A PROPOSAL BY
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UTTAN TRANSPORTATION
COMPETITION 2022

DESIGNING FOR EXTREME HEAT

09.07.2022

We would like to thank our excellent mentors, Trevor and Michelle, for guiding us through the competition process. We really appreciate your commitment to the UTTAN community. We'd also like to thank our interviewees - Anisha Patel, Kristina Hausmanis, Jen-Sion Tan, Maili Sedore, Shayna Stott, and Michael Hain - for their time and expertise. Your suggestions and experiences were critical to the success of our project.

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1. EXECUTIVE SUMMARY

1.0 THE CHALLENGE

A total of 36% of Greenhouse Gas (GHG) emissions is derived from the transportation sector, which is the second-largest source of emissions in Toronto (TransformTO, 2019). Shifting from automobility to active transportation modes will help achieve Canada's climate goals. However, the changing climate itself may make this shift more difficult. The number of yearly "very hot days" above 30°C in Toronto may grow nearly fivefold to upwards of 55 days per year in the latter half of the century, as shown in Figure 1 (Eyquem and Feltmate, 2022). The dual health risks from more frequent extreme temperatures and the reduced air quality that accompany them will be felt more acutely by anyone engaging in aerobic exercise - meaning that Toronto residents may be putting themselves at risk by engaging in active transportation.

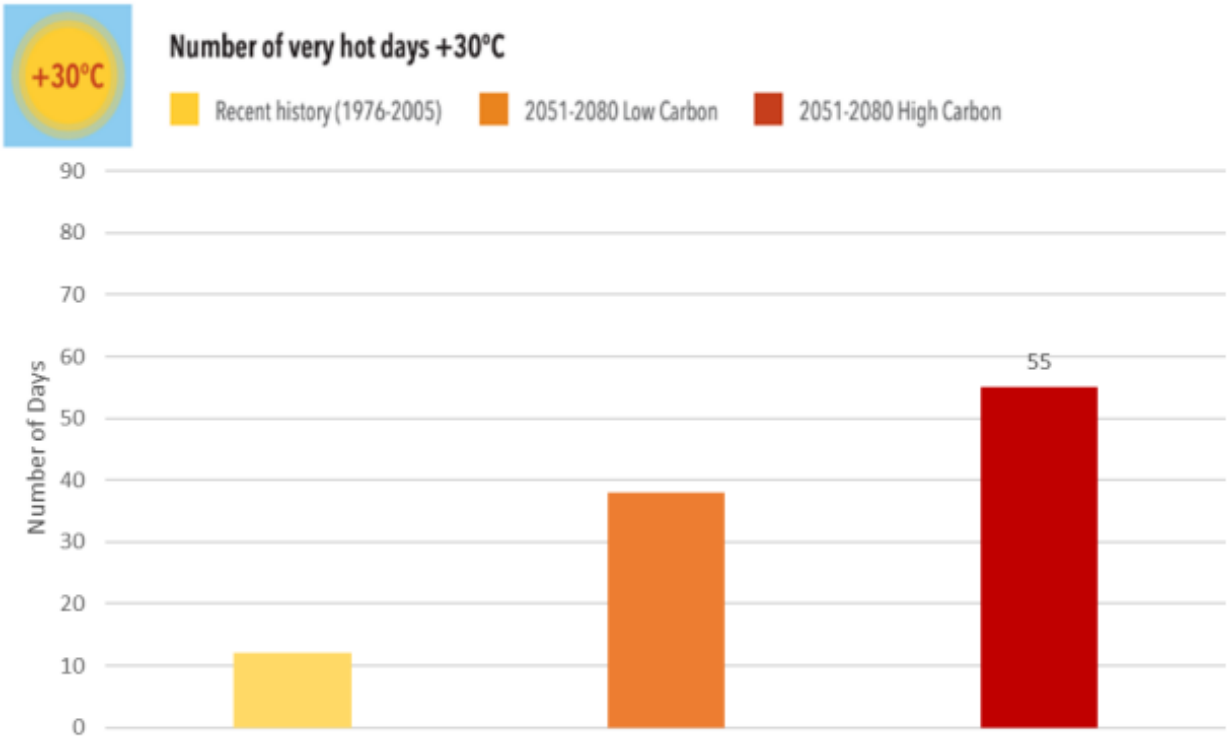
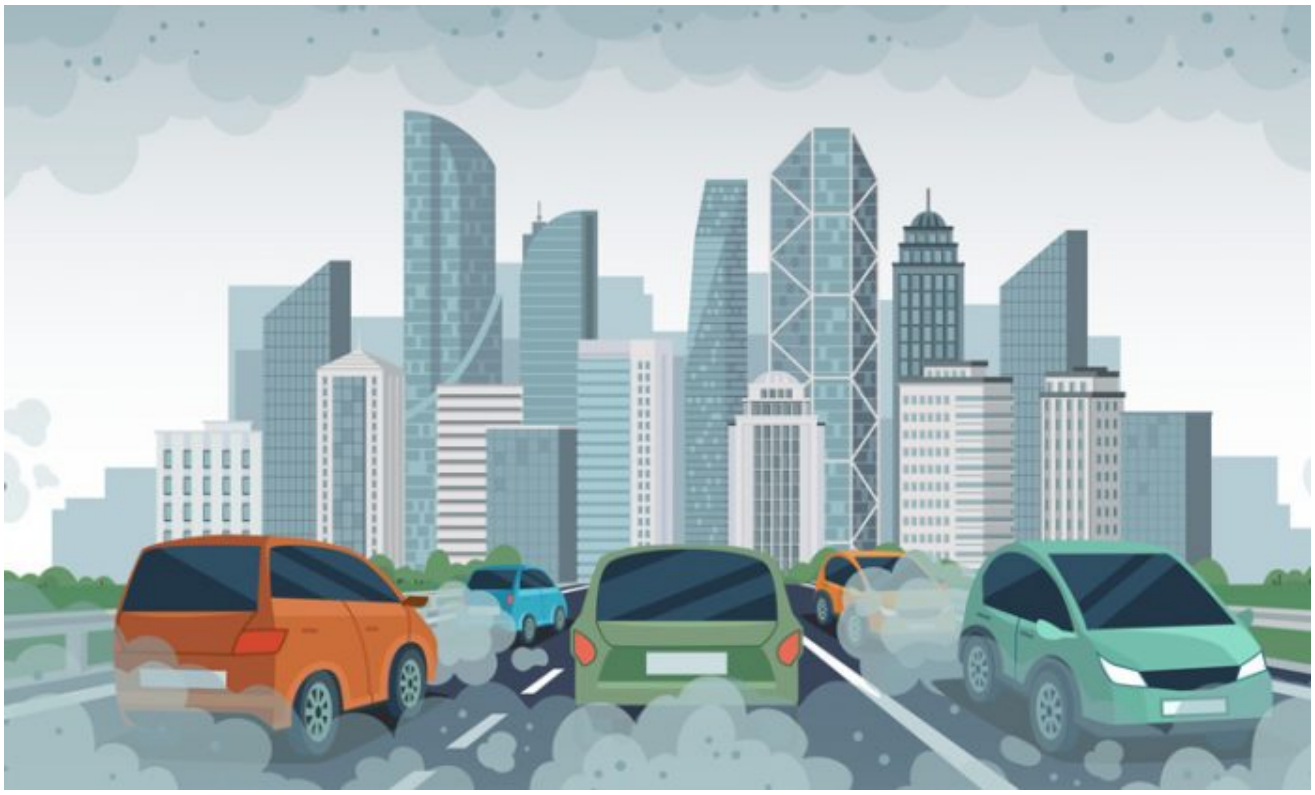


Figure 1: The number of very hot days in Toronto each year in the upcoming years (Eyquem and Feltmate, 2022)

1.1 THE OPPORTUNITY

There are a variety of ways available right now that may be used to encourage cycling in rising temperatures. Numerous environmental issues can be addressed with the aid of active transportation. The reduction of greenhouse gas emissions and air pollution is among the most significant advantages. Energy savings, a decrease in noise pollution, a decrease in water contamination, and more are all additional environmental benefits. Greenhouse gas emissions are rising along with the air temperatures. Even though there isn't much of a concern with excessive heat right now, action needs to be taken. It might be too hot to bike in the future, but even if people are not deterred from biking in heat, it is important to keep them comfortable and safe.



INTERVIEWEES

Anisha Patel - Anisha is a project manager at the City of Toronto specializing in transportation, construction, and Toronto water services. She graduated from the University of Waterloo with a bachelor's in environmental Engineering.

Kristina Hausmanis - Kristina Hausmanis is the Senior Project Manager of Green Streets for Transportation Services at the City of Toronto, where she coordinates the inter-divisional implementation of green infrastructure into right-of-way projects. She has over 14 years of experience working in municipal government developing, implementing and leading complex interdivisional and multidisciplinary programs such as Green Streets, CafeTO and StreetARToronto.

Jen-Sion Tan - Green Dtreets project lead for the City of Toronto. Currently, he aids his team in investigating Asset Management frameworks for green assets while planning for future Green Streets projects. He is also involved in strategic planning and policy of the group.

Maili Sedore- Senior Project Manager, Cycling and Pedestrian Projects at City of Toronto, Transportation Services. She is a graduate from the University of Guelph in Landscape Architecture andgained extensive experience as a designer for multiple firms before entering into City of Toronto's Transportation Services team where she eventually became the project lead on the Beutiful Streets project on Danforth Avenue, Toronto.

Michael Hain - Is currently a Program Manager in Transportation Planning Policy and Analysis at City of Toronto. He has a deep background in the field of transportation planning as he completed his MSc in Planning at the Univeresity of Toronto (UofT) with a concentration in transportation planning. Prior to his careeer aCity of Toronto her was a Network Modeller/Analyst fro the Travel Modelling Group at Cities Centreat UofT.

Shayna Stott - Is the City of Toronto's Senior Policy Planner in Environmental Planning. She is knowledablein the field of clean air policy and completed her MSc in Planning at UofT with a concentration in environmental policy and planning.

Marianne Hatzopoulou- Marianne is a Canada research chair in transportation and air quality, as well as the head of the Transportation and Air Quality research group TRAQ. She specializes in modeling of road transport emissions and urban air quality as well as evaluating population exposure to air pollution. We contacted her for more information about the health effects on cyclists caused by extreme heat.

2. PROBLEM DEFINITION AND RELEVANCE TO THE GTHA

2.0 SUMMARY OF PREVIOUS RESEARCH

During 2040-2050, extreme heat conditions caused by recurring heat waves have been projected to increase in both intensity and duration due to climate change. In Toronto, it is projected that approximately 66 days per year, temperatures above 30°C will be experienced. There are numerous negative health impacts which can result from extreme hot weather such as heat stroke to cardiovascular-related morbidity and mortality.

Currently, organizations such as TransformTO are working towards a Net- Zero Strategy which aims to accomplish 75% of work and school trips below 5km to be performed through active means of transportation such as walking, cycling, using public transit and so forth by 2030.

2.1 EFFECT OF HEAT ON ACTIVE TRANSPORTATION UPTAKE

The weather variable of temperature has been identified as the primary influencer of cycling rates (Pojani & YunLee, 2019). The 2nd most detrimentrimal influencer to cycling rates is precipitation.

In a study, where a positive effect might have been expected on the relationship between cycling and air temperature, cycling behavior displayed the opposite effect. Previous studies showed that high air temperature has a negative impact on cycling only for heat with air temperatures above 25°Celcius. In particular, high air temperatures were less frequent compared with other studies, with a maximum air temperature of 33.4 °C.

Acclimatizing to Heat

According to a Singaporean- based study, the ideal cycling temperature range is stated to be 17°C - 33°C. However, in regions with continental climates, cycling occurs in much wider temperature ranges of -4 to 41. For those who are acclimatized to heat, the climate and weather variations are considered less of a barrier in comparison to the universal factors of safety and convenience.

Heat sensitivity is increased for those who are not regularly exposed to hot environments. Extreme heat events early in the summer generally result in higher mortality and morbidity than those later in the season. This "acclimatization" is due to physiological adaptation in both cardiovascular and sweating systems. Furthermore, the body's ability to acclimatize may be limited for some, such as those with heart disease, older adults and young children, who are also considered to be heat-vulnerable.

3. METHODOLOGY

To solve the ongoing challenges brought forth by climate change, such as the inevitable rise in regional temperatures within Toronto we propose to support active transportation behaviors. First, we conducted an analysis on datasets relating temperatures to cycling volumes to observe what impact very hot temperatures have on cycling volumes. Next, we conducted a research review to create a clear picture of the health risks cyclists are exposed to when they choose to cycle in very hot conditions. Concurrently, we drew on the experience of professionals in the fields of active transportation and public health to guide our research, to provide insight into the Toronto context, and to identify possible partnerships for applying our suggestions to the real world. The results of our research are a set of policy and infrastructure recommendations that will help keep cycling and other active modes of transportation as safe and feasible mode choices during periods of hotter weather in Toronto’s changing climate.

The research for this project began with the hypothesis that cycling volumes will decrease with an increase in extreme heat events (temperatures above 30℃). The team then gathered bike share Toronto ridership datasets from the City of Toronto website, as well as daily temperature reports from the Government of Canada website. Combining the two, information was extracted and stored in a file, such as the date, total number of bikeshare trips that day, the normalized number of bikeshare trips, whether or not the date is a holiday or “free-ride Wednesday”, daily average temperature, and the daily high temperature. A code sample which was used to create this file can be found in Appendix A. Next, a linear regression was constructed for the daily cycling volumes over the daily high temperatures each year from 2018 to 2021.

3.1 RESEARCH REVIEW

Extreme heat is very damaging to the body as numerous heat-related health problems. Body heat overload can be the most serious type of heat illness. The following heat illnesses can occur as a result of extreme heat:

- Heat stroke
- Heat exhaustion
- Heat fainting (parade syncope)
- Heat cramps
- Heat rash (miliaria rubra)
- Heat edema

In the most extreme circumstances, being unable to lower your body temperature could result in death. Additionally, rising temperatures can impact our health by producing more air pollution since High temperatures “bake” vehicle exhaust, turning it into harmful surface-level ozone and smog. A Less direct impact of Air pollution is irritation of eyes, nose, and throat, as well pre-existing heart and lung problems can worsen, and long-term health issues can also result.

Importantly, heat can affect mental health and community well-being. Increase of mercury is linked to cause Occurrences of mood disorders, anxiety disorders, dementia, and psychological distress. Additionally, interpersonal interactions can are impacted by Heat since as irritability and aggression can result from the discomfort. Domestic violence and violent crimes have also been shown to spike during heat events.

3.2 Equity Concerns

All though climate change impacts all Torontonians, however not everyone will be impacted equally. Climate change is amplifying the vulnerability of some people including those with low incomes, Indigenous Peoples, 2SLGBTQ communities, undocumented individuals, immigrants and refugees, women, seniors, children, people with disabilities, and racialized people. People in these groups often have less power and access to resources and infrastructure, and poverty and marginalization leave people vulnerable to rising energy, food, and housing costs (TransformTO).Populations with a lower socio-economic status face intersecting barriers and disadvantages. Lower-income Torontonians tend to live in poorer-quality housing which reduces quality of life, costs more to heat, and has reduced access to cooling such as air conditioning, recreational facilities, and shady greenspace. These neighbourhoods are more likely to have lower levels of transit accessibility and active transportation infrastructure (TransformTO). Certain groups of citizens, such as seniors, face greater vulnerability in extreme heat. Other high-risk groups include isolated adults, homelessness or under-housed individuals, people with chronic illnesses, infants and young children (TransformTO).

3.3 Meeting the city's goals / Policy goals

Toronto City Council adopted The Cycling Network Plan. It uses the existing network of cycling routes and builds upon it to Connect gaps in the current network, expand the network, and Renew parts of the network to improve safety – and other factors to a evaluating success.

3 components of the Cycling Network Plan:

1) a Long-Term Cycling Network Vision
2) the Major City-Wide Cycling Route
3) a three year rolling Near-Term Implementation Program

The current Near-Term Implementation Program for
2022 – 2024 proposes 100 centreline km of new bikeways, as well as upgrades to existing routes and studies for future implementation.

3.4 EXISTING POLICY TO TIE INTO CANOPYTO

The Economic Benefits

Toronto's Urban forest provides annual services to the ecosystem through energy savings of $8.3 million, its gross carbon sequestration accounts to $4 million, along with 437.9 million in removal of pollution. Additionally, increasing tree canopies can also help to avoid $4.8 billion in avoiding runoff which will not only aid the natural environment, but help to mitigate extreme temperatures through lessening anthropocene causes of climate change. In total, expanding Toronto's urban forest can potentially result in $55 million in annual benefits.

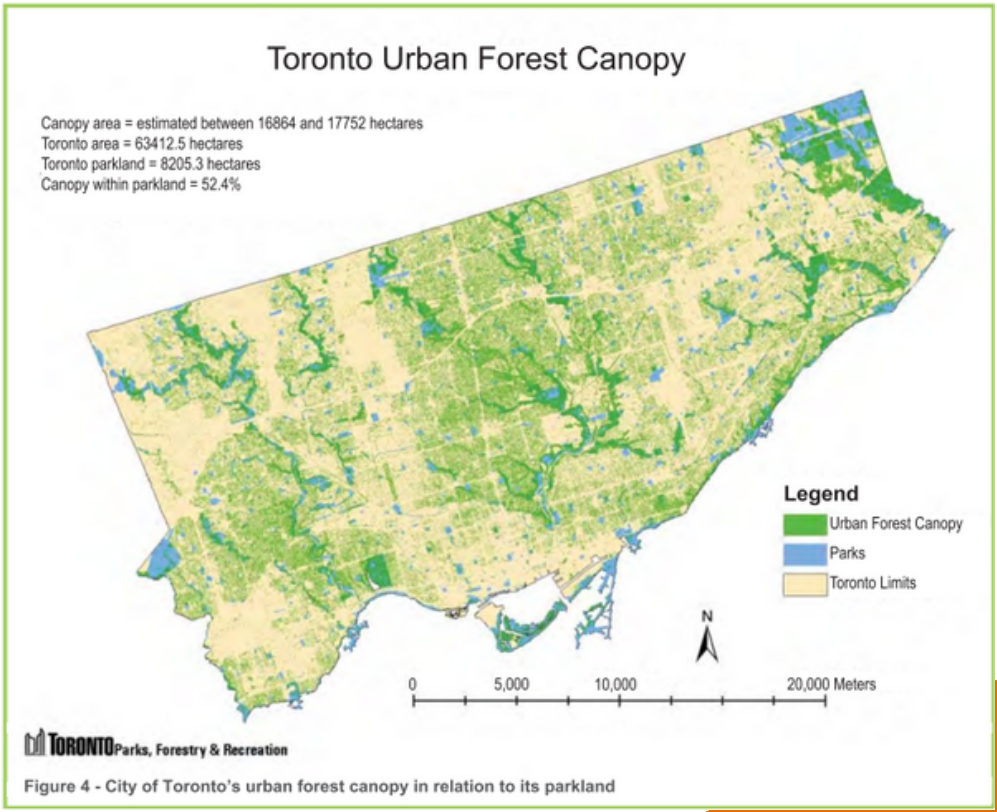


Figure 4 - City of Toronto's urban forest canopy in relation to its parkland

3.5 GREEN STREETS

Increasing urban greenspace increases active leisure, which can improve cardiovascular and mental health, as well as reduce obesity and increase social cohesion. Expanding the amount of canopy can remove air pollutants by the tree canopy while allowing residents to enjoy green space particularly in areas currently lacking an equitable share of greenspace (TransformTO).

3.6 RESILIENCY STRATEGY

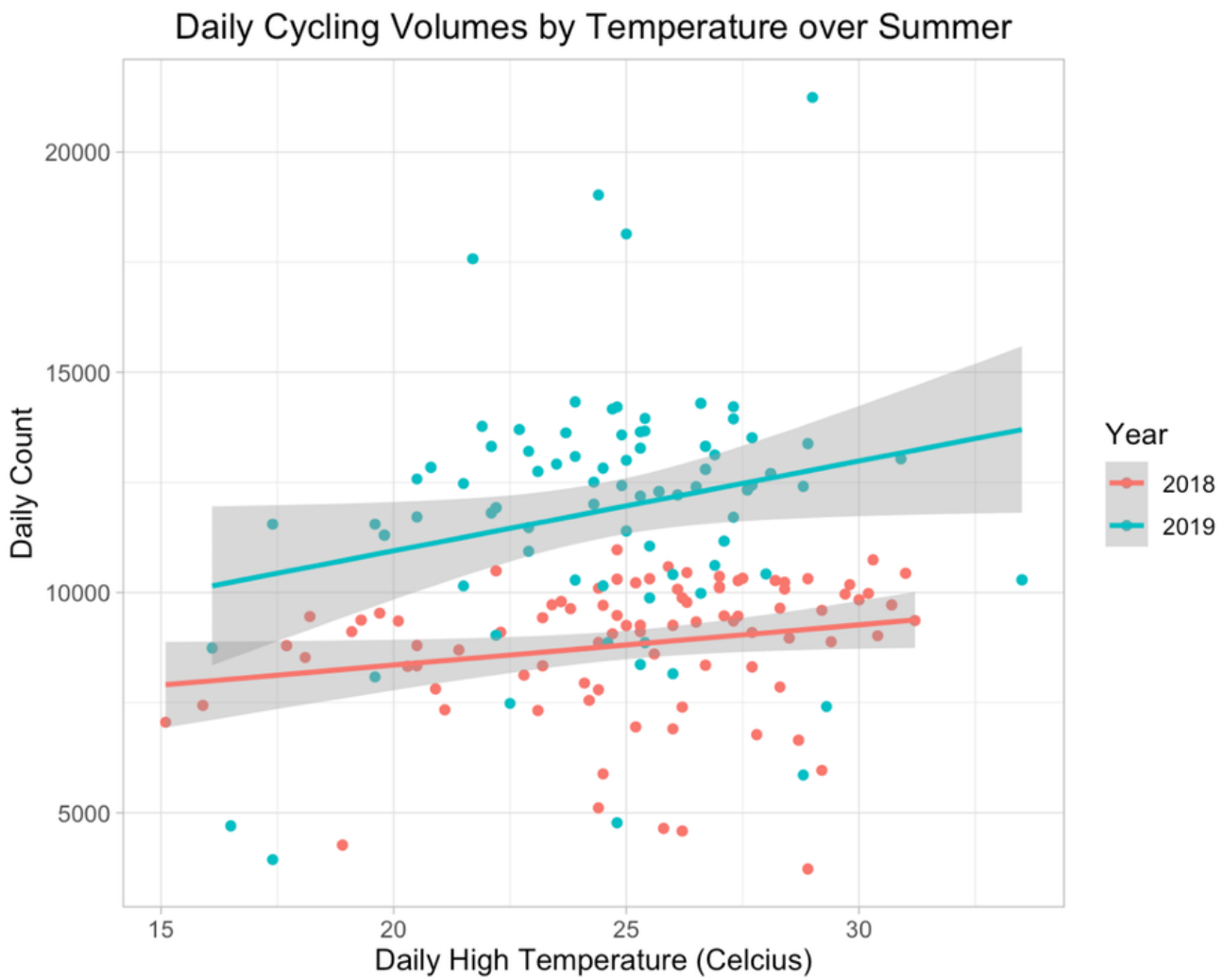
Toronto's Resilience Strategy sets out a vision, goals, and actions to help Toronto survive, adapt and thrive in the face of any challenge, particularly climate change and growing inequities.

Advancing equity is a core component of building resilience. The ability of a city to survive and thrive in the face of challenges is as much about the strength of its communities and neighborhoods as it is about the design and management of its infrastructure and buildings.

Making Toronto more resilient requires a focus on equity. We know that residents experience resilience differently based on which neighborhood they live in, and who they are, including in terms of their race, income, and gender.

4.0 ANALYSIS AND FINDINGS

The team conducted an analysis on the years from 2018 to 2021 in order to compare bikeshare patterns before and after COVID-19. Figure below shows a linear regression of the bikeshare volumes over an increasing temperature for the years 2018 and 2019. Contradicting the hypothesis, the cycling volumes appear to increase with an increase in temperature. One of the issues with the datasets was that in recent years, there have not been enough days where the temperature exceeded 30℃ to provide a useful analysis. A similar thing can be said for the regression shown in figure on page 17 which depicts the cycling volumes for the years 2020 and 2021. In this graph the points appear to be a lot more dispersed, however the average cycling volume is higher than in the years before COVID-19.



4.1 EXISTING POLICY AND PROCESS SHORTCOMINGS

Through the interview with employess from the City of Toronto, we learned that supporting policies are in place to implement green infrastructure (GI), however, no specific GI targets have been set. For example, aiming to capture 'x' amount of rainfall annually or reduce 'x' amount of pollution using GI.

There is an undergoing the Thermal Comfort Study where consultants are developing potential amendments to include in the official plan. In the Request for Proposal (RFP) documents, there is specific mention of the topic of cycling thermal comfort. It attempts to propose policies to guide built form and its connected impact on thermal com fort within the city.

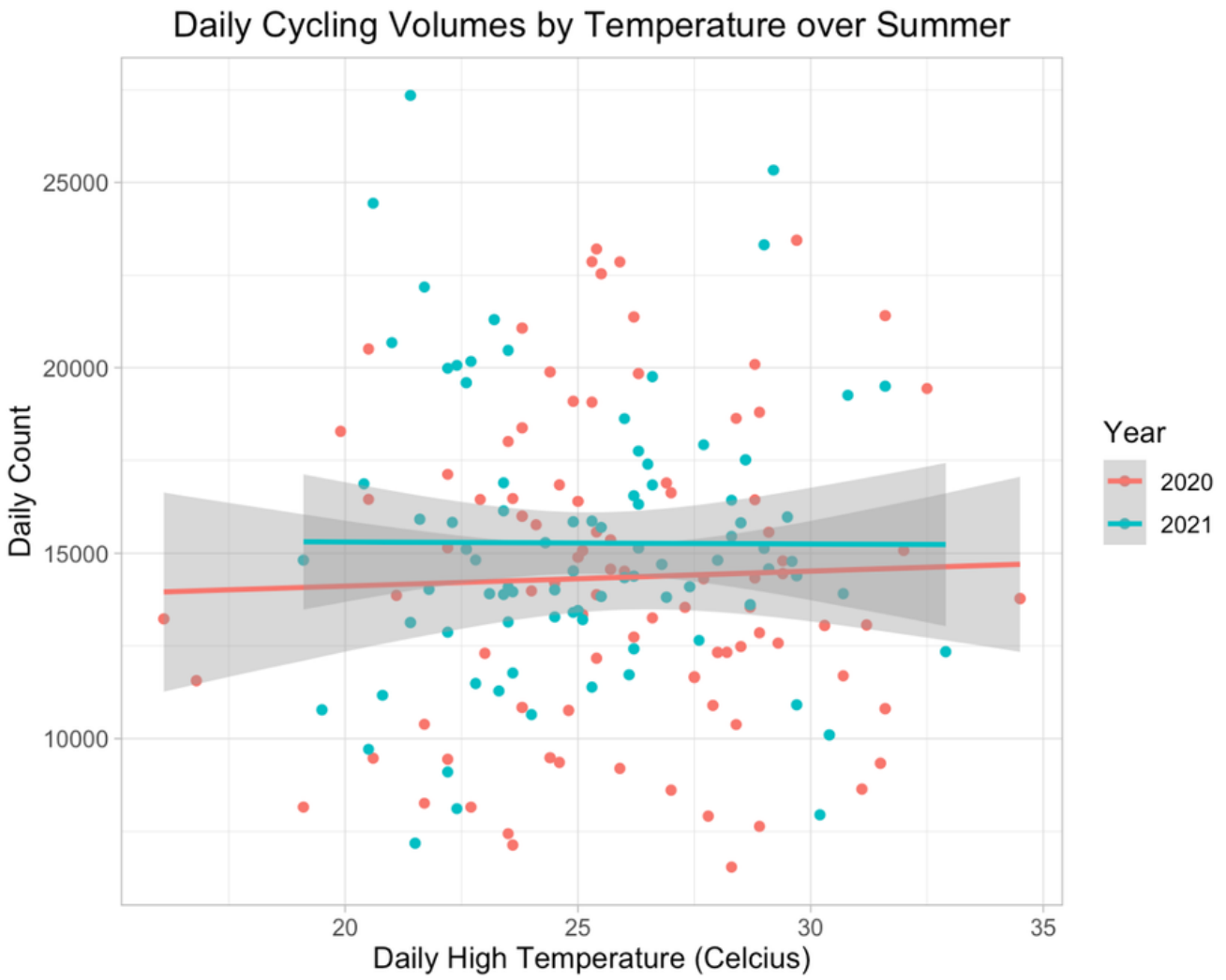
The City of Toronto is looking into including horticultural maintenance under transporation maintenance and recognizes that the transportation division can benefit from new staff with knowledge on factors such as cloud scaping and solar cells. Additionally, there is a pollinator grant which allows residents to plant varying non-grass species, such as trees in the right-of-way, which had the potential to provide shade to pedestrians and cyclists. Lastly, The city of Toronto is undergoing an exercise to ensure streets have adequate space accommodations for cycle lanes.

THE GAP

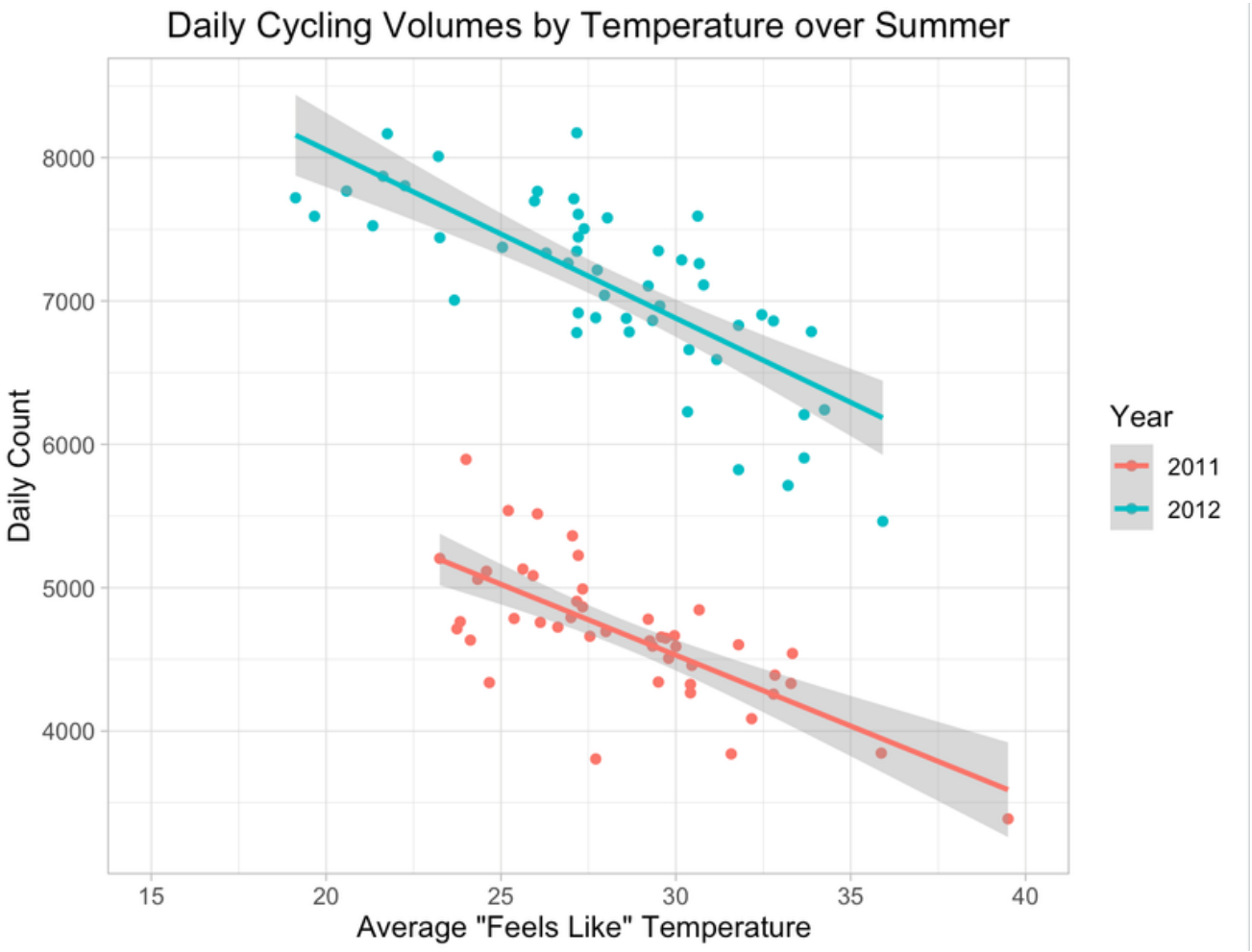
Municipal Horticultural Maintenance budget. When it comes to reconstruction. The opportunistic aspect of inputting Green Infrastructure (GI) is that it has not been a formal process for those that design and maintain the GI to consider a maintenance budget.

4.2 OUR PROPOSED POLICY/PROCESS SOLUTIONS

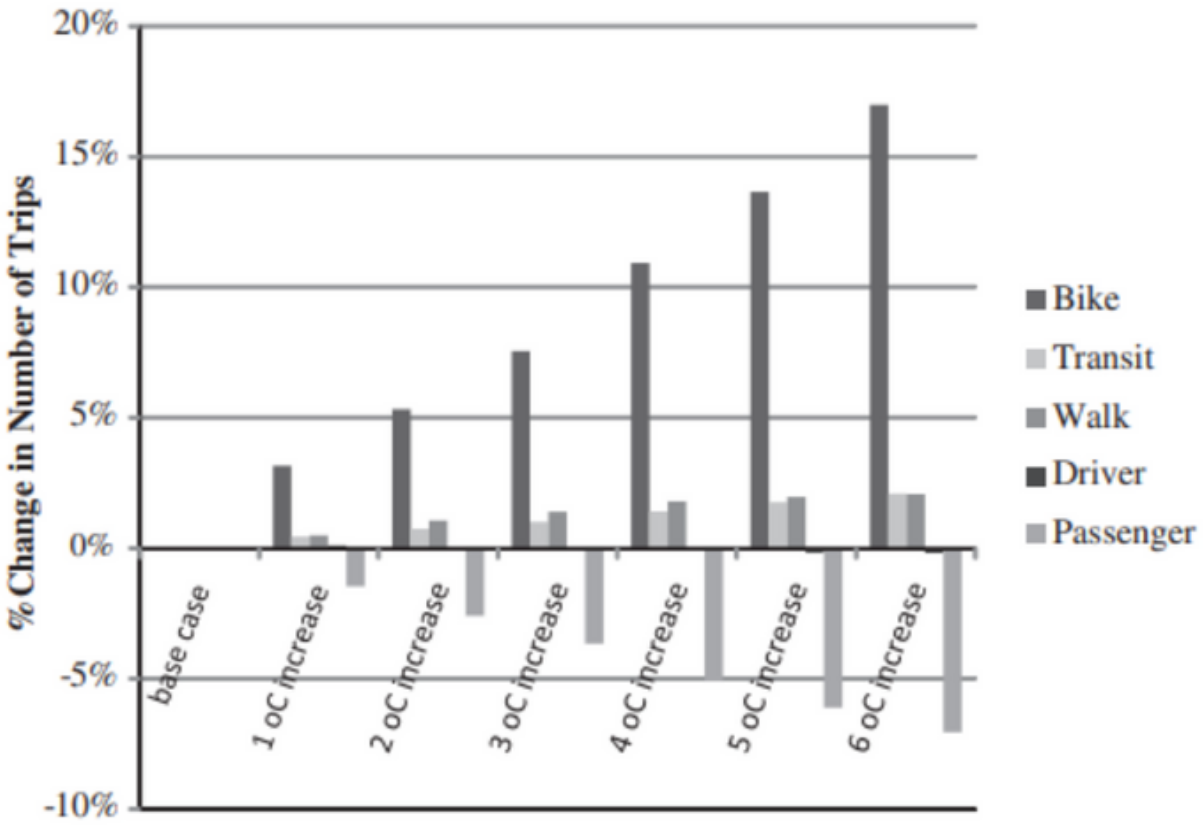
This is gap of considering a budget for maintenance provides a potential opportunity to improve the GI implementation process. Typically, the responsibility of tree maintenance falls within the field of horticulture, however, it can be a new service function of the transportation sector as well, whereas currently its responsibilities include only asphalt and sidewalk maintenance.



In order to compensate for the lack of useful data points in Toronto's database, a linear regression has been created for the daily cycling volumes for Washington DC, where the summer temperatures are much hotter than in Toronto. The figure above depicts the downwards trends in cycling volumes with an increase in temperature. As can be observed, the temperatures in Washington are much higher than in Toronto, providing a more accurate representation of cyclist behaviour during extreme heat events. As the temperature exceeds 30℃, the cycling volumes decrease further.



Supporting our analysis, another study has been conducted at the University of Toronto which looks at the impact of weather conditions on active transportation travel behavior. The figure above displays the combined effect of mode choice and trip rate as a result of temperature increase. It is evident that the bicycle mode is most positively affected by the temperature increase. The conclusions of this study were that the use of the bicycle is sensitive to conditions only below 15℃ which supports our analysis since the average cycling volumes remained relatively constant for temperatures between 15℃ to 30℃.



4.3 INFRASTRUCTURE SOLUTIONS

The city of Toronto is advised to execute each of the following remedies or infrastructure upgrades described in this section. Each approach will be described in detail, along with its benefits and drawbacks.

4.3.1 BIOPHILIC STREETS

Biophilic design attempts to achieve the benefits of contact between people and nature within the modern built environment by integrating nature, internally and externally, into buildings, built infrastructure and across the urban space. This first solution proposes planting trees near bike lanes, which are often located on busy roads.

Leafy canopies prevent sun rays from reaching our skin and the ground. This is especially important in cities, where asphalt, concrete buildings, the metal of cars and buses, and other man-made environments absorb more heat than natural surfaces. Vegetation is a simple and effective technique to reduce urban heat islands since trees and other plants help to cool the surroundings by providing shade and evapotranspiration. For instance, the peak temperatures of materials in shade may be 11–25 °C lower. Alone or in conjunction with shade, evapotranspiration can help lower extreme summer temperatures by 1 to 5°C (EPA, n.d.). Planting trees along the existing bike lanes in Toronto would reduce air temperatures for bikers to a tolerable level. Furthermore during the interview with Marianne Hatzopoulou, she mentioned that there is definitely evidence that climate change is going to exacerbate certain pollutants such as ozone. We are seeing a higher prevalence of the ozone base in Toronto compared to years ago due to extreme heat. Ozone is obtained from vehicle emissions, and is a summer pollutant. As the temperatures keep rising over the years, with more heat and sunlight more Ozone is observed in Toronto. It has more acute effects on people doing physical activity due to the fact that the breathing rate is higher, allowing more pollutants to go into a person's system. Therefore, people who have asthma or other cardiovascular issues are discouraged from exercising outside. Breathing ground-level ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ozone also can reduce lung function and inflame the lining of the lungs. Repeated exposure may permanently scar lung tissue. Because bike lanes are often located on busy roads, cyclists are more susceptible to inhaling ozone coming from the exhaust engine of vehicles. While roadside trees have a variety of benefits, it is useful to note that improper placement could cause damage to water lines and pipes underground. In addition, the trees take a while to grow, so this solution will not be effective right away. (IDNR, n.d). Aside from making cycling more comfortable for the general public in heat islands, trees also reduce any health risks associated with extreme heat.

4.3.2 COOLING STATIONS / AIR CONDITIONED BUS STOPS

A more expensive yet effective solution would be to upgrade the current bus stops to air conditioned bus stops. Such a solution already exists in Dubai, and one unit can hold up to 60 people at a time (Dennehy, 2021). In Toronto, the spacing between stops should be between 300m and 400m in most locations to balance access to transit with travel time for passengers, though this may vary based on context. Replacing every other bus stop with a cooled bus stop would still be very convenient for cyclists, since the average cycling speed is around 19 - 26 km / h (SustainabilityIfor, 2022). A cyclist will be able to reach a cooling station from anywhere in a matter of approximately 3 minutes. The cost for a single cooled bus stop is approximately $12,000 (Unknown, N.A.). There are 170 bus stops in Toronto, and replacing half of them would result in approximately $1,120,000 (TourbyTransit, n.d.). The bus stops are accessible to anyone.

4.3.3 WATER FOUNTAINS

Currently, there are a total of 700 water fountains in Toronto with potable water (Hart, n.d.). However, most of those fountains are located in public parks and are inaccessible for people biking to school or work. This third solution proposes to add water fountains next to the existing bus stops, which would give pedestrians a place to stop for water. Drinking water stations cost in the range of $4,000 to $7,500 and operating costs to open and test the water at a stand-alone water and repair the units due to vandalism or other malfunctions are approximately $700 per unit annually. This solution meets the accessibility needs of everyone, and would reduce the need for people to carry water bottles, some of which might be plastic. Bottled water has a huge plastic, energy and greenhouse gas footprint, in addition to waste produced (Kiger, P. J.,2022). The energy cost of bottled water is massive, and minimizing their use would be a small step towards a more sustainable planet.

4.3.4 ELECTRIC BIKES

The final proposed solution involves implementing electric bikes for people to use during extreme heat events. The low level of physical exertion will allow people to stay cooler during those periods of time, as well as get where they need to be quickly and efficiently. Electric bikes benefit the environment in the sense that they have an eco-friendly battery. The batteries are usually made of lithium-ion, which are eco-friendly as they don't contain acid. Furthermore, since they are rechargeable, there is no need to dispose of the batteries after usage. The batteries are charged using sustainable energy sources, making electric bikes zero emission vehicles [https://epiccycles.ca/huge-environmental-benefits-of-an-electric-bike/]. Furthermore, the beauty of e-bikes lies in the fact that they're more inclusive, allowing people of all ages and fitness levels to enjoy bicycling.

5.0 CONCLUSION

To conclude, the city's climate is on the rise with an increase in the number of very hot days in the next century. Through research and analysis conducted on existing datasets, cycling volumes are seen to decrease during cold temperatures (15℃ or lower), and very hot temperatures (30℃ or more). By opting for cars and other polluting modes of transportation, the cycle of emissions leading to climate change would continue. Even if people are not deterred from cycling in the heat, they would still be prone to a variety of health consequences that come with it. The goal of this study was to identify a series of policy and infrastructure changes which would make cycling in a changing climate more comfortable, appealing, and safe for Toronto's residents.

Through the Resiliency Strategy the City of Toronto aims to tackle inequities and the increased occurrence of extreme temperatures will have an even impact on the population as certain groups of Torontonians are more vulnerable to the negative impacts of climate change in comparison with others. Prioritizing green infrastructure such as increasing the tree canopy network can aid populations that reside in urban heat islands. The City also has strategies such as CanopyTO which proves to yield economic benefits. If we continue to enhance the existing policies and work towards enhancing green streets, it will aid in reducing inequity. Discussion with internal voices with the City of Toronto indicate there is awareness of the increased occurrence of extreme rise in temperatures. There are studies in process such as the Thermal Comfort Study through which potential amendments can be developed to shape city's official plans to consider the impact of extreme heat on the population. There are also monetary grants and budget adjustment considerations occurring to prepare for the impacts brought forth by the changing climate.

After conducting research, the team determined that solutions such as biophilic streets, cooling stations, water fountains, and electric bikes would be great ways to promote active transportation behaviours. These strategies could be implemented in conjunction or individually but nonetheless, each of them would be a step in the right direction towards reducing greenhouse gas emissions, and reducing climate change while keeping the public healthy and active.

APPENDIX A

```
def Bikeshares_2021_06(file1):
    '''
    file --> dict

    This function calculates the total number of bikeshare trips each day for the month of June in 2021.
    '''
    Date_06 = []
    trip_06_dict = {}
    all_dates = []
    free_rides_list = []

    with open(file1, 'r') as csv_file:
        csv_reader = csv.reader(csv_file, delimiter=',')
        line_count = 0
        for row in csv_reader:
            if line_count == 0:
                line_count += 1
            else:
                line_count += 1
                if row[4][0:2] == '06':
                    Date_06.append(row[4])
                    all_dates.append(row[4])

        Date_06_set = set(Date_06)
        for i in range (0, len(Date_06_set), 1):
            free_rides_list.append('no')
        Date_06_tuple = tuple(Date_06_set)
        all_date_set = set(all_dates)
        all_dates = list(all_date_set)

    for i in range (0, len(Date_06_tuple),1):
        trip_count = 0
        for j in range (i, len(Date_06),1):
            if Date_06[j] == Date_06_tuple[i]:
                trip_count += 1
        trip_06_dict[Date_06_tuple[i]] = trip_count

    return trip_06_dict, all_dates, free_rides_list

June_2021 = Bikeshares_2021_06("C:\\Users\\lisaa\\Downloads\\UTTAN Competition\\Datasets\\Bike share ridership 2021-06.csv")[0]
June_2021_dates = Bikeshares_2021_06("C:\\Users\\lisaa\\Downloads\\UTTAN Competition\\Datasets\\Bike share ridership 2021-06.csv")[1]
June_2021_free_rides = Bikeshares_2021_06("C:\\Users\\lisaa\\Downloads\\UTTAN Competition\\Datasets\\Bike share ridership 2021-06.csv")[2]
```

Code used to calculate the daily cycling volumes and identify all the free-ride Wednesdays

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