Integration of Climate in Asset Management Processes

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GLA 2029 - Sustainability, Team 10
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April 8, 2022

Word Count: 6,465 words

Section 1: Introduction to Municipal Asset Management and Climate Risk

The Environment & Energy Division (EED) leads, coordinates and is accountable for the City of Toronto's environment and energy sustainability outcomes. This division was directed by the Toronto City Council via the Climate Emergency Declaration to develop "a climate lens that evaluates and considers the climate impacts of all major City decisions, including financial decisions". Their policy/research team's goal is to facilitate the development and implementation of a corporate-wide Climate Lens program that helps equip city asset managers with the necessary training, information, tools and resources to create plans that address greenhouse gas (GHG) emissions and risks city assets will face due to the effects of climate change. Asset management (AM) planning as defined by the government of Ontario is "an ongoing and long-term process that allows municipalities to make the best possible investment decisions for their infrastructure needs. This includes building, operation, maintenance, renewal, replacement, and disposal."[1] Through this Climate Lens, the City hopes to spark an organisational culture shift to ensure climate considerations are present in capital projects and AM planning, to ensure their compliance with Toronto's GHG reduction goals and climate risk adaptation needs.

Keeping in mind that Toronto has over 12 different categories of LoS, the EED has requested our team focus on conducting jurisdictional scans and climate-related best practice reviews for water, waste, and transport-related assets.[2] Three case studies have been conducted per category, followed by a series of recommendations regarding takeaways that Toronto can apply in its own planning. These jurisdictional scans will be prefaced by an analysis of climate risks Toronto is likely to face within these three asset categories and a summary of Toronto's current AM strategies.

Our research questions are:

1. What governments or organisations are using or plan to use future climate projections to help shape their AM plans? Will these climate projections have specific climate parameters (e.g. freezing rain after snowfall) and scenarios tailored to the assets? If so, what are they?
2. What are good examples of climate-related levels of services (LoS) that take into account different types of climate hazards that are found in municipal or other (business, agencies, national, etc.) AM plans for water, waste and linear transportation infrastructure?

The case studies identified within the jurisdictional scans conducted for water AM include: Barrie, Ontario; Chicago, Illinois; and Auckland, New Zealand. The case studies identified

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[1] Ontario. 'Municipal Asset Management Planning'. ontario.ca. Accessed 25 March 2022. http://www.ontario.ca/page/municipal-asset-management-planning.

[2] Wastewater infrastructure (collection pipes, wastewater tanks, regulator sites, etc.) and stormwater collection (water courses, culverts, wetlands, etc.) are considered water-related assets. Waste management includes assets such as landfills, processing facilities, and waste collection. Transportation (roads, bridges, sidewalks, etc) and public transit (bus stops, bus shelters, transit fleet, track, etc) are considered transport-related assets.

within the jurisdictional scans conducted for waste AM include: Hong Kong (HK), China; Berlin, Germany and Prince Edward Island (PEI), Canada. The case studies identified within the jurisdictional scans conducted for transport AM include Sweden, Australia and Chicago, US.

For this report, LoS will be used synonymously with performance standards. It is defined as "what people experience from the municipality's infrastructure" as per the Ontario AM website.[3]

Additional case studies that the group have discovered during the research process have been listed in the appendix. While they may not have been directly relevant to the completion of this report, we believe this information could be useful and/or beneficial to city officials creating new AM plans within these specific divisions.

Section 2: Climate Risks

There is an extensive body of research demonstrating that climate change is an evidenced phenomenon which can be partly attributed to human activity[74]. These changes in climate have direct and indirect impacts and implications on the environment for different sectors in Toronto. There has been a 2.7 degree mean temperature increase in Toronto since the late 1800s- prompting the urban heat island effect which is expected to continue to escalate temperatures[4]. Moreover, there has been a gradual increase in precipitation intensity, where Toronto has seen heavier rainfall which pose the risk of flash flooding on streets or subway systems. Additionally, increased rainfall and risk of flooding has been problematic based on Northern Toronto's poor surface drainage design[4]. Rainfall is projected to increase between 0.5% to 14% in Southern Ontario[4]. Furthermore, it is projected there will be an increase in weather severity with events such as tornadoes, severe thunderstorms, and freezing rain. Overall, the result of altering climate trends is apt to adversely affect Toronto's infrastructure systems. These risks would result in the interruption of services, social activities, business and place limitations on available resources[4].

Section 3: Toronto's Asset Management Landscape

To inform our recommendations on our areas of focus, this section will provide the context of Toronto's current AM landscape, by identifying current LoS on water, waste and linear infrastructure. Reports, frameworks and approved AM plans published by the City of Toronto will be used to describe both the level to which city assets are currently being managed and the goals of city departments. Other contexts will be established, such as the legal framework in which AM plans are made in Ontario.

Municipal and Provincial Asset Management Policies

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[3] Ibid, 1

[4] Wieditz, I., Ligeti, E. and Penney, J., 2006. *A SCAN OF CLIMATE CHANGE IMPACTS ON TORONTO*: <https://acer-acre.ca/wp-content/uploads/2011/09/climate_change_impacts-in-toronto.pdf>

The task of managing municipal assets in Ontario is delegated to municipalities. Nonetheless, city governments must follow standards set by the province, namely Ontario's *Asset Management Planning for Municipal Infrastructure Regulation (2021)*. The goal of this bill is to standardise AM plans across Ontario and to align AM plans with provincial initiatives.

Ontario also regulates the contents of municipal AM plans, to ensure consistency, alignment with provincial initiatives, and to anticipate future needs. Ontario mandates that AM plans include: infrastructure asset inventory; levels of service; and a lifecycle management and financial strategy. This report will focus on levels of service, which are produced annually by most core departments within Toronto. Ontario has mandated several key deadlines for municipalities' creation of LoS recommendations, to expedite the AM streamlining process. By July 2022, all municipalities must have AM plans for core infrastructure (water, wastewater, storm water, roads, bridges and culverts). By July 2024, all infrastructure assets must be accounted for in AM plans, and by July 2025 all AM plans must include proposed LoS for each category of infrastructure assets[5].

This summary will observe the relevant and recently recommended LoS for Toronto's departments of Solid Waste Management Services; Toronto Water; and Transportation Services. Also included are other relevant documents that outline the long-term vision of each department, and their aspirations to meet the challenge of climate change, include the Core Infrastructure Asset Management Report (2021), and the Climate Resilience Framework (2019).

Current Service Levels for Water, Linear Transportation and Waste

Water

In 2021, the City's recommended LoS for Toronto Water was broken down into three categories: water treatment and supply; wastewater collection and treatment; and stormwater management. Service level descriptions consist of highly specified, operational tasks, such as 'Transmission Valve Chambers Inspected' and 'Electrical kWH per ML of Water Pumped'. Data has been collected on each service level since at least 2018. Each category uses an appropriate measurement to track its progress, e.g. percentages, megalitres, incident counts, etc.

While climate change is not explicitly mentioned in these service levels, many of them monitor crucial infrastructure and services that will be impacted by climate change. For example, water shortages are expected to hit the city as days with extreme heat rise[6], which will challenge the ability to ensure the 'Megalitres of reservoir storage capacity' service level. In other documents, Toronto Water has referenced the department's goals to adapt the City to new climate realities, yet these words have not translated into actions observable in LoS

[5] City of Toronto Core Infrastructure Asset Management Report, 2021
[6]Toronto Climate Resilience Framework, 2019

reports. Climate ambitions have not been integrated into LoS reports, which this department must do to accomplish its goals.

Waste

Just as Toronto Water did, Solid Waste Management Services divided its recommended LoS for 2021 into four categories: city beautification; residual management; solid waste management transfer and collection; and solid waste education and enforcement. These categories cover the enormous spread of tasks that this department is responsible for, and within them lies the LoS that are demanded. Service level descriptions include processing and transport of all types of waste (Green bins, residual waste, durable goods, hazardous, leaf and yard waste, recycling), park and litter bin collection, maintaining the Green lane landfill site, and hosting a multitude of events to promote public awareness of waste initiatives. Statistics of these service levels date to at least 2018, and measurements include percentage (in compliance of), frequency (once weekly), and total number per year.

Apart from the important public education section, these LoS largely appear to be a response to current demands for waste removal. Not a single LoS has changed its target in the last 4 years, despite the city growing in population and size (again barring the public education section). This is likely because many metrics used to evaluate these services are not indications of success, but merely completion. This is visible in the "in compliance with certificate of approval" metric, where this department has scored 100% in every activity every year since 2018. Toronto is not a particularly clean city; perhaps better evaluation or monitoring of this department could produce better results.

As part of its initiatives to curb environmental damage and adapt to climate change, Toronto's department of solid waste management aspires to divert 70% of new waste from landfills by 2026. To accomplish this, the department must implement more robust LoS, with corresponding data collection and enforcement, to better understand the sources and solutions to Toronto's waste.

Linear Transportation Infrastructure

Toronto's Transportation Services department is responsible for setting and achieving service standards for roads, bridges, pedestrian infrastructure, culverts and elevated expressways throughout the city. Service levels are divided in three sections: roads, encompassing pavement (including elevated expressways and off ramps); bridges, including cycling and pedestrian bridges; and culverts. Notably, rail is not included in the AM plan for transportation infrastructure. LoS are measured in terms of number of repairs (e.g. on potholes) and the percentage of assets that meet the requirements to be considered in good, fair or poor condition. These standards are set by the city, and reflect the asset's repair timeline. For example, a bridge that ranks in 'poor' condition will likely require repairs in the next 1-2 years[7]. Toronto sets annual asset condition targets, as a percentage of city assets in

[7] Core Infrastructure Asset Management Report, 2019

good condition. In 2021 and 2022, for example, Toronto aims to have 90% of its bridges in good condition[8]. To set these goals, service level targets and accomplishments from as far back as 2018 were considered. For several asset categories in transportation infrastructure, targets for 2021 and 2022 are identical to those from previous years, and many previous targets have not been attained.

Transportation Services uses these LoS to assess how and when an asset needs repair or replacement, to estimate the cost of repairs, and to communicate the lifecycle of the city's infrastructure. Despite climate change posing a direct threat to the city's transportation networks, there appears to be no direct consideration of adapting infrastructure to meet this challenge. The Toronto Climate Resilience Framework (2019) describes the elevated risk that Toronto faces due to the age and frequent use of our infrastructure, and identifies that climate change will make already backlogged infrastructure repairs even more urgent, necessary and expensive. The Department of Transportation Services should consider implementing stronger and more focused LoS that consider the new and heightened demands on transportation infrastructure caused by climate change.

Section 4: Jurisdictional Scans – Water Asset Management

This section will use the *Recommended 2021 Service Levels – Toronto Water* report to base the jurisdictional scans. The main features that encompass water AM, water treatment and supply, wastewater management, and stormwater management, are outlined.[9] These areas will structure the jurisdictional scans to explore how their governments utilise climate projections to guide their water-related AM strategies, and to influence water management LoS. This section will also identify strategies deployed in the jurisdictions that can inspire Toronto in its efforts to reach certain goals as outlined in the *Toronto Water* report, including: improving water pressure/connections, lowering electricity use in water pumping stations, minimising blockages in wastewater collection systems, and upgrading stormwater collection systems.[10]

Barrie, Ontario

Given their close proximity, Barrie and Toronto share similar climate concerns, mainly in increased temperatures, increased precipitation, and flooding.[11]

Barrie's main focus in water AM is to reduce electricity consumption and curb GHG emissions from its water operations, and lowering water demand per capita to accommodate for high population growth according to latest projections. The city's current Conservation and Demand Management Plan 2020-2024 (CDM) has identified water operations as a key opportunity for energy conservation, setting a target of 10% reduction in energy consumed per megalitre (ML) of processed drinking water, aiming to bring the 2018 consumption of

[8] Ibid., 7
[9] General Manager, Toronto Water, "Recommended 2021 Service Levels — Toronto Water," 2022. https://www.toronto.ca/legdocs/mmis/2020/ex/bgrd/backgroundfile-158992.pdf
[10] Ibid., 4.
[11] City of Barrie, "Water Asset Management Plan," 2021: 5. https://www.barrie.ca/City%20Hall/Asset-Management/plans/Documents/AMP-Water.pdf

1,212 ekWh/ML down to 1,097 ekWh/ML by 2024.[12] This reduction is estimated to yield energy savings of $143k/year. To aid this reduction, Barrie has committed to installing $1.4 million worth of solar panels in water treatment facilities by 2022, with this expected to reduce consumption of fuel- based electricity by 694MWh/year, leading to a projected reduction of GHG emissions of 136.1 tonnes of CO2/year.[13] To curb water demand and consumption, Barrie has used both asset and non-asset alternatives.[14]

Barrie shares Toronto's aspirations in upgrading stormwater systems. Climate projections for Barrie suggest that demand for stormwater infrastructure will increase due to higher frequency and severity of storms.[15] Barrie has evaluated in 2019 that "21%... of City stormwater assets are in poor or very poor condition and require short term financial investment."[16] Barrie's culverts, operating at 62% of expected service, and stormwater ponds, operating at 41% of expected service, require improvement.[17] Thus, Barrie has implemented AM strategies with objectives to develop a 5-year storm resiliency of the City's stormwater system and a 100-year storm resiliency of properties by: retrofitting and constructing stormwater ponds, investing in culvert/watercourse major drainage system improvements, and building low impact development assets.[18] This is important given that climate projections have stoked concerns that Barrie's stormwater infrastructure will be overwhelmed by heavy precipitation and constant flooding. Furthermore, Barrie has also committed to re-evaluating proposed LoS, and providing cost analyses and funding strategies by 2024 to adapt future LoS to climate projections.[19]

Chicago, Illinois

Chicago and Toronto share characteristics in geography, population, culture and economy. The cities also share climate risks, such as rising temperatures and drought, increased precipitation and flooding.[20]

Chicago is working to reduce water demand and consumption. Climate projections for Chicago show that climate change will have negative effects for surface water, causing

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[12] City of Barrie, "Water Asset Management Plan," 41.
[13] Ibid., 42.
[14] Examples strategies pertaining to non-assets include:
- Toilet Rebate Program: Residents who replace high-flow fixtures (>6L / flush) with low flow fixtures (6L / flush) receive a $50 rebate from the city (City of Barrie, "Water Asset Management Plan," 2021)
- Outdoor Water Use Restrictions: Barrie has implemented outdoor water use restrictions in times of peak water demand to avoid water delivery challenges for essential purposes, such as consumer drinking and fire-fighting uses (City of Barrie, "Water Asset Management Plan," 2021)

[15] City of Barrie, "Stormwater Asset Management Plan," 2021: 21. https://www.barrie.ca/City%20Hall/Asset-Management/plans/Documents/AMP-Stormwater.pdf?fbclid=IwAR37a9WHA0Hg1hukg6fXdtl9qxI2r3UR6GdhS2iS2Ew6-2g3aHhCywTgK_E
[16] Ibid., 12.
[17] Ibid., 19.
[18] Ibid., 28.
[19] Ibid., 48.
[20] Central Metropolitan Agency for Planning (CMAP) "Climate Resilience," 2016: 9-23. https://www.cmap.illinois.gov/documents/10180/517388/Climate+Resilience+Strategy+Paper.pdf/dd610883-d00f-407d-808b-484f9800a3f6?t=1501606245000

Chicago to rely more on a limited supply of groundwater. Increased droughts in the future will further exacerbate water demand, with estimates suggesting water demand from all sectors will increase by up to 12 percent in 10 years under a high-emissions scenario.[21] In Chicago's AM strategy *ON TO 2050*, the city identified water demand level goals that will be sustainable in the future environment as predicted by Chicago's climate projections, as well as accommodating the projected population growth the city will experience. The *ON TO 2050* goals for total daily water demand is 1129 million gallons of water in 2025, and 1150 million gallons in 2050; goals for daily water demand per capita is 72.7 gallons of water in 2025, and 65.2 gallons in 2050.[22] Strategies to achieve these ambitions include educational campaigns on water conservation, as well as increased water prices in off-peak hours. On the supply side, Chicago has aimed to implement water conservation measures to protect its water supply. The city has reformed its water management approach by introducing Integrated Water Resource Management (IWRM), also known as One Water, which seeks to integrate planning and management of water supply, wastewater, and stormwater in a way that: "considers the water cycle as a single integrated system in which all water flows are recognized as potential resources and minimizes or avoids impact on the environment."[23]

Increased precipitation and flooding is a major concern for Chicago's wastewater and stormwater management. Stormwater and sewer infrastructure in the city was not built to accommodate precipitation events as heavy as those depicted in climate projections, with current standards that most communities use to design stormwater and sewer systems being outdated and underestimate the occurrence of extreme rainfall that can overwhelm stormwater systems and cause flooding in homes, businesses, and roads.[24] Thus, *ON TO 2050* has advocated increased investment in better infrastructure and technology to efficiently remove biosolids from waste streams and prevent blockages in wastewater systems, as well as capturing excess heat and natural gas as a source of energy. Furthermore, Chicago is encouraging the use of rainwater and grey water in industrial operations and large scale residential developments, as rainwater is freely available and this strategy would also help to address stormwater management challenges.[25] Presently rainwater can not be used and must be treated first, posing a strain on wastewater treatment facilities as they have to treat both sewage and stormwater.[26] With increased precipitation in the future, stormwater entering wastewater systems will pose a greater challenge. As a result, Chicago has allocated $50

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[21] Central Metropolitan Agency for Planning (CMAP) "Climate Resilience," 26.
[22] Central Metropolitan Agency for Planning (CMAP) "ON TO 2050 Indicators Appendix," 2018: 22-23. https://www.cmap.illinois.gov/documents/10180/905585/FINAL+Indicators+Appendix.pdf/ae234d88-74c0-7a94-f70d-ea350c999810
[23] Central Metropolitan Agency for Planning (CMAP) "Water Resources Strategy Paper," 2017: 45. https://www.cmap.illinois.gov/documents/10180/71423/Water+Strategy+Paper_FINAL_+9-21-17.pdf/9e656004-e3c2-cbf7-de2e-3bb799a016ea?t=1510275872812
[24] Central Metropolitan Agency for Planning (CMAP) "Climate Resilience," 26.
[25] Central Metropolitan Agency for Planning (CMAP) "Water Resources Strategy Paper," 65.
[26] Central Metropolitan Agency for Planning (CMAP) "Stormwater and Flooding Strategy Paper," 2017: 12. https://www.cmap.illinois.gov/documents/10180/653821/FY18-0051+STORMWATER+AND+FLOODING_FINAL.pdf/42e7f8b1-c9ed-b7b5-0eeb-a03f4a51dee7?t=1515109215970

million over the next 5 years to build new stormwater collection sites and green stormwater infrastructure, such as permeable streets and bioswales.[27]

Auckland, New Zealand

Like Chicago, Auckland is trying to reduce water demand and consumption in reaction to both climate and population projections. Auckland faces rising temperatures, droughts, more extreme rainfall, and flooding from rising sea levels[28]. The city has an ambitious goal to reduce water usage by 20% by 2051, and is developing ways to recycle water in industrial processes where water does not need to be of drinkable quality.[29] Like Chicago, Auckland has been using education initiatives and financial incentives to decrease water consumption. The city has implemented standards to monitor the efficacy of its initiatives to decrease water consumption. One example would be Auckland's target to reduce domestic consumption from 516 litres per connection per day in 2019 to 481 litres per connection per day 2025, and to hold non-revenue water levels at or below 186 litres per connection per day.[30] On the supply side, Auckland's measures to protect water supply include: installing more district metres, increasing leak detection, having more rapid response teams to fix leakages, and reducing water pressure. The city plans to decrease water supply pressure to 200 kPa, as studies conducted in New Zealand in 2020 indicated that a minor reduction in pressure resulted in 1 to 2 million litres of water saved per day, and an average of 5% fewer reported leakages were observed.[31] The city also plans to replace 2 ageing water treatment plants with new 140 megalitres per day capacity plants to help meet peak demand and improve the system resilience.[32]

In terms of wastewater and stormwater management, Auckland has dedicated generous funding to upgrade and expand infrastructure and improve service levels. The city has declared intentions to invest $5.64 billion (NZD)[33] in thermal hydrolysis wastewater plants to reduce emissions, new treatment processes to mitigate waste blockages, and stormwater interceptors to prevent stormwater entry into wastewater systems.[34] Like Chicago, Auckland's water AM strategies are heavily integrated with considerations of water supply, wastewater

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[27] City of Chicago, "Green Stormwater Infrastructure Strategy," 2014: 32-36. https://www.chicago.gov/content/dam/city/progs/env/ChicagoGreenStormwaterInfrastructureStrategy.pdf

[28] Watercare, "Auckland Water Efficiency Plan 2021 to 2025," 2021: 19. https://assets-au-01.kc-usercontent.com/e86000d0-1334-02a5-836a-a502aff2554f/b51bcff4-bba0-4584-aa07-8ae6ee6212a5/Watercare-Water-efficiency-Plan-2021-2025.pdf

[29] Watercare, "Asset Management Plan 2021-2024," 2021: 52. https://wslpwstoreprd.blob.core.windows.net/kentico-media-libraries-prod/watercarepublicweb/media/watercare-media-library/reports-and-publications/watercare_asset_management_plan_2021-2041.pdf

[30] Watercare, "Auckland Water Efficiency Plan 2021 to 2025," 22.

[31] Ibid., 28.

[32] Watercare, "Asset Management Plan 2021-2024," 11.

[33] Watercare, "Asset Management Plan 2021-2024," 12-17.

[34] Furthermore, $1.3 billion (NZD) will be allocated to the Western Isthmus Water Quality Improvement Programme to use the works of the Central Interceptor Wastewater Tunnel to implement a combination of wastewater and stormwater options in each catchment to reduce the volume and frequency of overflows from the combined stormwater and wastewater networks, and remove as much stormwater from the wastewater network as possible. This is critical since in heavy rain, the stormwater that drains from the average roof is equivalent to the wastewater flows from more than 40 households. (Watercare, "Asset Management Plan 2021-2024," 25)

and stormwater, providing a comprehensive action plan to address climate-induced water challenges.

Section 5: Jurisdictional Scans – Waste Asset Management

Overview

This section will comparatively examine waste AM plans across three different jurisdictions to shed light on how current climate projections and climate risk analyses are used to shape transformation planning and performance standards for relevant LoS delivered. Bearing in mind Toronto's Long Term Waste Management Strategy (approved by City Council in 2016) and the TransformTO Net Zero Strategy (adopted by City Council in 2021), this section's analysis will be informed by our City's strategic focus on moving towards a circular economy and expanding waste diversion measures.[35]

Hong Kong (HK), China

The EPD's "Waste Blueprint for HK 2035" seeks to address growing concerns pertaining to sustainability and climate risks by setting out a blueprint through which HK will overhaul its waste AM processes up to 2035.[36] In this blueprint, the government committed to working with community and industry stakeholders towards "reducing HK's per capita MSW disposal rate by 40-45%" and to "raise the recovery rate to about 55% by implementing Municipal Solid Waste Charging."[37] The government further committed to moving away from its "reliance on landfills for direct waste disposal by developing adequate waste-to-energy facilities."[38] The EPD identified six policy areas of focus, namely waste reduction, waste separation, resources circulation, industry support, innovation and cooperation, and education and publicity.[39]

To begin with, the EPD identified expanding waste diversion measures to be a key priority for HK.[40] As a developed city with high population density and significant waste generation, HK can no longer rely on landfills as a major avenue of waste disposal. In cities like HK, and to some extent Toronto as well, the amount and breadth of waste generated far outstrips the cities' existing landfill capacity. Bearing in mind HK's limited land resources, as well as

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[35] "Waste Strategy Overview," *Long Term Waste Management Strategy*, City of Toronto, 2016-2022, https://www.toronto.ca/services-payments/recycling-organics-garbage/long-term-waste-strategy/overview/. ; "TransformTO," *Climate, Energy & Resilience*, City of Toronto, 2021-2022, https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/.

[36] For the purposes of this case study, the "Waste Blueprint for HK 2035" and the actions therein set out several key measures for the city to implement going forward in response to its growing waste loads and underdeveloped recycling infrastructure.

[37] Ibid.

[38] Ibid.

[39] Ibid.

[40] "Waste Blueprint for Hong Kong 2035," *Waste*, Environmental Protection Department, 10 October 2021, https://www.epd.gov.hk/epd/english/environmentinhk/waste/waste_maincontent.html. ; "Data & Statistics," *Waste*, Environmental Protection Department, 23 November 2021, https://www.epd.gov.hk/epd/english/environmentinhk/waste/data/waste_data.html.

nimbyism and other barriers to landfill expansion, the EPD has declared landfill space to be one of HK's "most precious assets" that can only be "prudently used as a last resort."[41] In lieu of landfill use and expansion, the EPD has publicly affirmed its ongoing commitment to HK's "sustainable waste reduction" approach to waste AM, first introduced in 2013.[42] This approach calls for not simply the implementation of multi-faceted waste reduction measures, including recycling, but also emphasises minimising community and industry-based waste generation as well as government-community collaboration in the execution of waste reduction measures across the city.

Bearing in mind the contextual information and the recent "Waste Blueprint for HK 2035," as presented above, the three major innovations called for by the EPD in regard to HK's waste AM plans going forward are subsequently presented. Firstly, the EPD has generated plans to develop a new LoS– a system of "Integrated Waste Management Facilities" (IWMF) – through which the city will leverage advanced incineration technologies to simultaneously reduce waste volume and recover energy.[43] The EPD anticipates that the introduction of IWMFs will divert a significant volume of waste away from landfills, thereby greatly extending the usability of existing landfills in the city.[44] Modelled in part on Germany's well-developed incineration infrastructure, the IWMFs will employ a multitude of "state-of-the-art technologies and pollution control measures" to minimise its environmental impact, bearing in mind the city's present climate concerns.[45]

Secondly, the EPD has generated plans to begin trialling the development of an Organic Resources Recovery Centre (ORRC), a new LoS through which the city will leverage advanced biological technologies, namely composting and anaerobic digestion, in various stabilisation processes to turn source-separated organic waste into broadly usable compost products and biogas for the purposes of energy recovery.[46] The EPD anticipates that the operations of the ORRC will allow the city to effectively recycle a wide range of organic-based waste, thereby diverting a significant volume of waste away from landfills and therefore extending the usability of existing landfills in the city.[47]

Thirdly, the EPD has, in collaboration with other relevant government departments, including HK's Food and Environmental Hygiene Department, generated a multifaceted set of plans to leverage existing and planned LoS to expand the city's waste reduction and recycling infrastructure through strengthening government-community collaboration and public buy-in

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[41]Ibid.
[42]Ibid.
[43]"Integrated Waste Management Facilities," *Problems & Solutions*, Environmental Protection Department, 16 November 2021, https://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/WFdev_IWMF.html.
[44]Ibid.
[45]Ibid.
[46]"Organic Resources Recovery Centre (ORRC)," *Problems & Solutions*, Environmental Protection Department, 16 January 2020, https://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/WFdev_OWTF.html.
[47]Ibid.

to waste AM measures.[48] The EPD strongly emphasised the importance of stakeholder consultation and collaboration, especially amongst the citizenry, in achieving the city's waste AM objectives.[49] The EPD affirmed its ongoing commitment to HK's multiple "source separation of waste" initiatives, first introduced in 2005.[50] Comparable to similar initiatives in Germany, "source separation" represents both a practical and a normative shift in which citizens are responsible for local waste organisation and separation, thereby decreasing the government's burden.

Berlin, Germany

For the purposes of this case study, a number of key parallels between Toronto, HK, and Berlin are identified in regard to the underlying rationale and execution of present-day and future waste AM plans. To begin with, Berlin acknowledges the volume and breadth of waste it generates as a highly populated developed city, with major waste categories including a range of organic, industrial, and commercial waste products generated by both private and public sector sources.[51] As set out in its "Berlin Energy and Climate Protection Programme 2030," the Senate of Berlin has enacted a series of legislative commitments with the objective of ensuring that Berlin is climate-neutral by 2050. As a part of the city's "integrated approach to climate protection" and "climate change mitigation," Berlin has identified several key "focal points" on which the government's attention and resources ought to be focused, one of which is "waste management."[52] The Senate of Berlin and other organisations from both within and outside the city have highlighted the work of Berlin Waste Management (BSR) in contributing to Germany's renowned "model waste separation strategy," which was pioneered in Berlin itself.[53] Berlin's ongoing emphasis on moving towards a circular economy is a focus shared by both Toronto and HK.

In addition, organisations from both within and outside Berlin have identified and affirmed the importance of the city's ongoing commitment to leveraging advanced technologies to accelerate and expand the city's waste diversion and waste reduction efforts.[54] At the federal

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[48]"Waste Diversion Plan: Multi-pronged approach on waste transfer, More efficient, more hygienic," *Problems & Solutions*, Environmental Protection Department, 2015-2022, https://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/waste-diversion-plan.html.

[49]Ibid.

[50]"Waste Blueprint for Hong Kong 2035," *Waste*, Environmental Protection Department, 10 October 2021, https://www.epd.gov.hk/epd/english/environmentinhk/waste/waste_maincontent.html.

[51]"Case Study Summary – Berlin," *Collectors Project*, European Union Horizon 2020 Research and innovation programme, 2020, https://www.collectors2020.eu/wp-content/uploads/2020/08/Case_Integration_Summary_Berlin.pdf.

[52]"BEK 2030: Berlin Energy and Climate Protection Programme 2030," Senate Department for the Environment, Transport, and Climate Protection, Berlin, 2019, https://www.berlin.de/sen/uvk/en/climate-action/publications/.

[53]"Case Study Summary – Berlin," *Collectors Project*, European Union Horizon 2020 Research and innovation programme, 2020, https://www.collectors2020.eu/wp-content/uploads/2020/08/Case_Integration_Summary_Berlin.pdf. ; "BSR information in English," *Berlin Waste Management*, Berliner Stadtreinigungsbetriebe, 2022, https://www.bsr.de/die-berliner-stadtreinigung-in-englischer-sprache-26142.php.

[54]"Case Study Summary – Berlin," *Collectors Project*, European Union Horizon 2020 Research and innovation programme, 2020, https://www.collectors2020.eu/wp-content/uploads/2020/08/Case_Integration_Summary_Berlin.pdf.

level, Germany's Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection affirms the strict criteria governing landfill use.[55] Echoing the findings and rationale articulated by HK's EPD, the German government further affirms the utility of its waste incineration infrastructure as a means to simultaneously reduce waste volume and reduce the pressure on landfills, while also recovering energy.[56]

Furthermore, Berlin has identified government-community collaboration and stakeholder alignment as key areas of focus for the government, which also echoes in HK the observations and consequent waste management plans generated by the EPD and other relevant departments. In the city itself, Berlin Waste Management (BSR) works at the nexus of government-community collaboration.[57] In summary, the BSR manages all the waste produced by Berlin's two million municipal households and directs local levels of service pertaining to the city's pioneering "model waste separation strategy," which is analogous to HK's "source separation of waste" initiatives. In addition to a colour-coded five-bin system, BSR also manages specialised "bulky waste" treatment processes as well as the agency's own free exchange and gift market.[58] The European Union Horizon 2020 Research and innovation programme highlighted Berlin as an example of successful "citizen participation and social acceptance" to the city's innovations pertaining to its waste AM practises.[59]

Prince Edward Island, Canada

For the purposes of this case study, a number of key parallels between Toronto, HK, Berlin, and PEI are identified in regard to the underlying rationale and the execution of present-day and future waste AM plans. To begin with, the island has identified waste AM as one of five "primary areas of focus" in its continued drive to "[reduce GHG] emissions" in order to address ongoing climate concerns.[60] In regard to waste AM, PEI has highlighted municipal solid waste, compost, and wastewater as significant areas of concern, including especially the fact that these waste categories can generate significant amounts of GHGs.[61] The province has affirmed its ongoing commitment to prioritise the maximisation of waste diversion away from landfills, bearing in mind the unsustainable and harmful nature of landfill-based waste disposal.[62] The government, in explaining its rationale, highlighted the links between

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[55]"Waste Management in Germany 2018: Facts, data, diagrams," *Federal Ministry for the Environment, Nature Conservation and Nuclear Safety*, Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, March 2018, https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/abfallwirtschaft_2018_en_bf.pdf.
[56]Ibid.
[57]"BSR information in English," *Berlin Waste Management*, Berliner Stadtreinigungsbetriebe, 2022, https://www.bsr.de/die-berliner-stadtreinigung-in-englischer-sprache-26142.php.
[58]Ibid.
[59]"Case Study Summary – Berlin," *Collectors Project*, European Union Horizon 2020 Research and innovation programme, 2020, https://www.collectors2020.eu/wp-content/uploads/2020/08/Case_Integration_Summary_Berlin.pdf.
[60]Ibid.
[61]Ibid.
[62]Ibid. ; "12 things you always wanted to know about P.E.I.'s only landfill, but were afraid to ask," *CBC News*, CBC/Radio-Canada, 10 October 2021, https://www.cbc.ca/news/canada/prince-edward-island/pei-landfill-east-prince-waste-heather-myers-1.6204626.

maximising waste diversion and enacting an active response to ongoing climate concerns, noting that landfills are a significant source of certain GHGs.[63] The PEI government's continued emphasis on expanding the island's LoS pertaining to waste diversion echoes the similar focus of governments in HK and Berlin, and indeed here in Toronto as well.

In addition, the PEI government has affirmed its continued commitment to its ongoing move towards a circular economy, which is a shared focus amongst the other jurisdictions examined in this section as well.[64] Statistics Canada conducted a waste-management survey in 2014, through which it found that PEI diverts more waste away from landfills per capita than any other jurisdiction in Canada.[65] Specifically, PEI residents divert about 429 kilograms of various categories of waste to the island's well-developed recycling and organic processing system.[66] The government highlighted a number of areas to receive continued attention and focused investment, including especially the promotion of government-community collaboration.[67] The island's emphasis on stakeholder consultation and collaboration mirrors similar attitudes in HK and Berlin. Of special note is the province's "Waste Watch source-separation program," first introduced in 2002, through which the responsibility of waste organisation and separation was shared between islanders and the government.[68] By incorporating the citizenry into the policy delivery network, the island has since then diverted around 50% of its waste away from landfills, further highlighting the importance of community and stakeholder buy-in to waste management-related LoS.[69]

Section 6: Jurisdictional Scans - Transportation Asset Management

Chicago, Illinois

Chicago established a strategy paper with a climate change resilience framework regarding transportation infrastructure[70]. The goal of this paper was to inform how ON TO 2050 goals can be implemented and how to evaluate land use and influence the planning, natural resource management and infrastructure planning of the city[70]. This paper addresses matters such as flooding and extreme heat and how the city can implement measures of adaptation and mitigation relating to current climate trends and climate projections.

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[63] Ibid.
[64] "Taking Action: A Climate Change Action Plan for Prince Edward Island 2018-2023," *Climate Change*, Government of Prince Edward Island, 2018, https://p1cdn4static.civiclive.com/UserFiles/Servers/Server_10500298/File/Environment%20and%20Sustainability/Sustainability/Climate%20Change/climatechangeactionplanPEI.pdf.
[65] "Island leads Canada in recycling and composting," *News*, Government of Prince Edward Island, 25 April 2017, https://www.princeedwardisland.ca/en/news/island-leads-canada-recycling-and-composting.
[66] Ibid.
[67] Ibid. ; "Taking Action: A Climate Change Action Plan for Prince Edward Island 2018-2023," *Climate Change*, Government of Prince Edward Island, 2018, https://p1cdn4static.civiclive.com/UserFiles/Servers/Server_10500298/File/Environment%20and%20Sustainability/Sustainability/Climate%20Change/climatechangeactionplanPEI.pdf.
[68] Ibid.
[69] Ibid.
[70] Cmap.illinois.gov. 2021. <https://www.cmap.illinois.gov/documents/10180/517388/Climate+Resilience+Strategy+Paper.pdf/dd610883-d00f-407d-808b-484f9800a3f6?t=1501606245000> [Accessed 8 April 2022].

Adaptation and Mitigation

1. An innovative approach to mitigating the effects of climate change included the recommendation of urban forestry and site-scale green infrastructure development. These can be integrated into site design and street layouts, in positions such as parkways or a rights-of-way sections[71]. Overall, the implementation of green infrastructure has the capacity to manage flood control by reducing the impacts of increased water tables and pressure. Moreover, the introduction of tree canopies can ameliorate the urban heat island effect as well as counteract the environmental impacts of development. Further, the sequestration of carbon can be achieved through the increased vegetation within the city[70].
2. The city's GHG emissions inventory reflected that the transportation sector accounted for almost 25% of all the region's GHG emissions, and so the city of Illinois developed regional targets and key performance indicators which could be used as a benchmark to guide the process of emissions reduction for the GP TO 2040 goals[72]. These KPI's include conservation of open space, transit capacity, access and greenway mileage. To achieve this, the city's goals are firstly to promote and elevate the experience of transportation alternatives such as walking, cycling and accessible and reliable transit[72]. Additionally, ensuring diverse resilient transportation systems can disincentivize the percentage of individuals who require personal car ownership - effectively reducing the contributions of GHG emissions. This endeavour would require reconceptualizing transit routes, schedules, networks and overall transit management and coordination[72].

Sweden

As has been seen all over the world, changing weather conditions and climate has posed a challenge for different facets of industry services, including transportation infrastructure[71]. As a result, many governments are faced with the need to adapt to changing conditions in order to maintain the integrity, viability and durability of transport infrastructure[71]. This case also stood true for the case of Sweden as the Swedish railway transport system was challenged to pay attention to the vulnerability caused by climate change and leverage the adaptive capacity of their systems. The railway system had to consider long time horizon planning and the adjustments required for the increasing demand for rail traffic; these decisions would influence next steps being taken regarding the planning, design and overall management of railways[71]. This case study was conducted through interviews with Swedish Rail Administration staff and the objective of this case study was to explore the documented vulnerabilities that have arisen from climate change, then also discuss how to improve methods of assessment and adaptation[71]. The major barriers being faced in regards to climate changes within the railway system were the following:

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[71] Lindgren, J., Jonsson, D. and Carlsson-Kanyama, A., 2009. *View of Climate Adaptation of Railways: Lessons from Sweden*. [online] Journals.open.tudelft.nl. Available at: <https://journals.open.tudelft.nl/ejtir/article/view/3295/3462> [Accessed 8 April 2022].

[72] Cmap.illinois.gov. 2021. Cmap.illinois.gov. 2021: <https://www.cmap.illinois.gov/documents/10180/798751/Transportation+Tech+Strategy+Paper_FINAL_11.13.17.pdf/e2e04dc7-25cb-b4c7-3ab1-ba2969ee2d25?t=1512715640882> [Accessed 8 April

1. Complications or maintenance with the track switches, train set doors and train engines
2. Limitations leading to delays- inefficient and unreliable systems
3. Breakdowns and severe accidents[71]

Adaptation and Mitigation

This paper explored two methodologies to overcome the challenges of climate change: adaptation and mitigation. In this context, adaptation entailed the exploration of initiatives and measures which help reduce climate related vulnerability, and mitigation related to the precautionary and preventive measure which can be taken to overcome barriers[71]. Overall, the adaptations which were adopted were the implementation of insulation, shading boards and ground cooling systems to better maintain and protect the embankments for future purposes[71]. This would address the matter of extreme heat to ensure the material used to develop the railways does not expand and harm the integrity of the embankment. This would help overcome matters such as rail buckling and failures in the drainage systems for outdoor railways such as the TTC/Streetcars in Toronto. Moreover, the adaptation of tree-free zones in high priority regions of the network, where in Sweden over 4000 km of the railway routes have been protected from the possibility of trees falling[71]. With the increase in storm severity within more extreme rainfall and hurricanes, a measure that was taken after the January 2005 hurricane in the country[71]. Drainage culverts can also be improved in order to handle higher loads of traffic on routes which have prioritised tracks

Mitigation has looked like the development of meandering water courses which lead water accumulation within different directions and act as a buffer to management of water levels[71]. The drainage systems are affected in that the ground does not absorb water well and can lead to flooding in underground paths such as the subway. With this matter in mind, it has been noted that typically the older parts of the network are usually the most adversely affected yet the most underserviced, so there is need to be mindful of this. Another method to follow in order to mitigate the effects of climate change would be the utilisation of systemic temperature maps which reflect the true temperatures; this will help collect accurate data which shows the vulnerabilities in climate and direct the future direction of climate related adaptations[71].

Australia

This case study in Australia was conducted by the Monash University, Centre for Population and Urban Research. This study assesses 8 different metropolitan regions of Australia and gathered data concerning climate change and its effects on roads and pavements and deduced how these key findings can influence settlement patterns, but also inform how road and pavement design, planning and maintenance should occur to adapt to the changing climate[74]. The goal is to ensure that roads have lives of up to 20 to 40 years and bridges have life spans of up to 100 years. As such, this project aimed to assess the effects of current and projected climate effects for the following 100 years in order to inform adaptations, construction and maintenance of road infrastructure which includes roads, pavements and bridges[74]. Similar to

Toronto, Australia has experienced and has projected flooding, extreme heat and severe weather.

Adaptations

1. Overall, research found that rainfall affects the moisture balances that affect the further deterioration of pavements[73]. A recommended adaptation as seen in Southern Canada and applicable in Toronto was the recommendation to mix the composition of asphalt used to create roads and pavements in order to improve water resistance and water damage. This can be accomplished by the addition of special additives and fillers[73]. It was also recommended to utilise relevant hydrophobic coatings for roadway and pavement surfaces.
2. Moreover, the increasing temperatures affect the bitumen on roads, and heighten its embrittlement which ultimately results in the cracking of roads and pavements and further results in a lack of waterproofing of surfaces; this in turn furthers the deterioration of pavements and roads[74]. In order to combat this, sulphur extended asphalt modifier including a patented Shell additive can be used as a mix modifier and binder[73].
3. Rising sea levels and flood heights have also become a factor as this affects the location and design of roads, especially with climate projections of increased intensity and occurrence of storm surges[73]. In order to manage the matter of increased water levels, and better the subsurface drainage it is recommended to install the use of geotextiles or mulch materials[74].
4. Lastly, as a matter of salinity in the buildup of water tables, this decreases the structural integrity of pavements as the salt is able to rust or corrode the concrete in more riverine environments[73]. It was suggested that there be an added layer of thickness in the asphalt mix, as it will play the role of guarding the base and subgrade layers.[74]

Section 7: Conclusions and Recommendations for the City of Toronto

After examining a variety of jurisdiction's strategies to incorporate climate change into their methods of managing water, waste and linear infrastructure assets, our recommendations to the City are threefold.

Firstly, more collaboration between partners and stakeholders across the public, private and non-profit sectors is necessary to bridge the gap between ambition and action. Toronto's climate goals, both in mitigation and adaptation, require multi-level collaboration between municipal departments, private corporations and civil-society, to prevent reductionism and address the multi-dimensional challenges that climate change brings. For example, our research on LoS pertaining to transportation infrastructure revealed that better incorporation of material knowledge can help increase the lifespan of assets. Understanding the temperature

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[73] Saleh, M. and Hashemian, L., 2022. *Addressing Climate Change Resilience in Pavements: Major Vulnerability Issues and Adaptation Measures*..

[74] Norwell, G., 2004. *Impact of Climate Change on Road Infrastructure*.: <https://www.bitre.gov.au/sites/default/files/cr_001_climate_change.pdf> [Accessed 8 April 2022].

in which steel will warp, for instance, can inform city planners to bring shade near streetcar lines to reduce temperatures, and therefore allow Transport Services to attain its service level targets.

This holistic approach to city management is underlined by the understanding that climate adaptation requires collaboration from many departments and corporations (such as the TTC). Additionally, decisions made in transportation will impact Toronto Water's ability to collect stormwater and to meet water demands, as more rain and less permeation means faster runoff, more evaporation and a greater urban heat island effect, and a drained water table on which Torontonians rely for drinking water.

Secondly, anticipating future needs of the city and its citizens is a crucial aspect of forming climate sensitive AM plans. Learning from waste and water management case studies, adapting to climate change requires governments to reflect on its capabilities to provide services to its people. Governments in Hong Kong, PEI and Berlin understood that innovative solutions are needed to manage their waste loads while maintaining citizen's quality of life. As is seen in Chicago and Barrie, where water conservation strategies are in place to protect supplies for their growing populations. Toronto should work to incorporate climate and population projections into its LoS standards, as laid out in various reports published by the city.

Finally, implementing more rigorous data collection strategies to core asset systems in Toronto will allow the city to better implement, enforce and track progress on service levels and climate initiatives. More in-depth data can better quantify the effectiveness of certain policy interventions, such as waste diversion programs, water conservation strategies, and temperature alleviations to protect rail lines. Understanding these issues in quantitative terms allows policy makers to adapt strategies as they unfold, to better react to unforeseen events, and to evaluate if the ultimate outcomes were achieved.

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Appendix

Appendix I: Waste Asset Management Jurisdictional Scans - Background information

Hong Kong, China

Our analysis of Hong Kong's waste asset management plans is rooted in the "Waste Blueprint for Hong Kong 2035," published in February 2021 by the Environmental Protection Department (EPD) of the city's Environment Bureau.[75] Hong Kong acknowledges the breadth of waste it generates as a developed city, with major waste categories highlighted including municipal solid waste (MSW), food waste, construction waste, chemical waste, clinical waste and more.[76] The EPD has identified key challenges facing the city pertaining to growing wasteloads and the development of its recycling industry, paralleling Toronto's focus on waste diversion measures and the circular economy.[77]

Berlin, Germany

Our analysis of Berlin's waste asset management plans is rooted in the "Berlin Energy and Climate Protection Programme 2030," published in April 2019 by the Department for the Environment, Urban Mobility, Consumer Protection and Climate Action of Berlin.[78] Our analysis is further informed by this Department's other publications pertaining to the city's ongoing multi-pronged climate action plans and the waste AM proposals contained therein, as well as the operational details of other relevant government agencies, including the *Berliner Stadtreinigung* (Berlin Waste Management, BSR).[79]

Prince Edward Island, Canada

Our analysis of PEI's waste AM plans is rooted in the island's "Taking Action: A Climate Change Action Plan for PEI 2018-2023" published in February 2019 by the province's Department of Environment, Energy and Climate Action.[80]

Appendix II: Transport Asset Management - Conclusions

Chicago, Illinois

<u>Case Study Conclusion</u>

Overall, these adaptations and mitigation measures serve to improve the lifespan, quality, design and usability of transportation. This case study highlights how these measures must

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[75]"Waste Blueprint for Hong Kong 2035," Waste, Environmental Protection Department, 10 October 2021, https://www.epd.gov.hk/epd/english/environmentinhk/waste/waste_maincontent.html.
[76]Ibid.
[77]Ibid.
[78]"BEK 2030: Berlin Energy and Climate Protection Programme 2030," Senate Department for the Environment, Transport, and Climate Protection, Berlin, 2019, https://www.berlin.de/sen/uvk/en/climate-action/publications/.
[79]"Publications," Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action, State of Berlin, 2022, https://www.berlin.de/sen/uvk/en/climate-action/publications/. ; "BSR information in English," Berlin Waste Management, Berliner Stadtreinigungsbetriebe, 2022, https://www.bsr.de/die-berliner-stadtreinigung-in-englischer-sprache-26142.php.
[80]"Taking Action: A Climate Change Action Plan for Prince Edward Island 2018-2023," *Climate Change*, Government of Prince Edward Island, 2018, https://p1cdn4static.civiclive.com/UserFiles/Servers/Server_10500298/File/Environment%20and%20Sustainability/Sustainability/Climate%20Change/climatechangeactionplanPEI.pdf.

continue to be retrofitted through continual updating of infrastructure design standards as climate trends continue to evolve. Lastly, there are uncertainties presented regarding the mass adoption, inclusive growth and land use patterns as it pertains to plans which support the increased implementation of more technologically advanced transport alternatives. This is a concern as this is an ever-growing industry, thus what is currently relevant may not be feasible by 2050.

Sweden

Case Study Conclusion

Overall with the adaptations and mitigation measures shown, we should always be mindful not to be counter-productive to one another and efforts be made to produce linear positive results. And all in all, new infrastructure is encouraged to be climate conscious and considered in planning, design and management.

Australia

Conclusion

Overall, utilising the case study in Australia, it's clear that overall, the material being utilised for roads and pavements is of great importance in regards to combating extreme heat and flooding or storm durability. choosing the rightful materials will impact the design and performance of the road infrastructure. However, this case study stresses the importance of continually monitoring key performance parameters, which can be related to LoS. This is crucial to ensure future adaptations can be implemented based on climate change trends. All in all, because of efforts to maintain strong road and pavement systems, it is critical to ensure that adaptation measures are integrated and incorporated into design, planning and decision making in the development of new infrastructure as well. (NEW PPR)