Assessing Risk of Extreme Weather on Facilities Maintenance

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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 its 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**.

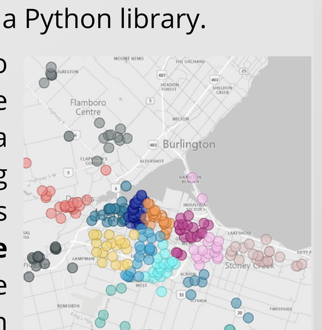
Data & Methodology

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 Climate.ca, offering high-resolution climate data in Canada.

Merged the three datasets performing additional derivations such as:

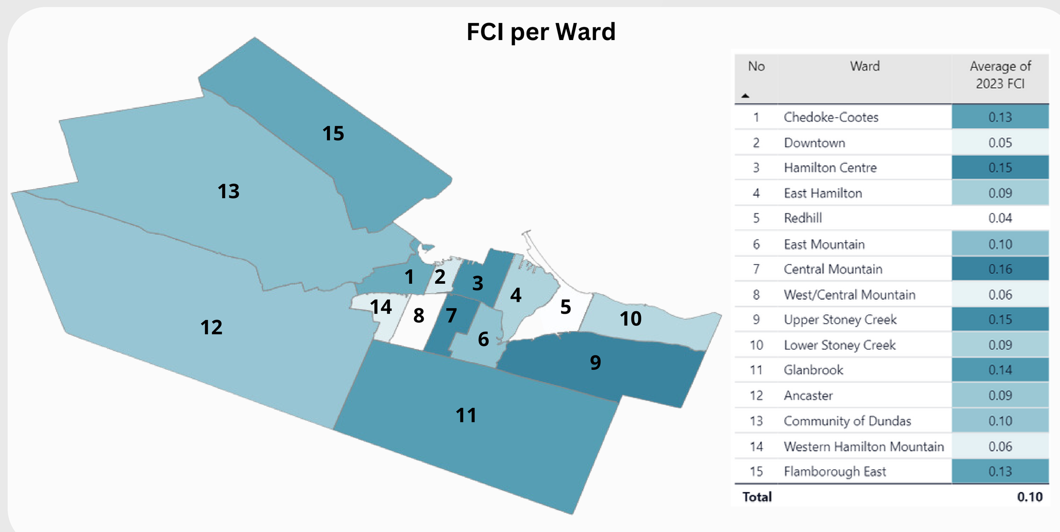
- Deriving exact **latitude** and **longitude** of each asset from addresses using a Python library.
- **Matching climate data** to each asset based on the **nearest quadrant** on a map and calculating **average** climate variables based on the **age of the building** (e.g., an average for buildings constructed in 1950 until 2024).



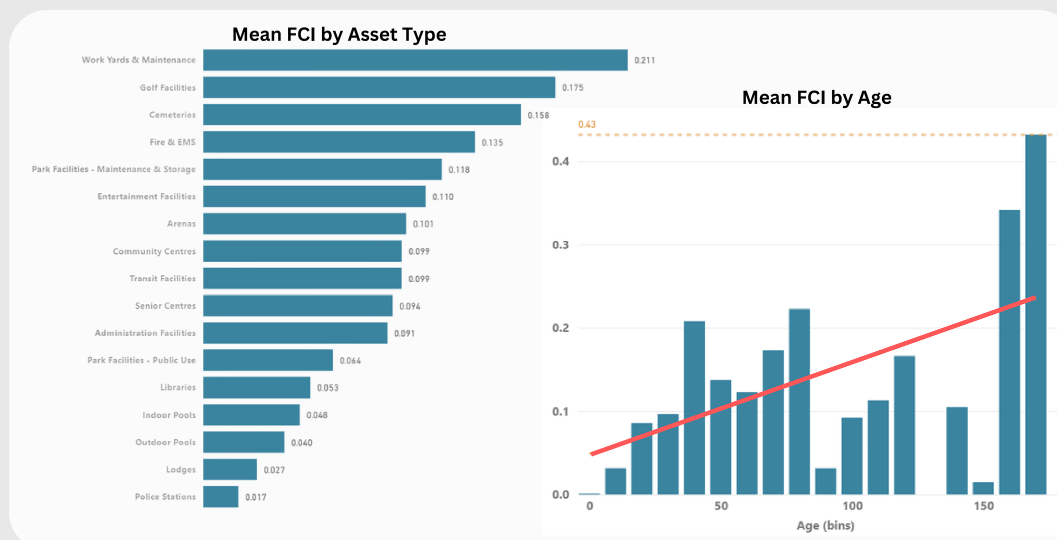
Analysis and Results

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.



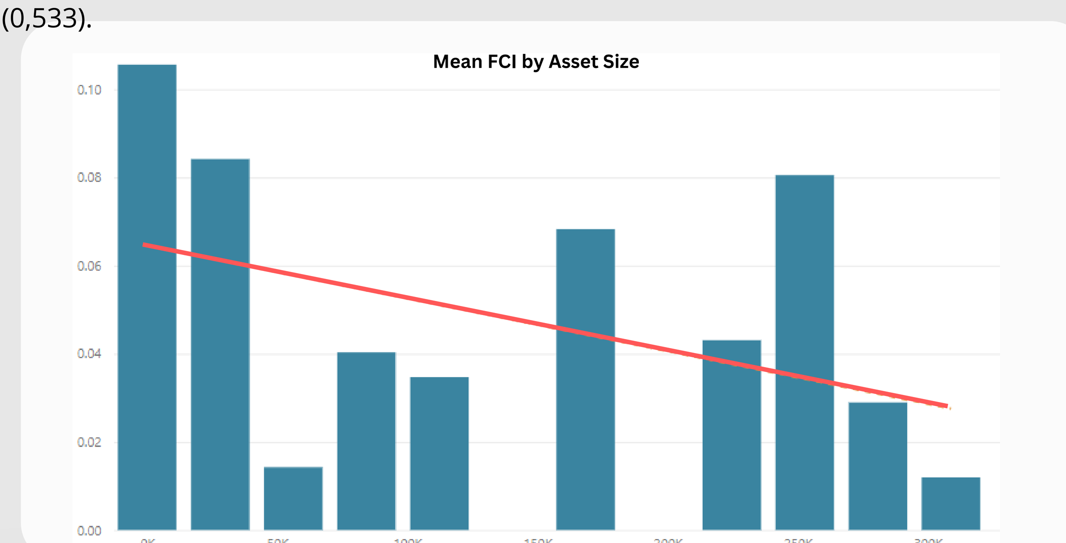
Data shows that that **14 out of the 15 wards** had an average FCI that fell into the "**Fair to Good**" range (less than 10-15%), and the **ward 7** (Central Mountain) had a rate slightly **above** the span with a rate of **16%**.



The trend shows an overall **positive relation** between the **FCI** and **the age of the buildings**. After age **50**, the **trend starts to fluctuate**. the fluctuation 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** (0,544) is **higher** than the rating for the bottom 9 combined (0,533).



The tendency indicates a **general decreasing trend** in the FCI as property size increases. However, there are significant variation, 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.

Climate Insights

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

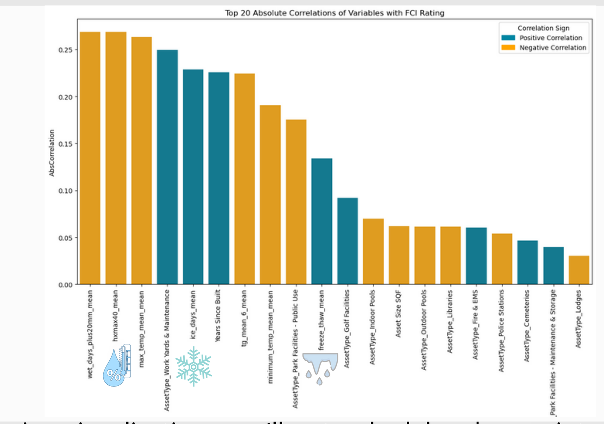
Precipitation: Annual total precipitation (in mm).

Humidex: Number Of Days Per year with Daily Humidex Greater Than 40

Ice days: Annual number of days with maximum daily temperature below 0 degC

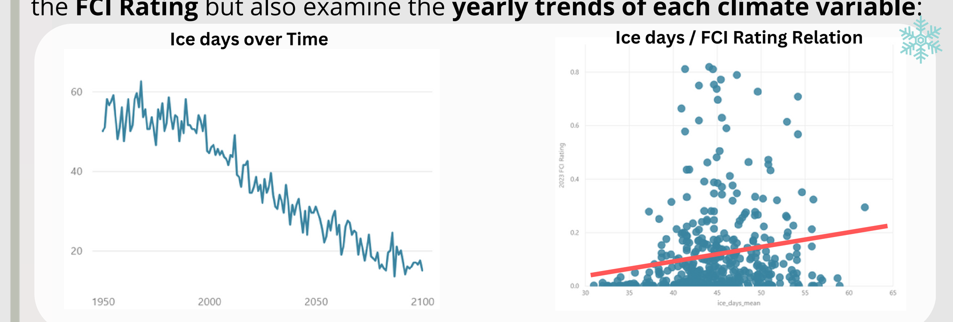
Freeze-Thaw cycle: Annual number of days with a diurnal freeze-thaw cycle

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.

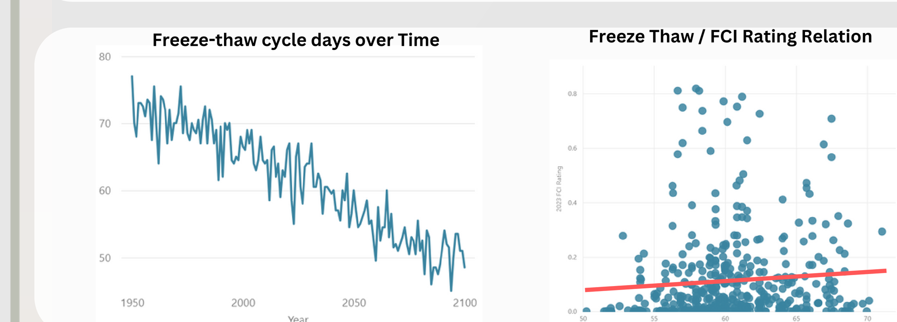


The **Humidex** shows a notably **strong** and **negative** linear relationship with the FCI Rating, indicating that **lower Humidex** values correspond to **higher FCI Ratings**. Similarly, the **Ice Days** Mean and **Freeze Thaw** Mean are also **significantly correlated** with the FCI Rating, highlighting the impact of colder weather conditions on facility assessments.

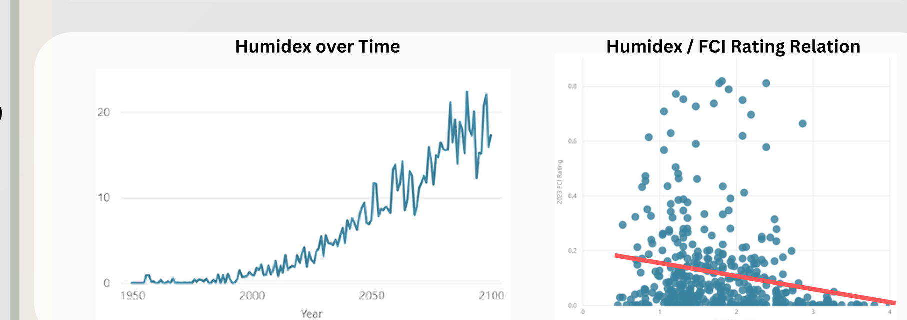
In the upcoming visualizations, we'll not only delve deeper into the **relationships** between key **climate variables** and the **FCI Rating** but also examine the **yearly trends of each climate variable**:



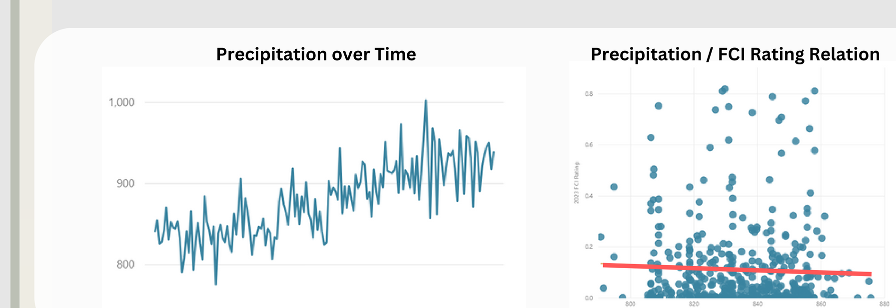
According to the scatter plot, there is a **positive relation** between the number of **ice days** and the **FCI rating.**
We can anticipate that this will have an impact on **lowering the FCI rating** because the amount of ice days is predicted to **decrease over time.**



The scatter plot suggests a **weak possitive 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 **humidex days** and the **FCI rating** and considering that **humidex 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** as humidex levels rise.

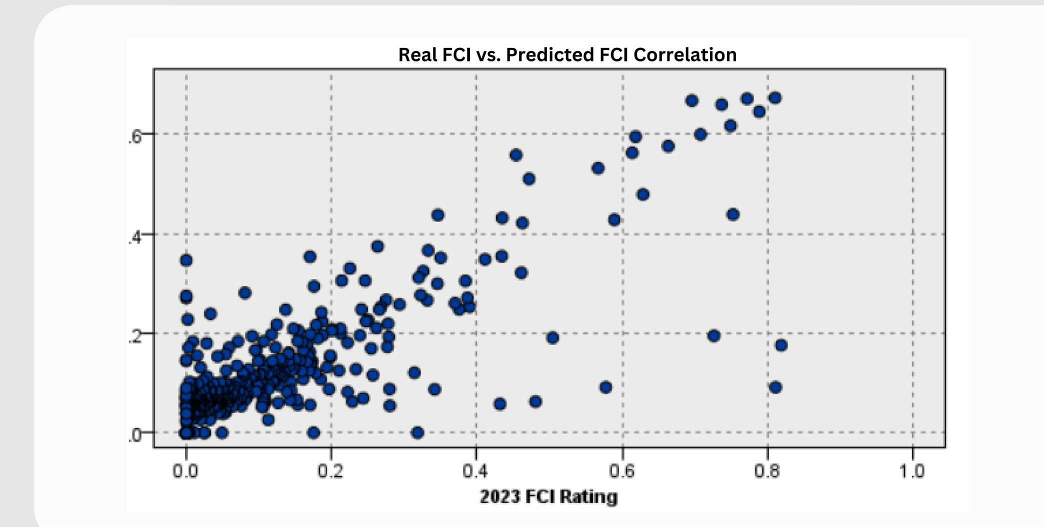


The correlation between precipitation and FCI rating is **negative** but so **weak that is tending to zero**.
There is a **predicted increase** in the **precipitation** for the next years, so **reduction** in the FCI is **expected**.

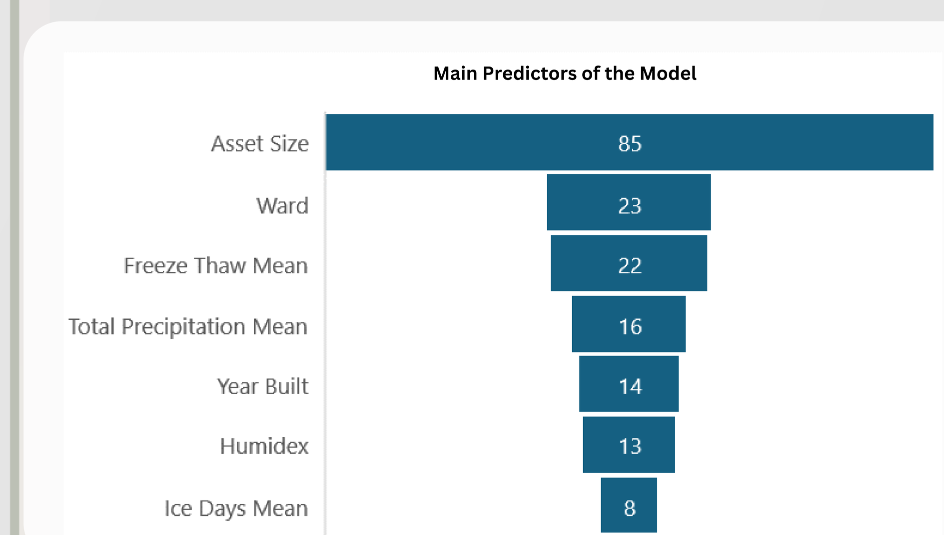
Our initial analysis focused on identifying **linear relationships** between climate variables and FCI Rating. Scatter plots highlighted some linear patterns, such as those between **Humidex** and the FCI, indicating a straightforward influence of certain climate factors on maintenance costs.
However, 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.

Predictive Model

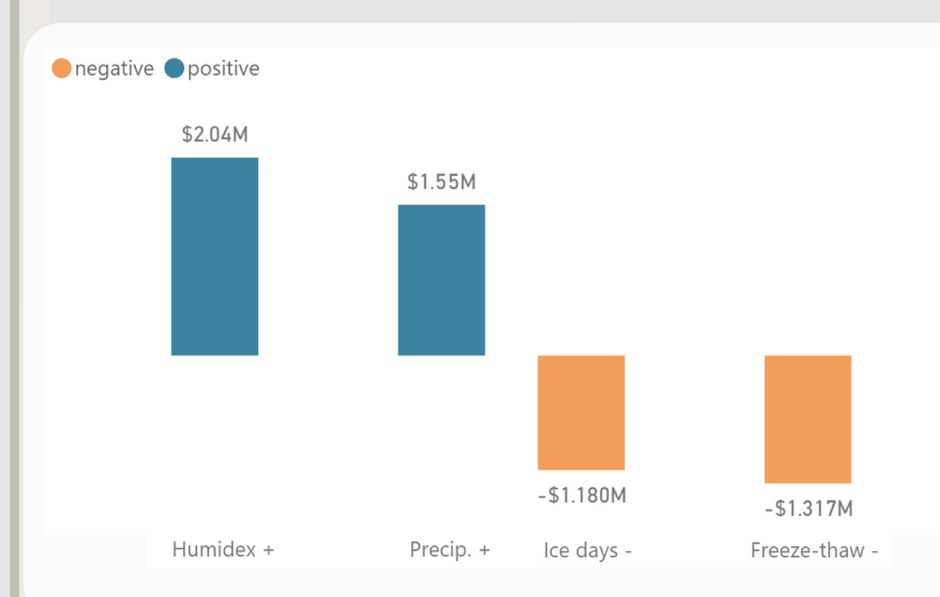
We use a **predictive machine learning** model with the FCI variable as the target. The purpose of this is to be able to make FCI predictions by changing certain key variables for the model. The goal is to **anticipate the cost change** in the current value needs of the assets as the climatic factors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



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, Humidex 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 Humidex 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 **Humidex** 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 Humidex is around **$3,589,000CAD**. And the total increased by the 4 variables is **$1,092,000CAD**.

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 **Humidex** 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**.
The decrease in **freeze-thaw mean** **decreases** the FCI of **Arenas**.

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**.

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 Humidex 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**.

References & Additional information