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SI 305 | Introduction to Information Analysis
Project Assignment 4: Final Deliverable Report

Project Summary

The water main infrastructure in Ann Arbor faces significant challenges due to aging and diverse pipe materials, leading to recurrent breaks and adverse impacts on the community. Frequent boil water advisories and contamination risks highlight the urgency for a reliable and cost-efficient water system. Research Questions (RQ1) aimed at identifying winter-resilient materials, revealed that Ductile Iron (DI) and HDPE are the most winter-resilient options. RQ2 delved into cost efficiency and sustainability. Despite initial expectations, Cast Iron (CI) emerged as the most economically viable pipe material. Recommendations propose DI and HDPE for winter resilience and CI for cost efficiency and sustainability. Justifications were drawn on detailed analyses of the City of Ann Arbor Water Department data.

Problem Diagnosis

The problem is simple but crucial. Like most of the United States, Ann Arbor's water main infrastructure is old and poorly maintained due to budget constraints. Adding to this challenge, Ann Arbor's water infrastructure is patched together with nearly six different types of pipes, including cast iron, ductile iron, PVC, HDPE, cement, and even wood. Consequently, the city faces recurrent water main breaks, posing a significant risk to the community's well-being.

This is a critical issue that needs to be resolved as it contributes to water wastage and impacts the health, finances, and water accessibility of community members. In addition, every time a water main pipe bursts, it leaves Ann Arbor residents without water and at risk of contamination. Many times in the past, Ann Arbor has issued boil water advisories, the latest being in 2021 due to a water main break. Ann Arbor's website states, "Advisories are issued when an event occurs that may cause the water distribution system to become contaminated, such as a loss of pressure from a water main break."[1] As seen by the Flint, MI, water crisis in 2014, contaminated water can be catastrophic for cities.

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[1] Boil water notifications, accessed October 27, 2023, https://www.a2gov.org/departments/water-treatment/about/Pages/Advisories-and-Notifications.aspx.

As mentioned by Dave Wilborn, Watermains break due to multiple reasons, including: “cold temperatures, change in temperature, stress on pipes, soil corrosion, construction, heavy equipment on roads, and poor pipe material.”[2] He also noted that “funding is a big challenge for the water system.” Most of the Ann Arbor water system was built before the 1980s with federal funds. As the Ann Arbor water infrastructure evolved, developers, tasked with selecting pipe materials often selected the “cheapest to operate,”[3] and neglected the long-term maintenance costs associated with pipe materials. After development, water mains were turned over to Ann Arbor for day-to-day operations. Today, the city does not provide an adequate budget to maintain the water system. Without sufficient capital, the water department cannot provide preventative maintenance, leading to deterioration and water main breaks.

With Ann Arbor’s limited water budget, it is important to identify what pipe material is best for maintaining and developing future water infrastructure so that we can have a reliable, safe, and cost-efficient water system in Ann Arbor.

Research Questions

RQ1. In the context of Ann Arbor's winter climate, which water main material types demonstrate the highest resilience by experiencing the least number of breaks?

RQ2. Which pipe materials demonstrate the highest cost efficiency and sustainability in Ann Arbor's water main infrastructure, considering factors such as maintenance costs and durability?

Analysis For RQ1

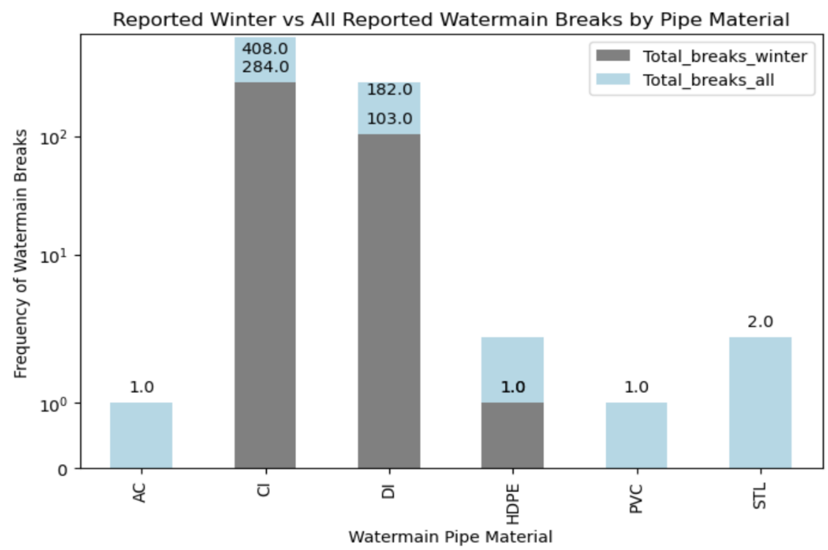
Answer

In the context of winter weather, the pipe materials that showed the most resilience to winter water main breaks are DI and HDPE.

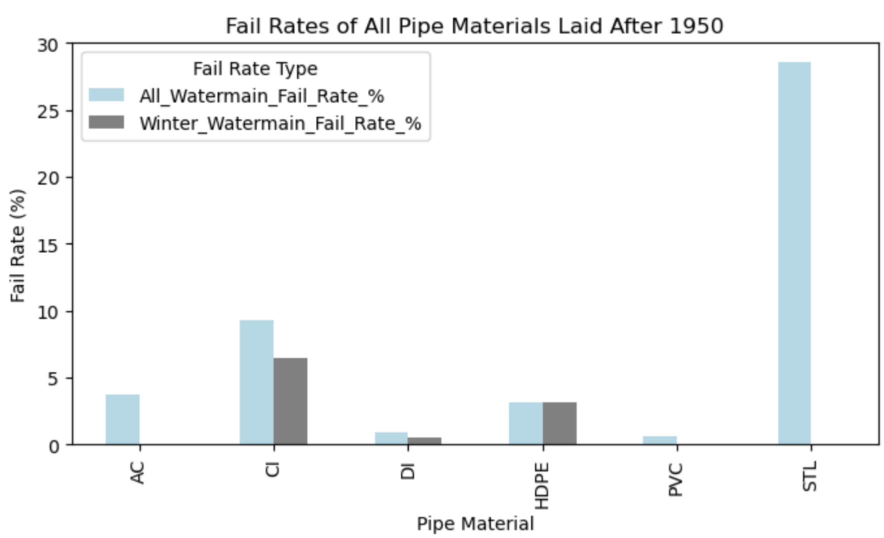
Summary of Findings

[2] Dave Wilburn, “Watermain Reporting System,” Ann Arbor Water Main Reporting System, September 19, 2023, https://drive.google.com/drive/folders/1DJxhHJT9PBjPx_18DX3GwZBNUgATTWuZ.
[3] Robert Czachorski, “Future Water Infrastructure,” Ann Arbor Water Infrastructure, September 23, 2023, https://docs.google.com/document/d/1eH7MbvjpFovqfhvm-4RWY--4GGi3nykA/edit.

Several insights emerged throughout my analysis and led to this conclusion. The initial breakthrough transpired when I grouped the datasets by pipe material and the month in which the water main break occurred. This facilitated the calculation of the proportion of water main breaks that took place during winter months, shedding light on materials that experience the least amount of water main breaks in winter months, specifically, DI and HPE.



While exploring the connection between winter water main breaks and the total number of water mains constructed per material, I analyzed how winter temperatures have influenced the entire population of water main materials. The findings revealed that the overall population of DI was the least affected during winter months. Specifically, only 0.87% of the entire DI population experienced a water main break in winter, followed by HDPE at 3.12%.



Last, I delved into the relationship between pipe material and diameter to uncover potential trends associated with different pipe diameters. This analysis allowed me to eliminate CI as a top-performing pipe material for winter conditions. A notable observation emerged when comparing the data between DI and CI on the line graph—DI consistently demonstrated a lower contribution to water main breaks across all pipe diameter sizes than CI.

Interpretation of Findings

The insights gained from this analysis paint a compelling picture. The dominance of CI in Ann Arbor's water main system, a material associated with the highest proportion of overall water main breaks, especially during winter, highlights the pressing need for a more robust material in future water main development. Notably, even though roughly half of the reported main breaks for DI occur in winter, this represents a considerable difference compared to CI, where 69% of main breaks occur during winter.

In addition, the comparison of water main breaks to the overall population of pipe materials utilized in the Ann Arbor water system sheds light on the influence of winter water main breaks on the broader material landscape. Once again, CI demonstrated the worst results, significantly affecting the overall CI population. In contrast, winter water main breaks affected less than one percent of DI and approximately three percent of HDPE. This not only underscores the resilience of certain pipes in winter conditions but also offers a preview of the durability of different pipe materials in RQ2.

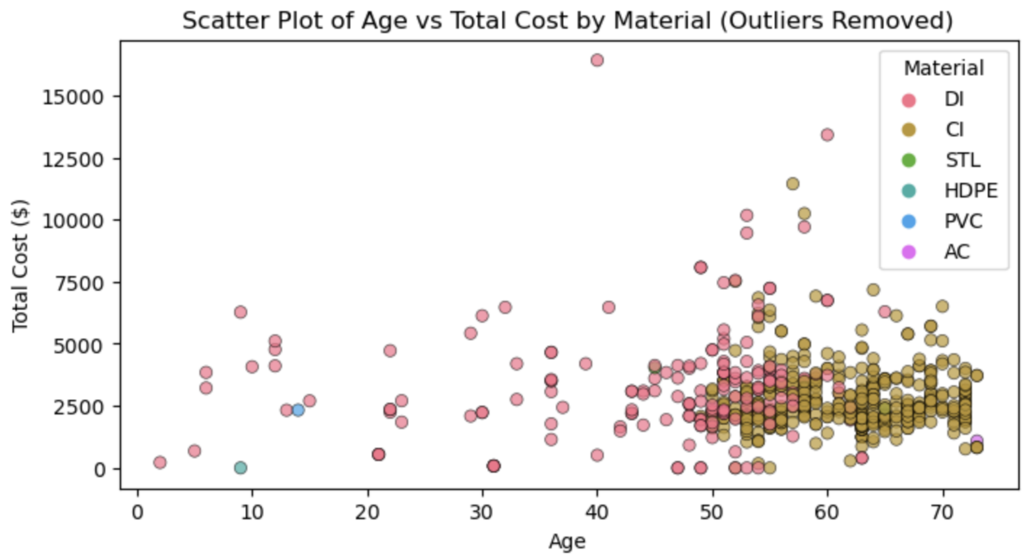
Analysis For RQ2

Answer

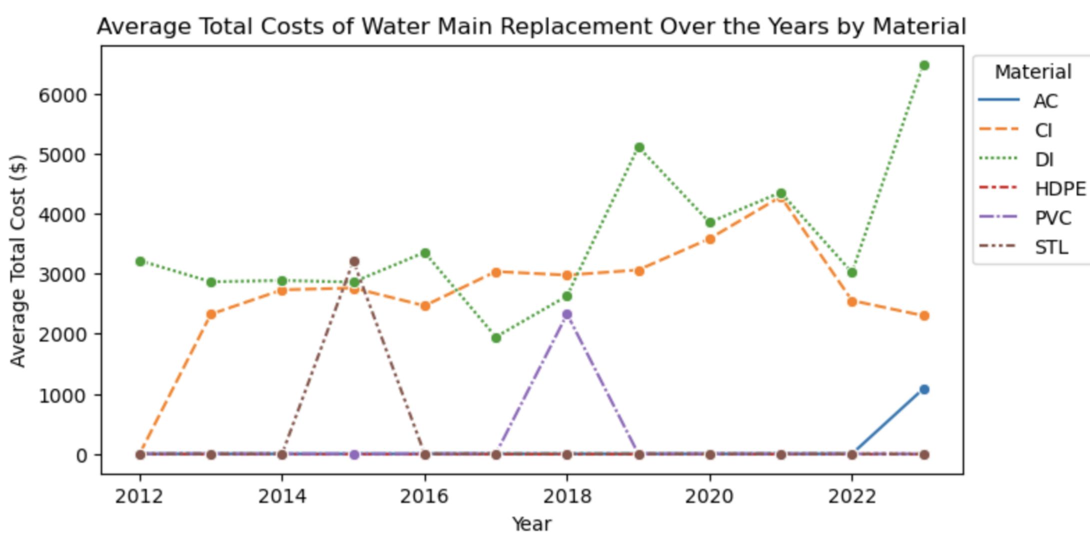
Within the realm of cost efficiency and sustainability, CI emerges as the most economically viable and sustainable pipe material.

Summary of Findings

My analysis first yielded valuable insights when grouping pipe materials by average age and total cost. The resulting Cost/Age Ratio highlighted the annual expenditure per year of a water main's lifespan. Notably, CI demonstrated a ratio of 46.6, outperforming DI at 72.0. This metric is a key indicator of cost efficiency for various pipe materials



Exploring the annual average work order costs of water main breaks revealed a noteworthy trend. Since 2012, CI pipe replacement expenses have consistently trended lower than those for DI. In addition, a valuable pattern emerged. Specifically, DI's average total work order costs are increasing annually, while CI's costs are decreasing. Diving deeper, I examined only the material costs and found a similar trend. This observation provides valuable insight into the potential future costs of water main breaks per material.



Last, I analyzed the relationship between pipe diameter and work order expenses, uncovering significant trends. Notably, 6.0 pipes, despite being less common than 8.0 pipes, contribute to 57% of water main breaks. Further analysis revealed that CI is more cost-effective for popular pipe diameters in Ann Arbor. Specifically, switching 6.0 CI pipes for 8.0 CI pipes could save money and decrease the frequency of water main breaks, making it a potential game-changer for Ann Arbor.

Interpretation of Findings

The findings reveal a surprising outcome in the analysis of cost efficiency and sustainability for future water main infrastructure. Opposite of my initial expectations that DI would emerge as the more cost-efficient option, based on hints from RQ1 regarding DI's durability in winter months, the analysis pointed decisively towards CI as the superior choice.

In light of this unexpected outcome, the analysis broadens the lens through which cost efficiency and sustainability are viewed. The data not only challenges expectations, but highlights the pipe diameter that contributes the most to watermain breaks. In addition, the data suggests that 8.0 CI pipes are both the superior performer and more budget-friendly option compared to 6.0 CI pipes. This discovery has the potential to significantly impact the city budget, introducing a shift in pipe material considerations for future water main development. The unexpected findings of 8.0 CI as more affordable and durable align more closely with economic and sustainable objectives.

Conclusion / Recommendations

Recommendation 1: In the context of winter weather, Ductile Iron and HDPE, Should be considered for future water main development as they demonstrated the most resilience in winter months.

Audience (Recommendation 1): Ann Arbor Water Department

Justification (Recommendation 1): Based on the analysis conducted, particularly evaluating water main breaks in winter conditions, the recommendation to consider DI and HDPE for future water main development is well-justified. The findings highlight that both materials display significant resilience to water main breaks during winter months, with DI showcasing notable advantages over other materials. The proportion of DI experiencing winter breaks is considerably lower (0.87%) than the prevalent material, CI (9.32%), reflecting a significant advantage in terms of durability in winter months. Additionally, when assessing the overall impact of each material on the entire population of materials, DI and HDPE emerge as standouts, with minimal disruption during winter compared to their counterparts. The recommendation is supported by a deep understanding of the evidence, confirming that DI and HDPE stand out as materials capable of withstanding water main breaks in winter months, therefore enhancing the reliability and durability of water mains.

Recommendation 2: In the context of cost efficiency and sustainability, Cast Iron pipes, should be recommended for future water main development, as they are the most cost-efficient and sustainable material compared to their counterparts.

Audience (Recommendation 2): Ann Arbor City Council, Ann Arbor Water Department

Justification (Recommendation 2): The recommendation to prioritize CI pipes, particularly emphasizing 8.0 CI pipes, for future water main development is supported by an analysis examining different cost efficiency and sustainability factors. The pivotal Cost/Age Ratio, a revealing stat reflecting the annual expenditure per year of a water main's lifespan, positions CI as the superior choice with a ratio of 46.6, outperforming DI at 72.0. This piece of evidence highlights CI's enduring cost-effectiveness over a water main's life. Additionally, exploring annual average work order costs since 2012 shows CI as a more economically viable option than DI. The trend of decreasing costs for CI and increasing costs for DI shows that choosing CI is a smarter financial decision in the long run.. Analyzing material costs and the effect of pipe diameter provides an additional layer of recommendation support, revealing that switching to 8.0 CI pipes could yield significant cost savings and decrease the frequency of water main breaks. This unexpected piece of evidence strongly justifies the recommendation, positioning CI, especially 8.0 CI pipes, as the preferred material for developing a cost-efficient and sustainable water main infrastructure in Ann Arbor.

Recommendation Limitations Summary

The results of the analysis, while supporting my conclusion, revealed that materials like STL, AC, and PVC seemed cost-efficient and resistant to cold weather. However, further investigation uncovered serious health risks associated with these materials, leading to their exclusion from the recommended list. Despite their promising qualities, their potential negative effects on people's health, and the limited data available influenced this decision. To prioritize safety and reliability, I focused on materials with a suitable sample size in forming my ultimate recommendation for future pipe development.