**Background**

Healthcare access in rural areas continues to be a significant challenge in the United States, where geographic isolation, limited infrastructure, and socio-economic disparities exacerbate health inequities. Rural populations often face long travel times to access basic healthcare services, leading to delays in care and worsening health outcomes. These challenges disproportionately affect underserved and vulnerable populations, amplifying health disparities.

Telehealth has emerged as a promising solution to bridge the healthcare access gap in rural areas. However, the effectiveness of telehealth services depends heavily on the strategic placement of telehealth infrastructure, such as kiosks, in areas where they can maximize their impact. While telehealth kiosks can serve as a critical access point for medical consultations, their placement must be optimized to ensure maximum coverage, minimize patient travel times, and address health equity. This research aims to develop, optimize, and evaluate a multi-objective model for telehealth kiosk placement in rural areas. By focusing on maximizing patient coverage, minimizing patient travel time, and enhancing health equity, this study will provide practical and scalable solutions for improving healthcare access in rural regions, thus addressing key public health challenges.

**My take on the background**

**Healthcare equity in the United States remains a significant issue, particularly affecting marginalized populations in rural areas and those impacted by various social determinants of health (SDoH). While initiatives like the Affordable Care Act have improved access for many, disparities persist, particularly for communities facing structural inequalities related to race, income, education, and geographic location.**

**In rural areas, access to healthcare is challenged by provider shortages, long travel distances, and inadequate transportation infrastructure. The closure or under-resourcing of rural hospitals further exacerbates these issues. Rural populations also experience higher rates of chronic diseases and face barriers to preventive care, leading to delayed diagnoses and poor health outcomes.**

**Social determinants of health, including income, education, housing, food security, and racial and ethnic identity, significantly influence healthcare access. Marginalized groups—such as racial and ethnic minorities and those with lower incomes or educational attainment—often encounter systemic barriers, such as being uninsured or underinsured, facing language and cultural barriers, and lacking access to culturally competent care. These barriers contribute to worse health outcomes due to limited access to essentials like nutritious food, stable housing, and supportive social services.**

**Efforts to bridge these disparities include expanding telehealth services, which can improve access by allowing remote consultations and reducing travel needs. Increasing telehealth availability, expanding Medicaid, incentivizing providers to work in underserved areas, and investing in community health centers are all strategies aimed at addressing these inequities. Additionally, addressing broader SDoH, such as affordable housing and food security, is crucial for improving health outcomes.**

**Telehealth kiosks represent a promising solution to enhance healthcare access in underserved areas. Positioned in community spaces such as pharmacies, libraries, and schools, these kiosks offer a private, secure environment for remote consultations with healthcare providers. However, several questions remain regarding their infrastructure, placement, technology, usability, patient engagement, and integration with existing health systems. Addressing these questions is key to optimizing the impact of telehealth kiosks and improving overall healthcare access.**

**Specific aims**

**Aim 1: Identify County-Level Healthcare Access Disparities**We will use data from the US Census, BRFSS (Behavioral Risk Factor Surveillance System), and NHANES (National Health and Nutrition Examination Survey) to analyze healthcare access disparities across US counties. Key variables, such as health insurance coverage, availability of healthcare providers, unmet medical needs due to cost, time since last checkup, and preventive service use, will be consolidated.

To create a comprehensive measure of healthcare access, we will apply dimensionality reduction techniques, including Principal Component Analysis (PCA) and Factor Analysis, to integrate these variables into a unified access score. Machine learning algorithms, such as neural networks, will further refine this score by identifying complex patterns that traditional methods might miss. We will validate the accuracy and robustness of the score using advanced statistical models and cross-validation techniques. By mapping these scores, we will highlight counties with the most significant disparities in healthcare access, providing a foundation for targeted interventions.

**Aim 2: Optimize Telehealth Kiosk Allocation to Address Disparities**  
Building on the access disparities identified in Aim 1, we will develop an optimization model to determine the most effective placement of Telehealth kiosks. This model will account for healthcare infrastructure, population density, and severity of access disparities to maximize the reach and impact of the kiosks while adhering to budget limitations.

To inform the model, we will assess the current healthcare landscape, including telehealth services, transportation networks, and facility availability. The optimization model will balance constraints and outcomes, ensuring the kiosks are placed in areas where they can have the most significant impact. By testing the model across multiple scenarios, we will identify the most cost-effective and impactful strategy for kiosk distribution.

**Aim 3: Adapt Telehealth Kiosk Placement for Dynamic Conditions**  
After developing an optimized allocation strategy in Aim 2, Aim 3 will evaluate the performance of these placements under changing real-world conditions, such as fluctuations in population demand, shifts in disease prevalence, and changes in patient behavior. We will incorporate various assumptions about future changes, including the expansion of telehealth services and demographic shifts, into the model.

This dynamic evaluation will allow us to refine the kiosk placement strategy and ensure that it remains effective over time, even as healthcare needs and conditions evolve. The goal is to create a flexible, adaptable framework that can maintain optimized service delivery in both static and dynamic environments.

**Expected Outcome**

The expected outcomes of this research are to significantly enhance healthcare access in rural areas by strategically optimizing the placement of telehealth kiosks. The findings are anticipated to demonstrate improved healthcare access for rural populations by maximizing patient coverage, minimizing travel time, and promoting health equity. By targeting underserved and vulnerable communities, the research aims to reduce health disparities and provide efficient resource allocation for telehealth infrastructure. Furthermore, the simulation model will evaluate the sustainability of optimized kiosk placements over time, accounting for changing healthcare demands and population dynamics, thereby ensuring that the kiosks continue to deliver effective services in evolving rural environments. Ultimately, this research aims to offer a scalable, data-driven solution for improving rural healthcare access and shaping policy decisions, providing long-term strategies to address healthcare disparities in rural areas.

**Importance of the Research (Significance and Innovation)**

The significance of this research lies in its potential to address a critical public health challenge: improving healthcare access in rural areas where geographic isolation, limited infrastructure, and socio-economic barriers often prevent timely and equitable healthcare delivery. By developing a multi-objective model for telehealth kiosk placement that incorporates patient coverage, travel time, and health equity, this study provides a novel, data-driven framework for addressing disparities in healthcare access. Rural populations, particularly underserved and vulnerable communities, stand to benefit from better health outcomes, reduced travel burdens, and more equitable access to essential healthcare services. This research not only proposes an innovative way of strategically deploying telehealth resources but also offers a scalable, practical solution that can be adapted to different rural settings across the country. Furthermore, by integrating simulation models, this study ensures that the proposed solutions are not only effective in the present but also adaptable to future changes in population demographics and healthcare demands, making it a forward-looking and sustainable approach. The innovative combination of multi-objective optimization and simulation techniques to guide telehealth deployment ensures that this research contributes both to the academic understanding of healthcare delivery optimization and the practical development of tools for policy and decision-making in public health.

**Rigor and Feasibility of the Approach**

The approach taken in this research is grounded in well-established methodologies—mathematical modeling, advanced optimization, and simulation—making it both rigorous and feasible. The development of a multi-objective model that balances key factors such as patient coverage, travel time, and health equity is supported by extensive healthcare data and advanced computational tools, which will enable precise and effective modeling. Additionally, the use of proven optimization techniques such as genetic algorithms or solvers like CPLEX and Gurobi ensures that the solutions generated will be both practical and efficient, overcoming the common trade-offs between competing objectives in healthcare delivery. The feasibility of this research is further enhanced by the simulation component, which will allow for testing and validating the model under dynamic, real-world conditions. By accounting for changing population sizes, healthcare demands, and other relevant factors over time, the simulation will provide a robust assessment of the optimized kiosk placements’ long-term viability and adaptability. Given the availability of relevant healthcare and socio-economic data, along with the accessibility of high-performance computational resources, the research plan is not only scientifically sound but also fully feasible to implement within the proposed timeline. The combination of rigorous methodology and practical applicability ensures that the research will yield valuable, actionable insights for improving rural healthcare access.