Redlining and Infrastructure: Examining the Legacy of Historical Zoning and its Influence on Current Water Infrastructure Maintenance

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PURPOSE

Over the past two decades, the American Society of Civil Engineers (ASCE) has given below-average ratings to the critical infrastructure services in the United States.[1] Here, we consider critical infrastructure to be the 16 manufactured systems that sustain essential services (e.g., piped drinking water access, transportation) as categorized by the United States' Cybersecurity and Infrastructure Agency.[2,3] Although drinking water infrastructure has a higher rating than the overall score, its C+ rating was described as a result of technical system age and the lack of consistent maintenance.[1] Furthermore, studies have suggested that marginalized communities may experience poorer infrastructure service quality and maintenance.[3–6] We posit that the relationship between critical infrastructure service and marginalized communities poses important implications for understanding the history and continued persistence of infrastructure inequalities. This discernment would better facilitate determinate areas of improvement for resilient and equitable systems.

Limited studies explore the widespread connection between the history of U.S. critical infrastructure and its current levels of service. Fortunately, the fourth industrial revolution (i.e., increased digitalization) has dramatically expanded the amount and quality of open infrastructure data in the United States. This new data allows for a novel opportunity to empirically examine geospatial variation in the quality of infrastructure services linked to inequalities and investigate the drivers of this variation.[7] One possible historical driver behind geospatial variations in infrastructure service quality is the legacy of redlining.[3] Redlining refers to distinctions made by the Homeowner's Loan Corporation (HOLC) in 1933 to decide which communities were considered hazardous investment areas or not. Due to the HOLC's usage of racial composition as an assessment metric, many neighborhoods restricted from community investment had predominately Black populations.[8] While redlining is no longer legal in the United States, there is some evidence that this history may impact current infrastructure service quality. For example, the recent water crisis in Flint, Michigan was caused by changing the city's water source without adapting the corrosion control to prevent lead contamination.[9,10] Soon after the shift, residents, primarily racial minorities, identified water discoloration, increased water main breaks, and skin inflammation, especially in children.[11] Although this water crisis occurred in the 21st century, many argue that it resulted from decades of disinvestment and spatial-structural racism, including its redlining past.[9,12,13] Thus, exploring the infrastructure service quality in previously redlined areas can point out areas of improvement in preparation from similar emergencies.

<u>Research Question</u>

In this proposed project, we will statistically test if there are geospatial correlations between neighborhood classifications from historic redlining maps and current critical water infrastructure service. We hypothesize that areas that experience longer times for water infrastructure maintenance are located in regions with poor classifications (i.e., definitely declining, hazardous) on redlining maps. To do so, we take advantage of the newly available open infrastructure data and demonstrate the potential of these datasets for engineering for the public good.

RESEARCH APPROACH

This research pulls data from multiple data sources: open infrastructure, historical redlining, and census data. We have sourced water main emergency data compiled by the Seattle Public Utilities (SPU) from the City of Seattle Public Records. The water main emergency data is comprised of instances of water main maintenance reported by the public or by SPU and are organized by categories such as type of maintenance (e.g., reactive, demand, predictive), location, and length of time needed to complete maintenance in days. Here, the length of time for maintenance response will be used as an indicator of the level of water infrastructure service. The historical redlining data will be sourced from Mapping Inequality, the geospatial collaboration between researchers at four U.S. universities. The map transposes the historical zoning distinctions atop the current maps for over 100 cities in the country and will be used to develop inferences about the City of Seattle.[14] Lastly, we will extract population information from census data to create different profiles of each city (e.g., 2000 and 2020 census data). This information would help provide the necessary background of each city's demographic makeup while identifying the shifting population dynamics over time. The coalescence of these varied data sources would provide the basis to explore statistical associations between historical redlining practices and present-day infrastructure.

Data Analysis

To complete the analysis, all the data will be joined by their geographic indicator using ArcGIS (i.e., overlaying geospatial coordinates of water main maintenance, redlining distinctions, and census tracts). After the data from all three sources are compiled, we will use spatial statistics (i.e., Global Moran’s I) to determine the influence of redlining distinctions on the length of time needed for maintenance.[15]

The analysis will be completed using three models. The first model will be a bivariate model between the independent and dependent variables (i.e., redlining distinction and water main maintenance duration). The second and third models will involve elaboration, in which additional variables consistent with the overarching theory are included in the analysis. The second model will enact an exclusionary strategy and control for the type of water main maintenance when determining the influence of redlining on maintenance duration. The third model will pass an inclusionary strategy to the previous two models and control for the change in the population for race and medium income from 2000 to 2020 (i.e., gentrification). Including additional variables in the analysis will allow for better predictions of the relationship between historical political decisions and present-day water infrastructure.

KEY FINDINGS

Previous studies have suggested that the underlying cause of inequalities in infrastructure service can often be tied to oppressive social structures such as redlining.[16] However, these connections are difficult to deduce given the number of variables that could be seen as potential contributors to infrastructure performance. With that in mind, we anticipate not seeing statistically significant associations in the first model as it does not include additional variables. We predict that statistically significant associations will arise in the third model that controls for the additional variables. Here, we believe that the gentrification variables could potentially support our theory of linking redlining and water infrastructure service to population dynamics and investment.

IMPLICATIONS

While the overall infrastructure rating in the U.S. has increased in the past several years, according to the ASCE,[17] targeted improvements to the technical system are needed to ensure that past discriminatory policies do not perpetuate social vulnerability. By determining statistically significant associations between historic redlining distinctions and current water infrastructure, we contribute to the ongoing work that identifies areas of improvement for equitable infrastructure investment. For example, the results of this study will be shared with SPU to enhance their current maintenance procedures. Furthermore, the next phase of this work will include the geospatial mapping of the data and will be shared with open data portals to assist in visual comprehension of the work and encourage the usage of open data with analyses involving civil infrastructure. By establishing a proof-of-concept, this research initiative demonstrates an avenue to identify infrastructure-related challenges and current issues experienced by marginalized communities that can be replicated in other regions and further expanded to include both qualitative and quantitative means of analysis.

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