**Cover Page**

**Project Name:** SHIELD Illinois Program and Underrepresented Communities: Evaluating Effectiveness and Informing Future Pandemic Response Efforts

**Lead Researcher:**

* Mohammad Samie Tootooni, Ph.D.  
  Assistant Professor, Department of Health Informatics and Data Science  
  Parkinson School of Health Sciences and Public health  
  Loyola University Chicago  
  2160 S 1st Ave, CTRE 447, Maywood, IL 60153  
  708-216-9181 | [mtootooni@luc.edu](mailto:mtootooni@luc.edu)

**Co-Investigators:**

* Sina Ansari, Ph.D.  
  Assistant Professor, Department of Management and Entrepreneurship   
  Driehaus College of Business  
  DePaul University  
  1 E. Jackson Blvd., Ste. 7021, Chicago, IL 60604  
  312-362-8580 | [sina.ansari@depaul.edu](mailto:sina.ansari@depaul.edu)
* William Parker, M.D., Ph.D.  
  Assistant Professor of Medicine and Public Health Sciences  
  Assistant Director, MacLean Center for Clinical Medical Ethics  
  Co-director, Clinical Ethics Consultation Service  
  Assistant Director, Masters of Public Health Sciences for Clinical Professionals  
  The University of Chicago  
  5841 S. Maryland Avenue, MC 2007, Chicago, IL 60637  
  847-525-4924 | [William.Parker@bsd.uchicago.edu](mailto:William.Parker@bsd.uchicago.edu)
* Milda Saunders, M.D., M.P.H.  
  Associate Professor of Medicine  
  Associate Dean of Health Equity, Diversity and Inclusion  
  The University of Chicago  
  5841 S. Maryland Avenue, MC 2007, Chicago, IL 60637  
  773-702-5941 | [msaunders@bsd.uchicago.edu](mailto:msaunders@bsd.uchicago.edu)

**Abstract**

The SHIELD Illinois program was established to mitigate COVID transmission and provide testing to communities in Illinois. However, its impact on underrepresented populations and potential for guiding future pandemic response efforts require further investigation. This proposal aims to address these gaps by focusing on testing centers located in higher education institutions. To achieve this goal, we will utilize data from the SHIELD Illinois program, the Chicago Department of Public Health, and electronic health records from two major health centers in the Chicagoland area. We will use the COVID Community Vulnerability Index (CCVI) and the Area Deprivation Index (ADI) to determine how underrepresented communities benefit from the program. Our primary objective is to evaluate the effect of the SHIELD testing program on COVID severe outcomes such as admission to the Intensive Care Unit (ICU), mechanical ventilation use, and death. We will employ a difference-in-differences approach to estimate the causal effect of the SHIELD Illinois testing program on the outcomes of interest. Additionally, we will deploy explainable AI approach to identify the most effective attributes related to the location of testing centers on the volume of the performed tests, which will provide guidance for future pandemic response planning. We will also adapt advanced optimization and stochastic models to optimize testing center operations and provide policy recommendations toward optimizing resource allocation and utilization of the testing sites. This study has the potential to provide valuable insights into the growth and capabilities of the SHIELD Illinois program, inform future pandemic response efforts, and ultimately improve patient outcomes.

**Project Description**

**Background**

communities experiencing higher morbidity and mortality rates compared to the general population [1]. We and others previously showed that social risk factors, such as poverty, food insecurity, and housing instability, also can contribute to poor health outcomes during the pandemic [2, 3]. In a related study, our team also found that low vaccination rates in certain Chicago zip codes were associated with higher rates of COVID mortality, exacerbating existing racial and ethnic disparities in deaths [4]. SHIELD Illinois is a statewide testing program that provides free COVID testing to all Illinois residents. The SHIELD Illinois program has been successful in increasing testing rates across the state, but it is unclear how effective it has been in improving COVID outcomes in underrepresented communities. The program has collected a large amount of data on testing, including information on the number of tests performed, the types of tests performed, the results of the tests, and the demographics of the people who were tested. This introduces a unique opportunity to get a thorough picture of the impact of SHIELD Illinois on the health of underrepresented communities in Chicago when combined with data from the Chicago Department of Public Health (CDPH) and Electronic Health Records (EHR). Our proposal aims to leverage artificial intelligence (AI) and operations research (OR) tools to scrutinize such voluminous datasets to determine how effective the SHIELD Illinois program was in addressing health disparities in Chicago and to develop strategies and recommendations to develop policies to optimize testing center operations in the future.

**Specific Aims**

**Aim-1:** **Determine if SHIELD sites reduced severe COVID and COVID deaths in disadvantaged neighborhoods.** We hypothesize that the program's implementation leads to earlier diagnosis, which in turn results in better treatment and ultimately reduces the likelihood of severe outcomes of COVID, including ICU admission, ventilation use, and death.

**Aim-2: Identify the effective attributes of the locations of higher education testing centers on testing volume.** We hypothesize that features such as being located in high ADI (disadvantaged) neighborhoods and near public transit are among the effective attributes in estimating the volume of the performed tests. We will train advanced machine learning models with several features of SHIELD Illinois test sites (e.g. in high ADI neighborhoods, near public transit) as well as elements from other datasets that can accurately predict the testing volume at the testing sites. With the aid of an explainable AI (XAI) approach, we will identify the most effective features of the testing sites for increasing testing volume.

**Aim-3: Develop policies to optimize testing center operations and maximize patient outcome measures.** Our hypothesis is that by utilizing OR tools and taking into account the operational attributes of higher education testing centers, such as daily/weekly testing rate and the number of operating days/weeks, we can provide policy recommendations that optimize testing center operations, decrease wait times, increase staffing levels, and enhance patient flow, ultimately improving patient outcomes. Through this assessment, we will also address disparities in underrepresented communities and consider their specific needs.

**Expected Outcome**

The general purpose of our project is to evaluate the impact, growth, and capabilities of the SHIELD Illinois program in mitigating geospatial health disparities and improving patient outcomes related to COVID pandemic, with a focus on underrepresented communities. The results of this analysis can be used to identify areas that require greater attention and resources, facilitating the development of targeted strategies to improve testing rates and patient outcomes. In addition, the findings can inform future pandemic response efforts and assist healthcare providers and policymakers in choosing the location of testing sites, allocating resources, and optimizing their operations to maximize patient outcomes. We will interpret our findings from all aims and provide recommendations for future pandemic response efforts in the final report to the Office of the Vice President for Economic Development and Innovation.

**Research Design and Method**

In **Aim-1,** the primary exposure of interest will be the presence of a SHIELD testing site in the patient's neighborhood, while the outcome of interest will be the occurrence of severe outcomes related to COVID, including ICU admission, mechanical ventilation, and death due to COVID. To estimate the causal effect of the SHIELD Illinois testing program on the outcomes of interest, a difference-in-difference approach will be employed. The outcomes among patients from neighborhoods with SHIELD testing sites will be compared to those without to evaluate the impact of the SHIELD testing program on COVID-19 outcomes in underrepresented communities. To identify underrepresented areas, we will extract neighborhood-level factors including the COVID Community Vulnerability Index (CCVI) [5] and the Area Deprivation Index (ADI) [6]. Using the institutional EHR data, we will estimate the association of a SHIELD testing site with the severity of COVID in patients hospitalized with COVID. We will match patients with SHIELD sites in their local neighborhood to patients without SHIELD sites using a propensity score with covariates age, medical comorbidities, and neighborhood ADI and CCVI. Also, using CDPH data, we will estimate the effect of SHIELD site openings on local neighborhood outcomes with a difference-in-difference approach, previously used to estimate the effect of vaccine coverage on COVID mortality [4]. Particularly, we will investigate the relationship between block/zip code-level testing sites and COVID mortality using City of Chicago’s the COVID Cases, Tests, and Deaths by ZIP Code data [7]. Finally, we will explore potential interactions between the SHIELD Illinois testing program and ADI and CCVI to determine if the program's impact varies across different levels of neighborhood vulnerability.

To accomplish the **Aim-2**, we will leverage SHIELD Illinois testing center data in conjunction with other data elements to develop advanced and unbiased AI models for the volume of tests performed at each testing site. To identify key features, we will adopt an explainable AI methodology, which analyzes a multitude of factors, including but not limited to geographical location, testing center capacity, and external factors such as COVID positivity rate and vaccination status. The obtained results will provide valuable insights into the most effective geographical features of the testing site that contributed in increasing the testing volumes.

For the **Aim-3,** we will develop stochastic models that incorporate multiple variables such as daily/weekly testing rate and the number of operating days/weeks, number of staff, testing supplies, availability of personal protective equipment (PPE), and adherence to infection control protocols, wait times. Mathematical algorithms will be utilized to identify the optimal allocation of resources to maximizing the efficiency and efficacy of testing centers, ultimately improving patient outcomes. Finally, policy recommendations will be provided to healthcare providers and policymakers to improve testing center operations with respect to outcome measures in Aim-1 and Aim-2 (severe cases and volume of tests). Moreover, these models will enable us to develop sound policies for pandemic response efforts and support SHIELD Illinois program planning and testing center operations.

**Scope of Work**

**Tasks:** To achieve the objectives, we will undertake the following tasks:

**T1 – Collecting EHR Data and Data Analysis:** We will collect EHR data of ICU admissions at Loyola University Chicago and the University of Chicago between 2020 and 2022. The data will be securely stored in HIPAA-compliant servers at Loyola University Chicago. We will identify patients who diagnosed with COVID and their geocodes, using tools such as Degauss, to determine if they live in neighborhoods where SHIELD Illinois testing centers were launched. We will analyze this data to identify the impact of testing sites on COVID outcomes.

**T2 - Obtaining Social Determinants of Health (SDoH):** The ADI is calculated by combining several indicators, including income, education, employment, housing quality, and other factors, to create a composite score that reflects the overall level of deprivation in a given area. Similarly, CCVI will be calculated, which is a composite index that includes 14 different indicators, such as socioeconomic status, household composition, and minority status, that are associated with increased risk for COVID morbidity and mortality. These tools will be used to identify areas that may be at higher risk for poor health outcomes or that may require additional resources and support. To extract geospatial determinants of health and connect them with the SHIELD testing centers, we will utilize GIS tools such as PolicyMap and publicly available data sets such as census, which is a mapping tool that Loyola already purchased its license.

**T3 - Assessing the Higher Education Testing Centers:** We will develop a wide range of ensemble machine learning models such as XGBoost and Random Forest to predict different patient outcomes and perform cross-validation techniques to validate. To assess their fairness, disparities, and group-level metrics, we will audit the developed models using Aequitas, a publicly available Python toolkit. Post-hoc bias mitigation approaches will be applied to mitigate bias in the final machine learning classifiers. This will be done either by varying the cut points for subgroups with biased fairness tests or by re-calibrating the machine learning models by the biased subgroup. Finally, to identify the important features we will employ SHAP (SHapley Additive exPlanations) XAI technique, which allows us to calculate the importance of each feature and its contribution towards the outcome measures.

**T4 – Developing Policies to Optimize Testing Center Operations:** We will develop advanced optimization, and stochastic models, which use operational features of testing sites extracted from SHIELD Illinois datasets. Specifically, we determine the optimal resource allocation of testing centers while balancing cost and effectiveness, using tools such as mixed integer programming, network optimization, stochastic analysis (e.g., Markov Decision Process and Queueing Theory), and simulation models. Specialized software packages such as Gurobi, CPLEX, and AMPL will be used to solve these models, and coding and testing will be done to ensure accuracy, efficiency, equity, and robustness. We will evaluate the effect of ADI and CCVI parameters in the models, which will help identify equitable strategies to improve testing rates, reduce wait times, and enhance the overall patient experience, focusing on underrepresented communities.

**T5 – Disseminate the Outcome:** We plan to disseminate our research findings through publications in peer-reviewed journals, conference presentations, and reports. We also plan to share our findings with SHIELD Illinois and other relevant stakeholders to inform public health policy and practice.

**Timeline:** We expect the proposed project to take 24 months from July 1, 2023 to June 30, 2025.

**References**

1. Figueroa, J.F., et al., *Community-Level Factors Associated With Racial And Ethnic Disparities In COVID Rates In Massachusetts: Study examines community-level factors associated with racial and ethnic disparities in COVID rates in Massachusetts.* Health affairs, 2020. **39**(11): p. 1984-1992.

2. Ge, D., et al., *Screening for Social Risk Factors in the ICU During the Pandemic.* Critical Care Explorations, 2022. **4**(10): p. e0761.

3. Bhayani, S., et al., *Dialysis, COVID, Poverty, and Race in Greater Chicago: An Ecological Analysis.* Kidney Medicine, 2020. **2**(5): p. 552-558.e1.

4. Zeng, S., et al., *Association of zip code vaccination rate with COVID mortality in Chicago, Illinois.* JAMA Network Open, 2022. **5**(5): p. e2214753-e2214753.

5. Index, C.C.-C.V. 4/15/2023]; Available from: h<ttps://www.chicago.gov/content/dam/city/sites/covid/reports/012521/Community_Vulnerability_Index_012521.pdf.>

6. *Association Of Neighborhood Disadvantage With Racial Disparities In COVID Positivity In Chicago.* Health Affairs, 2021. **40**(11): p. 1784-1791.

7. COVID Cases, T., and Deaths by ZIP Code. 4/15/2023]; Available from: [https://data.cityofchicago.org/Health-Human-Services/COVID-Cases-Tests-and-Deaths-by-ZIP-Code/yhhz-zm2v](https://data.cityofchicago.org/Health-Human-Services/COVID-19-Cases-Tests-and-Deaths-by-ZIP-Code/yhhz-zm2v).

**Team Biographies**

**Mohammad Samie Tootooni** is an Assistant Professor in the Department of Health Informatics and Data Science. His research interest is in developing AI models in different healthcare settings. Having an industrial and systems engineering background, Dr. Tootooni has also expertise in systems science, quality improvement, and optimization principles. His career research question is “How AI and informatics can promote the right decision at the right time to improve patient outcome and health equity”. Dr. Tootooni has been involved in several intramural and extramural grants as PI or co-investigator, including his recent career development award, where he studies the effect of SDoH on drug misdosing among a diverse cohort of ICU patients in Chicago. He also aims to develop unbiased deep learning models to identify risks for misdosing and use the outcome to advance OR models to provide equitable and individualized dosing recommendations for ICU practitioners. In another study, Dr. Tootooni found a significant correlation between positive COVID19 test results and end-stage kidney disease prevalence, poverty, Black race, and Hispanic ethnicity within a zip code. This highlights the exposure risk that people living in poor urban areas face, including those with end-stage kidney disease. Additionally, Dr. Tootooni is working to reduce health disparities by using natural language processing to extract social determinants of health. He hypothesizes that considering SDoH along with demographic and clinical variables in developing AI models result in more equitable management of hypertension patients. The study found that older age and higher comorbidity rates are associated with therapeutic inertia, which is the healthcare provider's failure to initiate or escalate the dose of blood pressure-lowering medication when it is not under control. The study was recognized as one of the top basic science abstracts by the American Heart Association Scientific Sessions in 2022 and invited for submission to Hypertension.

**Sina Ansari** is an assistant professor and incoming co-director of the MS Business Analytics program at the Driehaus College of Business at DePaul University. He received his Ph.D. from the Department of Industrial Engineering and Management Sciences at Northwestern University and worked as a postdoctoral research fellow at the Tuck School of Business at Dartmouth. He is serving as the vice president of INFORMS Chicago chapter. He also worked with the Northwestern Memorial Hospital Emergency Medicine on projects such as improving patient waiting experience and reducing discharge opioid prescribing. Prior to pursuing his Ph.D., Ansari was a co-founder and a manager at a supply chain management consulting company in Iran. Ansari teaches courses in business analytics, decision-making, and operations management, and his research has led to the development of mathematical models and practical policies to optimize the operational performance of systems in service and health care. His work has been published in the European Journal of Operational Research, Healthcare Management Science, Naval Research Logistics, Transportation Research Part B: Methodological, and Journal on Quality and Patient Safety, among other journals. He is an active member of several academic communities including the Institute for Operations Research and the Management Sciences, the Production and Operations Management Society, and the Decision Sciences Institute.

**William Parker** is an Assistant Professor of medicine and public health sciences, pulmonary and critical care physician, medical ethicist, and health services researcher at the University of Chicago, who studies the allocation of scarce medical resources. His specific focus is absolute scarcity problems, where demand greatly exceeds supply, forcing healthcare systems to triage life-saving treatments. He uses his comprehensive empirical and ethical training to evaluate allocation systems for a variety of these problems. Currently, he has a K08 award to design and simulate a new heart allocation system using machine learning and R01-level support from both the Greenwall Foundation and NIH to study life support allocation under Crisis Standards of Care. His lab’s work on heart, kidney, life support, and vaccine allocation has resulted in high-impact publications in JAMA, JACC, AJRCCM, and the American Journal of Transplantation, and he has received national recognition in the form of Young Investigator Awards from the American Society for Clinical Investigation and the American Thoracic Society. His original science and normative writing have been featured in the USA Today, Washington Post, and The New York Times. Dr. Parker has extensive experience in studying health equity before and during the COVID pandemic both nationally and in Chicago. Firstly, their research on the US heart allocation policy shift showed that the changes in outcomes and practices were in line with their predictions, and they advocated for evidence-based vaccine allocation policies during the early phases of the US vaccine rollout. Secondly, their national review of triage plans for life support resources during the pandemic highlighted how the protocols could worsen health disparities among Black patients in critical care. Their findings confirmed that using certain criteria for allocating care could systematically disadvantage Black patients, which was confirmed through a simulation model applied to a diverse Chicagoland dataset of critically ill COVID patients requiring mechanical ventilation. Their work has been influential in shaping the narrative in the transplant community and has been cited by national policy committees.

**Milda Saunders** is an Associate Professor of Medicine and Assistant Dean for Health Equity, Diversity and Inclusion in the Pritzker School of Medicine at the University of Chicago. She is a clinician and health services researcher with expertise in racial and geographic disparities in quality of care and access to care for patients. Over the past 10 years, her work has focused on examining quality of care, and health outcomes for patients with chronic kidney disease (CKD), with a focus on those from minoritized groups. Her prior published work demonstrates that African Americans receive lower quality care and have worse outcomes due to where they live and receive their care. African Americans living in poor, African American neighborhoods are half as likely to appear on the renal transplant waitlist as their more advantaged counterparts. Several analyses showed that dialysis facilities in predominately African American neighborhoods have lower quality measures, even after controlling for neighborhood poverty. Her work has also explored geographic, socioeconomic and clinical factors that influence hospitalization. Dr. Saunders’ work documenting health disparities and quality of care uses large databases and geospatial analytic techniques. In prior work, she has used national datasets (United States Renal Data System (USRDS), National Health and National Health and Nutrition Examination Survey (NHANES) as well as data from national studies (Chronic Renal Insufficiency Cohort) and local electronic medical record (EMR) data.