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Attachment 1

City of Vaughan
Asset Management Plans

(Urban Forestry)

City of Vaughan

Project number: 60641721

May 2021

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1. Introduction

The City of Vaughan ("the City") appointed AECOM Canada Ltd. ("AECOM") to assist in the renewal of the City's Asset Management (AM) Plans for its core infrastructure assets.

1.1 Overview

The City is one of nine area municipalities, located within the Regional Municipality of York. As a lower tier municipality, the City is responsible for providing such services as fire protection, public works, water distribution and wastewater collection, parks and recreation, building and planning and development control.

In 2018, by City Council approval, the Corporate AM Policy for the City came into effect; and, in 2013, the City's first Corporate AM Strategy was published. As identified in the Corporate AM Strategy, the City's first set of AM Plans (AMPs) were developed in 2014.

The purpose of this AMP is to capture new core infrastructure assets and any updates in the City's asset data, so as to provide the City with a comprehensive AMP. The objective is to deliver a financial and technical roadmap for the management of the City's core infrastructure assets, and to provide the means for the City to maximize value from its assets, at the lowest overall expense while, at the same time, providing enhanced service levels for its residents and promoting green initiatives.

Organizations that implement good AM practices will benefit from improved business and financial performance, effective investment decisions, and better risk management. Stakeholders can expect lower total asset life cycle costs, higher asset performance, and confidence in sustained future performance.

1.2 Asset Management Planning Provincial Requirements

The O. Reg. 588 / 17 came into effect in 2018 and stipulates specific AM requirements to be in place within Ontario municipalities by certain key dates **(Table 1-1**). The renewal of this AM Plan for the City is one of the steps towards meeting the July 1st, 2022 deadline.

Table 1-1: O. Reg. 588 / 17: AM Planning for Municipal Infrastructure

Description: A regulation made under the Infrastructure for Jobs and Prosperity Act, 2015, stating that every municipality shall prepare and update a Strategic AM Policy, and that every municipality shall prepare an AM Plan for its core infrastructure assets by July 1, 2022, and an AM Plan for all other infrastructure assets by July 1, 2024. The regulation outlines several requirements that each AM Plan must follow, such as including current and proposed level of service. Core municipal infrastructure assets include water, wastewater, stormwater, road, and bridge assets.	
Deadline Date	**Regulatory Requirement**
July 1st, 2019	All municipalities are required to prepare their first Strategic AM Policy.
July 1st, 2022	All municipalities are required to have an AM Plan for its entire core municipal infrastructure (i.e., water, sanitary, stormwater, and transportation).
July 1st, 2024	All municipalities are required to have an AM Plan for infrastructure assets not included under their core assets.
July 1st, 2025	All AM Plans must include information about the LoS that the municipality proposes to provide, the activities required to meet those level of service, and a strategy to fund activities.

1.3 Asset Management Plan Scope

This AMP has been developed for the City's four core asset categories, owned and maintained by the City, as shown in **Table 1-1**. The renewal of the City's AM Plans is consistent with the guidelines laid out in the City's Corporate AM Policy and Section 5 of O. Reg. 588 / 17.

Table 1-2: In-Scope Assets

Asset Category	Sub-Assets
Water Distribution System	Water mains, service connections, valves, hydrants, chambers, water meters, pump stations, and water filling stations.
Wastewater Collection System	Wastewater mains, laterals, manholes, flowmeters, pump stations, and generator stations.
Stormwater Management System	Stormwater mains, laterals, manholes, catch basins, stormwater culverts, inout structures, devices, pump stations, ditches, stormwater management ponds, lakes, rivers, and waterways.
Transportation	Roads, bridges, and culverts.

The following elements are included within the scope of this AM Plan for each of the asset categories shown in **Table 1-2**.

- A summary of the asset inventory, including the replacement cost of the assets, the average age of the assets, the condition of the assets, and the City's approach to assessing the condition of the assets (**Section 3.1, 3.2** & **3.3**);
- Current levels of service (LoS) based on data from 2018 to 2020 determined in accordance with the qualitative descriptions and technical metrics outlined in O. Reg 588 / 17 (**Section 3.4**); and
- Asset lifecycle management activities to maintain identified current LoS, minimize associated asset risks, and to optimize costs over the whole lifecycle of the asset (**Section 3.5**).

1.4 Growth Planning

The City is one of Canada's fastest growing cities, with a population of over 300,000. It is projected that the number of residents will increase to 430,000 by 2031. In addition to its rapidly growing population, the City is home to a well-diversified and expanding employment sector with over 8,000 businesses and 150,000 employees. The City has the largest supply of new employment lands in the Greater Toronto Area (GTA) and it is projected that the number of employees will increase to 278,000 by 2031. As shown in **Figure 1-1**, presented is the development of the City's water network over multiple decades, which is one of the most essential and critical assets and illustrates the City's development over time.

The next 25 years will see the City transition from a growing suburban municipality to a fully urban space. This type of transition will require long-term thinking about how best to accommodate and make the most of new opportunities. Planning for the future through strategic planning will position the City to deal with the many pressing issues impacting the organization such as community safety, access to health facilities, environment, traffic congestion and issues related to growth and the quality of municipal services.

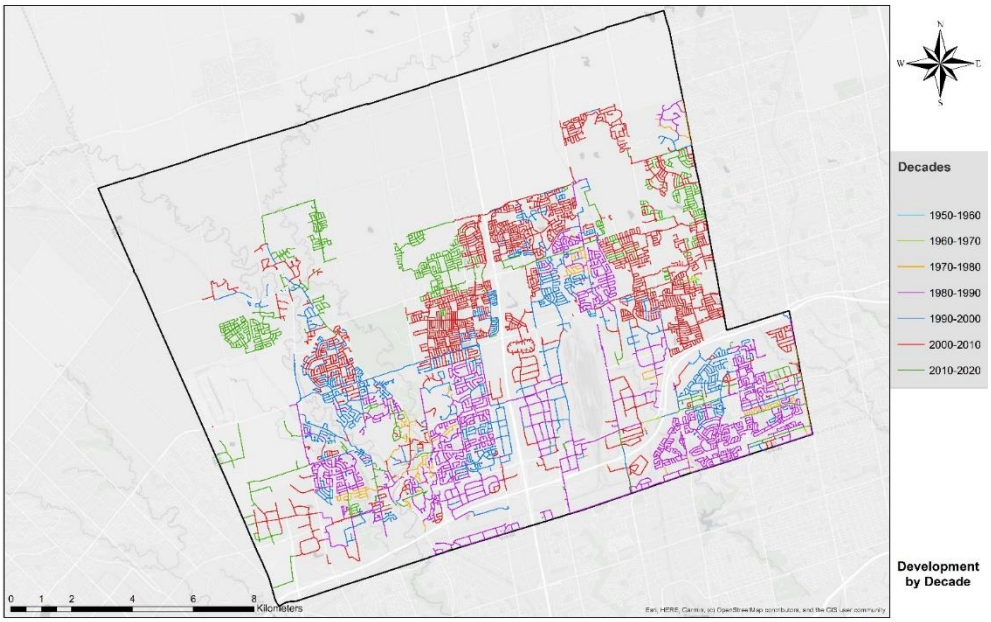


Figure 1-1: City of Vaughan Development Map

2. Approach for Asset Management Plan

The approach used in the renewal of this AM Plan is presented in **Figure 2-1**, and has been selected to ensure that the City can have the confidence to make fact-based and defensible business decisions from reliable and robust information.

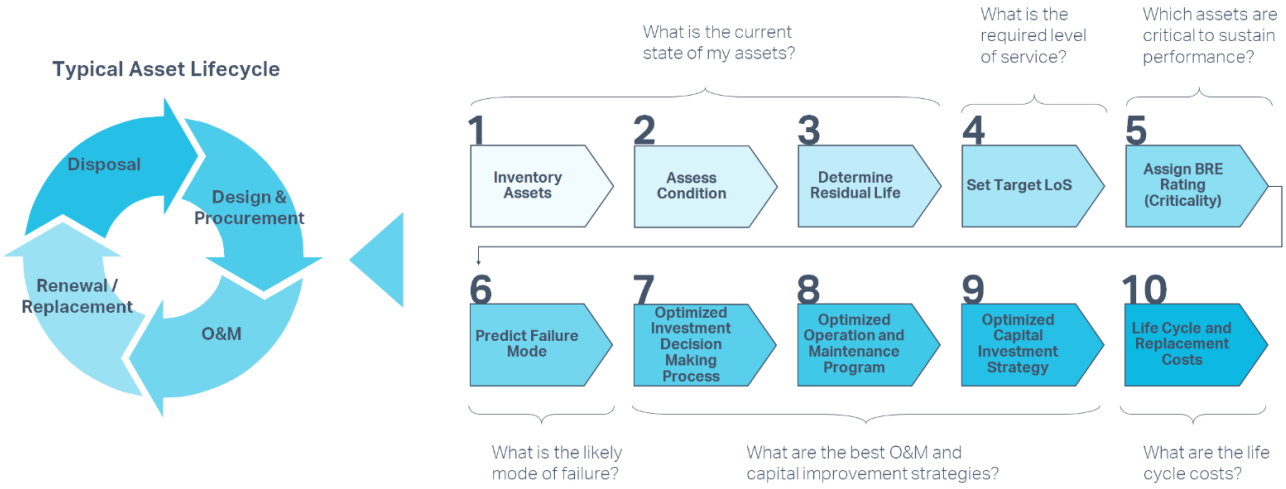


Figure 2-1: AM Plan Approach

2.1 State of Infrastructure

Defining the state of the infrastructure involves quantifying the assets owned, examining their age, replacement value, and condition. AECOM's approach to each of these asset characteristics is summarized below.

2.1.1 Expected Service Life & Remaining Service Life

The expected service life (ESL) is defined as the period over which an asset is available for use and able to provide the required level of service at an acceptable risk (i.e., without unforeseen costs of disruption for maintenance and repair). The ESL for this assignment will be based on discussions with City staff, information from previous studies, and any additional information that might inform the ESL. In terms of determining the Remaining Service Life (RSL), AECOM used the installation date together with the ESL.

In reality, different assets will deteriorate at different rates and not necessarily linearly over time, however, it is important to keep in mind the level of effort required to predict failure compared with the asset value. More sophisticated deterioration modelling may be warranted for very high value assets, whilst the cost of deterioration modeling for low-value assets may very well exceed the replacement cost of the asset. The actual service life can vary significantly from the ESL. In some instances, a variation in expected vs. actual service life is evident due to the following factors:

- **Operating conditions and demands:** Some equipment is operated intermittently or even infrequently, or is being operated a lower demand than its design capacity, thus the actual operating "age" of the asset is reduced.
- **Environment:** Some equipment is exposed to very aggressive environmental conditions (e.g., corrosive chemicals), while other assets are in relatively benign conditions, thus the deterioration of assets is affected differently.
- **Maintenance:** Equipment is maintained through refurbishment or replacement of components, which prolongs the service life of the asset.

- **Technological Obsolescence:** Some assets can theoretically be maintained indefinitely, although considerations such as maintenance cost, energy inefficiency and new technologies are likely to render this approach uneconomical.

2.1.2 Asset Replacement Cost

The estimated replacement value is the cost of replacing an existing asset in today's dollars, considering an inflation rate. These costs were developed based on the records used in the 2016 AECOM project titled "Integration of Underground Utilities with Pavement Management System", previous tenders and quotes, other municipalities similar in size to the City, and consultation with the City's staff. Where applicable, a 2% annual inflation rate was used to adjust the historical costs to 2021 values; this rate is representative of the average inflation rate in Canada for the past 5 to 10 years.

In the reinvestment need analysis for water, wastewater, and stormwater assets, the replacement costs are calculated considering the equation [1] and [2]:

$$Unit\ Cost\ (all-inclusive)\ =\ \{pipe\ unit\ rate, appurtenances/accessories\} \quad [1]$$

$$Total\ Replacement\ Value\ of\ Service\ Type\ (water, wastewater, storm) = \sum Unit\ Cost\ (all-inclusive) * Length\ +\ \sum Others \quad [2]$$

Where $Others$ refers to asset types that are not measured in the all-inclusive unit rate and can vary depending on the service type.

For example, in water, $Unit\ Cost\ (all-inclusive)$ is calculated by considering the total replacement values of pipes, hydrants, chambers, service connections, and valves. The total replacement value was proportionally distributed based on the total length of each pipe size in the network. $Others$ included meters, pressure reducing valves, and water facilities. Upon calculating the replacement costs, the values were rounded to the nearest thousand.

2.1.3 Asset Condition

All assets are expected to deteriorate over their lifetime, and their assigned condition reflects the physical state of the asset. No on-site condition assessments were carried out for this project; therefore, physical condition of the assets is based on consultations with City staff who have experience in managing the assets, combined with any existing condition data, and information from past studies.

Where empirical data is not available (i.e., previous condition assessments, inspections, and observations), Weibull three-parameter distribution was used to assess the current condition and project the future condition of the City's assets. The Weibull distribution has been used extensively in reliability studies and lifetime prediction models in industries ranging from the automotive to the oil and gas industries and provides a suitable distribution for this type of analysis.

The Weibull probability distribution provides a left-skewed distribution that rises slowly and diminishes quickly as the population is consumed. The underlying premise of the Weibull-shaped deterioration is that while some assets fail prematurely due to severe conditions or improper installation, other assets are very long-lived and function well beyond their theoretical expected service life. In order to perform a high order network-level analysis, it was assumed that assets would fail (and require replacement) within a deterioration envelope / curve approximated by a Weibull probability distribution. The Weibull probability distribution has three parameters for location, scale and shape, as set out in equation [3]:

$$f(x)\ =\ \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1} e^{-\left(\frac{x-\gamma}{\alpha}\right)^{\beta}} \quad [3]$$

Where: α = scale parameter
β = shape parameter (or slope)
γ = location parameter

A set of Weibull cumulative distributions were created to depict a set of deterioration curves for assets with different expected service lives (ESLs).

Table 2-1 presents the condition score ranges and the corresponding range of ESL and total life consumed.

Table 2-1: Age-Based Physical Condition Scale

Condition Score (minimum)	Condition Score (maximum)	Condition Rating	Range % of ESL Consumed	Range of % Operational Life Consumed *
1	1.5	Very Good	0% – 71%	0% – 47%
1.5	2.2	Good	72% – 84%	48% – 56%
2.2	2.8	Fair	85% – 92%	57% – 60%
2.8	>=3.5	Poor	93% – >100%	61% – 100%

* NOTE: WERF uses the term “operational life” to define the time period over which an asset remains operational irrespective of performance, risk or cost considerations.

2.2 Levels of Service

In AECOM’s experience, documenting LoS is a proven practice that will enable the City to:

- Link corporate strategic objectives to customer expectations and technical operations.
- Balance customer needs and expectations while evaluating the effectiveness of operations and whether the right LoS is being provided at the right cost.
- Transition from an “Asset Stewardship” approach that focuses on making decisions based on maintaining assets in an acceptable condition to a “Serviceability” approach that is geared towards making decisions based on balancing the costs, risks, and goals for the LoS being provided by the City’s assets.
- Communicate the physical nature of infrastructure that the City owns and is financially responsible for while promoting the use of LoS to enable effective consultation with stakeholders regarding alternative funding options according to desired LoS outcomes.
- Make recommendations on strategies that the City can take now to minimize future renewal costs while ensuring that adequate LoS can be delivered without burdening future generations.
- Assess internal (e.g., program changes) and external (e.g., climate change) factors that have the potential to impact the City’s ability to deliver services and how these factors may impact the LoS being provided.
- Implement a corporate continuous improvement program to further optimize asset management (AM) across all service areas.

The O. Reg. 588 / 17 requires all AM Plans to include information about LoS that the municipality proposes to provide, the activities required to meet those measures, and a strategy to fund activities. The deadline of the requirements for formalized LoS is July 1, 2025.

Successful AM programs aim to achieve targeted service levels through customer-based decision making. To achieve this, AECOM considered a customer-centric approach, where the customer is at the heart of every decision from development to implementation, consultation, and roll-out of the LoS Framework (Figure 2-2).

There are two types of LoS measures: Customer LoS (also called “Community” LoS) and Technical LoS. Customer LoS are recorded in a manner that attempts to describe the LoS in terms of what is actually being provided to the customer (i.e., the public) and how the customers experience the service. It is important to note that customers are not concerned with the specific operating requirements of the assets that provide the service, but rather the value they obtain from the operation of the assets. To achieve Customer LoS there needs to be line of sight between the value delivered and how that value is realized. This is the purpose of Technical LoS which attempts to describe how the City will provide and meet the expected Customer LoS.

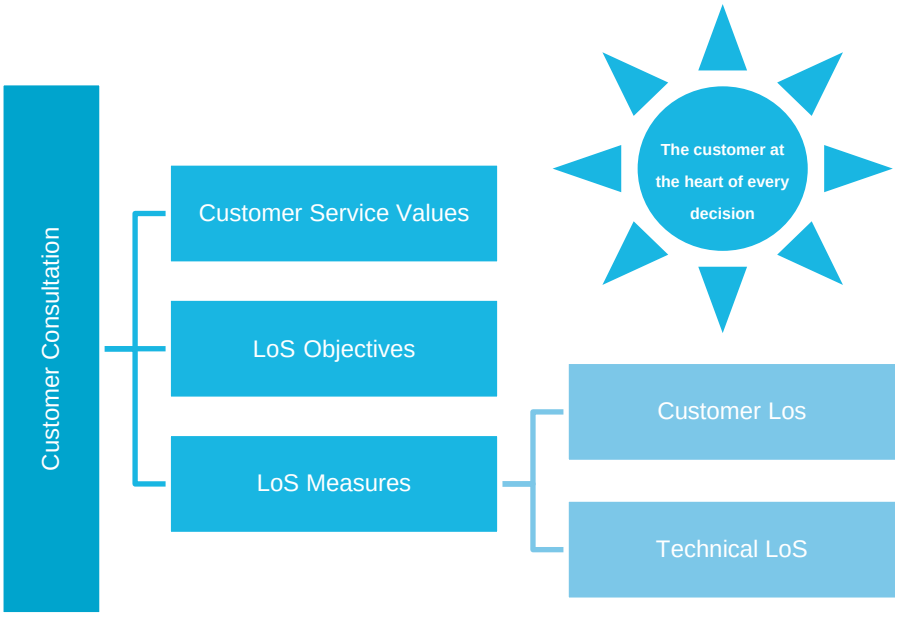


Figure 2-2: The LoS Framework Customer-Centric Approach

The LoS Framework was primarily conceived through a collaborative workshop process. In 2020, AECOM facilitated four workshops with City staff across each of the fourteen service areas. The following outcomes were achieved during each service area workshop:

- Staff were oriented as to the purpose and importance of establishing a consistent LoS Framework;
- Stakeholders were identified, including their expectations, interests, and any regulatory requirements;
- Customer service values were established and reviewed;
- LoS objectives were established for each customer service value;
- Staff provided several performance measures that are currently being tracked as well as those that the City would like to track in the future;
- Where information was available, current performance, targets, and data sources were documented; and
- Growth and shifts in future demand were discussed across the City's service areas.

2.3 Lifecycle Management Strategies

Life cycle management focuses on the specific activities we must undertake during all phases of the asset life cycle. Considering entire asset life cycles can ensure we make sound decisions that take into account present and future service delivery needs.

The overarching goal of life cycle management is to maximize the long-term benefits and services our assets deliver while minimizing the associated costs and risks in the long run. Every asset has a life cycle cost, which is the total cost of all the activities undertaken throughout its service life. The following sections describe activities across the life cycle of assets.

2.3.1 Life Cycle Activities

Any responsible owner of assets such as the City has a desire to preserve the condition of their existing assets for as long as possible, by maintaining or even extending their design lives through routine activities such as maintenance and active intervention. The City is continually acquiring infrastructure assets, but these assets require increased funding for operation and maintenance as they age. The City is also responsible for the replacement of deteriorated assets as long as the service is required. While individual assets may have a useful life that can be predicted in years or decades, the service that the asset provides could be for a substantially longer duration (perhaps in perpetuity). Part of the purpose of the AM planning process is to fully understand and predict the long-range financial

requirements for the City's infrastructure to facilitate planning and resource management in the most cost-effective manner possible. **Figure 2-3** illustrates how costs typically accumulate over an asset's life. It is worth noting that the accumulation of the ongoing operations and maintenance, refurbishment and disposal / replacement costs is many multiples of the initial acquisition costs. A key and important take-away from **Figure 2-3** is therefore for the City to fully understand the entire life cycle costs before proceeding with asset acquisition.

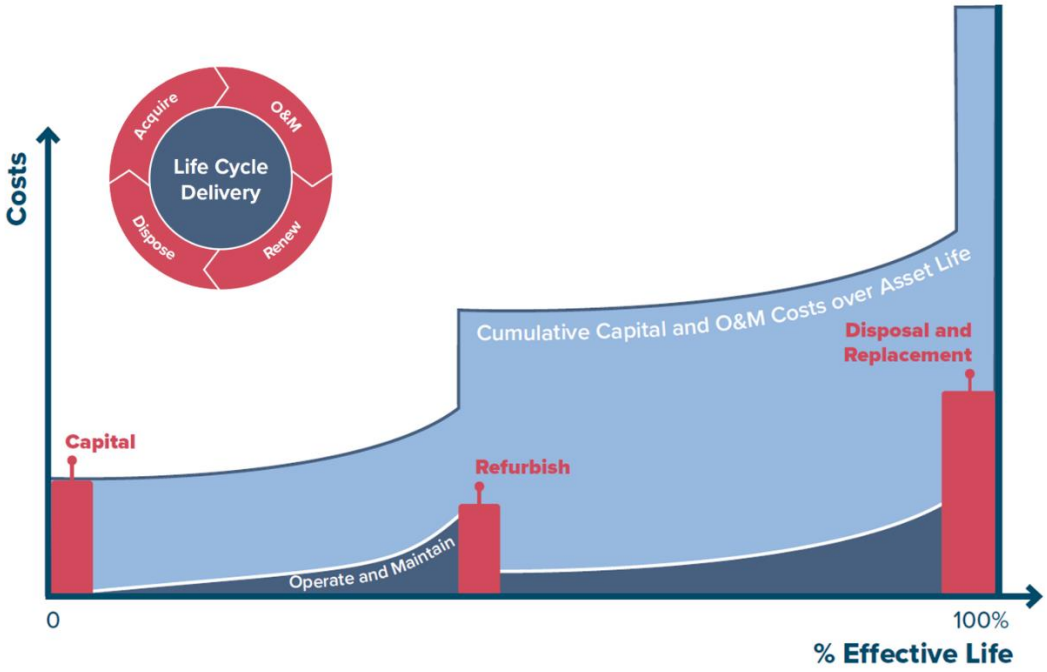
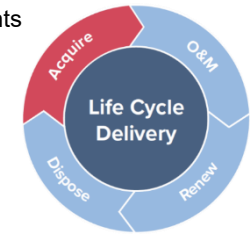


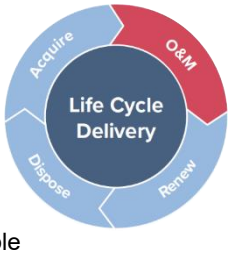
Figure 2-3: Life Cycle Cost Accumulation Over Asset Life

Expressed simply, full lifecycle cost of infrastructure can be accumulated under the following broad headings:

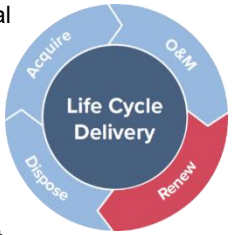


- **Asset Acquisition / Procurement / Construction**: The City has made significant investments in the design and acquisition of its municipal infrastructure assets. Added to City-purchased inventory is infrastructure that the City accepts (and takes immediate financial responsibility for) from developers as new neighborhoods are constructed. For example, as developers build new neighborhoods, the new local infrastructure (including local roads, water mains, sewer mains and storm mains) is paid for by the developer and then transferred to the City for operation, maintenance and ultimately replacement. The City's infrastructure inventory was therefore created over many decades through infrastructure paid for by the City or by developers Looking towards the future, when acquiring new assets, the City should evaluate credible alternative design solutions that consider how the asset is to be managed at each of its life cycle stages. Asset management and full life cycle considerations for the acquisition of new assets include, but are not limited to the following:
  - The asset's operability and maintainability;
  - Availability and management of spares;
  - Staff skill and availability to manage the asset;
  - The manner of the asset's eventual disposal.

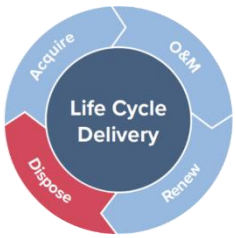
- **Asset Operations and Maintenance (O&M)**: As new infrastructure is commissioned, the City accepts the responsibility of operating and maintaining the infrastructure according to O&M standards to ensure that the infrastructure is safe and reliable. Operations staff provide the day-to-day support required to operate infrastructure. In few cases, operation costs are minor, but for most there are significant increases. For example, underground pipes require almost no operational support while a facility such as a pump station requires full-time staff to operate the facility safely and efficiently. Maintenance expenses include periodic preventive maintenance to ensure that the infrastructure can provide reliable service throughout the life of the asset and corrective maintenance that is required to repair defective assets as and when needed. Inadequate funding for O&M will have an adverse impact on the lifespan of assets. The amount of O&M resources required in any period is a function of the current inventory of infrastructure and total O&M needs required for each asset. As the inventory of infrastructure grows, total O&M requirements will also grow.



- **Renewal and Replacement:** The third portion of full life cycle costing relates to the renewal and replacement of infrastructure that has deteriorated to the point where it no longer provides the required service. Renewal cost is sometimes incurred during the life of an asset where an investment is made to improve the condition and / or functionality of the asset e.g., re-lining of a pipe or resurfacing of a road. Disposal and replacement costs are incurred at the end of an asset's life when it is disposed of and replaced by a fully new asset. Canadian municipalities, including City of Vaughan, have not traditionally factored renewal or replacement costs into future budget projections, except for assets that have a relatively short life such as computer equipment and vehicles. The main reason behind this is the fact that large portions of this infrastructure inventory can have a very long life e.g., from 75 to 100 years for underground pipes. For growing communities like the City, there has not been a historical need to forecast expenses that are not anticipated for decades. However, based on the experiences of more established Canadian cities (where vast inventories of old assets are now in dire need of renewal or replacement), it is vital that communities fully understand the looming obligations of infrastructure renewal or replacement and develop a strategy to respond in a manner that is fair and affordable. The general life cycle activities of asset renewal, and replacement will be explored in more detail as these activities are to be reflected in the Deighton's Total Infrastructure Management System (dTIMs) analysis to determine when City assets are to be intervened upon, what type of intervention is needed and the associated cost (refer to **Section** Error! Reference source not found.).



- **Decommissioning and Disposal:** There will inevitably come a point in time when an asset must be removed from service and, depending on the type of asset, there may be significant costs associated with its decommissioning and disposal. Factors that may influence the decision to remove an asset from service include: changes to legislation that cause the asset to be in non-compliance, the inability of the asset to cope with increased service levels, technology advances that render the asset obsolete, the cost of retaining the asset is greater than the benefit gained, or the current risk associated with the asset's failure is not tolerable. Normally, major costs that may be incurred during disposal and decommissioning derive from the environmental impact of the disposal and, if required, the rehabilitation and decontamination of land. In some cases, there will be residual liabilities and risks to consider if a decision is made to partially abandon the asset as oppose to fully disposing of its components (e.g., leaving a non-functioning pipe in the ground, or an inactive building standing). However, some cost savings may be achieved through the residual value of the asset or by exploring alternative uses for the asset. In all cases, it is important to consider disposal and decommissioning as the strategy employed has the potential to attract significant stakeholder attention. For that reason, the costs and risks associated with disposal and decommissioning should be equally considered in the City's capital investment decision-making process.



The infrastructure AMPs present the City's strategy for responding to the full lifecycle costs of all its infrastructure assets. Long-range estimates were prepared together with the AMPs, based on industry best practices to ensure the financial sustainability of the City's infrastructure assets over their full life cycle, as discussed in the next Chapters.

2.4 Financial Planning

2.4.1 Financial Policies

The City has taken the initiative to establish financial asset management policies in 2018, which provides directions on how financial principles apply to assets to ensure that service goals are met. The policy aligns the business model of AM with the City's financial planning, financial reporting, cost management, treasury and taxation functions. The City will integrate findings from the AM Plans into its long-term financial planning and budgeting processes. Sound financial analysis will be encompassed in AM planning in order for the AM Plan to be a sought-after guide for employees in budgeting and financial planning.

2.4.2 Financial Analysis

Financial analysis activities for asset management is centered on two essential quantities: revenues and expenditures. Revenues can come from many sources. Through asset operations, the City generate its own source revenues from taxes, development charges, etc. Expenditures are all the direct and indirect costs associated with capital, operating and maintaining, and disposing of assets.

Assessing the financial implications supports in the decision-making when there are competing priorities and trade-offs between projects. Financial analysis provides a better picture of how to fund the capital plan and make critical decisions about service delivery while providing the greatest benefit for the community at the lowest cost.

2.4.3 Aligning the Financial and Non-Financial Functions of AM

ISO 55010[1] identifies the that the financial and non-financial functions of AM within organizations are generally inadequately aligned, as follows:

- **Financial Accounting Functions:** Focused on retrospective reporting of accounting / regulatory financial activities. However, there is a growing awareness in organizations of the need to focus on providing a managerial costing approach in order to support decision-making for the future.
- **Non-Financial Functions:** Have a limited understanding of financial accounting functions but are recognizing the need to improve their understanding of the financial implications of their activities.

The lack of alignment between financial and non-financial functions can be attributed to silos in an organization, including reporting structures, functional / operational business processes, and related technical data. Silos generally bring forth the necessary level of specialization. However, with a lack a communication between the silos, organizations are at risk of inefficiencies and errors in AM results, or AM failures due to a lack of alignment between AM staff and senior management. Financial and non-financial alignment needs to work both "vertically" and "horizontally", as follows:

- **Vertical Alignment:** Financial and non-financial asset-related directives by management are informed by accurate upward information flows, effectively implemented across the appropriate levels of the organization.
- **Horizontal alignment:** Financial and non-financial information that flows between departments (conducting functions such as operations, engineering, maintenance, financial accounting and management) uses the same terminology and refers to the assets identified in the same way.

[1] International Organization for Standardization (2019): ISO 55010 - Asset management — Guidance on the alignment of financial and non-financial functions in asset management

Figure 2-4 presents the key elements in a framework to address the need to achieve the alignment.

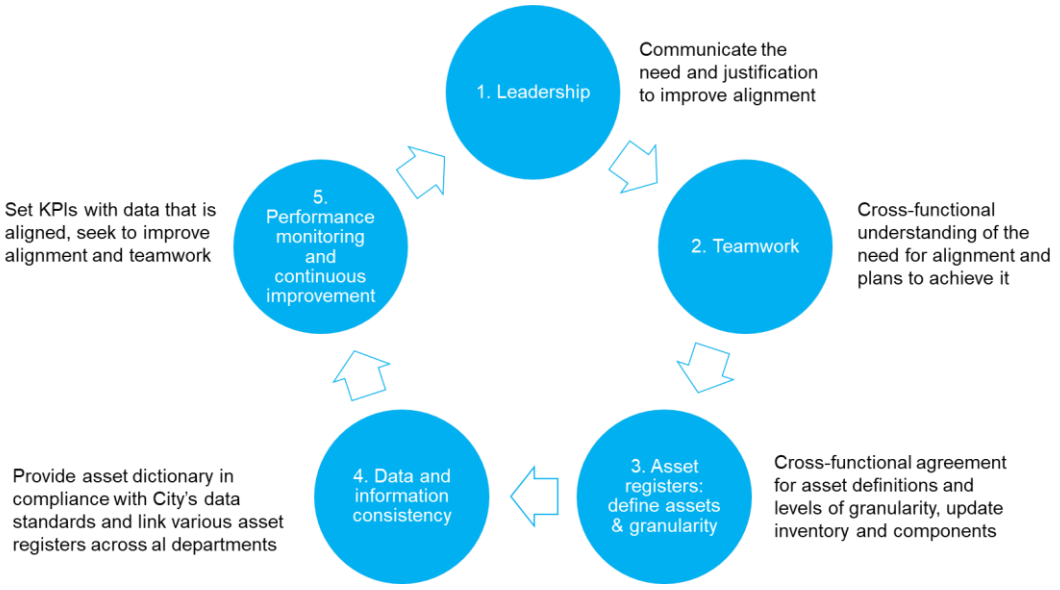


Figure 2-4: Key Elements of a Framework to Achieve Financial and Non-Financial Alignment

2.4.4 Long-Term Financial Planning

Strengthening the City's AM planning according to the recommendations in **Asset Management Strategy** will improve the City's long-term financial planning, by accounting for whole life cycle costs as presented in **Section 2.3.1**. This includes all capital, annual operation and maintenance, and disposal costs over the planning timeframe, thereby aligning financial requirements with long-term level of service objectives.

The challenge is often one of agreeing on a timeframe for such planning, recognizing that the AM perspective is ideally focused on the asset life cycle, versus the political / election cycle that could be as short as a three to four-year Council term. Accordingly, financial and non-financial staff, as well as top management and politicians, should agree on a long enough timeframe to provide useful forward planning information that aligns the financial and non-financial perspectives, as presented in **Figure 2-5**.

Figure 2-5: AM Planning Alignment Across the Organization

The City should have an appropriate long-term financial planning process that achieves the following:

- Stimulates long-term strategic thinking and perspective for stakeholders and decision-makers.
- Can be used as a tool to prevent or predict future financial shocks and demonstrate financial sustainability.
- Demonstrates to internal and external stakeholders that the organization has a financial strategy in place to meet their demands, now and in the future.

The long-term financial planning process needs to involve financial and non-financial staff working together to combine the important elements of strategy development, asset management planning and financial forecasting (**Figure 2-4** and **Figure 2-5**).

3. Urban Forestry

Urban forests turn the City green, and transform water, nutrients and carbon dioxide into clean air, oxygen, shade, and habitat. The City's Forestry Operations division is responsible for maintaining approximately 126,541 street trees and 4,377 hectares of open spaces across the community. Unlike other assets, trees are living natural assets and increase in value with age for most of their lifecycle. The City recognizes the significant role that the urban tree canopy plays in providing an improved quality of life. Preserving and protecting the health of trees will help the City achieve its commitment to maintaining and enhancing the urban forest and the environment.

Urban forests at the City bring many benefits including:

- Helping soils absorb stormwater which can substantially reduce stormwater runoff and flooding.
- Providing shade that keeps buildings cooler leading to less energy consumption in summer.
- Absorbing greenhouse gas emissions resulting in climate change mitigation.
- Reducing air temperatures through both shade and evapotranspiration combating the urban heat island effect and helping address extreme heat events.
- Offering a critical form of habitat to species living in urban areas.
- Preventing runoff and erosion, resulting in higher water quality and stable slopes.
- Sequestering pollutants and improves air quality by removing carbon dioxide.
- Improving public health in terms of psychological well-being and mental health, and physical health.
- Reducing noise by providing sound buffering from traffic, construction and other City noises.
- Other values such as benefits to community and add value to land.

Urban forests are always at risk from insects, disease, weather damage and development issues. The development of asset management practices is important to sustain a healthy urban forest asset.

3.1 Asset Inventory and Replacement Value

The City owned urban forests system has a value of approximately $473M. The urban forestry inventory is categorized into four types of trees: street trees, park trees, woodlots, and open spaces. The most common species of trees at the City are the Norway Maple, Honeylocust, and Basswood species. Woodlot are open spaces that has designated City's crew to operate and maintain, where open spaces are City owned but they do not need to take care of or there are less maintenance involved. Tree density of woodlots and open spaces are also different. For some open spaces (naturalized areas), the City shares responsibility with Toronto Region and Conservation Authority (TRCA).

The asset inventory and its valuation were determined by using the data from the City' GIS database and from consultant reports. **Table 3-1** presents the urban forestry inventory and replacement values. The i-Tree Eco method was adopted from the consultant report for studying the total tree species across the City[2]. The replacement values were estimated based on the cost of having to replace a tree with a similar tree and converted to inflated dollar value to represent current value.

[2] Vaughan Street Tree Inventory Phase 1 Urban Forest Effects and Values Vaughan Open Space Trees Inventory Phase 2 Urban Forest Effects and Values June 2019

Table 3-1 Asset Inventory & Valuation (Urban Forestry)

Asset Category	Asset Type	No.	Unit of Measure	Average DBH (cm)	New tree Unit Replacement Cost**	Mature tree Replacement Cost per DBH class per Species***	Total Replacement Cost****
Urban Forestry	Street* Trees	126,541	Ea.	18	$435 - $510	$1,100 - $12,484,000	$ 114,825,000
	Park Trees	-	Ea.	-	$435 - $510	-	-
	Woodlots	-	Ha.	-	-	-	-
	Open***** Spaces	4,377	Ha.	43	-	-	$ 357,723,000
Total							**$ 472,548,000**

* The number and diameter at breast height (DBH) of live street trees were sourced from City of Vaughan Parks & Urban Forestry 2019 inventory report.
** New tree unit replacement cost include supply, delivery, set up of the site, and two-year warranty period.
*** Mature tree replacement cost per DBH class was sourced from the City's 2019 iTree replacement cost report and inflated to current value; mature trees cost for various DBH groups is available for various tree species; the range of costs is for minimum and maximum cost for DBH groups of 6 to 12 in, which is considered to be approximately the size of mature trees.
**** Total replacement cost was sourced from the 2016 iTree Analysis reports, inflated to current value.
***** The number and DBH of open spaces was estimated based on three major assumptions: (1) trees<10cm DBH excluded; (2) Only groups of trees within City boundaries that >¼ ha on City managed lands or >1 ha on lands not managed by the City were included; (3) Only groups of trees where canopy cover was = or > than 20% were included; the average DBH of open space trees are weighted by canopy cover.

It should be noted that there can be different approaches for tree valuation. Similar to other municipal physical infrastructure assets, one tree can be replaced by another new tree. On the other hand, replacement values for trees can be treated differently than for typical City assets because trees continuously grow and increase in value. Another approach is to value trees based on the service the trees provided, meaning that one large tree should be replaced by many new trees to recover its service level. The determination of tree valuation approach is a decision that can be made differently at different municipalities.

The environmental and other benefits of trees increase exponentially with size, age and health. Table 3-2 shows the functional values and benefits of the City's urban forestry assets by using i-Tree modeling approach. The analysis is based on several assumptions including trees<10cm DBH excluded; only groups of trees within City boundaries that >¼ ha on City managed lands or >1 ha on lands not managed by the City were included; only groups of trees where canopy cover was = or > than 20% were included. Please refer to the City's 2016 i-Tree report for more detail.

Table 3-2: Functional Values and Benefits of The City's Urban Forestry Assets

Asset Type	Benefit Type	Amount	Unit of Measure	Value	Unit of Measure
Street trees	Pollution removal	13.73	Tons/year	$70,000	Per year
	Carbon Storage	15.63	Thousand tons	$1,799,660	Per year
	Carbon Sequestration	459.6	Tons	$52,890	Per year
	Oxygen production	1.226	Thousand tons/year	-	-
	Avoided runoff	1.408	Million cubic feet/year	$102,350	Per year
Open spaces	Pollution removal	28.3	Tons/year	$146,850	Per year
	Carbon Storage	43.4	Thousand tons	$4,692,350	Per year
	Carbon Sequestration	982	Tons	$112,620	Per year
	Oxygen production	2.619	Thousand tons/year	-	-
	Avoided runoff	2.907	Million cubic feet/year	$210,880	Per year
Total				**$7,187,600**	Per year

3.2 Age Summary

There are a variety of tree species that are planted and maintained at the City with differing lifespans. The trees are also grown under different environmental conditions. Therefore, estimating expected service life (ESL) for urban forestry assets is complicated. Based on workshop discussion with the City staff and information from similar municipalities, the average expected service life for street trees, park trees, and open street trees are determined to be 40, 40, and 100 years on average, respectively. Street trees often do not last as long as open space trees because of inadequate moisture, nutrition, more exposure to salt conditions, and other environmental factors. It should be noted that trees can achieve ages greater than 100 years if they are planted in the right place, monitored regularly, maintained proactively, and protected from development.

As the City's tree age information is not documented comprehensively, the age was estimated based on the DBH and tree growth factor for different species. When there is no adequate data for the estimation, the group median was used as shown below.

$$Age\ of\ Tree = DBH\ (in) \times Growth\ Factor$$

Figure 3-1 illustrates the average tree ages and remaining service life for street trees. The street trees are on average 80% through their expected service life.

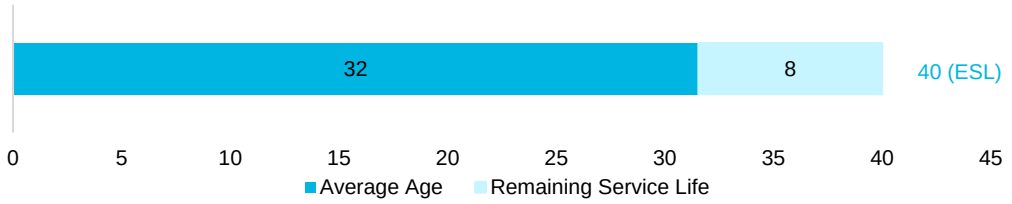


Figure 3-1: Average Asset Age as a Proportion of Average Expected Service Life (Street Trees)

For park trees, woodlots, and open space trees, age information has not been systematically documented or the information is not readily available.

3.3 Asset Condition

As the City's tree condition information is not available, an age and expected service life-based condition rating approach was applied as presented in **Section 2.1.3** and **Table 2-1**.

Figure 3-2 presents the condition profile for street trees based on the assumption of 40 years life expectancy. The City has 64% of street trees in Very Good to Good condition. There are approximately more than a quarter of trees in Poor condition meaning that they are approaching the end of their expected service lives, indicating a need for investment in the short to medium term. The remaining 8% of assets are in Fair condition indicating that the trees meet the current need. Attention may be required as these assets continue to age in future years.

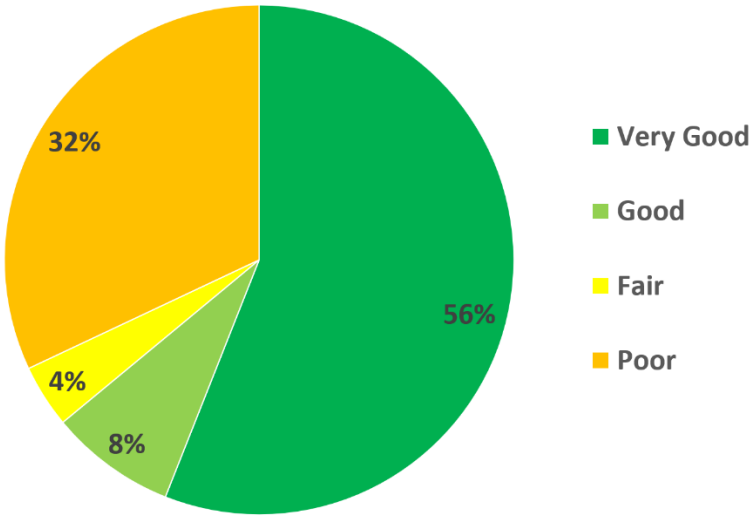


Figure 3-2: Asset Condition Summary (Street Trees)

For park trees, woodlots, and open space trees, age information has not been systematically documented or the information is not readily available, thus the condition profiles are not presented.

3.4 Levels of Service

While urban forestry Level of Service (LoS) is not required by Ontario regulation, the City has developed an urban forestry LoS metrics related to Quality & Reliability, Customer Service & Responsiveness, and Health & Safety. The City's urban forestry LoS performance measure metrics are presented in **Table 3-3.**

Table 3-3: Levels of Service Metrics (Urban Forestry)

Customer levels of service	Technical levels of service
• 5,771 new trees per year (2020).	• 11,252 trees inspected per year (2020).
• 21.9% canopy coverage (2020).	• 10,083 trees pruned per year (2020).

3.5 Life Cycle Strategies

3.5.1 Asset Acquisition / Procurement / Construction Strategies

The City is committed to planting trees for the enhancement of City parks, facilities, and streets. The City is taking a proactive approach to the identification of tree planting opportunities on a citywide basis.

The City acquires trees from developers as new neighborhoods are constructed. When planning trees in new subdivisions, the City's Forestry Operations division is involved in approving the locations of trees. The City will also determine which species to plant in the location to increase the health of the ecosystem by using City established criteria. If the trees are planted properly and in a healthy state, the City will assume the trees as new assets.

Considering tree protection in the initial stages of planning will result in the enhanced protection of trees and where trees are removed will provide for a clear replacement strategy. The City has a Tree Protection Protocol with procedures to maintain and enhance the public's tree canopy through the development approval process.

3.5.2 Asset Operations and Maintenance (O&M) Strategies

Urban Forestry asset O&M activities consists of two major components: pure urban forestry activities and other urban forestry O&M Activities. **Figure 3-4** presents the breakdown activities and five-year average cost for the City's Urban Forestry assets.

The five-year average annual pure urban forestry cost is approximately $1,029,000 and the average annual other activity cost is on average approximately $690,000 in the last five years. The City's pure tree O&M costs include forest maintenance (74%), forest enhancement (17.3%), tree mulching (0.1%), forest management (1.6%), tree fertilizing (0.2%), storm clean-up (1.8%), and invasive species management (5%).

Table 3-4: Urban Forestry O&M Activities and Five-Year Average Costs

O&M Activities	Description	Five-year Average Cost
Pure Urban Forestry O&M Activities	Include forest maintenance, forest enhancement, tree mulching, forest management, tree fertilizing, storm clean-up, and invasive species management.	$1,029,000
Other Urban Forestry O&M Activities	Include overhead cost and other activities such as Baker's Woods, Community Tree Planting Events, Uplands Golf Course etc.	$690,000
Total		**$1,719,000**

The following sections present the details of tree inspections and tree pruning that are the major urban forestry O&M activity at the City.

3.5.2.1 Street Trees and Park Trees

The City's O&M activities for urban forestry assets is largely comprised of tree inspections and tree pruning. Tree health and structure can be greatly increased by regular pruning, especially when the trees are young.

Generally, tree pruning brings many benefits to the City's trees including:

- Promoting tree health.
- Preventing insects and disease.
- Removing potential safety hazards.
- Making vehicle and pedestrian clearances.
- Reducing storm damage from high winds, snow, and freezing rain.
- Accommodating streetlights, buildings, and utilities.

The City prunes trees routinely according to species, age and, in some cases, location and uses different types of pruning:

- Crown cleaning consists of the removal of dead, dying, diseased, crowded, weakly attached and unhealthy branches from the crown of a tree.
- Crown thinning consists of the selective removal of branches to increase light penetration and air movement through the crown. Thinning opens the foliage of a tree, reduces weight on heavy limbs, reduces water intake, and helps retain the tree's natural shape.
- Crown clearance consists of the selective removal of the branches from the tree to provide clearance for buildings, vehicles, pedestrians, streetlights, traffic signals, road, regulatory signage and sight lines. Specification 2.4 metres (8 feet) over a sidewalk and 4.26 metres over a road.

- Crown reduction reduces the size of a tree, to make room for utility lines. Reducing the height or spread of a tree is best accomplished by pruning back the leaders and branch terminals to lateral branches that are large enough to assume the terminal roles. This method maintains the form and structural integrity of the tree.
- Crown restoration removes damaged limbs to restore an appropriate stable form to the tree. This is often necessary following storm damage.
- Crown complete is the holistic pruning of a tree that encompasses, cleaning and clearance.
- Crown establishment is the selective pruning of the crown of newly planted trees to promote an aesthetically and structurally sound branching system.

After being pruned, a tree might look rather bare. It will begin to look normal during the next growing season, with a healthier and more attractive form and structure. The City's current tree pruning activities include:

- Proactive tree pruning activities.
  - Rotational tree pruning. City staff examines the urban forest in a block pattern for possible hazards and tree health problems. The rotational pruning cycle was a 20- or 22-year cycle, and now the City is aiming to reduce the cycle of proactive pruning for all street trees to a seven-year cycle. These activities would result in a reduction in emergency pruning calls. Additionally, the City staff can find problems that would not have been reported by residents, such as an insect that needs to be controlled. The block pruning method can also focus on certain tree species that may require more attention.
  - Structural pruning for early age trees. Structural pruning is a type of pruning that aims to develop long-lived, low-risk, stable trees. The City believes that structural pruning for new assets is very critical which could effectively lessen the overall maintenance as trees growing. Immature trees that are left unpruned can develop many structural problems such as weak branch structure, crossing branches, and co-dominant leaders. As growth defects usually begin to develop at an early age and tend to become worse as trees mature. Prioritizing strategic structural pruning while a tree is young is important because it can help correct any problems before they progress far. Structural pruning can help promote proper trunk development, encourage good branching structure and establish permanent branches. Other pruning strategies can include removing branches that cross and correcting double leader. Most urban trees should only have one leader but can develop more if not managed properly.
- Reactive tree pruning activities. The City performs tree pruning to keep sidewalks safe and keep streets open. The tree cleaning work is performed on as per request basis including cleaning for stop signs, elevation of trees, sidelines, streetlights clearance, etc. Parks operations performs very limited pruning to allow winter operation vehicles on sidewalks. Parks will perform an assessment and then either pair with urban forestry or put a request to take care of the pruning that is required.

3.5.2.2 Woodlots

There are very limited O&M activities at the woodlots. It should be noted that the Baker's Woods (maple sugar bush), jointly own by the City, TRCA and the Region, is a woodlot where the City is responsible for maintenance work.

3.5.2.3 Open Spaces

The City generally do not maintain the trees in open spaces.

3.5.3 Asset Renewal and Replacement Strategies

The majority of tree planting activities is related to replacing trees. The City's renewal and replacement activities include tree removals and plantings. The trees are monitored, and problems addressed when triggered by staff observations and public feedback.

Most of the City's tree purchasing is for replacing existing trees. When the City purchases trees, the trees should meet the City's criteria related to species, structure of the tree, DBH size, etc. in the contract. For street trees and park trees, there is a process of tree purchasing from contractors. The process starts from inspection work order as requested from the residents. Then, the City inspects and determines if the trees can be replaced. After that, the City compiles a list and contacts the contractors. Currently, tree purchase cost will include a two-year warranty period.

During the warranty period, contactors are responsible for mulching, pruning, and regular watering. The purchased trees are actively patrolled by one of the City's forestry inspectors. The period between tree cutting down and planting in place is up to nine months including 30 days threshold of site inspection and eight months threshold of tree removal and planting or maintenance.

The City typically do not have planned tree planting at open spaces and woodlots.

3.5.4 Decommissioning and Disposal Activities

For street trees and park trees, when tree removal is considered necessary, disposal activities include tree brush and wood removal, stump removal, site restoration to prepare for replacement.

For woodlots and open spaces, trees are typically left in situ (original location) when they are deceased to decompose naturally. However, trees should be moved if the tree is deemed a hazard to a managed and well-used path, trail, or a house, etc. Disposal costs includes cutting logs and safety-related activities.

3.5.5 Risk Assessment

Risk assessment and prioritization approach can be an effective approach to develop prioritization plans. The City is a young, as time goes and tree growing, the urban forests management will become a greater component. The City needs to prioritize proactive maintenance activities when the trees are young to effectively reduce future damages.

As presented in **Section** Error! Reference source not found., risk scores can be calculated for each street tree by using its Probability of Failure (PoF) and Consequence of Failure (CoF) score. PoF can be estimated using the health condition and a condition rating system. The CoF or criticality rating considers evaluation of the relative importance of assets based on select criteria. With a comprehensive criticality rating, the following factors could be incorporated:

- Economic: Impact of the asset's failure on monetary resources e.g., replacement cost.
- Operational: Impact of the asset's failure on operational ability e.g., street location, AADT.
- Social: Impact of the asset's failure on society e.g., residential areas and commercial areas.
- Environmental: Impact of the asset's failure on the environment e.g., environmental sensitive areas.

It is recommended that the City perform a risk assessment to prioritize resources if there are budget constrains given prioritization under limited resources is very important for urban forestry at the City.

3.6 Urban Forestry 20-Year Funding Need Analysis

The average annual reinvestment rate for the City's urban forestry service is $3.5M over the next 20 years in inflated dollar values. This is equivalent to a total of approximately $70M over the next 20 year period, as presented in **Figure 3-3**. Looking ahead to the decade between 2031 and 2040, the City should prepare for more reinvestment funding as street trees continue to age and be exposed to the adverse urban environment.

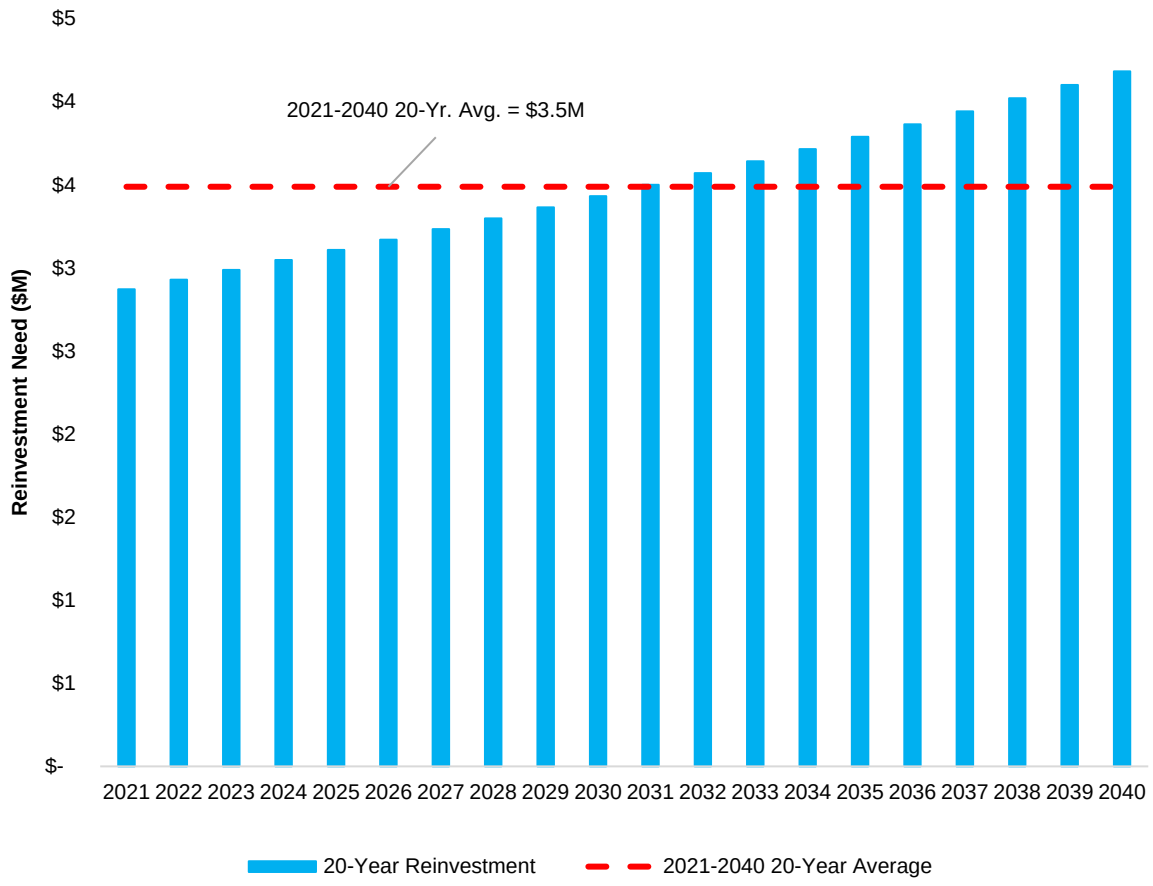


Figure 3-3: Urban Forestry 20-Year Total Reinvestment Need

Figure 3-4 shows a full picture of the City's Urban Forestry funding need forecast over the next 20 years, which provides the City the full funding requirements in order to perform effective financial planning activities.

Urban Forestry assets requires approximately $78M O&M cost over the next 20 years, equivalent to approximately $3.9M per year in inflated dollar value. It is important to note that the City is taking the initiative to reduce the pruning cycle from 20 to 22 year to seven years, which indicates more funding need for O&M cost in the next 20 years. The annual O&M was estimated by adding the extra cost for maintenance activities to the City's last five-year annual average O&M cost.

Unlike other service areas, urban forestry development costs in the last five years were close o zero as the new development trees were mostly acquired from developers. As such, with the additional of O&M, the total average annual reinvestment rate for the City's urban forestry assets increases to approximately $7.4M annually, for a total of $148M over the next 20-year period, as presented in Figure 3-4.

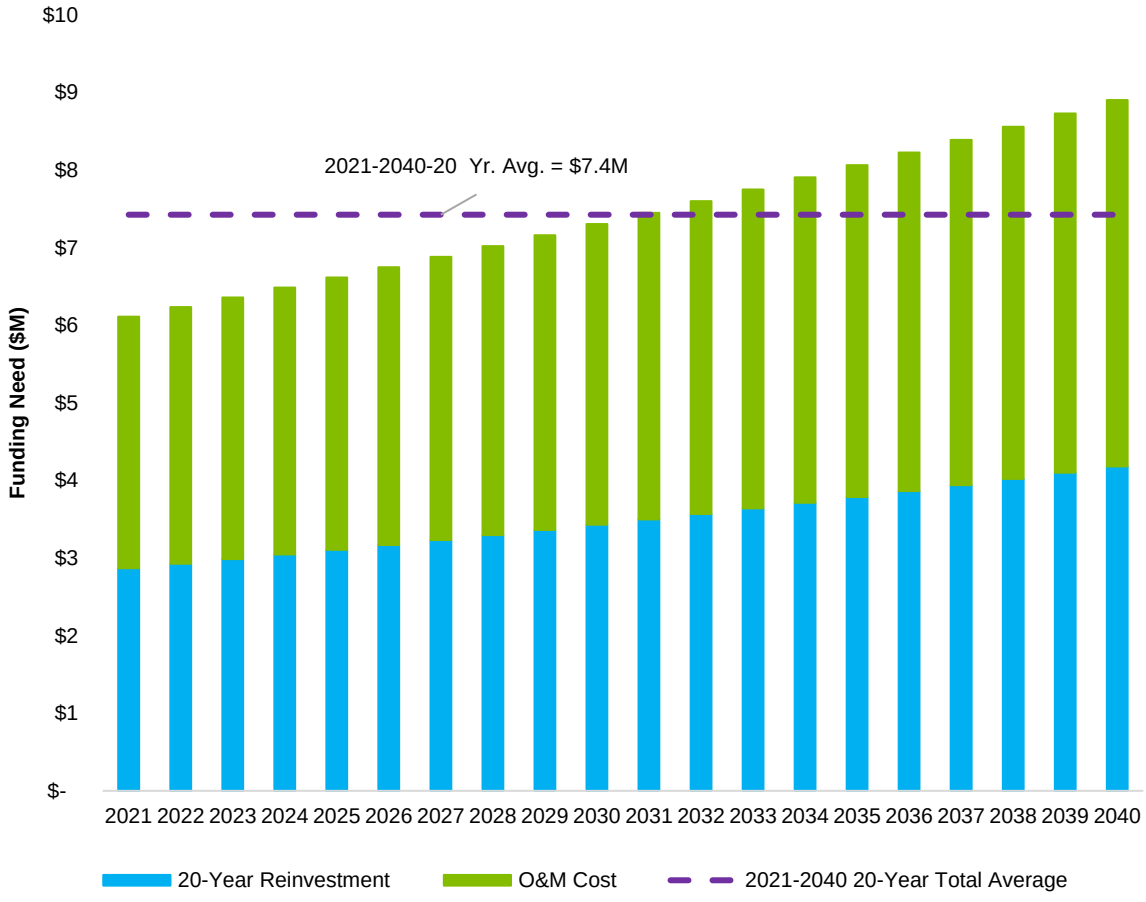


Figure 3-4: Urban Forestry 20-Year Reinvestment and O&M Cost Forecast

3.7 Recommendations for Urban Forestry AMP Continuous Improvement

Continuous improvement is an important component of any AM program and is achieved through the implementation of recommended improvement initiatives which support sustainable service delivery. While the City's urban forestry assets are young, there are current and future challenges that must be contended with. It is important to address these challenges thoroughly and promptly to leave a positive legacy for future generations.

AECOM has identified a set of activities that represents the next stage of AM planning and implementation within the City.

- **Continue to refine the asset inventory and close existing data gaps, so as to have a more accurate representation of the current state of the urban forestry assets; and, ultimately, to make more informed and defensible decisions**.
  - The City has made great efforts in establishing the street tree inventory. AECOM recommends the City to establish separate inventories for all urban forestry asset categories by developing park trees, woodlots, and open spaces inventories. Consideration should also be given to vegetation and other natural assets occurring within woodlots and open spaces.
  - The more robust asset data for Forestry assets along streets, parks, woodlots and open spaces would be leveraged in the development of the City's first Forestry Management Plan, which would be wider in scope than the accompanying Asset Management Plan for Urban Forestry.
  - Continue to collect missing asset information (or correct those that are known to be erroneous) through geospatial analysis, review of paper records, and verification by O&M personnel. The tree planting dates

are not available in GIS records and will require inputting this information into the GIS database to enhance the completeness of the asset age data. In addition, there are a number of trees with DBH of 0 in the GIS record.

  - The City should ensure that out-of-service tree assets are accurately represented in the inventory. Old legacy asset ID's from the GIS inventory should be removed or properly labeled. Assign a unique ID for a new asset and link the ID across data sources so that assets can be tracked throughout their whole lifecycle.
  - Develop a Data Governance Framework to define clear roles on data ownership and accountability, improve confidence in decision-making, improve asset data integrity and streamline information workflows.

- **Develop a consistent and structured health condition assessment process across all urban forestry assets.** This process will allow the City to:
  - Better forecast urban forestry assets replacement needs.
  - Avoid tree failures and the resulting economic, social, and environmental costs.
- **Continue the City's proactive tree maintenance approach including rotational tree pruning and early age structural pruning.**
  - Develop a rotational tree maintenance program to manage the change of tree pruning cycle. With the rotational tree pruning cycle reduced from 20- or 22-year to seven years, the City will need more staff resources and funding to implement the tree maintenance activities. The annual O&M cost is predicted to increase from $1.7M to $3.9M in inflated dollar values (**Figure 3-4).**
  - Continue the early age structural pruning activities. Early age strategic structural pruning for tree assets is very important as this proactive activity can effectively lessen the overall maintenance as trees grow. One of the leading practices is scheduling 3 pruning events for all trees within their first 10 years of life.
- **Continue to improve the living environment of street trees to extend their service life.** Salts are used at the City for winter control to keep roads and sidewalks clear of winter snow and ice, but it brings with it some side effects such as the damage (and even death) of trees and shrubs. The City has taken the initiative to reduce the usage of salts from an average of 1,000 tons / event to 700 tons / event using information supplied from the MDSS system. It is recommended that the City continues the initiative to achieve a balance between effectiveness of winter maintenance and extended service life of street trees.
- **Refine the Levels of Service Framework.**
  - Collect current asset performance data for key performance indicators (KPIs) that are not currently being tracked, including associated costs.
  - Analyze asset performance data to determine trends and to establish annual performance benchmarks.
  - Engage in a discussion with key stakeholders (see the **AM Strategy**) to establish service level targets and identify associated costs to meet those targets.
  - Once LoS targets have been decided upon, the City should develop strategies on how to meet service level targets considering its existing operating environment (i.e., staff availability, current funding, resources, etc.).
  - Develop a Customer Consultation Plan to engage the public and other stakeholders on the LoS framework and to better understand customers' willingness to pay for enhanced service levels.
- **Establish Urban Forestry risk assessment for future iterations of the AM plan, and use the risk assessment results to drive future condition assessments and financial needs forecasting.**
  - Calculate a risk score for each tree by using its Probability of Failure (PoF) and Consequence of Failure (CoF) score, to assess the ability of the assets to meet current and future operational requirements including capacity, regulatory, resilience and other LoS needs.
  - Continuing from previous bullet, incorporate more accurate expected service life information based on City's experience to better predict when trees need to be replaced.

  - Assess criticality and risk comprehensively for urban forestry assets in the inventory.
  - Frequently revisit and revise probability of failure and criticality model as needed.
  - Review risk attribute values periodically to ensure alignment with business objective and appetite.
  - Overlay the risk models with the current state of the assets (i.e., condition), and the 20-year financial forecast. Using this approach, the City could focus its monitoring, maintenance, and renewal and replacement budget and activities on high risk assets. Medium risk infrastructure could be addressed through the mitigation of failure through regular monitoring, and the low risk assets could be accepted with caution.

- **Establish a sustainable urban forestry funding model that fits the needs of the community.**
  - In light of the annual capital investment reinvestments outlined in **Figure 3-4**, the City should budget for urban forestry expenditures on asset replacement and O&M, to an average of $7.4M estimated per year over the next 20 years.
  - Review financial modeling assumptions on ESL and replacement values and update the financial model with new information as it becomes available. The financial model is based on a number of key assumptions that could have a significant impact on the outcomes of the model.
- **Continue to find ways to improve AM initiatives across the City by maintaining a high level of AM awareness through training, communication, and knowledge sharing.**
  - Conduct an AM Software Assessment to identify future system requirements that may include enhancing existing software, adding-on, or replacing.
  - Develop a Knowledge Retention Strategy & Internal Communications Plan to document staff AM knowledge and experience for reporting and succession planning purposes. Communicate AM improvement initiatives and enhance AM awareness internally through internal communication.
  - Aligning the Financial and Non-Financial Functions of Urban Forestry AM. Refer to **Section 2.4.3** for the framework to address the need to achieve the alignment.

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