

# Data Analytics

Assessing Risk of Extreme Weather on Facilities Maintenance



Explore how data analytics reveals the impact of climate change on Hamilton's buildings. This project uses machine learning to analyze climate factors like freeze-thaw cycles and precipitation, predicting their effect on maintenance costs. Dive into the findings to uncover strategies for resilient, climate-adaptive infrastructure.

— HEAD Competition 2024





# Data Analytics

Assessing Risk of Extreme Weather on Facilities Maintenance



## Project Objective

To evaluate the impact of climate change on building maintenance costs in Hamilton, Ontario, focusing on the Facility Condition Index (FCI).

## Final Deliverable

A comprehensive poster summarizing findings, analysis, and methodology.



— HEAD Competition 2024



# Data Analytics

## Assessing Risk of Extreme Weather on Facilities Maintenance

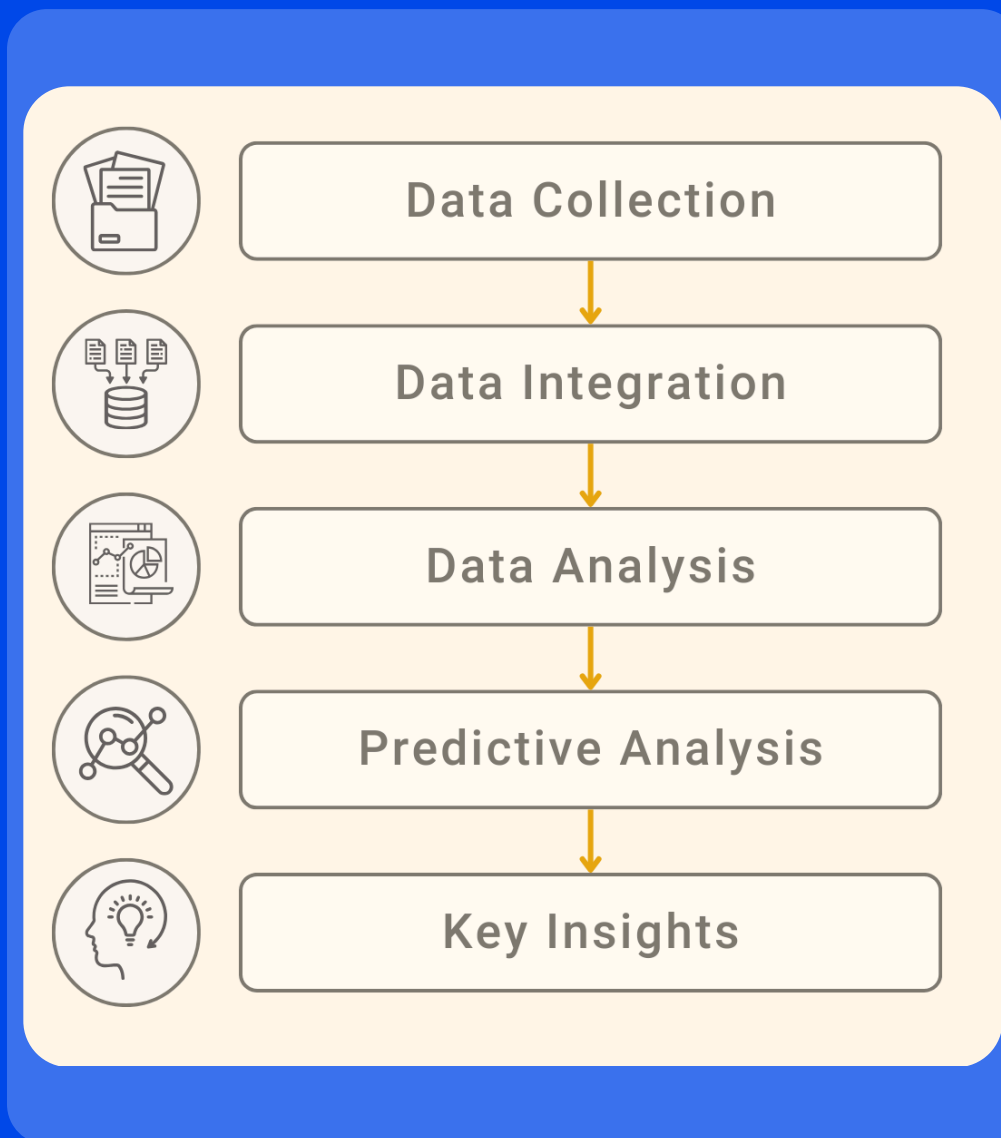


## Problem Statement

- **Climate Challenge:** Climate change is driving an increase in extreme weather events, posing risks to building safety, infrastructure integrity, and community well-being.
- **Current Shortcomings:** Existing building codes are based on historical climate data, which may no longer be adequate to ensure safety and resilience against future climate conditions.
- **Key Question:** How can Hamilton adapt its maintenance strategies to address the risks of extreme weather and ensure long-term infrastructure sustainability?

# Data Analytics

## Assessing Risk of Extreme Weather on Facilities Maintenance



## Methodology

- **Data Collection:**
  - **Climate Data:** Extracted from [climate.ca](https://climate.ca), offering high-resolution historical and predictive weather data.
  - **Building Data:** Provided by the City of Hamilton, including facility information, FCI, and current replacement value (CRV).
- **Data Integration:**
  - Derived geospatial coordinates for buildings using Python libraries.
  - Merged climate data with building information based on geographic proximity.
- **Data Analysis Tools:**
  - Machine learning models (XGBoost) for predictive analysis.
  - SPSS for correlation studies.
- **Predictive Modeling:**
  - Assessed the impact of key climate variables (e.g., freeze-thaw cycles, precipitation, Humidex) on FCI trends over an 8-year horizon.

# Data Analytics

## Assessing Risk of Extreme Weather on Facilities Maintenance Final Result

### Assessing Risk of Extreme Weather on Facilities Maintenance

Yaironil Germosen, Daniel Henao, Anja Wallentin, Edwin Santos



#### What is the Problem?

Climate change increases extreme weather, risking facility damage and disruption. Hamilton is updating maintenance to address weather impacts, considering facility types and most damaging weather events. This project seeks to guide a climate-informed maintenance approach for Hamilton's buildings.

#### Background

Given the increase in temperature to recent historical data, the current building rules, which are based on previous weather data, may not be sufficient to maintain the security and resilience of structures against impending extreme weather changes. To ensure the construction of safe and resilient buildings, it is imperative that building codes be updated to consider future climate predictions. In response to these changes, the City of Hamilton is adapting its maintenance techniques and is shifting from earlier approaches that depended on set timetables to a more comprehensive plan that considers the increasing frequency of severe weather events.

- Weather records from across Canada show that every year since 1998, has been warmer than all the 20th century average.
- A whole generation of Canadians has never experienced what used to be considered a "typical Canadian Climate".
- Canadian building codes currently rely on historical weather data, which can potentially be a threat to the community safety and infrastructure integrity.
- Buildings and infrastructure are vulnerable to future climate extremes and variation.
- There are variables that affect the FCI rating which aren't currently considered.
  - For example, more frequent freeze-thaw cycles can create heavy ice buildup on roofs.

#### What are our objectives?

- Evaluate facility vulnerability to extreme weather due to climate change.
- Integrate building condition, usage, and climate data for risk assessment.
- Recognize which building types are the most affected and by which type of extreme weather event.

#### Data & Methodology

We utilized three primary databases for the project:

- COH Building Condition Assessment Summary:** Contains building and facility information in Hamilton area, focusing on Facility Condition Index (FCI), Asset Type, and Address.
- Database on Current Replacement Value (CRV):** Provides assets Current Replacement Value.
- Climate Data:** Extracted from Climateck, offering high-resolution climate data in Canada.

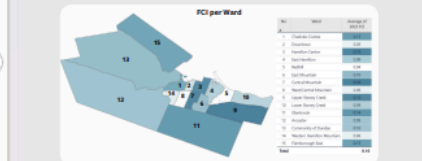
Merged the three datasets performing additional derivations such as:

- Deriving exact latitude and longitude of each asset from addresses using a Python library.
- Matching climate data to each asset based on the nearest quadrant on a map and calculating average climate variables based on the age of the building (e.g., an average for buildings constructed in 1950 until 2034).

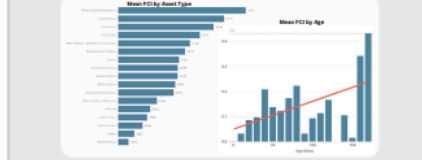
#### Analysis and Results

##### Asset related Insights

In this section, we embark on an in-depth analysis of our merged database. Our investigation begins by examining trends related to the Facility Condition Index (FCI) Rating in connection with asset-specific variables, such as FCI per Ward, per age of assets, etc.



Data shows that 14 out of the 15 wards had an average FCI that fell into the "Fair to Good" range (less than 10-15%), and the ward 7 (Central Mountain) had a rate slightly above the span with a rate of 16%.



The trend shows an overall positive relation between the FCI and the age of the buildings. After age 55, the trend starts to fluctuate. The fluctuations in the ratings over the years indicate that there are additional factors that affect the index.

Oldest buildings have the peak rating with 43%. Buildings located in work yards, golf facilities and cemeteries have an overall higher FCI rating. The average FCI rating of those 3 types of assets (5,544) is higher than the rating for the bottom 9 combined (5,533).



The tendency indicates a general decreasing trend in the FCI as property size increases. However, there are significant variations, indicating that the relationship is not constant. Having closely examined the variables linked to the asset, we now transition to exploring the relationships between the Facility Condition Index (FCI) Rating and the climate variables we have gathered. This next phase will further illuminate how climatic factors influence facility conditions.

#### Key Insights

- Using an eight-year horizon, the sample of 21 facilities should result in an increase of \$1,092,000CAD in the current value needs budget as a result of climate change variability.
- The increase in Humindex mainly increases the FCI of Park Facilities - Public Use. The increase in Precipitation mainly increases the FCI of Work Yards & Maintenance. The decrease in ice days decreases the FCI of Work Yards & Maintenance.
- In general, the type of facilities most affected by climate change are golf facilities, increasing by 4.2% the value of their FCI. Generating an increase in the value of the Current Value Needs budget of a total of \$510,000CAD.

##### Climate Insights

This section delves into the linear relationships between climate variables and the Facility Condition Index (FCI) Rating, focusing on the following:

- Precipitation:** Annual total precipitation (in mm).
- Humindex:** Number Of Days Per Year with Daily Humindex Greater Than 40.
- Ice days:** Annual number of days with maximum daily temperature below 0 degC.
- Freeze-Thaw cycle:** Annual number of days with a diurnal freeze-thaw cycle.

This first visualization presents a bar chart detailing the correlations between the variables and the FCI. The bars are arranged in descending order of their absolute impact, showcasing the strength of each correlation.



In the upcoming visualizations, we'll not only delve deeper into the relationships between key climate variables and the FCI Rating but also examine the yearly trends of each climate variable.



According to the scatter plot, there is a positive relation between the number of ice days and the FCI rating. We can anticipate that this will have an impact on lowering the FCI rating because the amount of ice days is predicted to decrease over time.

The scatter plot suggests a weak positive correlation between freeze-thaw mean and FCI rating. Considering that freeze-thaw cycles are expected to decrease over the years, we can expect a small reduction of the FCI rating.

Given the negative correlation observed in the scatter plot between Humindex days and the FCI rating, and considering that Humindex levels are projected to increase over the years, it is reasonable to anticipate that the FCI may experience a corresponding impact, potentially showing a tendency to reduce in Humindex levels rise.

The correlation between precipitation and FCI rating is negative but so weak that is tending to zero. There is a predicted increase in the precipitation for the next years, so reduction in the FCI is expected.

Our initial analysis focused on identifying linear relationships between climate variables and FCI Rating. Scatter plots highlighted some linear patterns, such as those between Humindex and the FCI, indicating a straightforward influence of certain climate factors on maintenance costs. However, this linear approach captures only one part of the intricate relations between variables. To show more complex interactions and non-linear relationships, we employ XGBoost, a sophisticated machine learning model. This is going to be reviewed in the next section.

#### Recommendations

- Given the insight that the increasing of precipitation will raise maintenance costs for buildings in Hamilton, the recommendation is to proactively upgrade infrastructure and implement sustainable drainage systems. By doing so, Hamilton can mitigate the financial impact of climate-induced precipitation on building maintenance, aligning with national resilience efforts. [1][7]
- Higher Humindex values increase the Current Value Needs (CVN) for buildings due to accelerated wear and tear on materials and structures from increased humidity and temperatures. This leads to more frequent maintenance for issues like mold, wood rot, and corrosion, and higher energy costs from extended HVAC operation. These factors necessitate investing in durable materials and efficient systems, raising initial and ongoing building costs. [3]
- Due to the complexity of relations between climate variables, we recommend using models that capture more complex relationships than linear. For this case XGBoost and Decision Trees had the best performance in capturing such relations.

##### Predictive Model

We use a predictive machine learning model with the FCI variable as the target. The purpose of this is to be able to make FCI predictions by changing certain key variables for the model. The goal is to anticipate the cost change in the current value needs of the assets as the climatic factors become more aggressive over time.

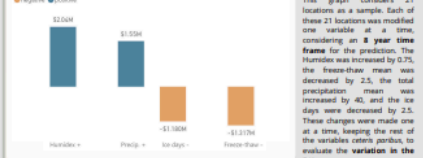


After applying the machine learning model in the SPSS tool, we obtained the following correlation graph between the actual FCI and the predicted FCI, with a correlation of 80%.

To obtain this correlation percentage, the XGBoost model was first applied to the data to separate the values of FCI=0 and those greater than 0. The result obtained was a model with a reliable correlation index and a mean absolute error of 0.047.

Asset Size	FCI
Ward	10
Freeze Thaw Mean	2.5
Total Precipitation Mean	16
Year Built	14
Humindex	12
Ice Days Mean	8

Considering the main predictors, we have tested the model on how the FCI will change if we change one of the predictors, maintaining ceteris paribus the others. The predictors in which we tested the variations are: total precipitation mean, freeze-thaw mean, Humindex and ice days mean.



This graph considers 21 locations as a sample. Each of these 21 locations was modified one variable at a time, considering an 8-year time frame for the prediction. The Humindex was increased by 0.75, the freeze-thaw mean was decreased by 2.5, the total precipitation mean was increased by 40, and the ice days were decreased by 2.5. These changes were made one at a time, keeping the rest of the variables ceteris paribus, to evaluate the variation in the FCI.

As a result, the variables that most affected the 21 sample facilities in monetary terms were Humindex and Precipitation. The reason for assuming increases for some variables and decreases for others is due to the trends of climatic factors in the future. Total Current Value Needs increased by Precipitation and Humindex is around \$1,589,000CAD. And the total increased by the 4-variables is \$1,092,000CAD.

#### References & Additional information





# Data Analytics

## Assessing Risk of Extreme Weather on Facilities Maintenance

### Conclusions

- **Integration of Diverse Data Sources:** Successfully merged building data, climate variables, and geospatial information to create a comprehensive dataset, enabling detailed analysis of the Facility Condition Index (FCI) across Hamilton's facilities.
- **Key Climate Drivers Identified:** Analytics revealed that factors like freeze-thaw cycles, Humidex levels, and precipitation have measurable impacts on FCI ratings, with Humidex and precipitation emerging as the most significant predictors of increased maintenance costs.
- **Predictive Model Insights:** The XGBoost model demonstrated an 80% correlation between predicted and actual FCI values, providing reliable forecasts for future maintenance needs. This validates the use of machine learning in understanding complex relationships between climate variables and infrastructure deterioration.
- **Data-Driven Decision Support:** The predictive model quantified the financial impact of climate variability, projecting over \$1M CAD in added maintenance costs for 21 sampled facilities over eight years. These insights offer valuable guidance for proactive budget planning and resource allocation.
- **Complex Relationships Unveiled:** Beyond linear correlations, the analysis captured non-linear interactions between variables, emphasizing the need for advanced modeling techniques to fully understand and predict climate impacts on infrastructure.