Urban Street Trees Investment Strategy

Urban Forestry

City Operations | Parks and Roads

City of Edmonton

Prepared by: EHan Engineering

May 2017

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1 INTRODUCTION

The City of Edmonton is a leader in infrastructure management through the development and implementation of various strategies that cover various assets, including mature neighbourhoods and back alleys. The focus of this project is the City of Edmonton's tree canopy, which has tremendous impact on the City's livability through the enhancement of air quality, landscaping and other tangible benefits. It is vital to maintain and promote the growth of the tree canopy in a healthy and sustainable manner.

It is a unique proposition to consider trees as an integrated part of the City's hard infrastructure (linear and vertical). On July 11, 2016 the City of Edmonton Executive Committee passed a motion to:

> *"Draft Reinvestment Strategy for urban street trees with regards to the use of new technologies to improve soil volumes and growing conditions", as outlined in the September 27, 2016 City Operations Report CR_3884*

The City undertook this study to establish a reinvestment strategy for urban street trees. The following objectives evolved through the development of the strategy:

1. Establish an asset management system for urban street trees;
2. Utilizing the asset management system, assess the following:
    a. Current inventory
    b. Current condition assessment
    c. Integrate trees environmental benefits into the analysis
    d. Conduct benefit/cost ratio for the following scenarios:
        i. Base growing conditions
        ii. Ideal growing condition (new technology to improve soil volume and growing conditions)

As we experienced through the strategy development stages, it was evident that trees shall be approached in a different way than the other assets (hard assets) due to the following factors:

1. A trees' interaction with its surroundings is different than that of other assets; it is a living thing, which is why, in approaching the level of service, the team decided to not limit the condition index (not appropriate in this case) and target that the trees shall age to their maximum length of life before being replaced
2. Ability to assess the trees' benefits, which is unique and different than other assets. This opened the opportunity to evaluate the benefit/cost ratio for the various growing condition scenarios, the team utilized the National Tree Benefit Calculator to evaluate the various benefits, including:
    a. Stormwater benefit

b. Property value benefit
c. Energy
d. Air quality
e. CO2
f. Overall benefits represented in dollars ($)

The team conducted several meetings to establish the overall framework of the system and modelling strategy. It also conducted field inspections to confirm the current condition of the trees (during the period of December 2016 – February 2017). The model used the most up to date inventory information for urban trees. The current tree inventory, condition and current environmental benefits are listed below:

1. Number of trees: 7,699 trees
2. Current condition:
    a. Condition Index = 2.89 in scale 1 to 5 (1=worst and 5=new)
    b. %F+D = 16.89%
    c. %F = 8.90%
3. Currently the trees produce the following benefits (in 2017)
    a. Storm water retention = 1,618,275 gallons
    b. Energy consumption reduction = 276,313 Kilowatt hours
    c. CO2 capture = 1,007,697 pounds (449.86 tons)
    d. Total Benefits in Dollars = $155,705 (for year 2017)

The analysis was conducted for two main scenarios:

1. Maintain the current growing condition by replacing the trees without any soil volume increase or enhancements
2. Apply soil volume enhancement when applicable depending on the area and applicability of the technology

Each scenario was analysed and the results are included in section 3. The resultant benefit/cost ratio is shown below in Figure 1, and by investigating the results, it is evident that Scenario 2 would provide a much higher value and benefit to the City, if adopted.

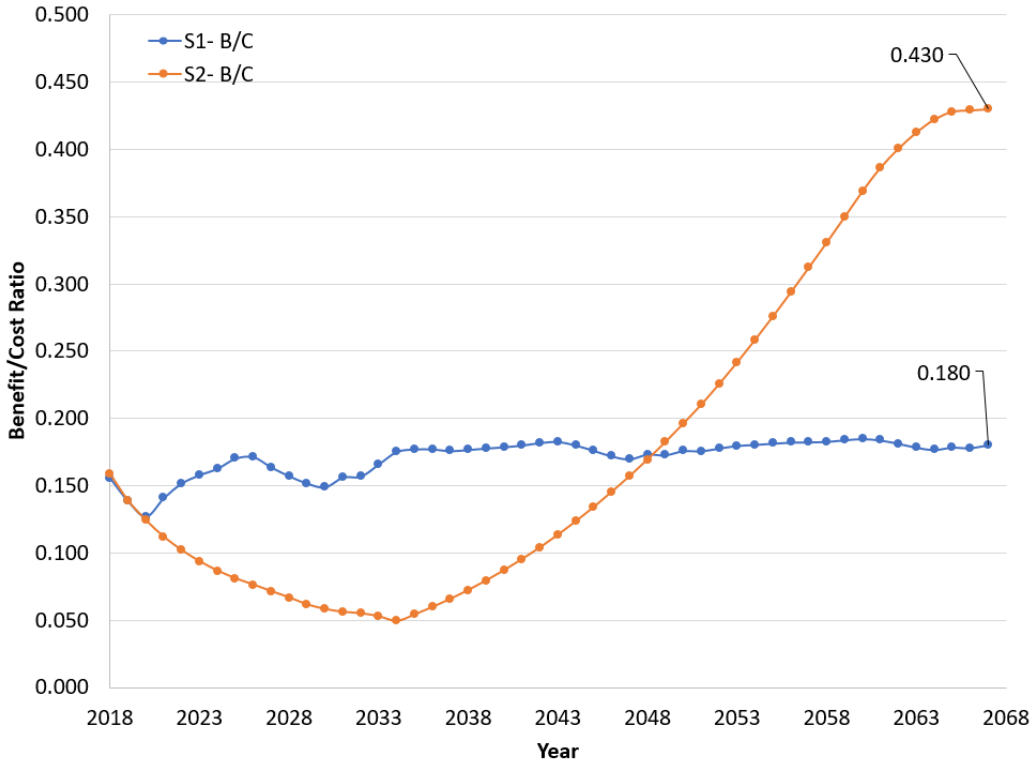

Figure 1. Urban Trees Growing Scenarios Benefit/Cost Ratio

The following sections will introduce the analysis framework and results.

2 Analysis Framework and Modelling Process

This section will introduce the following components used in the modeling and analysis:

1. Tree Species, Categorization and Analysis Hierarchy
2. Life Expectancy (growth curves) and Condition
3. Tree Benefits
4. Renewal Actions and Associated Cost
5. Modelling Process Description

2.1 Tree Species, Categorization and Analysis Hierarchy

The City of Edmonton's Urban Forestry department maintains an in-house inventory of all trees within the urban environment, which comprises the scope of this study. During the project's initiation phase, the team conducted meetings to discuss the available information and what is required for the analysis; in general the

available information was adequate for the analysis and the team decided to update the tree condition assessment to assure the validity of the results.

The original inventory of urban trees includes overlapping names of tree species, which was reviewed by the team, and decided to remove the overlap and revise the missing information. After the review, the team decided to use thirteen species in the analysis, shown in Table 1. These species also were categorized into two types, depending on their size, from small to large.

Table 1. Tree Species and Types

Number	Species	Tree Type
1	Apple	small
2	Ash, green	Large
3	Aspen, quaking	Small
4	Chokecherry, common	small
5	Elm, American	Large
6	Lilac, Japanese tree	small
7	Linden, littleleaf	Large
8	Maple, silver	Large
9	Oak, bur	Large
10	Pine, scotch	Large
11	Poplar, black	Large
12	Spruce, blue	Large
13	Willow	Large

The next step was to develop the urban trees hierarchy, which is a key element of any asset management analysis. The hierarchy development concepts are listed below:

1. Minimize the number of lower elements in the hierarchy to reduce analysis complexity
2. Divide the study area (urban streets) into a manageable number of locations
3. The size of each location should be manageable and sized appropriately to represent constructible projects in the future
4. The resultant hierarchy should be usable for reporting and development of projects
5. The developed hierarchy shall facilitate the analysis requirements (analysis scenarios)

Based on these concepts the team decided the following:

1. Divide the study area into 51 locations
2. Divide the tree inventory in the associated area

3. Each location will have 26 elements, representing:
    a. Thirteen tree species
    b. Two growing conditions:
        i. Base growing conditions
        ii. Ideal growing conditions

The adopted hierarchy is shown in Figure 2. The resultant analysis modelling components are the following:

1. 51-location model
2. Each model includes 26 elements
3. Total of 1,326 elements (analysis level)

The adopted final locations are shown in Table 2.

Table 2. Analysis Location ID and Names

ID	Location Name
1001	23 Ave. 66 St. Millwoods Rd. CT and EB
1002	28 Ave. 55 St. Hewes CT
1003	50 St. 102 to 109A Ave. EB and TT
1004	51 Ave. 111 to 122 St. CT
1005	53 Ave. 140 St. to Riverbend Rd. CT
1006	63 Ave. 99 to 92 St. TT and EB
1007	71 Ave. 114 to 116 St. CT
1008	75 St. 90 to 98 Ave. MC
1009	87 Ave. 140 St. to 169 St.
1010	90 Ave. 50 to 75 St. SB and CT
1011	97 St. 111 Ave. to Yellowhead Tr. EK CT
1012	99 St. 68 to 80 Ave. EB
1013	106 Ave. 50A St. to Hardisty Dr. EB
1014	106 St. and 40 Ave. MC
1015	107 Ave. 101 to 116 St. EK GS EB
1016	109 St. 105 to 108 Ave. EK GS EB
1017	111 Ave. 102 to 119 St.
1018	113 and 114 St. 61 University Ave. CT and MC
1019	118 Ave. 97 St. to 78 St. EK GS
1020	118 Ave. St. Albert Trail to 142 St. CT SB
1021	124 St. Jasper to 111 Ave. CT and MC and EK and SB
1022	127 Ave. 74 to 116 St. and 113A St. EB
1023	132 Ave. 66 to 127 St. GS
1024	142 St. 85 Ave. to Summit Drive
1025	144 Ave. 50 to 97 St. EB
1026	149 St. EB
1027	153 Ave. 97 to 127 St. SB CT
1028	178 St. 95 to 100 Ave. CT

1029	Beverly BRZ TT
1030	Downtown City Hall
1031	Downtown District 5
1032	Downtown District 6
1033	Downtown District 7
1034	Downtown Grant McEwan
1035	Downtown Ice District
1036	Downtown Jasper Ave
1037	Downtown South of 99 Ave
1038	French Quarter TT
1039	Groat Rd. 111 to 114 Ave. CT SB
1040	Riverbend Road MC and CT
1041	St. Albert Trail and Groat Rd. CT and SB
1042	Strathcona BRZ and Whyte Ave. TT
1043	34 Ave. 50 to 66 St.
1044	84 St. 98 Ave. to 101 Ave. and 85 St. 95 Ave. to 96 Ave.
1045	98 Ave. 84 St. to 75A St.
1046	101 Ave. 50 to 70 St. and 101A Ave. 67 St. to 70 St.
1047	121 St. Jasper Ave. to 104 Ave.
1048	137 Ave. CM 27 50 St. on NE side
1049	137 Ave. CM 123 149 St. on NW side
1050	Boyle St.
1051	University Ave. 114 St. Sask Dr.

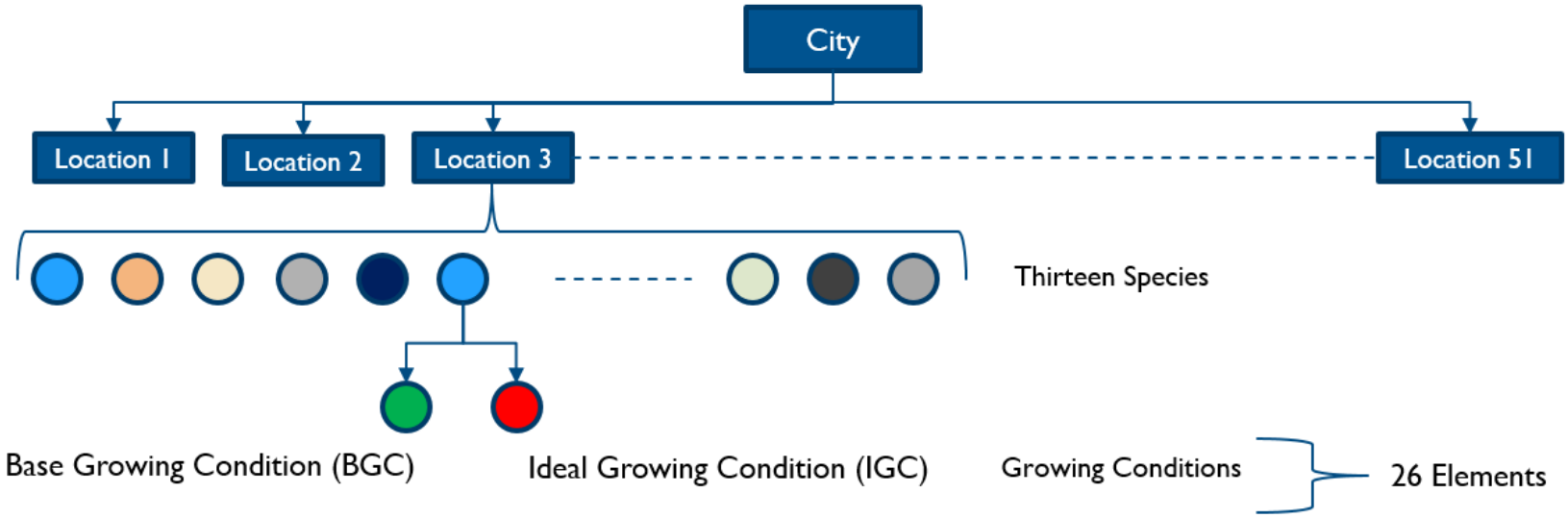

Figure 2. Urban Trees Modelling Hierarchy

2.2 LIFE EXPECTANCY AND CONDITION

In developing the life expectancy curves and condition assessments the team discussed the available information (RIMS model) and the expert opinion about various trees' growth and decided to link that information with the tree type (small, large) and their growing conditions and then developed the growth curve and condition. The used life expectancy is shown in Table 3. This table also shows tree benefit efficiency.

Table 3. Life Expectancy and Benefits Efficiency

Condition	Without Soil Amendment		With Soil Amendment	
	Duration	Tree Efficiency	Duration	Tree Efficiency
A	4	100%	12	100%
B	5	80%	20	90%
C	8	70%	12	80%
D	2	40%	5	40%
F	1	10%	1	10%

Tree growth was developed as a function of growing conditions (soil volume) and tree type (small or large). These growth curves are linked with each individual tree and were used during the analysis to evaluate the tree's environmental benefits. In the case of base growing conditions (replacing the tree without soil volume enhancement) the trees will not grow to their fullest potential, as they would given adequate soil volume. As a result, the tree would live for 20 years and grow to a maximum size of 8", as shown in Figure 3.

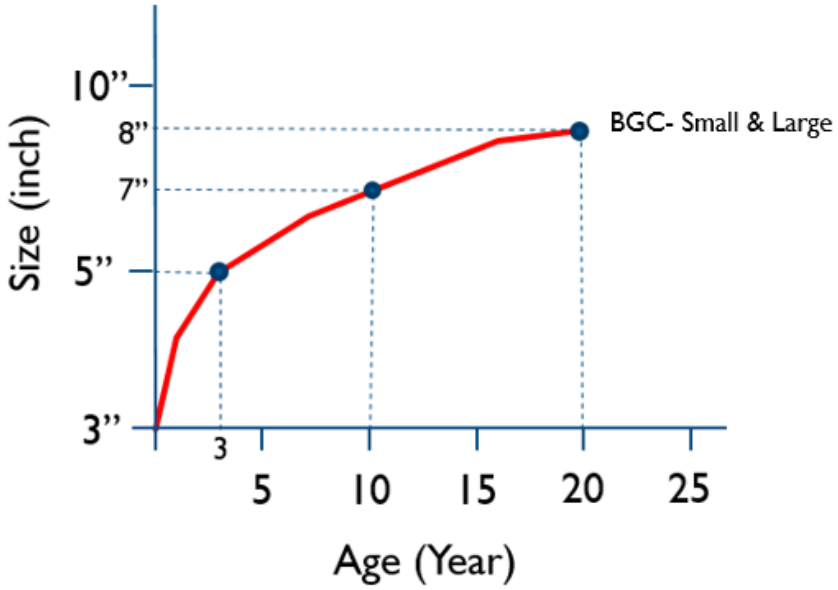

Figure 3. Base Growing Condition – Growth Curve

When the tree is planted in an ideal environment, with adequate soil volume, then the tree would thrive and live to its maximum life expectancy, and its size would be larger than in the base growing conditions. A large tree in ideal growing conditions would live for 50 years and its size would grow to 30 inches. The growth curve in ideal conditions is shown in Figure 4.

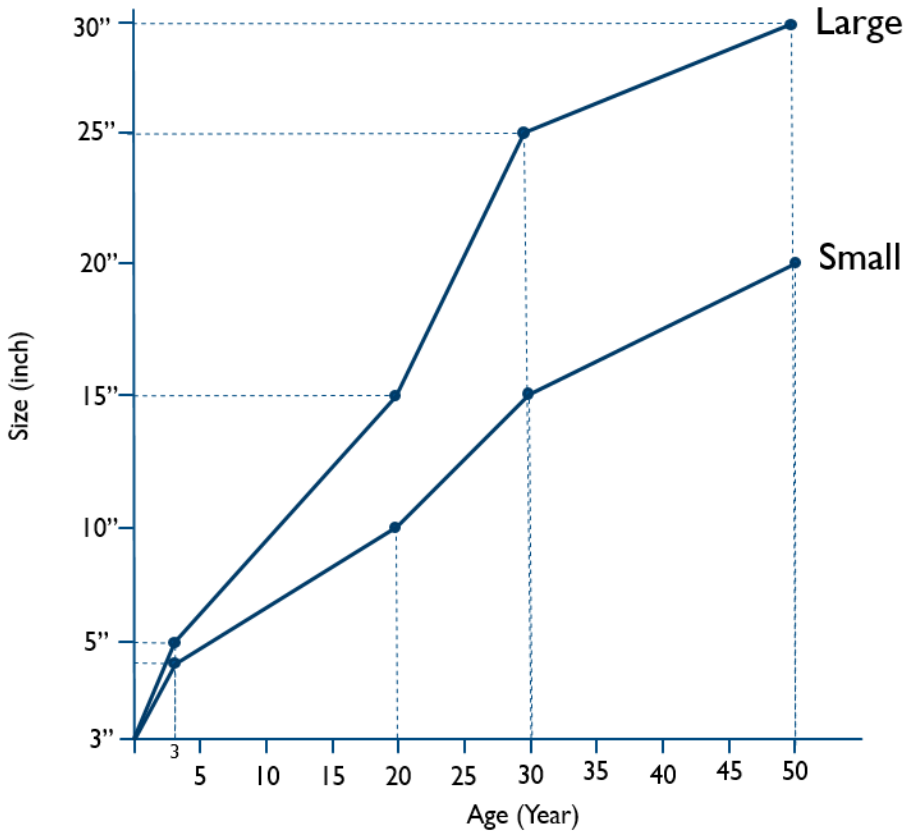

Figure 4. Ideal Growing Condition – Growth Curve

The condition index is a function of age and the team decided to use the continuous deterioration curves that represent the aging of the tree. As can be seen above, the life cycle under the ideal conditions is about 50 years. The team decided to analyse the urban trees for the 50-year analysis span.

2.3 TREE BENEFITS[1]

In order to reflect the unique nature of trees as an asset the team decided to incorporate tree benefits into the analysis. This is a critical component of the analysis to distinguish between the two analysis scenarios: 1) Base Growing Conditions (BGC), and 2) Ideal Growing Conditions (IGC). The calculation of these benefits is very complex and EHAN Engineering Ltd. does not take any ownership for the calculation. Therefore, EHan Engineering Ltd. decided to use an established calculator which is readily available online (National Tree Benefit Calculator)[2]. The calculator requires the following inputs:

1. Location (Edmonton)

[1] National Tree Benefit Calculator: Online Access
[2]http://treebenefits.com/calculator/treeinfor.cfm?zip=T0N%201A0&city=Edmonton&state=AB&climatezone=Midwest&country=CA

2. Tree Species
3. Tree Diameter
4. Land Use (Small Commercial Business)

We used the calculator for each of the 13 tree species and for the size within the analysis boundary (3 to 30), then these numbers were compiled into the model database and used during the analysis. Sample calculation is shown below in Figure 5 and Figure 6.

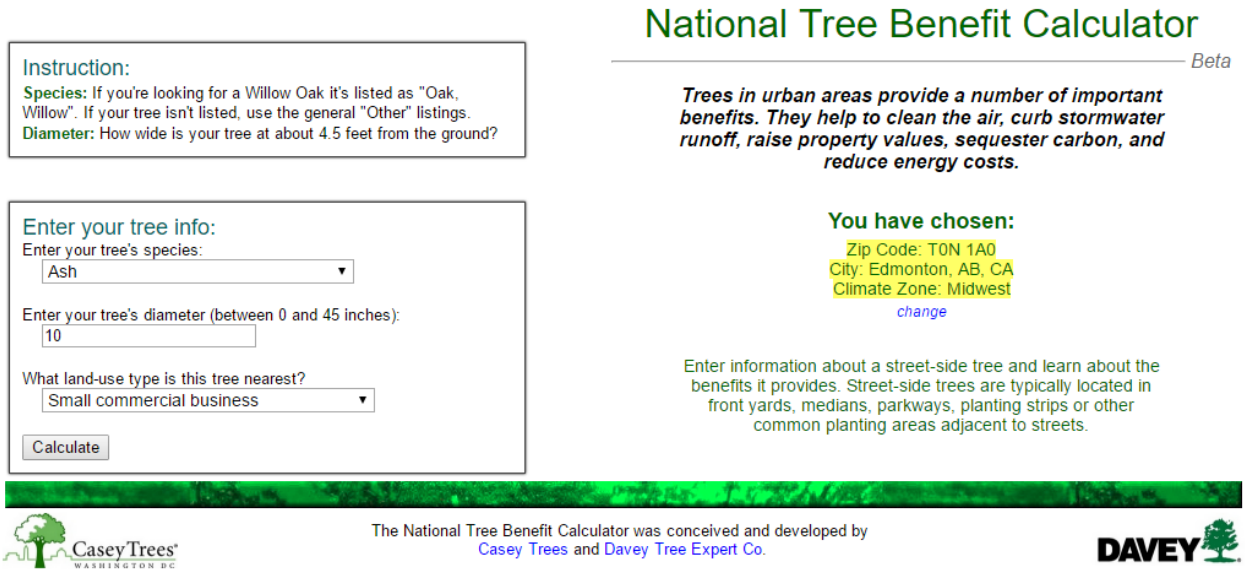

Figure 5. National Tree Benefit Calculator (Input sample)

Figure 6. National Tree Benefit Calculator (Output sample)

As shown in Figure 6, tree benefits include the following:

1. Stormwater retention and interception by:
    a. Intercepting and holding rain on leaves, branches and bark
    b. Increasing infiltration and storage of rainwater through the tree's root system
    c. Reducing soil erosion by slowing rainfall before it strikes the soil
2. Property Value: trees increase property values
3. Energy: reducing electricity use for cooling and reducing consumption of oil or natural gas. Trees modify climate and conserve energy use in three principal ways:
    a. Shading reduces the amount of heat absorbed and stored by buildings
    b. Evapotranspiration converts liquid water to water vapor and cools the air by using solar energy that would otherwise result in heating of the air
    c. Tree canopies slow down winds, thereby reducing the amount of heat lost from a home, especially where conductivity is high (e.g. glass windows)
4. Air Quality: trees mitigate health effects caused by pollution
5. CO2: trees can have an impact by reducing atmospheric carbon in two primary ways:
    a. They sequester ("lock up") CO2 in their roots, trunks, stems and leaves while they grow, and in wood products after they are harvested
    b. Trees near buildings can reduce heating and air conditioning demands, thereby reducing emissions associated with power production

6. Overall Benefits: a final representation of the total tree benefits each year

The urban street trees model utilized four benefits from the calculator (see Figure 7) including:

1. Energy
2. Storm Water
3. CO2
4. Overall Benefits

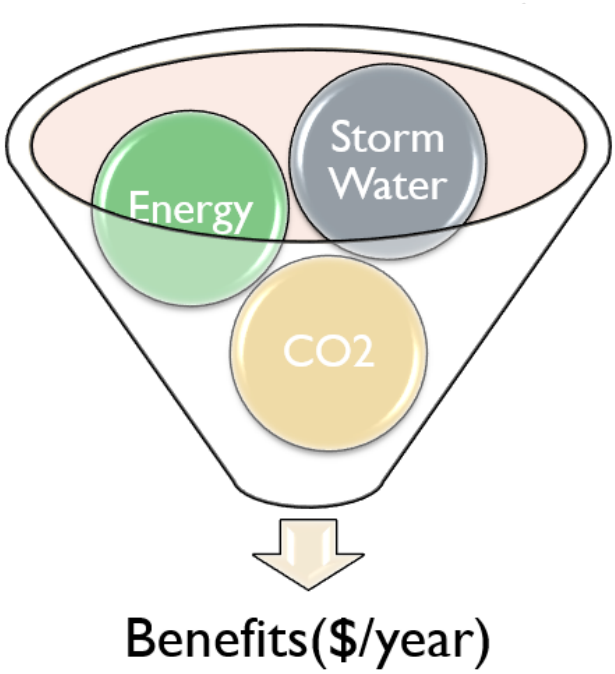

Figure 7. Urban Street Trees Model

When considering the urban street trees inventory as per 2017, the following are the current benefits the City gains from these 7,699 trees:

Table 4. City of Edmonton – Urban Street Trees Benefits

Benefit	Unit	Value
Storm Water	Gallons	1,618,275
Energy	Kilowatt hours	276,313
CO2	Pounds	1,007,697
Overall Benefits	Dollars ($)	$155,705

2.4 RENEWAL ACTIONS AND ASSOCIATED COST

Tree renewal is done through replanting the tree only; there are no rehabilitation actions, and the model does not account for yearly maintenance and watering, as shown in Figure 8.

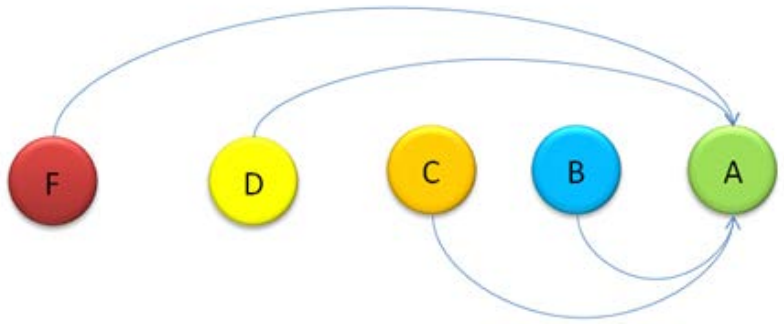

Figure 8. Tree Renewal Action (Replace Only)

The cost of replanting a tree depends on the location and growing conditions. The team discussed the cost and used current tender costs and identified the cost of renewal for each location, especially for the ideal growing conditions which would include soil volume increases which could be done through:

1. Soil Cell
2. Suspended Pavement
3. Continuous Trench

The cost for the base growing condition is about $1,600 to $2,800 per tree, and the ideal growing condition cost ranges between $4,156 to $14,875 per tree. The cost per location is shown in Table 5.

Table 5. Trees Replacement Cost Per Location and Growing Conditions

ID	Name	Tree without amendment (Thous.)	Large Tree (soil amend) (Thous.)	Small Tree (soil amend) (Thous.)
1001	23 Ave. 66 St. Millwoods Rd. CT and EB	$1.60	$4.15	$4.15
1002	28 Ave. 55 St Hewes. CT	$2.80	$14.88	$7.87
1003	50 St. 102 to 109A Ave. EB and TT	$1.60	$4.15	$4.15
1004	51 Ave. 111 to 122 St. CT	$1.60	$4.15	$4.15
1005	53 Ave. 140 St. to Riverbend Rd. CT	$1.60	$4.15	$4.15
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1030	Downtown City Hall	$2.80	$14.88	$7.87
1031	Downtown District 5	$2.80	$14.88	$7.87
1032	Downtown District 6	$2.67	$8.82	$4.15
1033	Downtown District 7	$2.13	$9.19	$5.18
1034	Downtown Grant McEwan	$2.07	$8.97	$4.15
1035	Downtown Ice District	$2.65	$13.78	$4.15
1036	Downtown Jasper Ave.	$2.71	$14.23	$4.15
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1050	Boyle St.	$1.60	$4.15	$4.15
1051	University Ave. 114 St. Sask Dr.	$1.60	$4.15	$4.15

2.5 MODELLING PROCESS DESCRIPTION

The two-step process enables optimization at two levels: the first is the location level, in which all investment plans are being explored and established. The second step is implemented on the inventory level (City Level), as shown in Figure 9. Input data, including inventory information, deterioration curves, and renewal strategies, are compiled to establish base models. These models are then optimized for all potential solutions.

The first step results in the development of a program profile (Location). These profiles are then used to optimize various investment plans at the City Level. The expected outcome is a prioritization list, the associated budget needs, and the corresponding conditions. Based on this concept, each neighbourhood will have 51 scenarios, as shown in Table 6.

Table 6. Urban Street Trees Investment Plan (Profile)

Scenario #	Explanation
1	Do Nothing- Do not renew the tree assets in this location
2	Select this location in year 1 and keep the asset condition within the acceptable level of performance for the next 49 years.
3	Select this location in year 2 and keep the asset condition within the acceptable level of performance for the next 48 years.
...	...
50	Select this location in year 49 and keep the asset condition within the acceptable level of performance for the next year.
51	Select this location in year 50.

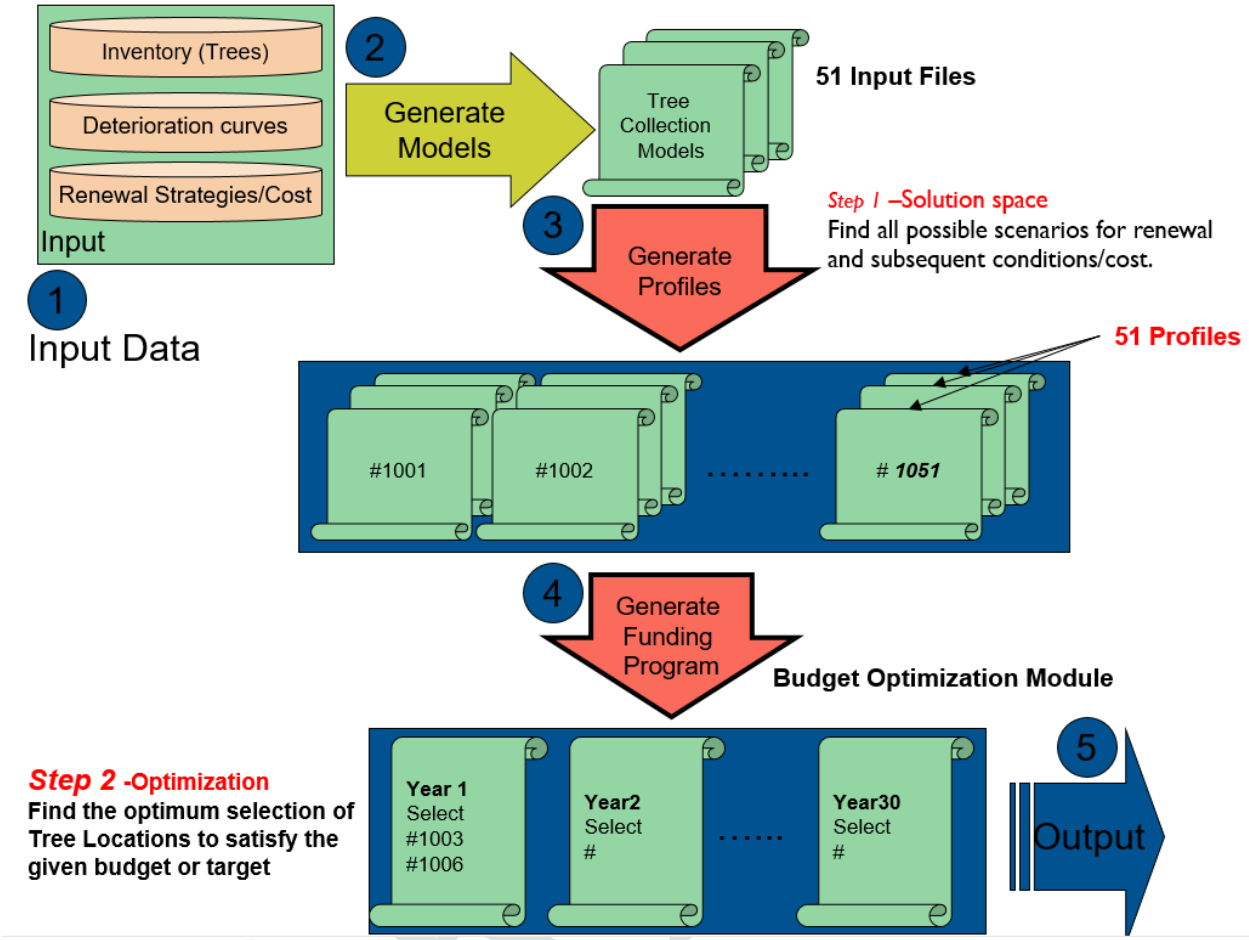

Figure 9. Urban Street Trees Two-step Optimization Process

Models were established to simulate the progression of the assets over 50 years based on all possible investment strategies for each location. The developed models include the following information:

1. Each neighbourhood includes 26 subsystems (tree species and growing condition)
2. The total number of locations is 51. The input properties of each location are prepared in a location model
3. Deterioration/Growth curves are specified for each subsystem
4. Distribution of assets in various conditions (A, B, C, D, and F) are queried from tree inventory data
5. For each of the subsystems, all possible renewal (rehabilitation and replacement) actions and the associated unit costs are specified

When analyzing urban street trees the acceptable level of performance was set to be:

1. C.I. (not enforced in this analysis)

2. %F+D <= 10%
3. %F = 0%

Step two optimization at the city level: output from step one is used to conduct an optimization scheme to solve the following:

1. Objective:
    a. Maximize C.I. & Minimize %F+D by selecting a set of locations each year
2. Output. For each scenario, the results encompass:
    a. Prioritization list (for each scenario)
    b. Investment need/year
    c. Performance Measures C.I. & %F+D & %F, and Benefits

3 ANALYSIS AND RESULTS

This section will present the analysis scenarios and results. For this project the main objective was to assess the investment required to maintain urban street trees and explore the impact of changing planting practice by increasing soil volume. The following scenarios were analyzed:

1. Do Nothing: no investment in urban street trees for 50 years
2. Benefit Maximization Analysis: in this analysis, the two growing scenarios were analyzed under the same available budget:
    a. Scenario 1 (S1): Base Growing Conditions
    b. Scenario 2 (S2): Ideal Growing Conditions

The results were compared for the two scenarios, including:

a. Proposed investment for each scenario, based on available budget profile as shown in Table 7
b. Resultant Performance (City Level)
    i. Condition Index (C.I.)
    ii. %F+D
    iii. %F
c. Resultant Environmental Benefits
d. Benefit/Cost Ratio

Table 7. Available Budget

Step	Year	Available Budget (Thous.)
1	2018	1000.00
2	2019	1250.00
3	2020	1500.00
4	2021	1750.00
5	2022	2000.00
6	2023	2250.00
7	2024	2500.00
8	2025	2750.00
9	2026	3000.00
10	2027	3500.00
11	2028	4000.00
12	2029	5000.00
13	2030	5000.00
14	2031	5000.00
15	2032	5000.00
16	2033	8000.00
17	2034	8000.00
18	2035	9000.00
19 to 50	2036 to 2067	9000.00

3.1 RESULTS – PROPOSED INVESTMENT

The two scenarios were analyzed under the same budget and for the same level of service. The required investment for each scenario is shown in Figure 10 and Table 8.

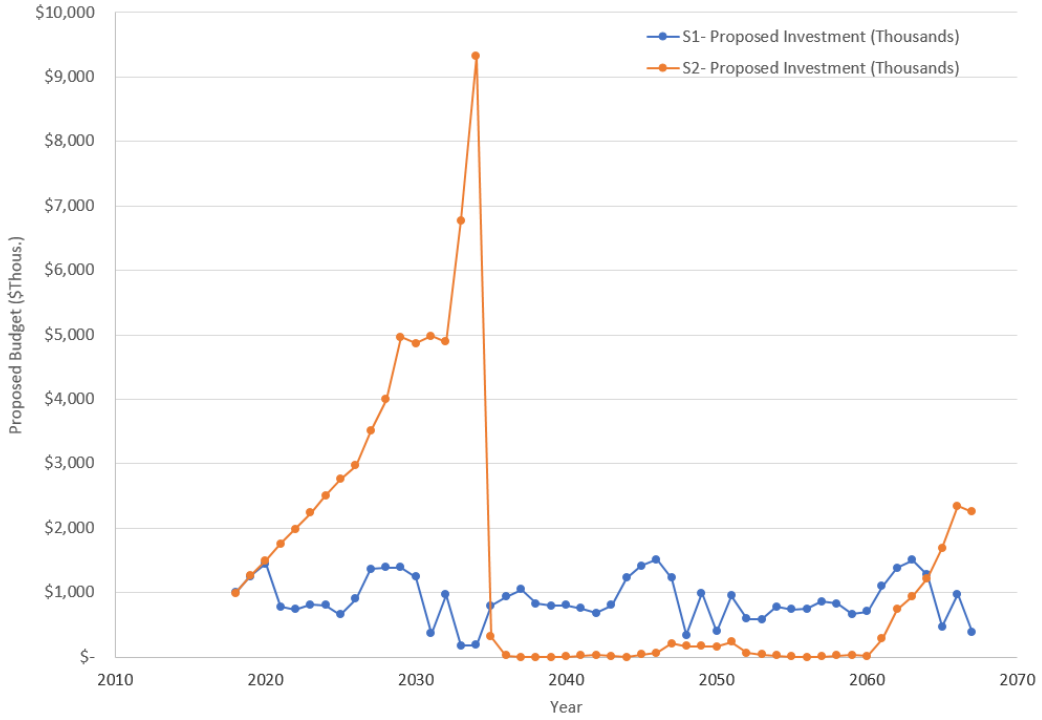

Figure 10. Proposed Required Investment for each Scenario

Table 8 Proposed Required Investment for each Scenario

Year	Available Budget (Thousands)	S1- Proposed Investment (Thousands)	S2- Proposed Investment (Thousands)
2018	1000.00	$999.79	$988.34
2019	1250.00	$1,249.37	$1,259.38
2020	1500.00	$1,444.90	$1,496.72
2021	1750.00	$776.76	$1,753.55
2022	2000.00	$741.94	$1,985.93
2023	2250.00	$813.79	$2,236.74
2024	2500.00	$806.24	$2,501.61
2025	2750.00	$660.57	$2,759.33
2026	3000.00	$902.90	$2,969.23
2027	3500.00	$1,363.97	$3,509.09
2028	4000.00	$1,387.27	$3,993.52
2029	5000.00	$1,393.25	$4,960.80

2030	5000.00	$1,246.11	$4,863.97
2031	5000.00	$365.85	$4,981.35
2032	5000.00	$969.29	$4,887.43
2033	8000.00	$180.43	$6,767.43
2034	8000.00	$185.84	$9,331.11
2035	9000.00	$798.81	$318.18
2036	9000.00	$933.36	$23.18
2037	9000.00	$1,047.99	$-
2038	9000.00	$827.56	$-
2039	9000.00	$798.09	$-
2040	9000.00	$807.07	$8.82
2041	9000.00	$754.07	$24.92
2042	9000.00	$684.46	$30.85
2043	9000.00	$800.83	$12.46
2044	9000.00	$1,229.22	$-
2045	9000.00	$1,413.33	$34.76
2046	9000.00	$1,512.46	$66.45
2047	9000.00	$1,230.56	$212.02
2048	9000.00	$343.13	$169.98
2049	9000.00	$987.51	$169.89
2050	9000.00	$399.77	$156.79
2051	9000.00	$951.52	$236.07
2052	9000.00	$588.05	$65.31
2053	9000.00	$585.47	$39.35
2054	9000.00	$777.07	$20.68
2055	9000.00	$740.37	$4.15
2056	9000.00	$748.69	$-
2057	9000.00	$858.95	$8.82
2058	9000.00	$824.28	$24.92
2059	9000.00	$668.01	$30.85
2060	9000.00	$708.06	$12.46
2061	9000.00	$1,097.11	$282.91
2062	9000.00	$1,377.50	$735.60
2063	9000.00	$1,501.36	$945.11
2064	9000.00	$1,271.97	$1,217.11
2065	9000.00	$471.89	$1,689.59
2066	9000.00	$971.96	$2,345.82
2067	9000.00	$377.06	$2,256.55
	Total Investment	$44,575.83	$72,389.13

The total investment for Scenario 2 is lower than Scenario 1 due to the difference in life expectancy between the trees in the base growing conditions and the ideal growing conditions.

3.2 RESULTS – CONDITION INDEX

The two scenarios were analyzed under the same budget and for the same level of service. The resultant condition index for each scenario, in addition to the do-nothing scenario, is shown in Figure 11.

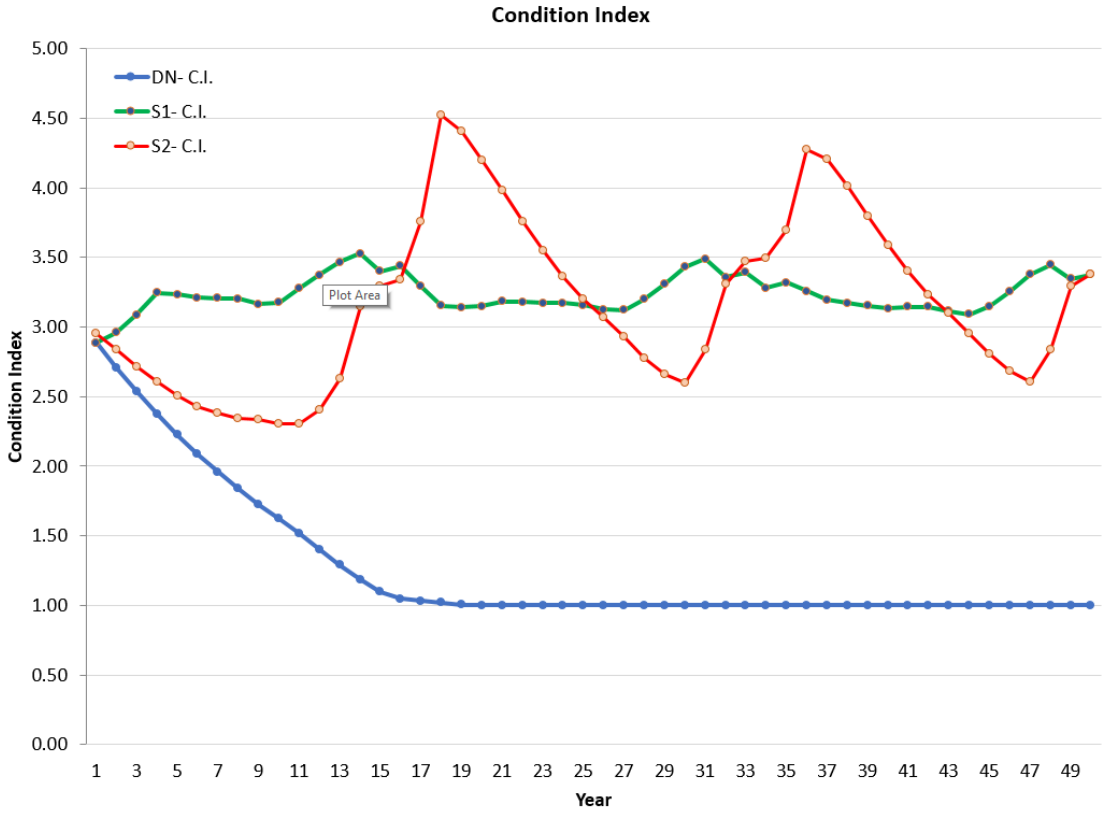

Figure 11 Analysis Results – Condition Index

3.3 RESULTS – PERCENTAGE OF ASSETS CONDITION F&D

The two scenarios were analyzed under the same budget and for the same level of service. The resultant percentage of assets in condition F&D, in addition to the do-nothing scenario, is shown in Figure 12.

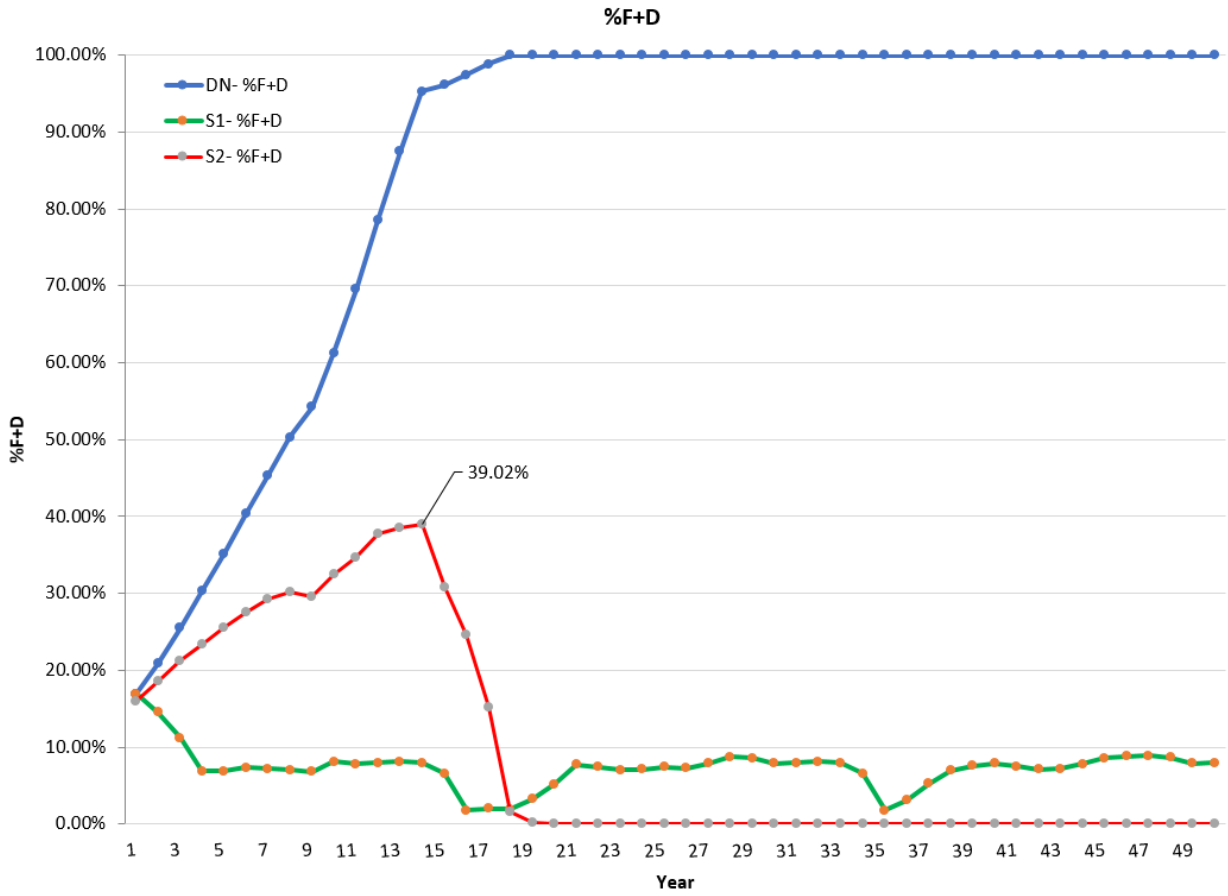

Figure 12. Analysis Results %F+D

3.4 RESULTS – PERCENTAGE OF ASSETS CONDITION F

The two scenarios were analyzed under the same budget and for the same level of service, the resulted percentage of assets in condition F, in addition to the do-nothing scenario, is shown in Figure 13.

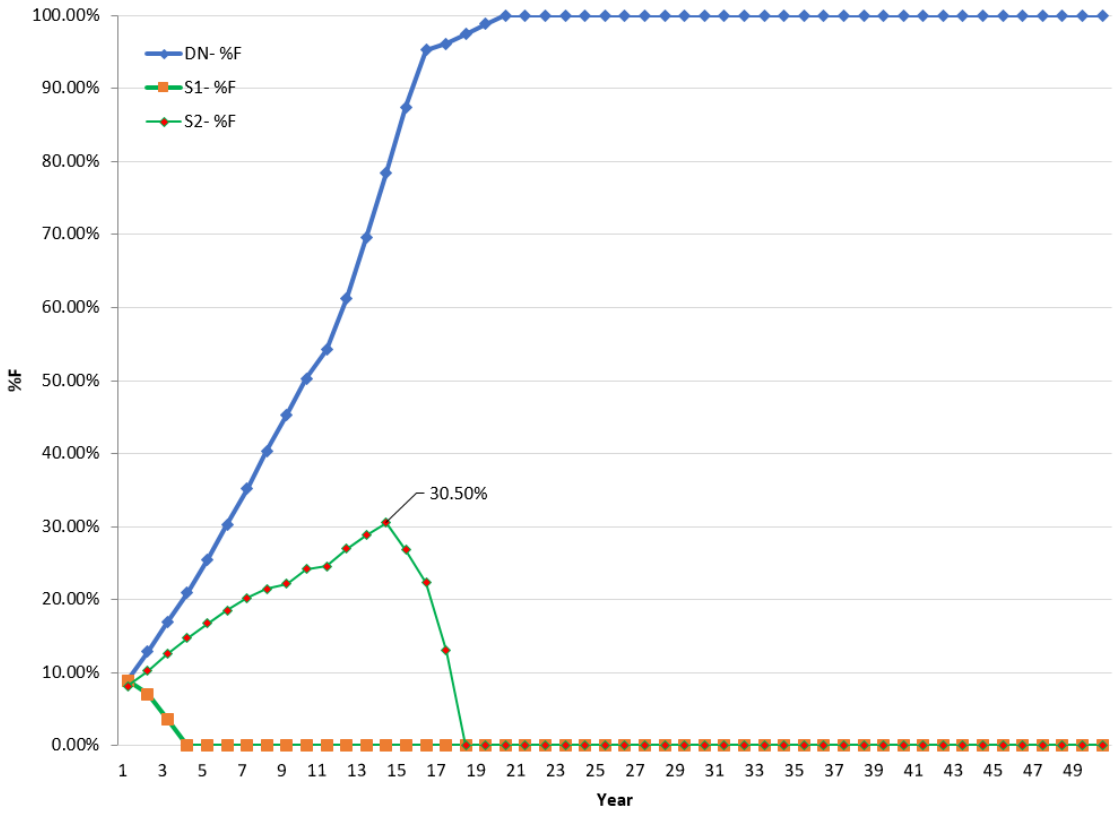

Figure 13. Analysis Results- %F

3.5 RESULTS – TREES BENEFITS

The two scenarios were analyzed under the same budget and for the same level of service, the resulted trees benefits are shown in Table 9 and Table 10.

Table 9. Trees Benefits for Scenario 1

Year	Scenario 1			
	Storm Water (Gallons)	Energy (Kilowatt hours)	CO2 (Pounds)	Benefits ($/year)
Year- now	1,618,275	276,313	1,007,697	155,705
Year- 50	1,655,651	284,186	1,042,185	160,828
Total	82,663,639	14,207,720	51,936,623	8,034,555

Table 10. Trees Benefits for Scenario 2

Year	Scenario 2			
	Storm Water (Gallons)	Energy (Kilowatt hours)	CO2 (Pounds)	Benefits ($/year)
Year- now	1,629,746	278,330	1,013,519	156,756
Year- 50	17,863,150	1,534,106	5,447,723	1,034,309
Total	465,427,929	51,841,690	178,279,473	31,089,143

3.6 RESULTS – SCENARIOS BENEFIT/COST RATIO

The results benefit/cost ratio indicates that Scenario 2 would be more advantageous for the City. The results are shown in Figure 14.

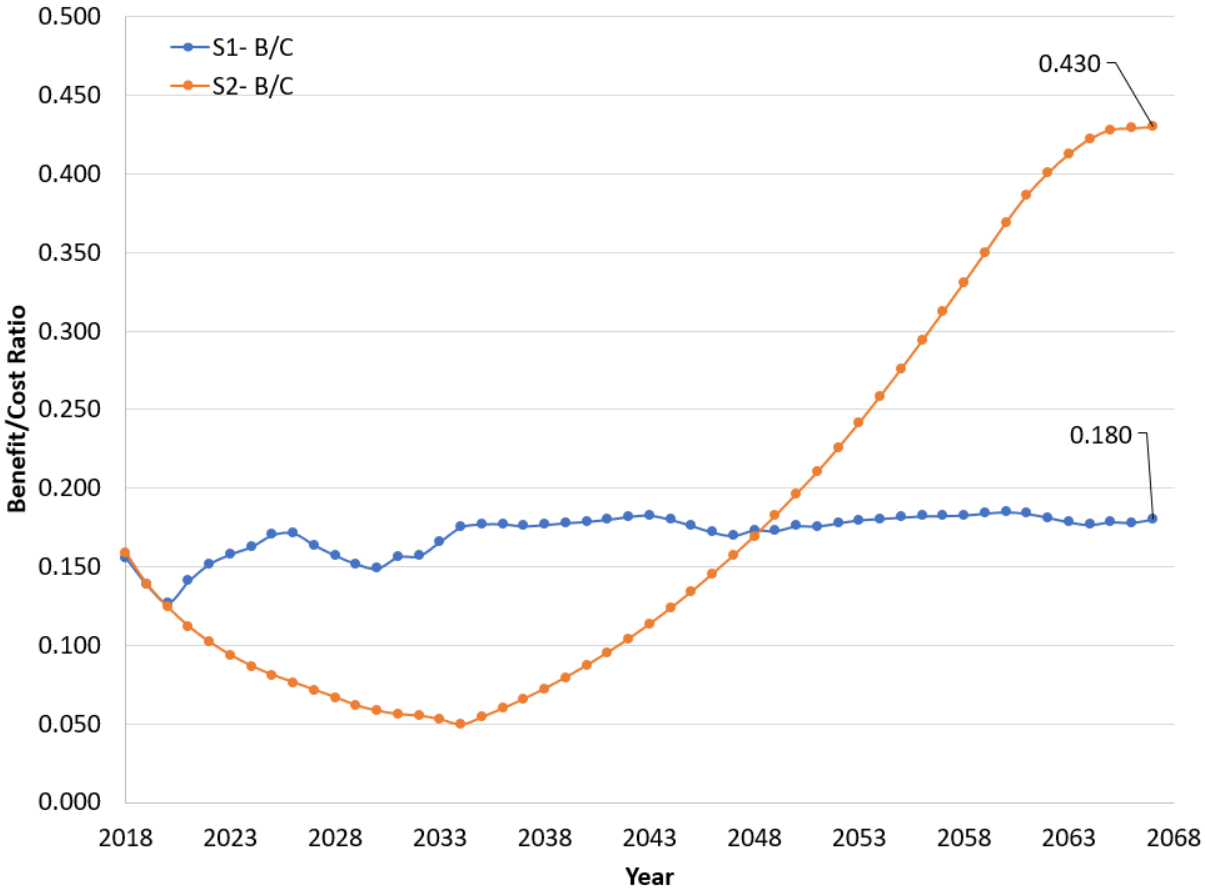

Figure 14 Scenarios Benefit/Cost Ratio

4 CONCLUSION AND RECOMMENDATIONS

The project's objectives were achieved by developing an investment strategy for urban street trees and by evaluating the impact of changing the current planting practice and assessing the impact of introducing the increase of soil volume options. In general, the following are the project's findings and conclusions:

1. Scenario 2, adopting the ideal growing conditions, is highly recommended due to the fact that it produces higher benefits over the 50-year analysis scenarios, and costs less
2. The total investment required over 50 years is about $72.39 million (refer to Table 8)
3. Trees are living beings and they contribute tangible environmental benefits to society that need to be explored and integrated with the City's overall vision
4. There is opportunity in optimizing the selected species of trees to maximize the environmental benefits and overall or specific benefits
5. The modelling framework has been developed and could be used to assess other "What If" scenarios
6. When comparing the two scenarios over 50 years analysis horizon, it is obvious that Scenario 2 is superior to Scenario 1, with about 62% higher investment over 50 years, The urban street trees would result in a benefits increase ranging between 243% to 463%, as shown below.

Table 11 Comparing Investment Scenarios over 50 years

	Outcome	Scenario #2	Scenario #1	Difference %
Benefit	Storm Water (Gallons)	465,427,929	82,663,639	463%
	Energy (Kilowatt hours)	51,841,690	14,207,720	265%
	CO2 (Pounds)	178,279,473	51,936,623	243%
	Benefits ($/year)	$31,089,143	$8,034,555	287%
Cost	Investment need ($ Million)	$72.39	$44.58	62%
B/C	Benefit/Cost Ratio (total)	0.43	0.18	138%

7. Scenario #2 has higher benefit to cost ratio, for each dollar the City invest in scenario #2 the return is about 43 cent, while in scenario #1 the return is only 18 cents.
8. Recommendation is to adopt Scenario 2

5 Appendix 1. Urban Street Tree Locations and Current Conditions and Benefits

Table 12. Locations Current Conditions

Number	ID	Location Name	Value (Thous.)	Current Performance			New Performance		
				Condition Index	%F+D	%F	Condition Index	%F+D	%F
1	1001	23 Ave 66 St Millwoods Rd CT and EB	$139.20	2.67	6.90%	4.60%	2.53	14.94%	5.75%
2	1002	28 Ave 55 St Hewes CT	$75.60	3.06	7.41%	3.70%	2.89	14.81%	7.41%
3	1003	50 St 102 to 109A Ave EB and TT	$353.60	3.38	1.36%	1.36%	3.20	4.07%	1.36%
4	1004	51 Ave 111 to 122 St CT	$70.40	3.12	18.18%	18.18%	2.96	18.18%	18.18%
5	1005	53 Ave 140 St to Riverbend Rd CT	$105.60	2.37	40.91%	21.21%	2.18	45.45%	30.30%
6	1006	63 Ave 99 92 St TT and EB	$201.60	1.92	53.17%	38.89%	1.78	53.17%	47.62%
7	1007	71 Ave 114 to 116 St CT	$94.40	2.14	37.29%	22.03%	1.98	38.98%	33.90%
8	1008	75 St 90 to 98 Ave MC	$275.20	2.40	24.42%	13.95%	2.25	32.56%	18.02%
9	1009	87 Ave 140 St to 169 St	$539.20	2.95	14.54%	9.50%	2.78	16.91%	11.87%
10	1010	90 Ave 50 to 75 St SB and CT	$334.40	3.13	3.35%	3.35%	2.97	8.61%	3.35%
11	1011	97 St 111 Ave to Yellowhead Tr EK CT	$467.20	2.75	21.92%	9.93%	2.56	27.74%	14.38%
12	1012	99 St 68 to 80 Ave EB	$76.80	2.42	22.92%	4.17%	2.23	22.92%	16.67%
13	1013	106 Ave 50A St to Hardisty Dr EB	$131.20	2.48	23.17%	4.88%	2.28	26.83%	10.98%
14	1014	106 St and 40 Ave MC	$155.20	1.34	86.60%	71.13%	1.25	89.69%	79.38%
15	1015	107 Ave 101 to 116 St EK GS EB	$599.20	2.87	14.49%	1.87%	2.67	16.82%	10.28%
16	1016	109 St 105 to 108 Ave EK GS EB	$40.00	1.52	68.00%	68.00%	1.48	68.00%	68.00%
17	1017	111 Ave 102 to 119 St	$137.60	1.41	77.91%	70.93%	1.35	79.07%	76.74%
18	1018	113 and 114 St 61 University Ave CT and MC	$145.60	1.71	70.33%	37.36%	1.51	73.63%	50.55%
19	1019	118 Ave 97 St 78 St EK GS	$935.20	3.52	4.49%	1.80%	3.32	4.49%	2.40%
20	1020	118 Ave St Albert Tr to 142 St CT SB	$153.60	2.95	16.67%	2.08%	2.73	17.71%	11.46%
21	1021	124 St Jasper to 111 Ave CT and MC and EK and SB	$722.40	3.17	16.67%	3.49%	2.95	21.32%	10.85%
22	1022	127 Ave 74 to 116 St and 113A St EB	$164.80	3.26	1.94%	1.94%	3.08	7.77%	1.94%
23	1023	132 Ave 66 to 127 St GS	$412.80	3.01	7.36%	3.10%	2.83	12.02%	5.04%
24	1024	142 St 85 Ave to Summit Drive	$404.80	2.93	11.86%	7.51%	2.76	17.39%	10.67%
25	1025	144 Ave 50 to 97 St EB	$304.00	2.81	4.74%	2.63%	2.66	7.37%	4.21%
26	1026	149 St EB	$284.80	3.19	11.80%	5.62%	3.00	11.80%	7.30%
27	1027	153 Ave 97 to 127 St SB CT	$280.00	3.14	3.43%	1.14%	2.96	6.29%	1.71%
28	1028	178 St 95 to 100 Ave CT	$83.20	3.39	1.92%	0.00%	3.20	9.62%	0.00%
29	1029	Beverly BRZ TT	$310.80	3.24	0.90%	0.00%	3.07	1.80%	0.90%
30	1030	Downtown City Hall	$876.40	2.82	16.61%	6.39%	2.64	22.04%	10.54%
31	1031	Downtown District 5	$1,671.60	2.93	16.58%	8.04%	2.74	20.10%	12.56%
32	1032	Downtown District 6	$723.88	2.96	18.82%	5.17%	2.75	21.77%	12.92%
33	1033	Downtown District 7	$497.99	2.96	9.40%	3.85%	2.78	11.97%	7.26%
34	1034	Downtown Grant McEwan	$338.10	2.91	15.95%	6.13%	2.72	21.47%	10.43%
35	1035	Downtown Ice District	$212.00	2.44	37.50%	27.50%	2.29	41.25%	32.50%
36	1036	Downtown Jasper Ave	$553.20	2.40	32.35%	21.57%	2.24	39.22%	26.47%
37	1037	Downtown South of 99 Ave	$174.40	2.69	25.69%	15.60%	2.51	27.52%	21.10%

38	1038	French Quarter TT	$341.60	2.43	25.41%	19.67%	2.30	31.97%	22.95%
39	1039	Groat Rd 111 to 114 Ave CT SB	$41.60	1.59	73.08%	53.85%	1.46	73.08%	69.23%
40	1040	Riverbend Road MC and CT	$185.60	2.68	29.31%	8.62%	2.46	34.48%	15.52%
41	1041	St Albert Trail and Groat Rd CT and SB	$254.40	2.52	25.79%	5.66%	2.31	32.70%	13.84%
42	1042	Strathcona BRZ and Whyte Ave TT	$1,027.37	3.28	5.05%	2.88%	3.10	11.06%	3.85%
43	1043	34 Ave 50 to 66 St	$75.20	2.87	0.00%	0.00%	2.72	10.64%	0.00%
44	1044	84 St 98 Ave to 101 Ave and 85 St 95 Ave to 96 Ave	$112.00	2.74	7.14%	4.29%	2.60	17.14%	4.29%
45	1045	98 Ave 84 St to 75A St	$132.80	2.79	7.23%	2.41%	2.63	18.07%	4.82%
46	1046	101 Ave 50 to 70 St and 101A Ave 67 St to 70 St	$67.20	3.18	0.00%	0.00%	3.01	4.76%	0.00%
47	1047	121 St Jasper Ave to 104 Ave	$100.80	2.35	30.16%	0.00%	2.11	39.68%	15.87%
48	1048	137 Ave CM 27 50 St on NE side	$126.40	3.56	0.00%	0.00%	3.36	1.27%	0.00%
49	1049	137 Ave CM 123 149 Street on NW side	$137.60	3.26	8.14%	8.14%	3.09	11.63%	8.14%
50	1050	Boyle Street	$81.60	2.24	39.22%	37.25%	2.13	41.18%	37.25%
51	1051	University Ave 114 St Sask Dr	$59.20	2.98	13.51%	13.51%	2.83	16.22%	13.51%

Table 13. Locations Current Benefits

Number	ID	Location Name	Current Benefits (2018)				New Benefits (2019)			
			Storm Water (Gallons)	Energy (Kilowatt hours)	CO2 (Pounds)	Benefits ($/year)	Storm Water (Gallons)	Energy (Kilowatt hours)	CO2 (Pounds)	Benefits ($/year)
1	1001	23 Ave 66 St Millwoods Rd CT and EB	17217	3269	10328	1691	16989	3227	10147	1669
2	1002	28 Ave 55 St Hewes CT	5802	1005	3608	557	5763	1005	3558	554
3	1003	50 St 102 to 109A Ave EB and TT	52558	7876	26789	4738	54068	8044	27315	4835
4	1004	51 Ave 111 to 122 St CT	6085	1152	3835	596	6883	1303	4271	675
5	1005	53 Ave 140 St to Riverbend Rd CT	6693	1744	5833	796	6721	1726	5791	792
6	1006	63 Ave 99 92 St TT and EB	15055	2839	8998	1475	16072	3032	9563	1574
7	1007	71 Ave 114 to 116 St CT	11095	1942	7352	1083	10799	1900	7169	1055
8	1008	75 St 90 to 98 Ave MC	43146	6780	26822	4047	42432	6662	26314	3968
9	1009	87 Ave 140 St to 169 St	69106	11909	43835	6737	71973	12374	45278	6986
10	1010	90 Ave 50 to 75 St SB and CT	54026	8475	31817	5037	55264	8654	32276	5124
11	1011	97 St 111 Ave to Yellowhead Tr EK CT	56728	9880	34339	5442	56873	9918	34275	5451
12	1012	99 St 68 to 80 Ave EB	13161	2065	8152	1229	12645	1983	7822	1179
13	1013	106 Ave 50A St to Hardisty Dr EB	18015	3142	10961	1732	17767	3088	10784	1704
14	1014	106 St and 40 Ave MC	4809	913	2856	471	6258	1188	3691	613
15	1015	107 Ave 101 to 116 St EK GS EB	58054	9154	36418	5506	56857	8951	35533	5368
16	1016	109 St 105 to 108 Ave EK GS EB	2283	373	1404	216	3065	507	1870	289
17	1017	111 Ave 102 to 119 St	6243	1042	3819	592	8245	1380	5015	780
18	1018	113 and 114 St 61 University Ave CT and MC	10071	1914	5949	988	9919	1885	5843	972
19	1019	118 Ave 97 St 78 St EK GS	57719	10776	36319	5654	61869	11565	38405	6063
20	1020	118 Ave St Albert Tr to 142 St CT SB	17812	3321	10904	1743	17618	3284	10716	1724
21	1021	124 St Jasper to 111 Ave CT and MC and EK and SB	47839	8598	31171	4692	47351	8531	30704	4640
22	1022	127 Ave 74 to 116 St and 113A St EB	21531	4030	14920	2186	21562	4059	14937	2186
23	1023	132 Ave 66 to 127 St GS	61682	10343	38607	5945	62803	10503	39130	6026
24	1024	142 St 85 Ave to Summit Drive	57842	9660	36116	5568	58548	9759	36355	5610

25	1025	144 Ave 50 to 97 St EB	47700	7987	29454	4544	48234	8087	29656	4587
26	1026	149 St EB	38395	6621	24986	3781	40196	6920	25957	3931
27	1027	153 Ave 97 to 127 St SB CT	42219	7072	26384	4036	43073	7233	26723	4110
28	1028	178 St 95 to 100 Ave CT	11548	1935	7317	1102	11810	1989	7427	1127
29	1029	Beverly BRZ TT	25040	4329	15616	2413	26012	4501	16098	2502
30	1030	Downtown City Hall	66339	11567	42593	6470	65377	11490	42058	6388
31	1031	Downtown District 5	127894	21604	82053	12378	129687	21898	82666	12505
32	1032	Downtown District 6	58650	9799	36765	5609	57985	9729	36244	5541
33	1033	Downtown District 7	56266	9363	35770	5430	57012	9494	36025	5482
34	1034	Downtown Grant McEwan	39123	6289	24567	3709	38740	6230	24237	3660
35	1035	Downtown Ice District	13200	2247	8212	1272	13885	2361	8578	1332
36	1036	Downtown Jasper Ave	36964	6369	23164	3578	37100	6400	23102	3583
37	1037	Downtown South of 99 Ave	25031	3877	15222	2346	25155	3927	15289	2355
38	1038	French Quarter TT	26581	4331	16656	2528	26920	4386	16825	2553
39	1039	Groat Rd 111 to 114 Ave CT SB	2157	410	1281	212	2280	433	1349	224
40	1040	Riverbend Road MC and CT	24218	4056	15026	2295	23353	3941	14407	2217
41	1041	St Albert Trail and Groat Rd CT and SB	34383	5928	21023	3289	32816	5656	20010	3136
42	1042	Strathcona BRZ and Whyte Ave TT	82636	14584	51184	8007	84523	14920	51916	8172
43	1043	34 Ave 50 to 66 St	13647	2165	8508	1285	13310	2113	8272	1250
44	1044	84 St 98 Ave to 101 Ave and 85 St 95 Ave to 96 Ave	16809	2836	10360	1597	16543	2804	10152	1572
45	1045	98 Ave 84 St to 75A St	21756	3555	13482	2061	20872	3409	12897	1972
46	1046	101 Ave 50 to 70 St and 101A Ave 67 St to 70 St	8083	1531	4949	793	8277	1570	5025	813
47	1047	121 St Jasper Ave to 104 Ave	12309	2320	7366	1207	10866	2050	6501	1066
48	1048	137 Ave CM 27 50 St on NE side	13959	2636	8735	1368	14842	2810	9158	1457
49	1049	137 Ave CM 123 149 Street on NW side	16204	2821	9730	1556	16880	2947	10054	1620
50	1050	Boyle Street	8166	1355	5075	777	9132	1520	5632	866
51	1051	University Ave 114 St Sask Dr	6865	1223	4378	668	7272	1300	4599	707