

Designing a More Resilient Healthcare System for Heart Attack Care in Indiana

(Technical Paper)

An Analysis of Inequalities in Access to Healthcare and the Impact of Unintended Consequences of Current Healthcare Distribution

(STS Paper)

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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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Introduction

There are significant gaps in current healthcare delivery models that require patients to physically receive non-emergent and routine, or preventative, care at fixed facilities. These gaps include a lack of alternative options, such as telemedicine or at-home care (Meyer et al., 2020). When the healthcare system is strained during a pandemic, the fixed facility model creates a bottleneck and it fails to deliver basic needs to portions of the patient population, while at the same time some regional medical resources may sit idle. Bouillon-Minois et al. (2021) describes how an increased demand for healthcare yet decrease in hospital beds and staff size led to overcrowding becoming a significant public health problem over the last decade. This situation was exacerbated by the outbreak of COVID-19, which resulted in a 58% increase in overcrowding in 2020 (Bouillon-Minois et al., 2021). Therefore, a study of healthcare resilience, which is the ability of a healthcare system to adapt to outside stressors without a significant change in efficiency, is crucial in order to develop healthcare delivery models that can handle stressful events like a pandemic (Mallak, 1998).

One of the most significant conditions that healthcare systems are faced with is cardiovascular disease, which is the leading cause of death in the United States (Frieden & Berwick, 2011). Every year, more than 800,000 Americans suffer from a heart attack and about 12% of these annual heart attacks are fatal (CDC, 2021b; Benjamin et al., 2019). Factors that can cause a greater probability of having a heart attack include gender, race, household income, age, tobacco and drug use, obesity, and diabetes, among others (Mayo Clinic, 2020; Ford et al., 2007). During a heart attack, rapid treatment is critical to prevent patient death. However, heart attack prevention and care is not efficient or adequate across the United States. This is especially visible in the state of Indiana, which is ranked 32 out 50 for best healthcare by US states, yet it is

ranked 13 out of 50 for the highest heart disease mortality rates, indicating poor quality of healthcare for heart attack patients (US News, 2021; CDC, 2021a). Therefore, for the technical project, our team has decided to apply an operations research approach to evaluate and remodel Indiana's healthcare system for heart attack patients to improve efficiency and resiliency.

In addition to improving efficiency and resiliency of the healthcare system, it is also important to develop a healthcare system that minimizes inequalities across different social groups. Inequalities in healthcare occur when certain groups of people have better access to healthcare resources and facilities over others, resulting in better care, treatment, and overall health. Currently, the American healthcare system shows significant disparities in health outcomes across various social determinants, which include income group, sex, and age (Amadeo, 2021). Taylor (2019) also establishes racial disparities in access to healthcare as well, with people of color, particularly African Americans, experiencing poor health outcomes and unequal access to healthcare services (Taylor, 2019). Studies by the National Academies of Science et al. (2017) and Dickman et al. (2017) highlighted some of the underlying causes that fuel inequalities in healthcare for these social groups as well as others, such as racism, classism, sexism, and lack of insurance (National Academies of Sciences et al., 2017) (Dickman et al., 2017). The goal of the STS research is to perform a more comprehensive analysis of inequalities in access to healthcare in the United States and understand how current healthcare distribution contributes to these inequalities.

The technical portion of the paper will detail a design for a more resilient and efficient healthcare system for heart attack care in the state of Indiana, while the STS research will describe the most prevalent inequalities that currently exist in access to healthcare in the United States.

Technical Topic

In terms of current healthcare for heart attack patients in Indiana, 7 of 16 state hospitals are qualified for the 24/7 Level One Heart Attack treatment program. These hospitals aim to treat their patients with heart attacks in 90 minutes from the moment they enter the door to the surgical intervention. The treatment timeline includes ground and air emergency services to the hospital, surgery with balloon angioplasty, stent placement, coronary artery bypass, cardiac rehabilitation, and then ongoing medications (Indiana University Health, 2021). However, to improve healthcare for heart attack patients, it is also important to consider alternative options like preventative care, such as through eating healthy, lowering alcohol intake, exercising, detecting lipid buildup early, and receiving post-heart attack care (American Heart Association, 2015). This will help reduce the burden on healthcare facilities.

The first aim of our research team is to use data envelopment analysis (DEA), a popular operations research method used to measure productive efficiency, to develop a function that quantifies efficacy in the healthcare system for patients suffering from heart attacks in Indiana (Stefko et al., 2018; Jaafaripooyan et al., 2017). More specifically, DEA measures the relative efficiency of decision making units (DMUs) using an objective function that can take a series of input variables and output variables to produce an efficiency ratio (Asandului et al., 2014). In our project, initial input variables will include nurse-to-patient ratios, number of hospitals, and average cost of treatment, while output variables will include heart attack mortality rate, time between heart stopping and successful resuscitation, and time between onset of heart attacks and hospital intervention. However, more variables may be added or removed as the model is refined in order to produce a more accurate measure of efficiency.

Next, we will use multiple-criteria decision analysis (MCDA), another operations research method, to modify the use of healthcare resources and pick alternative healthcare options to improve efficiency. MCDA considers different criteria, which often conflict with one another, in making a decision (Adem Esmail & Geneletti, 2018). The steps of MCDA include defining an objective for the decision, defining criteria to be considered when making the decision, assigning a weight to each criteria based on importance, listing the options, and rating these options based on how they meet the criteria (undesirable factors like cost will contribute negatively to rating while desirable factors like lower mortality rate will contribute positively to the rating) (Natural Resources Leadership Institute, 2011). MCDA in our project will be used to explore the impact of alternative healthcare options in addition to the use of fixed facilities and make alterations to the current variables in the DEA to improve efficiency.

Finally, our last aim is to use simulations to visualize and validate the efficacy and resiliency of the proposed healthcare delivery model in informing recommendations on public health delivery strategies. We will consider an online agent-based modeling software to accomplish this and will include real-world constraints in the simulation that put pressure on the healthcare delivery system (such as the effects of a pandemic) to assess the resilience and adaptiveness of the model. Agent-based modeling is a type of modeling that treats a system as a group of autonomous agents that can interact with one another (Bonabeau, 2002). In our project, these autonomous agents will consist of people that are at risk of heart attacks and the various healthcare facilities and resources available for their use. By using software such as NetLogo to control the distribution and actions of these agents, we will be able to visualize the effects of the healthcare decisions made in the MCDA. More importantly, we will impose pressures on the model, such as the dramatic rise in hospital occupancy seen in a pandemic, to test the resiliency

of the proposed healthcare delivery model. Alterations to the MCDA and DEA will be made as needed based on these results. Together, these three operations methods/models will help to quantify the current efficiency of healthcare for heart attack patients in Indiana, as well as propose a way to improve it along with its resiliency.

STS Topic

The objective of the technical project is to understand the quality of current healthcare delivery and how it can be improved in Indiana. Further, I will seek to understand what kind of inequalities currently exist in access to healthcare across different social groups in the United States and how unintended consequences of healthcare distribution contribute to these inequalities.

Inequalities in access to healthcare occur across a wide range of factors, including socioeconomic status, age, geography, language, gender, disability status, citizenship status, and sexual identity and orientation (Ndugga & Artiga, 2021). A major form of inequality in the healthcare system is income inequality (Amadeo, 2021). A study by Steven H. Woolf et al. (2015) showed that a higher income is correlated with having a lower risk of disease and premature death as well as having improved health. The data to support this conclusion was obtained through a survey of health statistics for U.S. adults in 2011. Importantly, this study notes that a significant reason behind this correlation is that those with higher income are able to support a healthier lifestyle, afford medical care, and access worksite wellness programs among other factors (Woolf et al., 2015). Another study by Hero et. al. (2017) supported this finding by analyzing data from a health module of the International Social Survey Programme to measure disparities in health care across a variety of countries. This study focused on answers from

survey participants that conveyed experiences such as past barriers in accessing health care resources, satisfaction with recent care received, and the confidence in being able to access preferred care in the future. It was found that, compared to other countries, the United States showed some of the largest disparities in both self-reported health and healthcare measures among three income groups (Hero et al., 2017).

Disparities in healthcare can be seen across other equity stratifiers as well, such as between different racial groups. A report published by Artiga and Orgera (2019), which analyzed current disparities in health status and healthcare, found that black people and Hispanics experienced worse health coverage, as well as lower access to and utilization of health care services, than white people across a variety of different measures (Artiga & Orgera, 2019). Similar inequalities were described by Fiscella and Sanders (2016) in their analysis of racial disparities in the quality of health care. They observed that the second largest number and percentage of disparities in quality of healthcare occurred between black and white people, with the largest disparities occurring between low-income and high-income groups (Fiscella & Sanders, 2016).

While the research conducted thus far has developed an understanding of some of the types of disparities that currently exist in access to the healthcare system, further research is needed to more comprehensively identify inequalities across major equity stratifiers in the United States. Additionally, the framework of unintended consequences will be used to understand how current healthcare delivery gives rise to these identified disparities. Unintended consequences refer to outcomes from the implementation of a technology into a system that can be unanticipated and/or undesirable. Harrison et al. (2007) explained how unintended consequences of an implemented health information technology (HIT) can be understood by

analyzing the sociotechnical interactions between the new HIT and the existing system. Specifically, they proposed a framework known as Interactive Sociotechnical Analysis (ISTA) to describe these relationships and their potential in producing unintended consequences. ISTA has four key features and outlines five kinds of interactions within a sociotechnical system specific to HIT. These four features include examining actual uses of HIT (rather than intended use), the impact on HIT use of technical and physical settings of work, users' renegotiation and reinterpretation of HIT features, and interaction and interdependence among social and technical systems and recursive relations among sociotechnical subcomponents. The five kinds of interactions outlined by Harrison et al. include how new HIT changes the existing social system, how technical and physical infrastructure mediate HIT use, how the social system mediates HIT use (the interaction of new HIT with the social system affects HIT-in-use), how HIT-in-use changes the social system, and how the HIT-social system interactions engender HIT redesign (or causes changes in HIT properties) (Harrison et al., 2007). In my STS research, I will use the ISTA framework to uncover how the implementation of certain healthcare resources in society may have led to unintended consequences in the form of increased inequality in access among different social groups.

Research Question and Methods

The research question is, *what are the major sources of inequality in access to healthcare today in the United States, and how does the current distribution of healthcare resources contribute to those inequalities?* Understanding the kind of disparities that exist in the healthcare system today is an important first step in making healthcare decisions that will remove these barriers and equalize access for all groups of people. Furthermore, uncovering the impact that the

healthcare delivery system has on these disparities will help inform legislative and engineering decisions to remodel this system in a way that improves health outcomes for underserved groups.

In order to answer the research question, data will be collected by analyzing regional studies of inequalities in healthcare across various urban, suburban, and rural areas across the United States as well as what kind of healthcare resources are available in those regions. More specifically, a small but representative samples of areas will be chosen. In each area, the demographic composition of the area will be noted along key stratifiers such as race, income, sex, and education level. After that, a list of the major healthcare resources in that area will be compiled (hospitals, clinics, etc.), and the demographic composition of the patients that use these resources will be determined. Finally, statistical analysis will be performed to see if there are significant differences or disparities in access for any demographic group. After that, the framework of analyzing unintended consequences will be used to theorize how the healthcare delivery in a specific region led rise to or contributed to the observed inequalities there. More specifically, each healthcare resource that shows significant disparity in access will be analyzed by considering each of the five interactions outlined in the ISTA framework of unintended consequences by Harrison et al (2017) (Harrison et al., 2007). The findings from each area will be compared to draw patterns and commonalities in how implementation of certain healthcare resources can generally have unintended consequences that create inequalities in access to these resources. These findings can then be used in future studies to propose ways in which healthcare distribution can be remodeled to lower these inequalities.

Conclusion

The goal of the technical project will be to improve the efficiency and resiliency of healthcare for heart attack patients in Indiana. Meanwhile, the secondary objective is to analyze the disparities that exist today in access to healthcare in the United States and understand the impact that the current healthcare system has on those disparities. The methods used in the technical project will help inform patients and healthcare professionals on how heart attacks can be prevented and efficiently treated under an improved healthcare model, even when it is faced with pressures that normally would threaten efficiency. Further, the research will provide insights on which groups of people face the most inequalities within the current healthcare system and will ultimately aid in making decisions in the future that will help equalize access to healthcare resources for all groups of people.

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