SI 305 | Final Deliverable: Report
Aayana Anand

Summary
My project examined the impact of outdated water infrastructure in Ann Arbor. I discovered that frequency and cost of water main break repairs peaked during winter, predominantly in the Mack School-Sunset, Bader Ann Arbor Hills, and Dicken neighborhoods. Winter breaks occurred mostly with older (60 years or older), cast iron water mains as compared to younger (less than 60 years), ductile iron water mains. Analyses showed that water main age was extremely significant in predicting repair costs, whereas material and season were not. This information will impact the way resources are allocated by the city, prioritizing highly-reported neighborhoods to withstand the winter. (102)

Problem Diagnosis
In the United States, there is a water main break reported every 2 minutes[1] – This is the unfortunate yet expected outcome of national water infrastructure that has been outdated for decades with insufficient improvements.

This problem can be traced back to the foundations of water infrastructure in America. Since utilities such as water are managed on the local level rather than the federal level, water infrastructures across the country are all vastly different from each other.[2] This fragmented system makes it difficult to pass legislation and provide tangible solutions that can be generalized to all regions of the United States. Corresponding to the fragmented nature of utilities, they are not equipped with the same resources as each other. Despite utilities handling water main breaks as they arise, this is proving to be insufficient. These utilities are also operating largely on paid bills, which generally aren't enough to make significant improvements and subsequently reduce the frequency of water main breaks.
[3]

There have been past and present mitigation efforts. The Clean Water Act, for example, made significant strides to build new water infrastructures, but it unfortunately accomplished very little

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[1] Why America's Water Infrastructure Is Crumbling." The Wall Street Journal, Dow Jones & Company, www.wsj.com/video/series/wsj-explains/why-americas-water-infrastructure-is-crumbling/954FCBDE-03AE-434F-9904-B5B9AA0DFBEA. Accessed 26 Oct. 2023.
[2] Why America's Water Infrastructure Is Crumbling." The Wall Street Journal, Dow Jones & Company, www.wsj.com/video/series/wsj-explains/why-americas-water-infrastructure-is-crumbling/954FCBDE-03AE-434F-9904-B5B9AA0DFBEA. Accessed 26 Oct. 2023.
[3] Why America's Water Infrastructure Is Crumbling." The Wall Street Journal, Dow Jones & Company, www.wsj.com/video/series/wsj-explains/why-americas-water-infrastructure-is-crumbling/954FCBDE-03AE-434F-9904-B5B9AA0DFBEA. Accessed 26 Oct. 2023.

with regards to maintaining what already existed.[4] Recently, the Biden Administration signed a major infrastructure bill, allocating $55 billion dollars to expand access to clean drinking water by investing in water infrastructure and replacing lead service pipes.[5] Despite this being a major step forward for current faulty water infrastructures, this initiative still raises several questions and concerns regarding cost and prioritization.
[6]

Because the rebuilding of water infrastructure is costly, it's important to keep an eye on neighborhoods with the most frequent and most costly breaks, as this may indicate older infrastructure in need of improvements. Certain factors significantly influence the frequency and total costs of water main breaks, one of these being seasonality. During extreme weather events and rapid temperature changes, pipes are likely to expand and contract, causing them to burst.[7] Additionally, pipe material plays an important role in water main durability, as materials that corrode over time lead to more water main breakage. Materials such as cast iron, for example, have high failure rates.[8] Considering these variables is critical as scientists and policy makers in Ann Arbor decide when and where to prioritize the rebuilding of outdated water mains. For example, neighborhoods that spike in water main breaks during certain seasons or with certain materials may be prioritized over others. (399)

Research Questions

RQ1. How do the frequency and total cost of water main breaks change across Ann Arbor neighborhoods over several seasons?

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[4] Why America's Water Infrastructure Is Crumbling." The Wall Street Journal, Dow Jones & Company, www.wsj.com/video/series/wsj-explains/why-americas-water-infrastructure-is-crumbling/954FCBDE-03AE-434F-9904-B5B9AA0DFBEA. Accessed 26 Oct. 2023.

[5] "Fact Sheet: The Bipartisan Infrastructure Deal." The White House, The United States Government, 29 Mar. 2023, www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/.

[6] Why America's Water Infrastructure Is Crumbling." The Wall Street Journal, Dow Jones & Company, www.wsj.com/video/series/wsj-explains/why-americas-water-infrastructure-is-crumbling/954FCBDE-03AE-434F-9904-B5B9AA0DFBEA. Accessed 26 Oct. 2023.

[7] Hu, Charlotte. "Disruptive Water Main Breaks Happen More Often than You Think." Popular Science, September 1, 2023. https://www.popsci.com/technology/why-water-main-breaks-happen/#:~:text=Extreme%20weather%20like%20droughts%20or,them%20more%20susceptible%20to%20damage.

[8]Weuvcare. "Impact of Water Main Breaks on Food & Beverage Establishments." Berson, Hanovia & Aquionics UV, December 28, 2020. https://www.weuvcare.com/impact-of-water-main-breaks-on-drinking-water/#:~:text=Pipe%20material%20and%20Corrosion%3A%20Both,failure%20rate%20due%20to%20corrosion.

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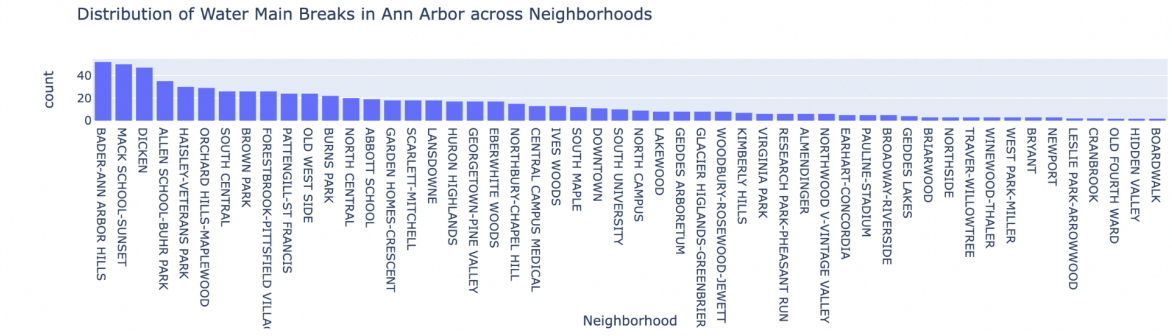
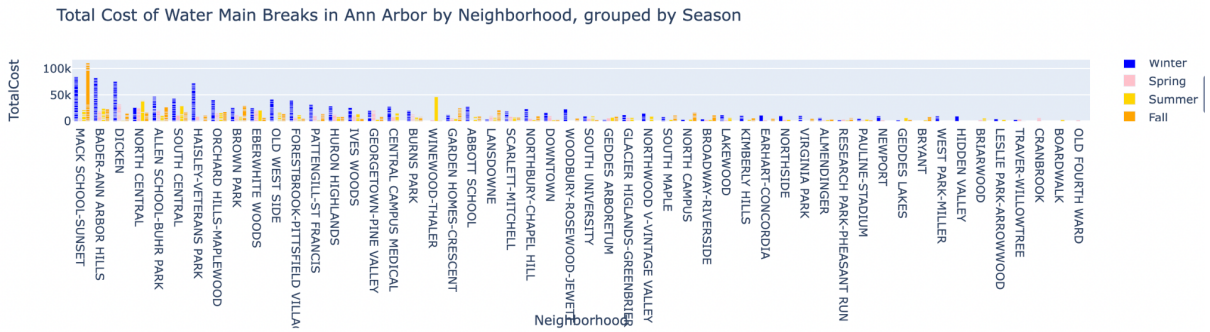
RQ2. Which materials are being used in water mains of varying ages for Ann Arbor neighborhoods during vulnerable months (as identified in RQ1)?

Analysis for RQ1

This RQ examined how frequency and total cost of water main breaks changed across Ann Arbor neighborhoods over several seasons. In Ann Arbor, the neighborhoods with the highest frequencies of water main breaks were Mack School-Sunset, Bader Ann Arbor Hills, and Dicken. Broken down by season across all neighborhoods, water mains broke predominantly during winter months (December, January, February), leading to higher total repair costs during these months as well. Unfortunately, a limitation of this analysis is a lack of detail regarding the neighborhoods themselves. In the datasets provided, there is no information about population density, income, or other factors that may provide context as to why certain neighborhoods have more frequent breaks. Additionally, because of the nature of the data, there is no formal categorization of seasons – I had to arbitrarily assign groups of adjacent months to seasons. Despite this not being perfectly accurate, I stuck to the groupings commonly used in class to inform my analysis throughout. (159)



Bar chart displaying count of water main breaks for each neighborhood, displayed in descending order



Grouped bar chart displaying total cost of water main breaks for each neighborhood, grouped

by season and displayed in descending order

The quantitative measures reflected the pipe breakage that occurs as a result of extreme weather and temperatures, commonly occurring during winter months. The seasonalities of the breaks aligned with my expectations, given the context of when water mains are more likely to break. The neighborhood distribution of the breaks conflicted with my expectations, given my personal context. As someone who is from Ann Arbor, I found it odd to see neighborhoods I know to be wealthier be ones with the most frequent breaks. I suspected that wealthier neighborhoods were also older neighborhoods, leading to outdated infrastructure and increased breaks, however, this conclusion was unverified. The seasonality findings informed my approach to RQ2. Since winter was the most common time for breakage, I subset my data in RQ2 to focus and prioritize these occurrences. These findings would inform city officials about how to rebuild water mains to be durable for vulnerable months, identified by the analysis as winter months. The analysis would also help the city prioritize rebuilding in specific neighborhoods based on frequency. (173)

Analysis for RQ2

This RQ examined the materials involved in water main breaks of varying ages across Ann Arbor neighborhoods. Taking into consideration the analysis from RQ1, I subset the data to focus on the months with the highest frequency of breaks, which ended up being winter months (December, January, February). The water main breaks across neighborhoods mostly involved cast iron pipes. Subsequently, the neighborhoods with the highest frequency of water main breaks in the winter had most of their total costs associated with cast iron. Overall, older water mains (60 years or older) used mostly cast iron, while younger water mains (60 years or younger) used mostly ductile iron. Older water mains broke in distinct ages, whereas newer water mains broke across several ages continuously. This analysis faces the same limitations as RQ1. In the datasets provided, there is no information about population density, income, or other factors that may provide context as to why certain neighborhoods have more frequent breaks. Additionally, because of the nature of the data, there is no formal categorization of seasons – I had to arbitrarily assign groups of adjacent months to seasons. Despite this not being perfectly accurate, I stuck to the groupings commonly used in class to inform my analysis throughout. (205)

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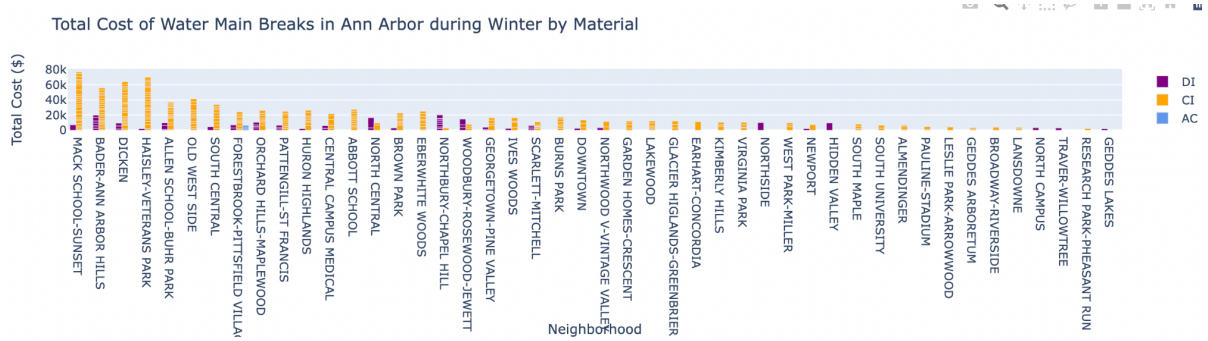
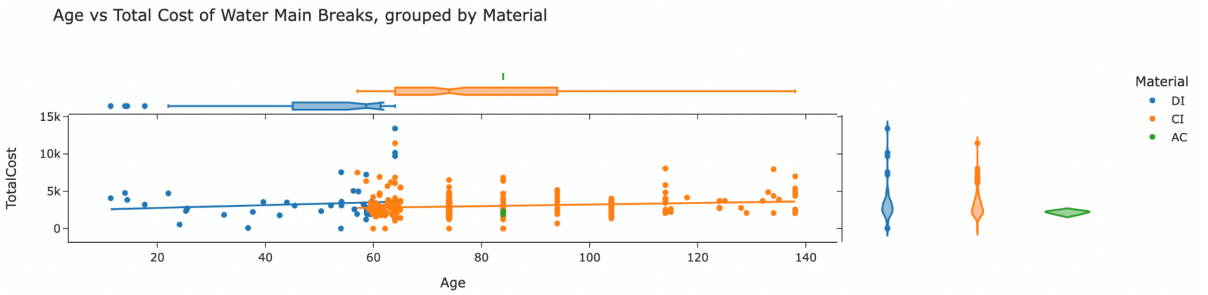


Grouped bar chart displaying total cost of water main breaks for each neighborhood, grouped by material used and displayed in descending order



Scatterplot displaying age versus total cost of water main breaks across all neighborhoods, grouped by material and supplemented by box and violin plots

The findings pertaining to material and age reflect the corrosive behaviors of cast iron. Since cast iron is a material that corrodes easily with a high failure rate, it makes sense that they have led to higher break amounts and are highly contained in older water mains rather than newer ones. The findings regarding age and total cost conflicted with my expectations. I expected age to reflect more significant changes in total cost, however, my analysis showed that there weren't any significant changes as age of water mains increased. The findings regarding changes in material aligned with my expectations. I expected to see a difference in material used in older water mains, which was shown starkly in the analysis. These findings would inform city officials about which materials work best in terms of durability. This analysis reveals that older water mains are made with cast iron pipes, so in order to rebuild water infrastructure, they now know to shift to a less corrosive, more durable material for winter like ductile iron. (171)

Conclusion: Recommendations

Recommendation 1: Switch to Ductile Iron-based Water Mains; Audience: City Planners

This recommendation builds upon the information that the analyses provided about materials being used in water mains of varying ages. The analysis showed that older water mains use mostly cast iron, while newer water mains use ductile iron. It was also revealed that most of the

costs of water main break repairs across neighborhoods in Ann Arbor were associated with cast iron pipes. Switching to ductile iron would ensure pipes to be more durable and to match the construction of other newer water mains. Having similarly constructed water mains would also make them easier to maintain. To act on this, city planners should start in neighborhoods with the highest frequency of water main breaks and begin rebuilding from there with ductile iron. Rather than rebuilding completely new structures, it's important for city planners to use this analysis to prioritize the rebuilding of current water mains in neighborhoods. This will involve the allocating of ductile iron resources to these neighborhoods, as well as arranging maintenance workers and scheduling to complete the task. (171)

Recommendation 2: Establish Yearly Maintenance Plans; Audience: Public Works

When it comes to rebuilding water infrastructure, there needs to be a plan or routine to properly make long lasting improvements. Having a periodic schedule for routine maintenance on rebuilt water mains in Ann Arbor would prevent long lasting damage and reduce the frequency of breaks during the year. Additionally, this would enable Public Works to better prepare the infrastructure in the city for peak break seasons, which, as identified by the analysis, happens during winter months (December, January, and February). Scheduling these maintenance checks strategically as to have sound infrastructure going into winter months would also reduce the frequency of breaks during that time. Public Works should take this analysis into consideration as they make plans to routinely and periodically maintain their existing water mains, in tandem with a routine to rebuild existing water mains as guided in Recommendation 1, prioritizing high frequency neighborhoods. They should work with other city planners to see when it's feasible to allocate workers and resources before winter kicks in. (166)