Tree Protection for Transit Corridor Development

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Abstract

Urban forests are an integral part of many communities. They provide many benefits, including reducing air pollution, mitigating stormwater run-off, reducing building energy use, and increasing property values. Complete Streets is a program that addresses the planning, design, construction, and use of roadways to improve both the safety of vulnerable users and connections across metropolitan areas. Building a "complete street" involves redevelopment of the roadway to accommodate changing traffic patterns and adding pedestrian facilities and bike lanes, which can damage tree roots unless proper precautions are taken. Precautions include determining critical root zones (CRZs) and establishing (and enforcing) tree protection zones (TPZs). We reviewed the literature, assembled a panel of experts, and conducted a national survey of industry professionals to understand best practices for tree preservation. Very effective techniques to protect trees during construction included having an inventory prior to construction, having designated storage areas for equipment and materials, and having TPZ fencing. Very effective techniques to improve the odds of successfully planting replacement trees were using setback planting and improving soil quality. Our most important finding was that the best way to successfully protect trees was to involve a credentialed arborist in the planning stage of the project. Early involvement allows the arborist to emphasize tree value and why it is important to preserve them.

Introduction

Since trees in the built environment have value but can be damaged by construction, and since Complete Streets are being implemented in many communities throughout the United States, our main objective was to determine the most effective tree preservation practices. Since trees are inevitably removed during construction projects—despite best efforts—our secondary objective was to determine how best to include replacement tree plantings in the design of the post-construction landscape.

Background and Literature Review

In communities, public and private trees provide many benefits. They include ecosystem services such as reducing air pollution, sequestering atmospheric carbon dioxide and storing it in wood, managing stormwater, and providing wildlife habitat; functional benefits such as reducing building energy use, providing shade, and improving aesthetics; increasing property values; creating welcoming streets and downtowns; and many others (Roy et al. 2012). The economic value of many benefits has been quantified, demonstrating that trees in the built environment often have impressive benefit-cost ratios (Song et al. 2018). Trees should therefore be viewed as assets, but only if properly maintained.

Tree value generally increases as trees increase in size because most benefits accrue in proportion with leaf area (McPherson et al. 2007), which increases parabolically with trunk diameter (Nowak 1996). As a result, large trees provide disproportionally more benefits and have disproportionally more value than smaller trees. Replacing a single large tree with smaller trees with cumulative trunk diameter equal to trunk diameter of the large tree is meant well, but results in a net loss of benefits and value. This is why it is essential to protect trees along roadways during transit corridor development.

Transit corridor development often includes redesigning roadways to provide room for pedestrians and cyclists. Complete Streets is a nationwide initiative of Smart Growth America and the National Complete Streets Coalition to reimagine roadways across the country to improve safety and accessibility for all users (https://smartgrowthamerica.org/what-are-complete-streets/). The main priorities of Complete Streets address the planning, design, construction, and use of roadways. They include improving (1) safety of vulnerable users such as cyclists and pedestrians, and (2) connections across metropolitan areas to serve all communities. The initiative tackles systemic problems of safety and equity, and will result in improved safety, mobility, and connection for individuals nationwide. Two common themes in building a complete street are (1) the redevelopment of the transit corridor to accommodate changing traffic patterns and (2) the addition of pedestrian facilities and bike lanes. In effecting such changes, transit corridors may be widened, resurfaced, or otherwise altered in ways that have significant impacts on existing vegetation in the corridor.

Transit corridor development projects, and construction projects in general, can severely damage trees unless the proper precautions are taken to preserve and protect them. We will refer to the more general term "construction projects" throughout the paper. Damage to the aboveground portions of the tree (trunk and branches) is usually obvious, but unseen damage to the root system is typically more serious and has the most adverse impact on tree health (Matheny and Clark 1998). The two primary causes of root damage are soil compaction and breaking roots. Common causes of soil compaction include vehicular traffic; equipment operations; and storage of vehicles, equipment, construction materials, or fill soil. Common causes of broken roots include digging or trenching (Jim 2019). Roots typically grow shallow and wide, usually within the top eighteen inches of soil, and extending well beyond the dripline of the tree (Matheny and Clark 1998). The critical root zone (CRZ) is the extent of the root system most critical to tree health; precautions must be taken to protect roots and soil in the CRZ (Figure 1). To do so involves establishing a tree protection zone (TPZ); it is the area in which construction activity is excluded (Matheny and Clark 1998). Depending on the site and project, a single TPZ may be created to protect multiple trees, which is often more effective than multiple smaller TPZs (Figure 1).

Because trees are long-lived and have evolved to survive adverse growing conditions, construction damage to the root system may not manifest for many years. The time it takes depends on the severity of damage (e.g., what proportion of the root system has been damaged); the species, age, health, and history of the tree; and current and future growing conditions, including climate, sunlight, and soil type. Obvious visual indicators of root damage (e.g., dieback at the crown perimeter) may not occur until it is too late to successfully mitigate the damage, putting the tree into a decline spiral. Another outcome of root damage is acute, the uprooting of a tree, and can cause personal injury or property damage. Costly litigation often accompanies tree failure in the built environment (Mortimer and Kane 2004).

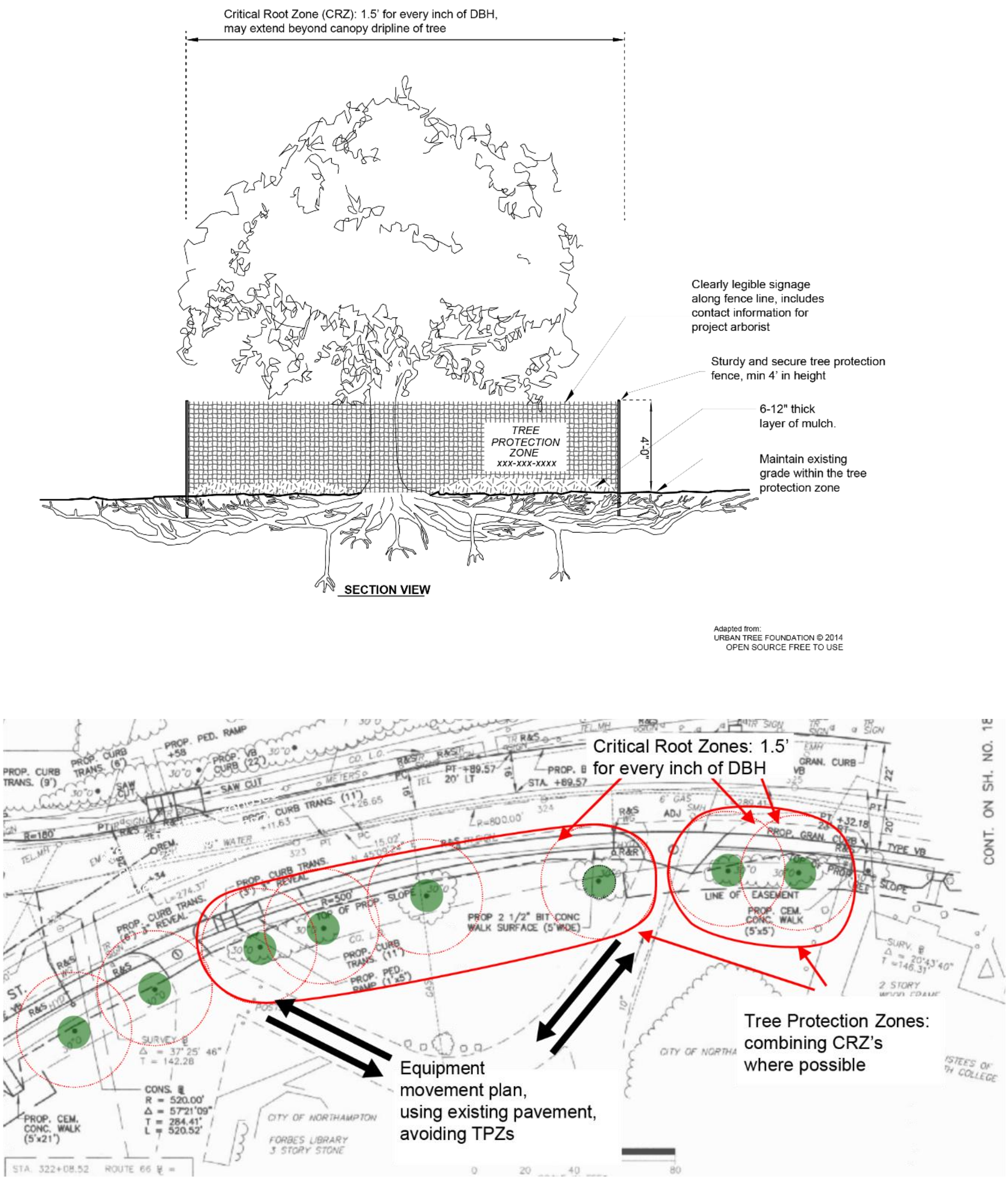

Figure 1. Section view of tree protection zone (TPZ) fence with sign to protect the tree's critical root zone (CRZ) (top); if two or more trees share rooting space, a single TPZ is preferred to protect the collective CRZ (bottom, courtesy of R. Parasiliti).

Methods and Data

To achieve our objective, we used three methods: (1) we reviewed the academic and professional literature on tree preservation; (2) we assembled a panel of cross disciplinary experts; and (3) we conducted a survey of industry professionals. In the literature review and survey, we considered four stages of a construction project: (i) planning, (ii) design, (iii) active construction, and (iv) post-construction. We met regularly with the panel of experts to solicit feedback on the literature review, to develop the survey, and to discuss our findings.

Three core areas in the literature review were: (1) preserving trees during construction (including preliminary assessment of trees that may be impacted); (2) restoring or enhancing trees after construction; and (3) design alternatives and site enhancements to improve survival and growth rate of trees planted after construction. The literature review involved searching databases in the University of Massachusetts' library system for phrases such as "preserving trees during construction," "protecting trees during construction," "construction damage 'and' trees," "trees 'and' soil compaction," and so on. Many guidelines on tree preservation are based on anecdotal evidence and industry consensus, so we reviewed both the academic and professional literature in disciplines including arboriculture, engineering, landscape architecture, and planning. Members of the expert panel contributed examples of tree preservation guidelines from projects they had worked on.

The panel of cross-disciplinary experts included nine members: two landscape architects and two project engineers from the Massachusetts Department of Transportation (MassDOT), two consulting arborists who regularly work with MassDOT on tree preservation projects, the Massachusetts Urban Forester, a professional engineer who is the department of public works supervisor and "tree warden" (urban forester) of a community in Massachusetts in which a Complete Streets project recently occurred, and the research manager of the Transportation Center at the University of Massachusetts. During fifteen meetings over two years, the panel discussed the literature review's findings and helped develop the survey (described below) and interpret the findings.

With input from the expert panel and assistance from the UMass Institute for Social Science Research (ISSR), we developed an online survey to gauge professional opinions on street tree preservation across the United States. We used the Qualtrics XM platform (Qualtrics, 2005) to conduct the survey, which included 40 questions in various formats (multiple choice, ranking and rating, open-ended). Questions inquired of respondents' demographics, their job description, and their experience and opinions on techniques and strategies for tree preservation and replanting. Questions chronologically followed the four stages of project development listed above.

We attempted to gain the perspectives of a disciplinarily diverse audience and announced the survey to the following associations: the Massachusetts chapter of the American Council of Engineering Companies, the Boston chapter of the American Society of Landscape Architects, the American Society of Consulting Arborists, the New England chapter of the International Society of Arboriculture, the Massachusetts Tree Wardens and Foresters Association, the New York City Parks Department, and the University of Massachusetts Transportation Center. The timing of the survey announcement and follow-up reminders followed Dillman et al. (2014).

We did not obtain enough responses to conduct inferential statistical analyses. Instead, we used descriptive statistics of survey responses (except open-ended questions) to search for patterns and explore trends. We used Microsoft Excel to analyze the responses for each question (except open-ended questions) and to create graphical presentations.

Results

We received 52 usable responses, of which 45 were complete and 7 were partially complete. We included incomplete responses in the results. Most respondents (73%) came from California, Massachusetts, New York, Florida, Texas, and Virginia. Most respondents (74%) were arborists and urban foresters; some were civil engineers (8%), landscape architects (4%), or managers (10%).

Seventy-six percent of respondents indicated that there was a tree protection document for road and sidewalk construction projects. Of 25 who indicated the document(s) they used, 13 reported the ISA BMP (Matheny et al. 2023), ANSI A300 Clause 9 (ANSI 2023), or both. Local ordinances or in-house guidelines were also used (8 of 25 respondents). Most respondents (84%) indicated that tree protection was considered in the planning stage, with 10% waiting until the design stage. Only 7% of respondents did not determine a CRZ, while 53% indicated that the CRZ depended on site conditions and 28% used the ISA's recommendation of 1.5 feet (0.46 m) of root zone diameter for 1.0 inch (2.5 cm) of trunk diameter at 4.5 feet (1.4 m) above ground—this is known as diameter at breast height or DBH. The most common ways to ensure awareness of TPZs was by holding meetings (38% of respondents) and posting signs (36% of respondents). During construction, 35 of 39 respondents indicated that they regularly visited a construction site to check on trees and TPZs. Figure 2 includes respondents' ratings of the efficacy of techniques to protect trees during construction. The largest proportions of "very effective" responses were for having an inventory prior to construction, having designated storage areas for equipment and materials, and having TPZ fencing. The largest proportions of "not effective" responses were for root pruning and using mats and ground covers to reduce soil compaction.

Seventy-two percent of respondents indicated that one or more aspects of replanting trees after construction were mandated in the planning stage, although it depended on the project for 28% of them. Examples of mandates include the number of new plantings or area to be replanted, and instructions for planting and maintenance. Sixty-six percent of respondents noted that there were guidelines for planting replacement trees after construction. The most common guidelines were recommended species (20%), long-term maintenance plans (18%), dimensions of the planting area (15%), and adding soil amendments (14%). The largest proportions of "very effective" techniques to improve the likelihood of success of replacement trees were using setback planting and improving the soil by aerating and remediating soil quality (Figure 3). The largest proportion of "not effective" or "detrimental" techniques to improve the likelihood of success of replacement trees was for root barriers. The highest long-term maintenance priority for trees planted after construction was watering, followed closely by mulching and risk assessment (Table 1). The largest proportion of "very effective" irrigation techniques was for drip irrigation systems (69%).

The largest proportions of "very effective" permanent design strategies to avoid conflicts between planted trees and the built environment were for maintaining minimum planting distances and root bridging (Figure 4). The largest proportions of "not effective" or "detrimental" permanent design strategies were for root barriers, raised tree planters, and tree pits.

Table 1. Prioritized long-term maintenance activities for replanted trees (n=40). 1 is the highest priority.

Activity	Median Priority
Watering	**2**
Mulching	**3**
Risk Assessment	**3.5**
Pruning	**4**
Fertilizing	**5**
Weeding	**5**

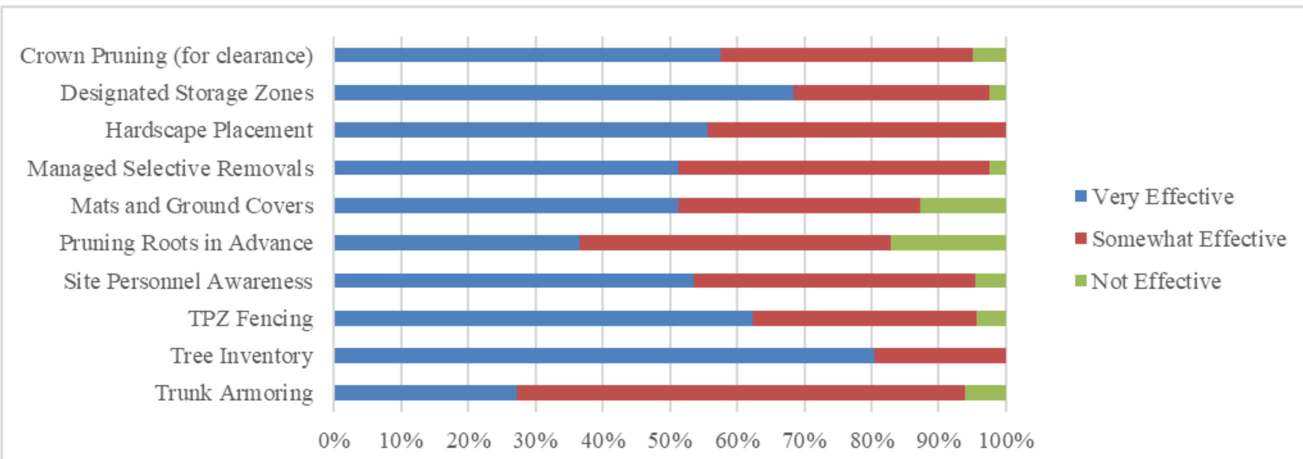

Figure 2. Methods used to protect trees during construction (n=49).

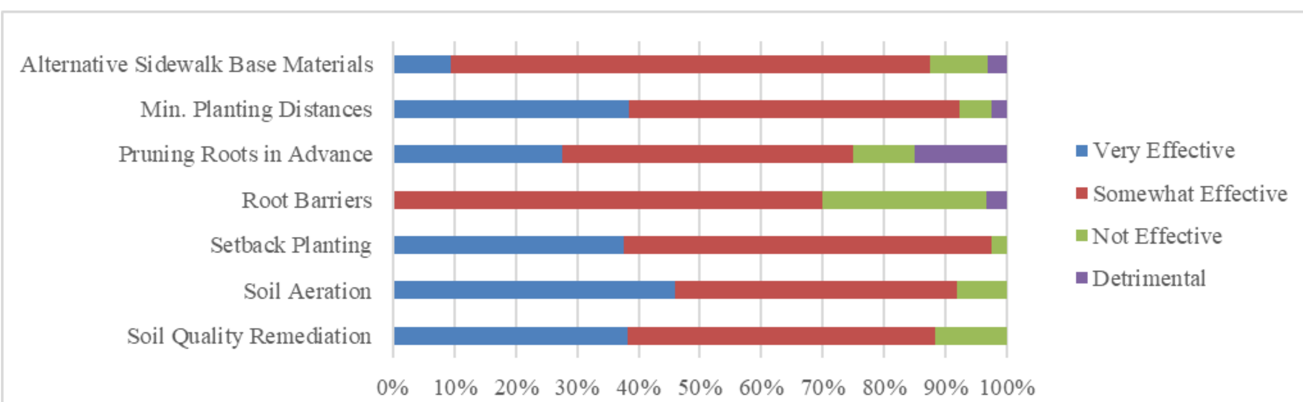

Figure 3. Methods to increase the likelihood of successfully planting replacement trees after construction (n=49).

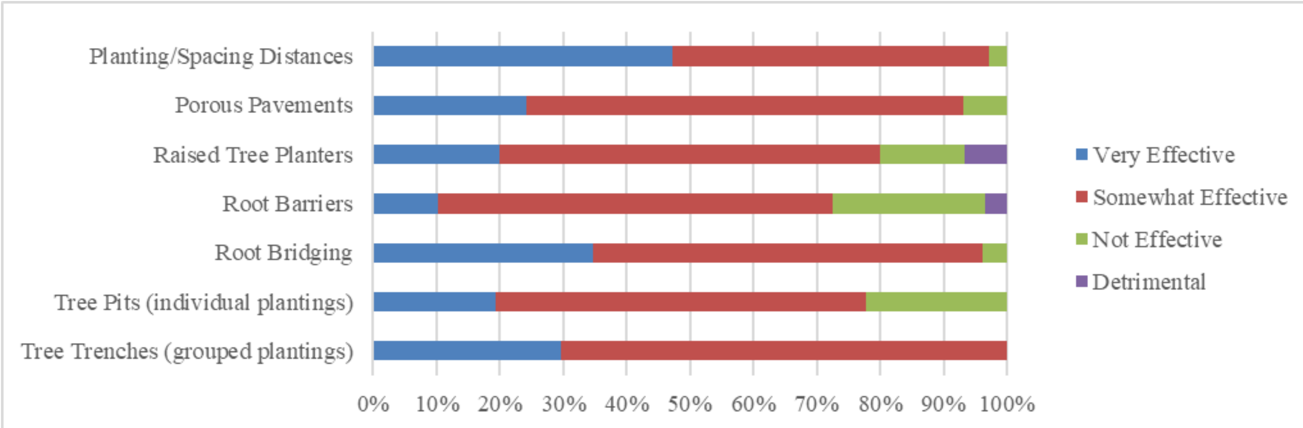

Figure 4. Permanent design strategies to minimize conflicts between trees and the transportation corridor (n=49).

Discussion and Conclusions

The most important finding from our work was that the best way to increase the likelihood of successfully protecting trees was to involve an arborist in the planning stage of the project. In the planning stage, architects, developers, engineers, and planners begin to assess the site and decide on the needs and limitations of the project. If a credentialed arborist(s) is involved, it is much more likely that trees will be considered. Relevant credentials include Registered Consulting Arborist (American Society of Consulting Arborists), Board Certified Master Arborist or Certified Arborist (International Society of Arboriculture), Massachusetts Certified Arborist (Massachusetts Arborists Association), among others. The main tools for raising awareness of trees in the planning stage are to conduct an inventory of trees on site and develop a tree preservation plan.

Conducting an inventory allows the arborist to share information about the trees with the project team, including species, size, condition, risk rating, value, and susceptibility to damage from the project. It is also helpful if the inventory includes soil condition, water table and flow, and prevailing winds. An inventory allows the arborist to emphasize both the benefits and values of trees, as well as why it is important to preserve trees—especially larger trees. Formalizing a tree preservation plan allows the arborist to explain how trees grow and increases the likelihood that the project's design can accommodate large, healthy trees. It also increases the likelihood that the project team will be aware of the trees to preserve throughout the project because the tree preservation plan includes the critical root zone (CRZ) of individual trees—or, where appropriate, groups of trees sharing a CRZ (Figure 4). It is also notable that using the tree's dripline as an estimate of the CRZ will underestimate the CRZ of trees with excurrent form; it is best to use diameter at breast height (DBH) to estimate the diameter of the CRZ.

It was notable that respondents did not express confidence in root treatments for tree preservation, planting, or permanent design elements. Root barriers and pruning roots in advance consistently received the highest proportion of "not effective" or "detrimental" ratings from respondents. It is unclear why root pruning was not seen more favorably because it is often suggested in best management guides. We speculate that it is due to timing challenges. Depending on the species, age, and health of the tree, as well as growing conditions, root pruning may only be effective if it can be done years in advance. The timing of construction projects may not allow enough time to prune roots and allow the tree to adjust to new growing conditions.

The final aspect of the planning stage relevant to trees is establishment of a process for replacing trees removed prior to construction. A key element is base the number of replacement trees on trunk cross-sectional area, rather than diameter, of removed trees.

Involving the arborist in the planning stage facilitates communication with the project team from the beginning, and communication in all project stages is critical. In the design stage, the site is mapped out, and buildings and built infrastructure are situated. Trees are designated for removal, transplanting, or preservation, and the arborist must clearly communicate justifications for each category. The arborist must also anticipate future growth to maintain appropriate clearance between trees and built infrastructure. The design stage is also when site logistics are considered such as temporary structures, construction zone access and parking, and storage of materials and equipment. Logistics must consider trees to be protected (Bassuk 2019), and the locations of replacement trees after construction. This is why having designated storage zones was the second most common "very effective" method to protect trees during construction.

The most effective tree protection zone (TPZ) consists of a sturdy fence that is fixed in the ground and plainly marked with signage that explains its purpose. Signage should also include contact information for the arborist, and the consequences for entering the TPZ, which must include a fine. There may be circumstances when a TPZ must be modified, and it is best to discuss the circumstances in the design stage to reach a solution that minimizes the potential for root damage or soil compaction.

The most effective ways to raise awareness of TPZs is through meetings (before construction begins) and signage. The arborist must visit the site regularly to increase the likelihood that TPZs will be respected. These findings aligned with the experience of panel members, who emphasized the need to communicate tree value and the need to protect root systems at all project stages. An important challenge, however, is limited resources to make it possible for the arborist to visit a site often enough to provide adequate monitoring. Panel members noted that frequent site visits by the arborist will make it much less likely that a TPZ will be breached, but they acknowledged the rarity of daily site visits.

In the post-construction plan, many respondents emphasized the importance of thoughtful plant selection and placement given the site conditions. New trees and shrubs should be sited with longevity in mind. An understanding of how the plant will grow and develop is critical, as is the consideration of anticipated site changes that may impact the plantings. Communication is vital for reconciling these difficulties, with all responsible parties understanding the long-term vision for the site. There was less support for root barriers, which was presumably due to their high cost and inconsistent effectiveness (Randrup et al. 2003). The most preferred permanent design strategies involved planting—either with appropriate distances between trees or grouped together in a planting trench rather than a planting pit. Such alternatives increase soil volume, which is essential for the establishment and growth of transplanted trees.

Since most respondents were arborists or urban foresters, it was not surprising that the survey results generally aligned with guidance from the ISA BMP on tree preservation (Matheny et al.

2023) and Clause 9 of the ANSI A300 (ANSI 2023). But our study was limited by the smaller number of respondents from other disciplines (e.g., engineering, landscape architecture) that are integral to transportation corridor projects. Because of the limited disciplinary diversity, our survey findings likely overestimate the degree to which trees are considered on transportation corridor projects.

With a concerted effort and communication, it is possible to raise awareness of the key elements of tree preservation and replacement during transportation corridor projects. The biggest challenge appears to be ensuring that a credentialed arborist is a member of the project team from the beginning, rather than retained only after a problem or complaint has occurred. Retaining as many large, healthy trees on a site will provide many benefits to the residents who live on the street where construction occurs.

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