcare costs have been rising at high rates. Healthcare spending in the United States in 2017 grew by 4.2%. In 2018, spending grew by an even higher percentage of 4.6% and reached approximately $3.6 trillion or about $11,000 per person (Centers for Medicare and Medicaid Services, 2019). Due to the increase in healthcare spending, the cost of ambulances has increased as well. However, the rise in costs is not necessarily associated with better care. Rural and low income areas continue to be marginalized when it comes to ambulance service. High costs for ambulances make it difficult for low income households to receive care, and even when they do, the care is inefficient.

Both the technical and STS project will research ways to make ambulance delivery more efficient overall in order to better serve the population. The technical project involves creating an optimization framework that would place air ambulance base locations such that access to patients will be improved. The STS project will investigate how the technology in ambulance delivery systems marginalize low income and rural communities. This project would determine key weaknesses in the system that would need to be rectified in the future.

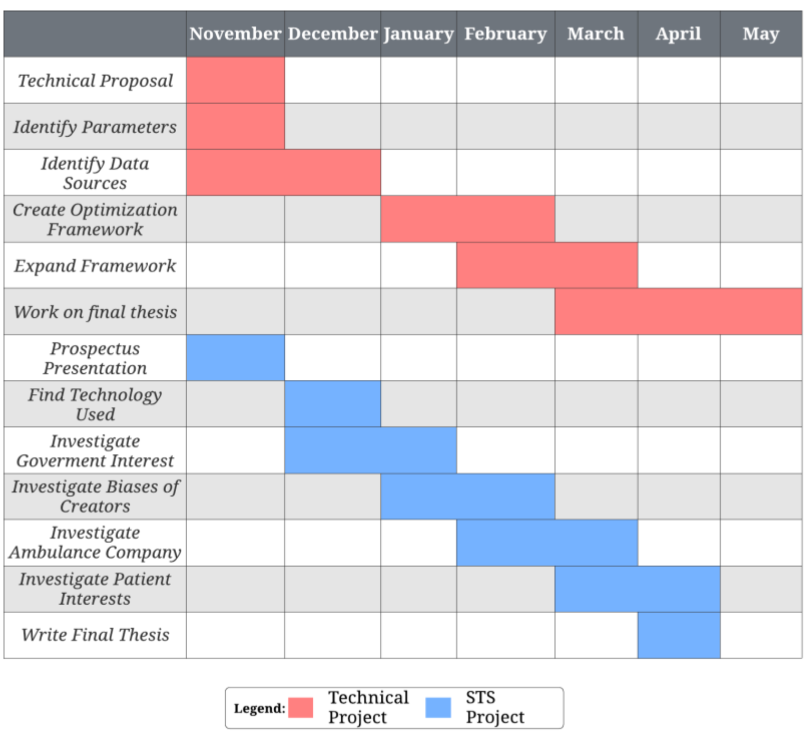

Figure 1: Gantt chart depicting timeline of projects

The technical project will be done in collaboration with Ryan Finley, a 4th year Biomedical Engineering student.

Our advisors include Sabin Ahmed and Rob Lieberthal, who are affiliated with MITRE. Our work will also be overseen by Professor Timothy Allen from the Biomedical Engineering Department at UVA. Figure 1 discusses the anticipated timeline for the projects.

OPTIMIZATION FRAMEWORK FOR OPTIMIZING AIR AMBULANCE LOCATIONS

The air ambulance industry must deal with several issues such as high cost, patient outcomes, and health equity. Currently, air ambulance providers are distributed to emergencies without knowledge of the patients' health insurance coverage (MedPac, 2013). The cost of using an out-of-network ambulance provider is exorbitant and many low income households would not be able to pay that price. This contributes to high health care costs in the US and deters low income households from getting the care they need. Furthermore, air ambulance bases are currently localized around urban areas, so access to rural areas is greatly reduced (United States Government Accountability Office, 2019). Our goal is to determine the locations where air ambulance fleets should be placed in order to best serve the needs of the United

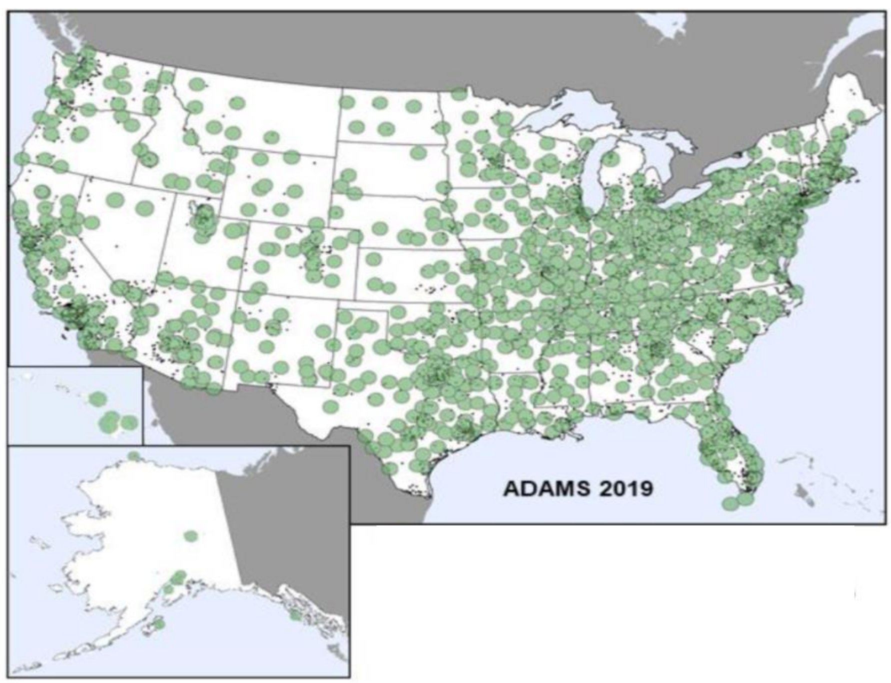

Figure 2: Air ambulance allocation in 2019 overlayed onto map with population density (The Association of Air Medical Services, 2019)

States population. Figure 2 on page 2 shows the allocation of air ambulances and population density in 2019. Each black dot in the image represents 10,000 people, and the green circles represent the location of air ambulance bases and an area where a 15-20 minute response time can be achieved. In the image, many black dots are visible that are outside of the green circle. An estimated 42.5 million people live outside of a 20 minute response time circle from an air ambulance base (The Association of Air Medical Services, 2019). This means that a 20 minute response time, which is imperative in some emergency cases, cannot be achieved for 42.5 million people. This number could be significantly decreased if the locations of the fleet were optimized. In the rural U.S., there are an estimated 85 million people who without air ambulances, would be unable to reach a health care facility within an hour after the injury or illness has occurred (Hinsdale, 2018). Rural communities rely on air ambulance travel the most, so it is imperative that

Instead of reallocating the current fleets, we will be utilizing an optimization model with a Greenfield approach to determine the best locations for air ambulance fleets to serve rural and urban communities across the country. A Greenfield approach involves not considering the current environment when conducting analysis and developing the optimization framework (Berg et al., 2019). This will allow us to create an optimization model that will show the most optimal locations for air ambulance bases. From there, it would be easier to determine what can be done with current resources.

This project of optimizing fleet locations hopes to improve upon the knowledge and capabilities of the air ambulance fleet. It will improve the technical capabilities of the fleets by reducing the time needed to travel. By placing the fleets in the right locations, we hope to decrease response times to patients and provide quicker transport to emergency medical care. It is essential to serve rural communities while ensuring that the urban communities in the United States are not negatively impacted. Ensuring ambulance bases are close enough to a hospital is also important for improving clinical practices. Clinicians will be able to treat patients more rapidly and improve the quality of care patients receive if the fleets are located near a hospital.

Through optimization of the fleet locations and meeting our specific aims, we would ensure that access to medical treatments are improved. Through designing and constructing an optimization model based on the maximal coverage problem (MLCP) and demand, we are able to reduce patient transportation times, improve patient outcomes, and lower cost of transportation (Røislien et al., 2017). As mentioned above, reducing patient travel time is essential because immediate and efficient aid is vital.

In addition to reducing transportation times and improving patient outcomes, we want to lower the cost. Since the travel distances will be lower (on average), we will hopefully be able to lower the amount of materials used by the fleets. This will reduce the cost burden on patients, who often need treatment immediately, regardless of whether their insurance covers the transportation.

Our project hopes to revolutionize the current air ambulance transportation network through the provision of an ideal allocation of air ambulances to optimize trade-offs between outcomes, costs, and health equity. It will provide a biomedical engineering solution that can be implemented by the healthcare industry and health policymakers to improve the air ambulance industry.

Our group, with the help of our advisors, will be writing a scholarly article to outline the optimization framework created and the key parameters used in the model.

HOW AMBULANCE DELIVERY SYSTEMS MARGINALIZE LOW-INCOME AND RURAL COMMUNITIES

RURAL AND LOW INCOME COMMUNITIES

Rural and low income areas are most affected by the rising cost of healthcare, and high out of pocket costs for ambulances deter members of these communities from getting the help they need. Low income countries lack an organized emergency system (Suryanto et al., 2017). Similarly, current ambulance systems are not built to care for low income and rural states and counties. The delivery systems are built using urban populations as a model. Urban communities are built completely different than rural communities so the models are not transferable to rural populations (Wong et al., 2019).

Ambulances are exceptionally inefficient in delivering fast care. One study found that ambulance response times are much higher for emergencies in low income communities than high income communities (R. Y. Hsia et al., 2018). Patient outcomes after certain health events, such as cardiac arrest, largely depend on the speed of treatment. Even a few minutes in delay of treatment could be the difference between life and death. In the case of cardiac arrest, treatment needs to begin immediately to have the greatest effect. A stopped heart means that no blood is being pumped through the body, and more than 20 minutes in this condition greatly increases the likelihood of brain death.

One study found that rural residents were more likely to die after a trauma incident than nonrural residents (Jarman et. al., 2016). This could be linked to the higher response times for rural communities. In order to make the healthcare system less biased, the causes of racial and income disparities in the healthcare system must be analyzed. When the weaknesses are understood, new systems can be put into place that rectify the current disparities. This will lead to better patient outcomes as patients in rural and low income communities will get care faster. In many cases, faster care means better results.

AMBULANCE DELIVERY TECHNOLOGIES

The specific technologies in ambulance delivery systems in the United States has not been investigated. Through this project, the mechanisms by which ambulance delivery system technologies marginalize communities will be investigated. One study found that minority communities were more often subjected to ambulance diversions (R. Y.-J. Hsia et al., 2012). These diversions occur when hospitals are overcrowded and patients must be taken to a different hospital to receive care. This greatly delays the patient's care which is imperative in certain cases.

Technologies are not without bias. They are created by people who impart their own biases on the technologies they create. These are then used for many years without revisions. This project will identify key revisions that need to be made in order to better serve the population, especially low income and rural populations.

Ambulance delivery system processes include many steps. The complex nature of the system could increase the biases in the technology due to increased human intervention required to decrease complexity of the system. Figure 3 describes the ambulance delivery

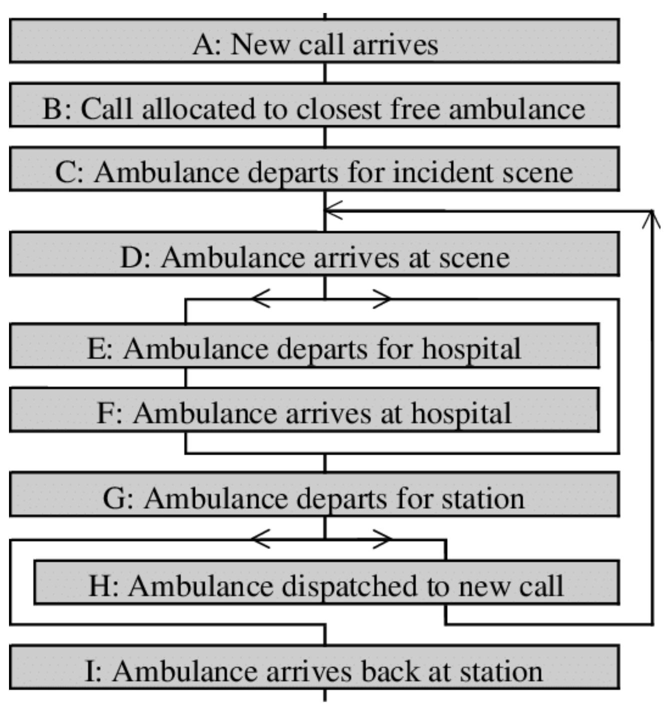

Figure 3: Outline of ambulance delivery system (Henderson & Mason, 2005)

system and shows the convoluted nature of the system (Henderson & Mason, 2005). An ambulance has multiple paths it can take at every step. What determines the path the ambulance will take? What biases are inherent and present in the system? These are questions will be answered throughout the STS project.

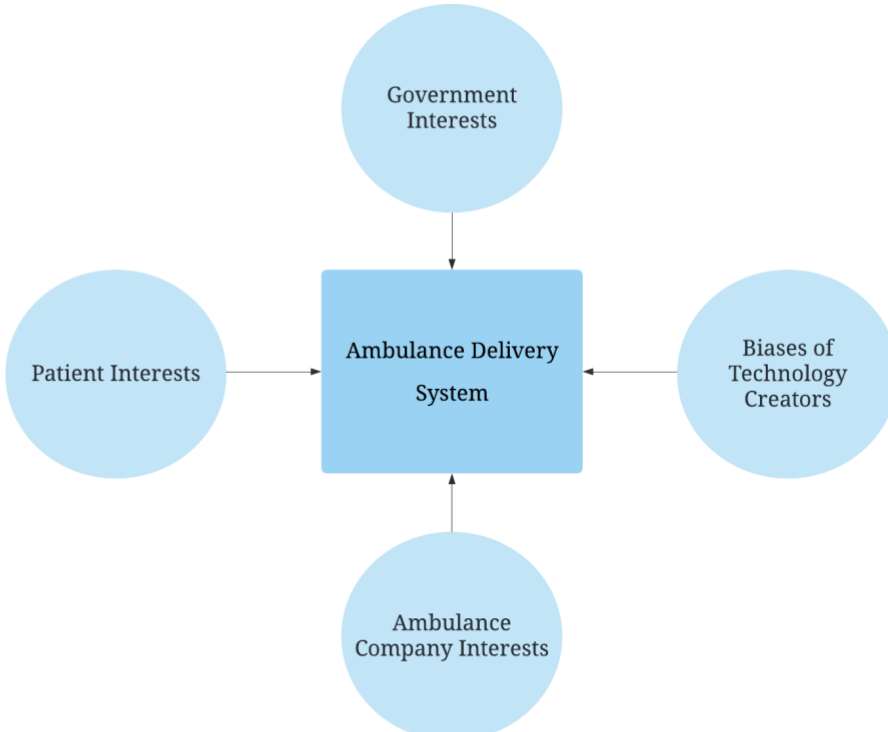

Figure 4: Factors that affect ambulance delivery systems

SOCIAL CONSTRUCTION OF TECHNOLOGY (SCOT)

Social Construction of Technology (SCOT) analysis will be used to investigate ambulance delivery systems (Pinch & Bijker, 1987). Through this approach, the social aspects that affected the development of ambulance delivery system will be analyzed. To limit the scope of the four factors that may have affected the development of the ambulance delivery systems will be focused on, as outlined in Figure 4. Government interests, biases of technology creators, ambulance company interests, and patient interests will likely be the major factors that most affect the system.

Through this project, specific factors that affect ambulance delivery systems within each of the four divisions shown in Figure 4 will be identified. This information could lead to an ambulance delivery system that is more impartial in nature. This could allow for rural and low-income patients to receive better care. The type of model that is currently being used in the delivery system will be identified based on the writings of Brotcorne et. al. (2003). By determining the type of model used, biases that are inherent in the model could be found. From there, a new and more impartial model could be researched and developed. Using the information about key factors that influence ambulance delivery systems, a better model that could be used to minimize the effects of these factors will be proposed.

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