Prioritizing the Needs of Green Infrastructure: Street Tree Spacing in Halifax, Nova Scotia

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1. Introduction

Street trees represent valuable green infrastructure, providing urban residents with important social and environmental benefits, while adding value to the municipality (Anderson & Cordell, 1988; Kuo & Sullivan, 2001; Seamans, 2013). In Halifax Regional Municipality (HRM), street trees are estimated to sequester 100,000 tonnes of carbon annually and provide approximately $2.1 million worth of stormwater reduction services (Halifax Regional Municipality, 2013). Yet, due to our aging street trees, the maintenance and growth of our existing urban canopy is becoming increasingly difficult.

Street trees are amongst the easiest to manage in the urban forest due to their residence on city property; however, street trees can also cause conflict due to their coexistence with grey infrastructure in the urban landscape. The need for spacing standards between trees, as well as between street trees and grey infrastructure is not only defined by the need to mitigate future green-grey infrastructure conflict, but also to ensure we can continue to increase the urban tree canopy in HRM. Ultimately, spacing standards should seek to balance the needs of green infrastructure with the safety and efficiency of the urban environment.

Street tree spacing standards determine the arrangement and intensity of urban forest canopy in cities. While the HRM Urban Forest Master Plan (UFMP) seeks to maintain and increase canopy cover, spacing standards between grey and green infrastructure have yet to be developed. The objective of this study was to inform the development of such standards by testing the application of a proposed set of standards on existing tree populations and in future planting scenarios. For 11 separate transects, three tree population scenarios were reported. The first scenario involved recording the total number of trees on the transect. The second scenario imagined the number of trees which would be removed due to conflict with grey infrastructure. The final scenario imagined the same transect with no trees, and noted the number of trees which could be planted according to the standards. The following paper first briefly describes the practice of street tree spacing from infrastructure in other municipalities and a description of our study follows. The methods and results are described, and the paper concludes with a discussion of the implications of such standards.

2. Literature review

In terms of physical structure, cities are heterogeneous environments where buildings and streets of varied age and design form networks. Different streets in the same city may be structured differently - some have curbs, sidewalks, tree lawns, and grass medians, and some do not. Some streets are narrow, while others are wide. Streets in Halifax, Nova Scotia may differ in build or arrangement from those in Toronto, Ontario. As is the case with physical structure, spacing standards for street trees vary among cities.

The recommended distance between planted street trees generally varies according to the mature size class of the tree species, available soil volumes, and surrounding infrastructure (Urban, 2013; City of Vancouver, 2011; City of Waterloo, 2001). In situations where soil volume is not a limiting factor, trees may thrive closer together, depending on their overall architecture and crown development at maturity.

The template being tested in our study recommends spacing trees 10 meters apart (Table 2), while street tree guidelines in Vancouver recommend spacing based on four average size classes of trees: Large (9-11 m), Medium (8-10 m), Small (8-10 m), and Columnar (6-10 m) (City of Vancouver, 2011). Along with mature tree size class, Vancouver determines spacing recommendations between trees based on site carrying capacity (available soil, aerial space, etc.), and in relation to other infrastructure present (City of Vancouver, 2011). The city of Waterloo recommends spacing large trees eight meters apart, and smaller trees six meters apart (City of Waterloo, 2001). Waterloo also requires trees to be no closer than 18 meters to an intersection (City of Waterloo, 2001), while Halifax is testing a distance of six meters to the intersection or 10 meters to an intersection with a stop light (Table 2). Further, for streets surrounded by impervious or hard surfaces, the City of Toronto recommends spacing trees 10 meters apart to ensure sufficient soil availability for each tree (Urban, 2013). This inconsistency between cities for spacing standards indicates the heterogeneity of urban environments, and implies the need to have municipality-specific standards.

3. Methods

Transect Selection

A total of 11 transects were included in this study. These transects were selected based on their proximity to Dalhousie University, but also to include 3 different neighbourhoods included in the UFMP (Figure 1). Table 1 lists street names, side of street studied, UFMP neighbourhood, number of segments included, and length.

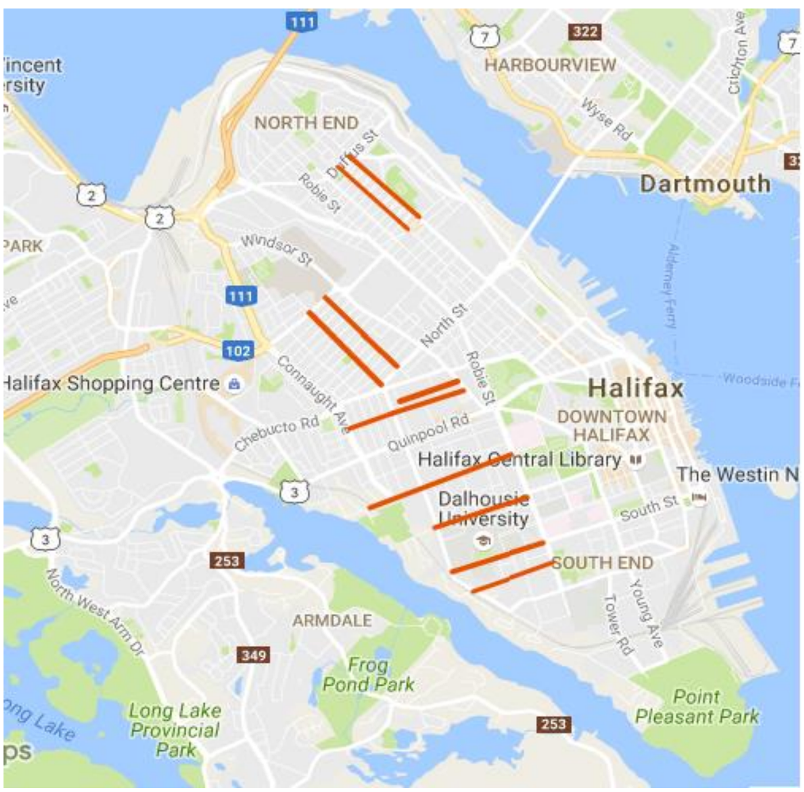

Figure 1. Map of the eleven transects on the Halifax Peninsula where spacing standards were tested (Sept.-Nov. 2016) (Google Maps, 2016).

Table 1. Summary of transects included in this study. Street name, side of street studied, UFMP neighbourhood, number of segments, and total distance of each transect.

Street	**Side of street studied**	**UMFP neighbourhood**	**# of Segments**	**Total distance (m)**
South St.	South	South End	7	1130
Oakland Rd.	North	South End	4	720
Coburg Rd.	North	South End	9	870
Jubilee Rd.	South	South End	11	1287
Allan St.	South	Connaught/ Quinpool	3	657
Oak St.	South	Connaught/ Quinpool	5	403
Lawrence St.	North	Connaught/ Quinpool	2	543
Dublin St.	West	Connaught/ Quinpool	10	792
Oxford St.	East	Connaught/ Quinpool	10	800
Isleville St.	West	North End	10	783
Novalea Dr.	East	North End	10	812
Total				**8797**

Spacing Standards Selection

The spacing standards used for this study are summarized in Table 2. These standards were selected based on conversations with Dr. Peter Duinker, who consulted with other urban forest experts in HRM and researched other municipalities' infrastructure spacing standards.

Table 2. Spacing standards tested in HRM, from tree to grey infrastructure, and also between trees.

Type of Infrastructure	**Distance to tree**
Intersections	6 m (from curb)
Light standards	3 m
Private approaches (including tree-lawn sidewalks)	1.5 m
Hydrants	3 m
Cable-utility poles	3 m
Manholes & sewer grates	3 m
Stop signs & traffic lights	10 m (on approach) 3 m (otherwise)
Tree (green infrastructure)	10m

Data Collection
Each transect was walked twice to collect data. During the first pass the number of trees on the transect were counted. Next, the number of trees which would have to be removed based on conflict with grey infrastructure were recorded. During second pass, walked from the opposite direction, we imagined the same transect with no trees, and recorded how many trees would be planted according to the standards. All data were recorded by hand and then digitized.

Data Analysis
All data were digitized in Excel. Frequency (meters per tree) was calculated under three different scenarios - existing tree population, population of trees after removal, and population of trees if transects were planted as per the standards (Table 5). Frequency was calculated by dividing the total number of trees by the length of the transect.

4. Results
When proposed spacing standards were applied, each one of the 11 transects would require the removal of trees found to be in conflict with grey infrastructure (Table 3, Figure 2). Removal rates ranged from as low as 5% of the total trees on the Dublin Street transect, to as high as 41% of the total trees found on the Allan Street transect (Table 3, Figure 4). Although Allan St. and Lawrence St. represent two of the three shortest transects studied, they also had the highest frequency of trees in terms of meters per tree (Table 5). The Jubilee St. transect was the longest of all studied (Table 3), and also had the largest street tree population in all three scenarios (Figure 2).

Under the third planting scenario conflict with grey infrastructure was highest on Coburg St., Allan St., and Lawrence St., and the existing tree population on these streets would need to be reduced by 23%, 4%, and 2% respectively (Figure 3, Table 4). When comparing existing street trees not in violation with urban spacing standards with the theoretical populations possible under scenario three, an overall increase in total street tree population was possible for seven of the 11 transects, while the Novalea St. transect showed no change (Figure 2, Table 4).

Table 3. Results of infrastructure spacing guidelines along 11 transects studied.

Street	Segment Length (m)	Total Trees	Removal Required	Percent Removal (%)	Remaining Trees	New-Tree Total
South	1130	54	19	35	35	60
Oakland	720	42	6	14	36	49
Coburg	870	43	11	26	32	33
Jubilee	1287	67	18	27	49	78
Allan	657	51	21	41	30	49
Oak	403	21	3	14	18	24
Lawrence	543	42	11	26	31	41
Dublin	792	43	2	5	41	53
Oxford	800	37	13	35	24	38
Isleville	783	39	3	10	36	45
Novalea	812	43	12	28	31	43
Total	**8797**	**482**	**119**	**--**	**363**	**513**

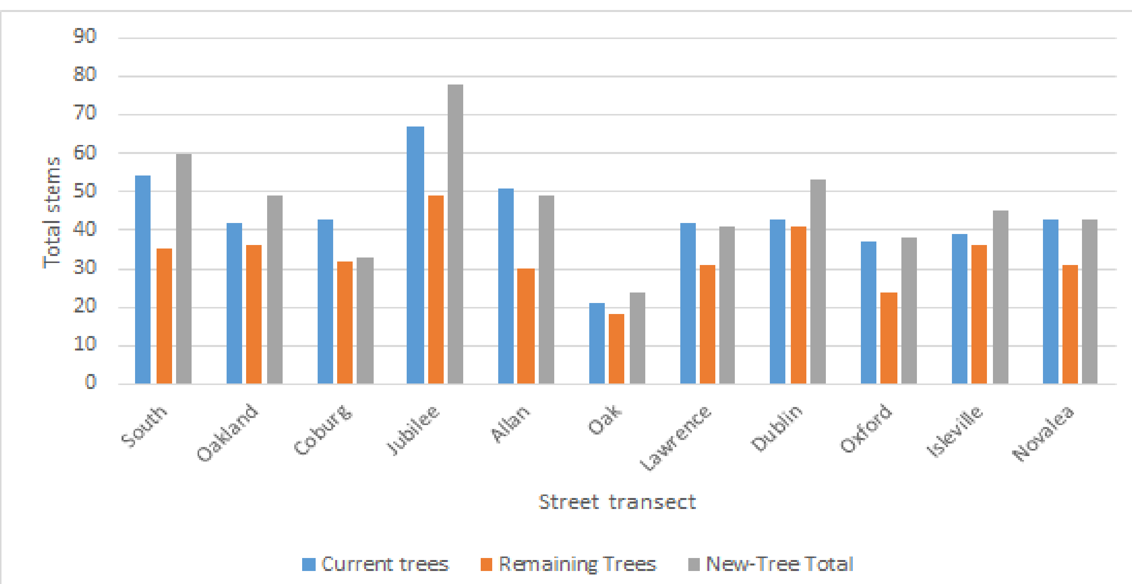

Figure 2. Total trees under each of the three scenarios tested - current number of trees, remaining trees once the standards were applied, and number of trees which could be planted under the standards.

Table 4. Comparison of existing street tree population to projected population on the same transect if planted according to spacing standards.

Street	Existing Population	Theoretical Population	Population Change (%)
South	54	60	11
Oakland	42	49	17
Coburg	43	33	-23
Jubilee	67	78	16
Allan	51	49	-4
Oak	21	24	14
Lawrence	42	41	-2
Dublin	43	53	23
Oxford	37	38	3
Isleville	39	45	15
Novalea	43	43	0
Total	**482**	**513**	**--**

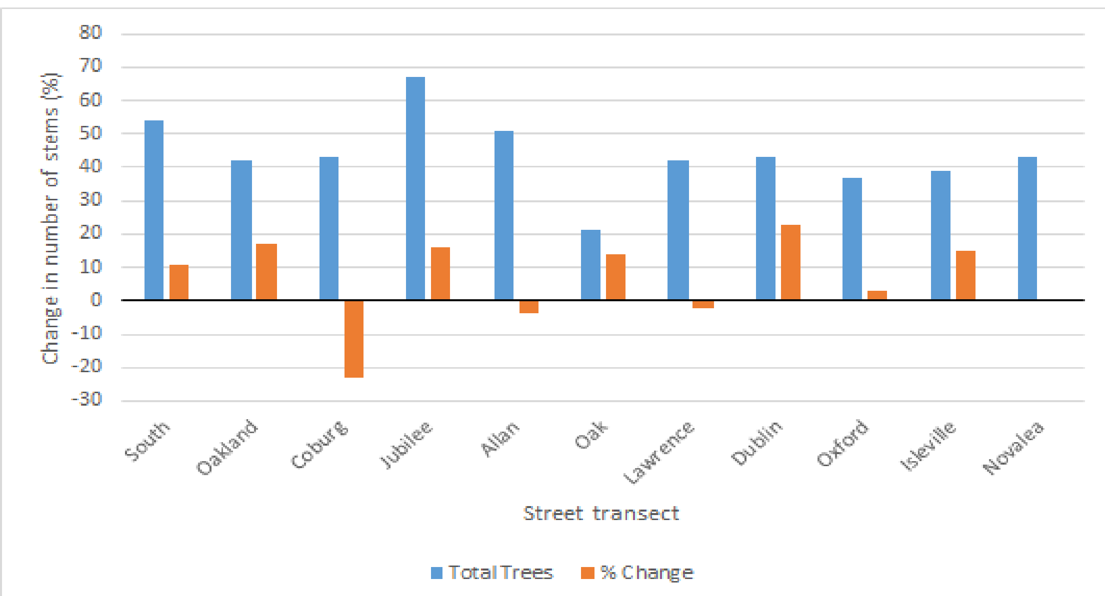

Figure 3. Existing street tree populations and percent (%) change in population for each of the 11 transects studied, South (n=54), Oakland (n=42), Coburg (n=43), Jubilee (n=67), Allan (n=51), Oak (n=21), Lawrence (n=42), Dublin (n=43), Oxford (n=37), Isleville (n=39), and Novalea (n=43).

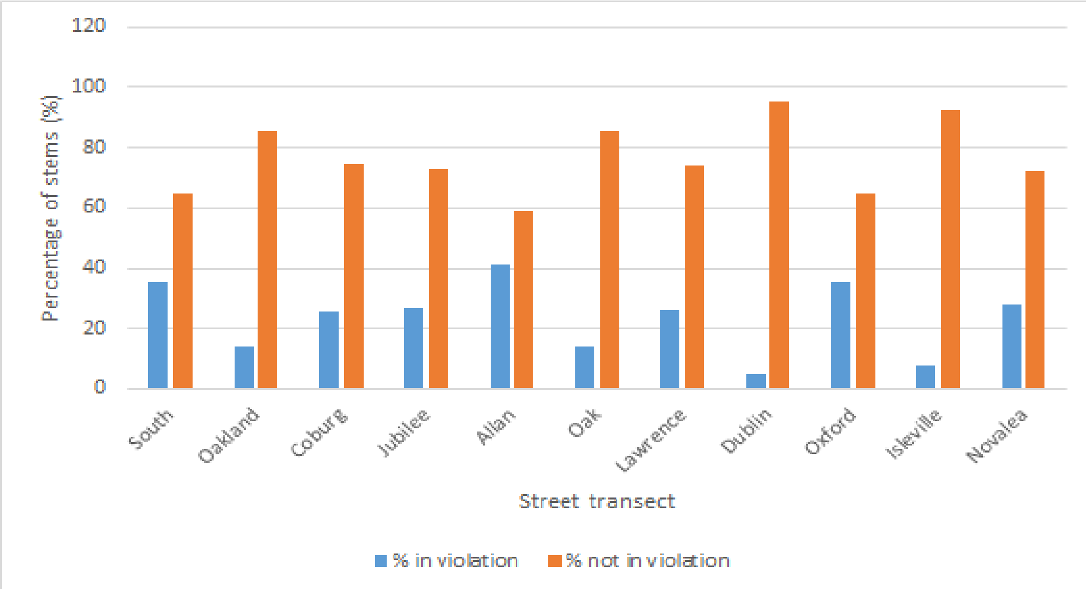

Figure 4. Percentage of stems in violation of and not in violation of urban spacing standards for 11 transects in Halifax, Nova Scotia, South (n=54), Oakland (n=42), Coburg (n=43), Jubilee (n=67), Allan (n=51), Oak (n=21), Lawrence (n=42), Dublin (n=43), Oxford (n=37), Isleville (n=39), and Novalea (n=43).

Table 5. Tree frequency on transects under three different scenarios (existing population, population when trees are removed due to infrastructure conflict, and population on transects that were newly planted as per the specifications). For each scenario, red indicates lowest density and green indicates highest density.

Street Transect	**Existing m/tree**	**Removed m/tree**	**Future m/tree**
South (1130 m)	20.93	32.29	18.83
Oakland (720 m)	17.14	20.0	14.69
Coburg (870 m)	20.23	27.19	26.36
Jubilee (1287 m)	19.21	26.27	16.5
Allan (657 m)	12.88	21.9	13.41
Oak (403 m)	19.19	22.39	16.79
Lawrence (543 m)	12.93	17.52	13.24
Dublin (792 m)	18.42	19.32	14.94
Oxford (800 m)	21.62	33.33	21.05
Isleville (783 m)	20.08	21.75	17.4
Novalea (812 m)	18.88	26.19	18.88

5. Discussion & Conclusions

Existing mature neighbourhoods in the HRM provide examples of the interplay between grey and green infrastructure. The purpose of this study was to test the implications on the street tree canopy when spacing standards were applied. Based on our study, implementation of these guidelines would result in canopies of similar or increased densities if used in new planting situations for similar sized neighbourhoods.

Effectiveness of these standards could be improved through the adoption of site specific tree spacing and species selection. Tree spacing that is determined by the mature size of tree species being planted and the space available for canopy and root growth can maximize canopy cover and increase the lifespan of trees planted (Urban, 2013). Including such considerations into the development of street tree spacing standards for the HRM will help balance the needs of trees with the needs of the city, and assist in the maintenance and growth of the urban forest canopy. Finally, while it is important for urban forest managers to acknowledge the needs of grey infrastructure, we insist that the consideration of trees be integrated into the planning of grey infrastructure as well.

6. References

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