PRESERVING TREES IN CONSTRUCTION PROJECTS: IDENTIFYING INCENTIVES AND BARRIERS

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Abstract. Two surveys of individuals from three professions instrumental in preserving trees in construction projects (professions related to tree care, site design, and construction) revealed their level of knowledge and use of tree preservation practices and identified some of the incentives and barriers to preserving trees. Many tree preservation practices have low frequencies of use, despite knowledge that they are inexpensive and effective. A large majority of respondents believed that customers would pay a premium for properties containing healthy, mature trees. Builders made some attempt to preserve trees on only half of their projects; arborists and designers apparently had even fewer opportunities. Many arborists commented that they had been asked for advice too late in the construction process. The Building with Trees seminars, sponsored by the National Arbor Day Foundation, apparently increased knowledge and use of tree preservation practices. Awareness of the value of trees to the finished project was the most important reason why tree preservation practices were used. State and local laws were seen as less important, especially by builders. Site constraints were cited as the major barrier to tree preservation, though these constraints were not specifically identified. Arborists scored highest on a scale that measured knowledge of tree preservation practices. For builders and designers, there was a positive but weak correlation between knowledge and use of tree preservation practices. Educational and marketing efforts aimed at property owners, site designers, and construction professionals could increase the number of healthy trees that survive the construction process.

Key Words. Tree preservation; tree protection zone; construction sites; tree protection fencing; Building with Trees seminar; land development; construction damage.

Construction activities threaten the health of trees on both public and private property (Sandfort and Runck 1986; Vander Weit and Miller 1986). Modern, more effective construction techniques generally degrade the environment necessary for the establishment, growth, and survival of nearby trees (Alberty et al. 1984; Craul 1994; Randrup and Lichter 2001). Builders often may be unaware of the destructive nature of construction processes, because some effects will not show up until years later. Unless tree preservation is planned well in advance of construction, the survival of nearby trees is problematic (MacDonald 1994).

Literature on tree preservation in construction projects is widely available and the process is well understood and documented (Ball 1990; Lichter and Lindsey 1994; Coder 1995; Matheny and Clark 1998a). While additional research could help fine-tune the process, the basic knowledge necessary to preserve trees is available. However, trees are frequently damaged or destroyed in construction projects because the knowledge and methods available to save them are not applied (Gilbert 1996).

The goal of this study was to help determine why tree preservation methods are underutilized to save trees impacted by construction. We surveyed three groups of professionals regarded as essential to the successful preservation of trees in construction projects: builders and developers (construction), landscape architects and civil engineers (site design), and consulting arborists and foresters (tree care). The study measured the level of knowledge held by the respondents, how often tree preservation practices were used, and the perceived incentives and barriers to their use. It also examined the effectiveness of the Building with Trees seminars.

METHODS

Two surveys were conducted, one restricted to Pennsylvania, U.S., residents, and a second with a national scope. In August 2000, questionnaires were sent to 1,367 individuals in the construction, design, and tree care professions. Each person was contacted up to four times by first-class mail, following recommendations made by Dillman (2000).

The 613 individuals in the Pennsylvania survey (approximately 200 from each professional group) were selected from membership lists provided by the following professional organizations: Pennsylvania Builders Association, American Society of Landscape Architects, and Pennsylvania-Delaware Chapter of the International Society of Arboriculture (directory of Certified Arborists).

For the national survey, questionnaires were mailed to 752 individuals selected from a list of 1,595 people who at some time during the past 10 years attended a Building with Trees seminar sponsored by the National Arbor Day Foundation (NADF). Individuals apparently involved with construction, design, or tree care were selected based on their job title and employer. They resided in 42 states and Washington, D.C.

The eight-page questionnaire contained 66 questions. Survey questions were designed to be appropriate for

members of all three groups, so all subjects in the study received identical questionnaires. Thirteen questions measured the respondent's knowledge about tree preservation, and 19 additional questions measured how frequently the individual used various tree preservation practices. Further questions measured the distribution of each respondent's work across various types of construction projects, the percentage of projects that were funded by private versus public funds, details concerning educational priorities on the subject of tree preservation, and the reasons trees were or were not preserved in various construction projects.

Use of Preservation Practices

The use of practices that are conducive to preserving trees in construction projects was measured with nineteen items, each with five possible responses ranging from 5 = always to 1 = never. The slightly paraphrased items were

1. Began the project with a tree inventory to provide information for the designers.
2. Designed space for trees worthy of protection to survive and grow.
3. Erected tree protection fencing to protect root zones, trunks, and branches.
4. Installed signs to identify tree protection zones.
5. Had meetings to inform workers about tree protection.
6. Avoided grade changes in the root zones of trees.
7. Avoided trenching in the root zones of trees.
8. Restricted construction traffic to specific areas to avoid tree root zones.
9. Someone provided post-construction inspections and care of the trees.
10. Someone monitored the site to enforce tree protection rules.
11. Soil for the project was stored away from tree roots.
12. Boring equipment was used instead of trenching to route utilities under tree roots.
13. Utility trenches were located close together, to reduce the area disturbed by excavation.
14. A concrete washout site was designated to prevent soil contamination.
15. Geotextile fabric covered with wood chips or gravel was used to reduce soil compaction by vehicles around tree roots.
16. Excavation equipment with tracks, not wheels, was used purposefully to reduce soil compaction.
17. Off-site parking for workers prevented vehicles from unnecessarily compacting the site.
18. Raised foundations, spanning tree roots, minimized soil compaction and damage to roots.
19. Retaining walls were constructed to avoid grade changes in the root zone of trees.

Exploratory factor analysis was used to examine correlations between variables (Kline 1994). To help reveal any underlying dimensions in the use scale, the data were factor analyzed using principal factor analysis with a varimax rotation, as described by Despot (2001).

Respondents were asked to rate the relative utility of five general ways for promoting tree preservation by using a scale ranging from 5 = very useful, to 3 = moderately useful, to 1 = not useful:

1. Education.
2. Technical assistance.
3. Local laws or ordinances.
4. State laws.
5. Government incentives such as tax breaks.

Among those construction projects in which trees had been preserved, respondents were asked to estimate the percentage of projects for which each of four possible reasons was the single most important one:

1. Laws and ordinances required it.
2. Owner or client's awareness of the value of trees.
3. My own awareness of the value of trees.
4. The site had unusually valuable trees.

Each statement was scored on a scale of 5 = the most important reason in 76% to 100% of projects, 4 = the most important reason in 51% to 75% of projects, 3 = the most important reason in 26% to 50% of projects, 2 = the most important reason in 1% to 25% of projects, and 1 = not important in any projects.

To measure the perceived costs and benefits of preserving trees, participants were asked to rank six statements according to how accurately each described the costs or benefits of tree preservation (5 = very accurately, 3 = undecided, 1 = very inaccurately):

1. Customers are willing to pay a premium for houses, apartments, or commercial property with healthy, mature trees on the site.
2. The primary cost of preserving trees in construction projects is the extra time required to complete a project while meeting tree preservation regulations or specifications.
3. If all contractors are aware of the tree preservation specifications prior to submitting their bids, the cost of tree preservation will be passed on to the property owner.
4. Tree preservation unnecessarily slows down a job and reduces the profit margins of the contractor.
5. Mature trees contribute little to reducing the cost to heat or cool a building, regardless of where they are located in relation to the structure.
6. Most home buyers indicate that a partially wooded lot is not an important feature to consider when choosing a home to purchase.

For those of their construction projects in which trees had not been preserved, respondents were asked to estimate the percentage of projects for which each of six statements represented the primary reason:

1. Site constraints.
2. Takes too much time.
3. Costs too much.
4. Customer imposed deadlines.
5. Building codes or ordinances.
6. Insufficient knowledge of tree preservation.

The statements were scored on a scale as follows: 5 = the most important reason in 76% to 100% of projects, 4 = the most important reason in 51% to 75% of projects, 3 = the most important reason in 26% to 50% of projects, 2 = the most important reason in 1% to 25% of projects, and 1 = not important in any projects.

Knowledge of Preservation Practices

The first measure of knowledge was obtained by asking respondents to rate their own knowledge on three items, scored from 1 to 5, with 5 = strongly agree, 3 = undecided, and 1 = strongly disagree:

1. I know enough about the effects of soil properties on tree survival and growth to effectively recommend, specify, or use tree preservation methods.
2. I know enough about the growth and function of trees and their reaction to injuries to effectively recommend, specify, or use tree preservation methods.
3. I know enough about tree preservation in construction projects to effectively recommend, specify, or use tree preservation methods.

A second measure of knowledge consisted of ten statements rated on how harmful or helpful certain procedures were to the preservation of trees in construction projects:

1. Begin the development process with a tree inventory to determine which trees are suitable for preservation.
2. Install substantial tree protection fencing to protect the roots, trunk, and branches of the trees to be preserved.
3. Store soil intended for later use in piles located well outside of the root zones of trees to be preserved.
4. Operate construction equipment over the root zones of trees only when the soil is wet.
5. Use a layer of wood chips over geotextile fabric to reduce soil compaction from construction activities.
6. Use a bulldozer to selectively remove trees that are not to be preserved.
7. Temporarily remove tree protection fencing to allow vehicles or equipment access to deliver materials.
8. Remove the topsoil from the root zones of trees that are being preserved so that it can be stored and reused at the completion of the project.
9. Remove leaf litter and establish turf up to the tree trunks as soon as landscaping can begin.
10. Use paving techniques that minimize soil compaction near trees.

Responses were scored from 1 to 5, with 5 = very helpful, 3 = no effect, and 1 = very harmful. Statements that would indicate adverse effects (4, 6, 7, 8, and 9) were recoded so that a higher scored reflected greater knowledge. Responses to item number 10 had the weakest correlation with responses to the other statements in the scale and were eliminated from further analysis.

Composite scores were calculated for each respondent by summing the scores for the 12 individual items (from the self-assessment and the measurement of knowledge), yielding a maximum possible score of 60. Factor analysis, as described for the use scale, was also used for analysis of the knowledge data.

Participants were asked to rate how beneficial an improved knowledge about five topics would be, scored on a scale of 5 = very beneficial, 3 = moderately beneficial, and 1= not beneficial:

1. Tree health and its relationship to construction activity.
2. Soil conditions necessary for tree health.
3. The tree preservation process.
4. The benefits of landscape trees.
5. The cost of tree preservation.

Respondents also were asked to indicate the relative importance of five sources of education on the topic of tree preservation in construction projects, rating each on a scale of 5 = very important, 3 = moderately important, and 1 = not important:

1. Trade organization.
2. Professional organization.
3. Cooperative Extension.
4. The National Arbor Day Foundation.
5. In-house training.

Relationship Between Knowledge and Use

The bivariate relationships between knowledge and use of tree preservation practices were investigated for arborists, builders, and designers. In addition, the bivariate relationships between relevant independent variables and use of tree preservation practices (for all groups combined) were analyzed as described by Despot (2001). Differences were judged to be significant if the statistical probability was 5% or below.

RESULTS

A total of 1,367 questionnaires were mailed, of which 46 were returned as undeliverable. The overall response rate was 55%, with 729 persons representing 40 states returning

useful questionnaires. From the Pennsylvania survey, 121 arborists (42% of the Pennsylvania responses), 57 builders (21%), and 106 designers (37%) returned useful questionnaires. The NADF survey generated responses from 170 arborists (51%), 44 builders (13%), and 118 designers (36%). The 69 individuals (10% of respondents) who responded that they did not have the opportunity to preserve any trees in the last 3 years, because they were not involved with any projects that had existing trees on the site, provided demographic and business size information only and were not included in the balance of the analysis.

The survey from the Pennsylvania population generated a 51% response rate and the groups within the survey—arborists, designers, and builders—had response rates of 68%, 62%, and 27%, respectively. The NADF population produced an overall response rate of 58%. It was not possible to calculate response rates for individual groups within the NADF population because the professions of the individuals in this database could not be identified prior to the return of questionnaires. Because some individuals may have attended the NADF seminar up to 10 years ago, this study represents their current state of knowledge rather than a measure taken immediately after the seminar.

The mean age of respondents for the entire study was 45 years, half of whom ranged from 38 to 51 years. The majority were male (Pennsylvania 88% and NADF 80%). Respondents had worked in their profession an average of 21 years.

Arborists worked most frequently on single-family residential projects (37%) and less than 16% worked primarily in any of the other three categories. Builders also did most of their work in single-family residential projects (65%). In contrast, designers worked at similar levels on nonresidential (26%), single-family residential (24%), and other types of projects (22%). These results suggest that members of each group may have had different types of projects in mind as they answered the questionnaire, which likely affected the answers they provided.

Arborists (62%) and builders (55%) indicated that greater than 50% of their projects were small (under 1.2 ha) while designers (37%) worked most frequently on large projects (over 4 ha). All three groups (arborists 50%, builders 60%, and designers 50%) indicated that they did more work in suburban areas than rural or urban environments.

Use of Tree Preservation Practices

Arborists were involved in the largest number of projects (whether or not trees were preserved) followed by designers and builders, with reported mean project numbers of 203, 109, and 25 per person in the past 3 years, respectively. Builders were most likely to have used, recommended, or specified at least one form of tree preservation practices on their projects (50% of projects) during the 3 years, followed by arborists (44%), and designers (21%). In contrast, when awareness of the usefulness of five techniques for preserving trees was measured (begin with a tree inventory, erect protective fencing, store soil outside of the root zone of trees to be preserved, minimize soil compaction by installing geotextile fabric and wood chips, and enforcing the tree protection zone), arborists scored highest followed by designers and builders.

Overall, 96% of respondents indicated that they would like to see more trees preserved in construction projects. Nineteen percent of builders, and 3% each of arborists and designers, indicated that they did not want to see more trees preserved.

In order to examine relationships as thoroughly as possible, the use data were characterized at three different levels: the total scale level (included all 19 use statements), the factor level (underlying dimensions), and the statement level (how individual statements from the questionnaire relate to each other).

Respondents in the NADF survey scored significantly higher (55.0) on the total use scale (19 items; 95 maximum possible score) than the participants from the Pennsylvania survey (51.9). Use of preservation practices was about 8% higher for NADF respondents (Figure 1). Designers were the only group for which NADF scores were significantly different than those recorded for Pennsylvania respondents, with mean scores of 56.0 and 49.8, respectively.

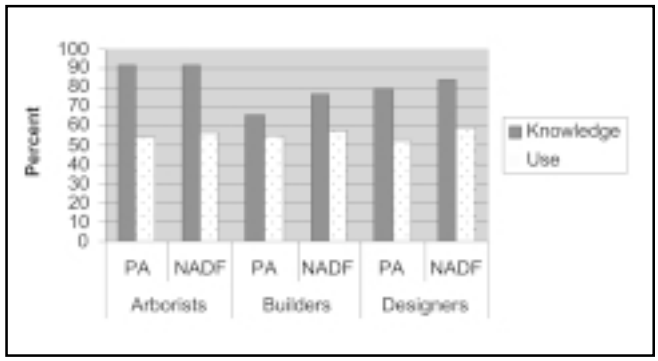

Figure 1. Comparison of knowledge (combined scale scores as percentage of maximum score) with use of tree preservation practices (total scale score as percentage of maximum score), by group and survey.

Three factors emerged in the factor analysis of use. Five statements from the original 19 were dropped in a stepwise manner in the process, because their contributions were below predetermined criteria for retention.

Use Factor 1 (Table 1*) contained statements associated with protecting enough space for trees to survive and grow. Arborists (16.0) scored significantly lower than builders

*Tables appear on pp. 276–279.

(18.3) in the Pennsylvania survey, and lower (15.9) than builders (18.4) and designers (18.1) in the NADF survey.

Use Factor 2 contained statements that describe construction techniques that can be used to preserve trees. Overall, NADF respondents significantly outscored those from Pennsylvania (14.3 vs. 13.2). Within each survey, scores were similar among the three groups.

Statements in Use Factor 3 were related to communicating the message of tree preservation. NADF respondents scored significantly higher than those from the Pennsylvania survey both overall and for each of the three groups. Within the Pennsylvania survey, arborists had the highest level of use represented by a mean score of 7.8, and builders had the lowest (6.1).

Strong contrasts appeared among responses to those statements that were used to evaluate the level of knowledge and use in the combined NADF and Pennsylvania surveys (first five statements in Table 2). Values for knowledge were much higher than those for use for each of these items. None of the other statements were present in both the use and knowledge scales.

Differences were found in percentages of each group who felt that knowledge of the various tree preservation practices was helpful to preserving trees (code K, Table 2). Beginning a construction project with a tree inventory was considered helpful or very helpful by high percentages of both designers (97.7%) and arborists (99.6%). All arborists (100%) indicated that erecting substantial tree protection fencing was helpful or very helpful, and so did 97.3% of designers. Builders chose the statement "knowledge about paving techniques that minimize soil compaction in the root zone of trees" most frequently (84.6 %) as being helpful or very helpful for tree preservation.

For knowledge about the type of practices least likely to be helpful or very helpful to tree preservation, builders (32%), and designers (67%) selected the statement "avoid the selective removal of trees with a bulldozer" while arborists (84%) selected "use paving techniques that minimize compaction."

The three groups differed substantially in their responses to statements that represent self-evaluation of knowledge (code SK in Table 2). The percentages represent individuals who agreed or strongly agreed to statements rating their confidence to use, specify, or recommend tree preservation methods based on their knowledge of soils, tree biology, and tree preservation in general. Most arborists indicated a high level of confidence on these topics (93% to 98%), while builders had the lowest level of confidence in their knowledge (knowledge of soils 34%, tree biology 48%, and tree preservation 58%), and designers were intermediate.

The frequencies with which various tree preservation practices were always or frequently used, recommended, or specified by individuals in the three groups (U in Table 2) are generally lower than the knowledge statements. Twenty percent of arborists, 11% of designers, and only 0.1% of builders indicated that they commonly use or specify geotextile fabric covered with wood chips to reduce soil compaction, yet at least 55% of respondents knew that the procedure was helpful. The practice that most arborists (53%) and builders (64%) recommended or used was to avoid trenching in the root zone, while most designers (65%) specified that soil be stored outside of the tree protection zone. The use of raised foundations was uncommon, with only 0.1% of arborists, builders, and designers indicating that they always or frequently used, recommended, or specified the practice. Builders indicated infrequent use of some very effective practices, including tree protection fencing (29%), enforcing the tree protection zone boundaries (28%), and wood chips covering geotextile fabric (<1%), especially in comparison to the other groups (69% to 100%).

Mean percentages for all knowledge items indicated that 94% of arborists had knowledge of the topics in the questionnaire, followed by 85% of designers, and 64% of builders (Table 2). The percentages of individuals in the three groups always or frequently recommending, specifying, or using tree preservation practices were much lower: 42% of designers, 35% of builders, and 34% of arborists. Arborists had the highest mean score of the three groups for knowledge but the lowest for recommendation, specification, or use.

Education was ranked as the most important method of promoting the use of tree preservation by both Pennsylvania and NADF respondents and by all three professional groups (Table 3). State laws were regarded as the least effective method; many respondents commented that they are often too general and inflexible. Participants from the NADF sample indicated that local ordinances (median score 4.16) were more important than did Pennsylvania respondents (3.71), and this was the only significant difference between the surveys in the utility of various methods. Builders rated laws, both local and state, significantly less important than did both arborists and designers.

The reason most often cited for preserving trees was the "professional's awareness of the value of trees" followed by "owner or client's awareness of the value of trees" according to both surveys and the three groups (Table 4). The only significant difference between the two surveys was for the statement "laws or ordinances required it," where NADF respondents (mean score 2.94) rated this reason as more important than did Pennsylvania respondents (2.21). Builders rated the statement "laws or ordinances required it" significantly lower than both arborists and designers, and gave greater weight to awareness by themselves or property owners.

An overwhelming majority of all respondents (83%) believed that customers were willing to pay a premium for properties that contained healthy, mature trees (Table 5). A

larger percentage of NADF respondents (86%) indicated that customers were willing to pay for such trees, compared to the Pennsylvania survey (78%). More respondents from the Pennsylvania survey (16%) than from NADF (6%) believed that tree preservation unnecessarily slows down construction. Builders were more likely than arborists and designers to believe that tree preservation unnecessarily slows down construction (24% vs. 8% or 9%) and that trees contribute little to energy conservation (10% vs. 0.1% or 5%).

The single most important reason why trees were not preserved in the highest percentage of projects (Table 6) was due to site constraints, which received the highest mean scores in both surveys (Pennsylvania 3.27, NADF 3.42), and by groups (arborists 3.00, builders 4.00, and designers 3.64). Unfortunately, the questionnaire was not designed to inquire about which site constraints respondents had in mind. Insufficient knowledge was ranked as the second most important reason overall (2.43). Only two statements, "costs too much" and "building codes or ordinances," generated mean scores that were significantly different between the Pennsylvania (2.50 and 1.67 respectively) and NADF (2.25 and 1.92 respectively) surveys.

Analyses by groups indicated that arborists, builders, and designers all believed that "site constraints" was the most important reason why trees were not preserved in the highest percentage of their projects. Arborists ranked insufficient knowledge as the most important reason in the second highest percentage of projects, while builders and designers indicated that cost ranked second.

Knowledge of Preservation Practices

Similar to the analyses relating to the use of tree preservation practices, the knowledge data also were characterized at the total scale, factor, and single statement levels.

Twelve statements were retained in the total knowledge scale. The statement "use paving techniques that minimize the soil compaction near trees" was dropped because it did not contribute to the reliability of the scale.

Respondents in the NADF survey scored significantly higher (51.9 of a 60 maximum) on the composite knowledge scale than the participants from the Pennsylvania survey (49.7). Within both the Pennsylvania and NADF surveys, the patterns among groups were the same: Arborists scored highest on the composite knowledge scale (54.6 and 54.8 respectively), followed by designers (47.9 and 50.7) and builders (43.3 and 50.5). In the NADF survey, both builders and designers had higher scores than their corresponding scores in the Pennsylvania survey.

Factor analysis of the knowledge data revealed that the relationships within each of the three factors, for the groups of professionals and the survey populations from which they were selected (Table 7), displayed patterns similar to the one described for the total knowledge scale. For Knowledge Factor 1, which is a measure of the self-assessment of knowledge concerning tree biology, soils, and tree preservation practices, NADF respondents (12.3 of a 15 maximum) scored significantly higher than did Pennsylvania respondents (11.7). Among the groups, arborists scored highest, builders scored lowest.

For Knowledge Factor 2, which measured knowledge of procedures that might damage trees during the construction process, respondents from the NADF survey scored higher than respondents from Pennsylvania, overall (21.5 and 20.4, respectively, of a 25 maximum), and also in two of the three professional groups: builders (18.6 vs. 15.4) and designers (21.1 vs.19.9). In both the NADF and Pennsylvania surveys, arborists had the highest level of knowledge, and builders had the lowest.

On Knowledge Factor 3, knowledge of practices that can be used to preserve trees, arborists again recorded the highest scores, and builders scored lowest. NADF respondents scored significantly higher than respondents in the Pennsylvania survey, overall (18.2 and 17.6, respectively, of a 20 maximum).

The lower self-assessments by builders (68%) and designers (75%), compared to arborists (90%) (Table 8), corresponded to their lower knowledge about damaging procedures and protective practices described above.

Impact of Knowledge on Use of Tree Preservation Practices

A positive and significant relationship exists between knowledge (12-item scale) and use (19-item scale) of tree preservation practices for builders and designers, although it is rather weak according to scatter plots of the relationship (Figure 2). Knowledge accounts for 17.8% and 11.4% of the variation in use for builders and designers, respectively. For arborists, the relationship between knowledge and use is not statistically significant, and knowledge accounts for only 0.3% of the variation in use.

All of the subjects that were rated as to how beneficial improved knowledge would be received high scores, ranging from 3.55 to 4.55 of a 5.0 maximum (Table 9). Overall, respondents ranked "tree health relative to construction activities" as the subject that would be most beneficial toward improving their knowledge, with a mean score of 4.43, followed closely by "soil conditions necessary for tree health" (4.38) and "the tree preservation process" (4.38), "the cost of tree preservation" (4.28), and "the benefits of landscape trees" (3.94). NADF respondents scored significantly higher than their Pennsylvania counterparts (4.49 vs. 4.34) for only one of the five statements, "tree health relative to construction activities". In the analysis of mean scores organized by profession, arborists compiled the highest mean scores on each of the five statements, while builders had somewhat lower scores.

Overall, respondents indicated that professional organizations were the most important sources for education

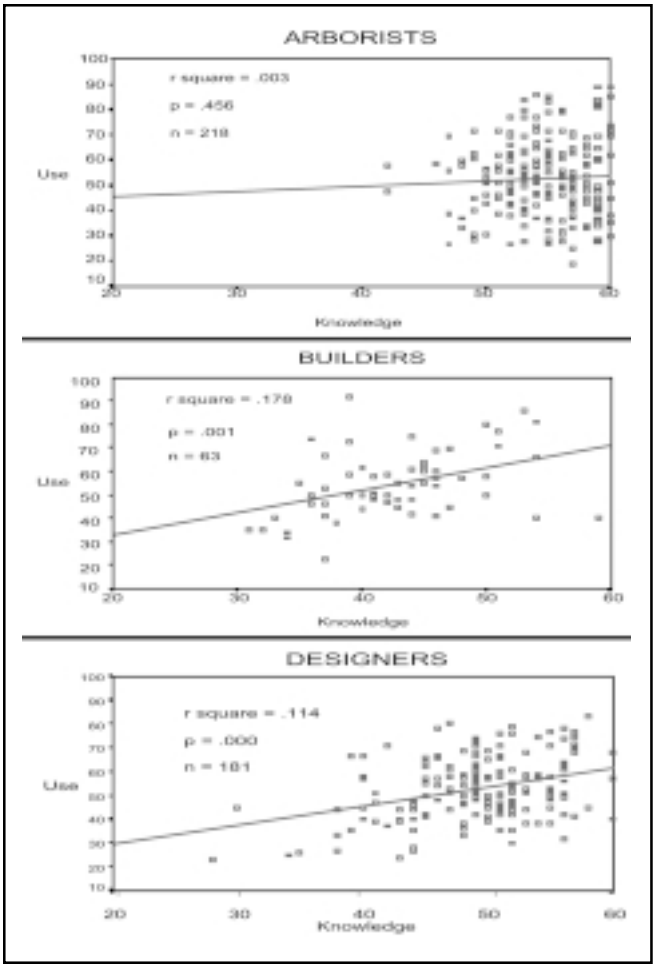

Figure 2. Bivariate relationships between total use and total knowledge scales for arborists, builders, and designers.

about tree preservation, with a mean score of 4.23 (Table 10), followed by trade organizations (3.75). Significant differences between respondents from the two surveys were evident for only two sources, the National Arbor Day Foundation and in-house training. NADF respondents outscored Pennsylvania participants in both cases (3.89 vs. 2.89) and (3.55 vs. 3.32), respectively.

Arborists, builders, and designers all indicated in both surveys that professional organizations were their most important source of education on tree preservation topics, with mean scores of 4.45, 3.52, and 4.19 respectively. Builders ranked Cooperative Extension and in-house training as relatively unimportant.

DISCUSSION

The similarity of respondent populations and their responsiveness makes it possible to compare attitudes and use of tree preservation practices in Pennsylvania with those who had attended a tree preservation seminar, the latter by people throughout the nation. The seminar apparently increased knowledge up to 10 years after the seminar (builders about 17%, designers approximately 6%, arborists no significant change) and use (builders 10%, designers 12%, arborists 4%) of tree preservation, especially through better communication with workers. A comparison of arborists from Pennsylvania with those who had attended the NADF seminar showed little improvement in knowledge or use from the seminar. Perhaps arborists may have been exposed to tree preservation training in the process of arborist certification and continuing education, as indicated by their high knowledge scores. Most respondents seemed to have a good understanding of the costs and benefits of preserving trees.

The low response rate by builders implies that those who responded may not be representative of all builders, and the respondents may have a greater than usual interest in trees. Even so, 18% of builders indicated that they would not like to see more trees preserved.

Builders made some attempt to preserve trees on only half of all projects where it would have been possible; arborists and designers apparently had even fewer opportunities. Many arborists volunteered comments indicating that they had been asked for advice too late in the process. Designers did not comment on the reason for their low frequency of preserving trees. Tree preservation practices that are known to be effective have been used at low frequencies, despite knowledge about them. Some of the most effective, yet inexpensive, practices have been used by builders at very low frequencies: fencing, signs, enforcement, wood chips, and post-construction care. Builders would be more responsive to education and technical assistance than laws or government incentives as approaches for promoting tree preservation; arborists and designers concur, but nevertheless indicated that local ordinances can be effective.

It appears that an opportunity exists for arborists to market their services more effectively to builders who wish to preserve trees (Vander Weit and Miller 1986). Presentations at meetings of professional and trade organizations for the construction industry and the design professions may provide a useful platform to inform builders about the value of consulting an arborist concerning the use of tree preservation practices, especially at the design stage.

Opinions about why some trees are not preserved differed among the three groups, though all agreed that site constraints were most important. Arborists recognized that insufficient knowledge was responsible, more so than designers and builders. Excessive costs were regarded as more of a problem by arborists and builders than by designers. Surprisingly, time requirements and impact on deadlines were of less concern to builders than to the others.

Knowledge about tree preservation was significantly higher by designers and builders who had attended the seminar, but not by arborists, who scored highest in both

surveys. Builders and designers recognized that they were lacking in knowledge about tree preservation. Knowledgeable builders and designers tended to use more tree preservation practices, but this is a loose relationship.

For the variables of both knowledge and use, in every case where a significant difference between the scores of respondents from the NADF and Pennsylvania populations existed, the NADF respondents scored higher. The NADF respondents knew more and were more involved in tree preservation than Pennsylvania respondents. The building with trees seminar that the NADF respondents had attended seems to have been effective in increasing the knowledge and use of tree preservation practices. It is also possible that these individuals who were interested enough in the topic to attend the seminar may have gained knowledge elsewhere.

A major barrier to the use of tree preservation is that designers and arborists had opportunities or chose to influence the use of tree preservation on only 21% and 44% of their projects, respectively; builders indicated that they used some sort of tree preservation on only 50% of their projects. This occurred despite the fact that all three groups had intermediate to high levels of knowledge about specific tree preservation practices. Arborists commented that they are rarely consulted concerning tree preservation until the construction had begun, a finding consistent with Matheny and Clark (1998a).

Site constraints (not identified by the surveys) was chosen as the single most important reason why trees were not preserved, followed by insufficient knowledge of tree preservation and the perceived higher cost of tree preservation. The importance of these issues suggests that education along with better planning and the use of innovative construction practices may increase the number of trees successfully preserved.

Clearly there is a gap between knowledge and use of tree preservation practices. Possibly, awareness of the importance of trees to the finished project and to the community in general could help bridge this gap (Ball 1990). The cost of tree preservation may be partially offset by the benefits that trees contribute to the completed project (Matheny and Clark 1998b).

Awareness of the value of trees to the finished project, both by the professionals involved and the owners of the property, emerged as a major incentive for tree preservation for all three groups of respondents. More than 96% of designers and arborists indicated that more trees should be preserved. Tree preservation laws were seen as less important than awareness of the value of trees, especially by builders. However respondents from the NADF survey seemed to have a greater appreciation for the benefits of laws and ordinances.

Overall and also when analyzed by survey group, respondents indicated that they would benefit most from learning more about "tree health in relation to construction activities." Builders ranked "the benefits of landscaping" as the least beneficial topic to learn more about.

The graphs of the bivariate relationship between knowledge and use show that a significant but loose relationship exists between knowledge and use for both builders and designers, but that no such relationship exists for arborists. These relationships are proposed to be a consequence of the different roles played by respondents from each group during the process used to design and construct building projects. While it is essential that construction projects have builders and site designers to ensure successful completion, arborists are not considered to be essential members of the team found on most construction projects. Arborists in many cases have been unable to use their high level of knowledge to further tree preservation because they are not consulted, or in some cases, consulted too late in the process (Coder 1995). Many arborists commented that typically their involvement in construction projects begins when the new owners called to request help with dead or dying trees.

CONCLUSION

Successfully preserving trees in construction projects requires a comprehensive mix of knowledge, incentives, and timely cooperation by the professionals involved in the construction process. Awareness of the value of trees, both by the professionals involved and the landowner, contributes significantly toward tree preservation. While knowledge is the cornerstone of the process, it does not always translate directly into the successful tree preservation unless applied deliberately and properly.

Site designers and builders, essential participants in preserving trees during the development and building process, are sometimes lacking in knowledge about the conditions required to successfully preserve trees. Specifically, builders and designers could improve their effectiveness by installing and enforcing tree protection zones and understanding more about tree biology, soil conditions necessary for tree growth, the importance of allowing leaf litter and topsoil in the root zone to remain undisturbed, the effectiveness of geotextile fabric covered with wood chips for reducing soil compaction, and the problems associated with selectively removing trees with heavy equipment.

Arborists, the professionals with the greatest level of knowledge about how to preserve trees, are often excluded from the planning and design of construction projects or called upon too late. This study suggests that knowledge does translate into use of tree preservation practices if the proper professionals are consulted in a timely manner. Perhaps experienced arborists could be more aggressive in marketing their talents to designers and builders.

Respondents identified site constraints as the primary reason why trees were not preserved. However, this study did not identify specific site constraints, how they affected the tree preservation process, and the difficulties involved in

circumventing them. This would be a prime topic for additional research.

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Table 1. Mean scores for Use Factor 1 (use of tree preservation practices that provide enough space for trees to grow), Use Factor 2 (use of construction techniques for preserving trees), and Use Factor 3 (communication of the tree preservation message to workers). A score of 5 represented the highest level of use, and a score of 1 represented the lowest for each statement.

	Use factor 1[z] mean score		Use factor 2[y] mean score		Use factor 3[x] mean score	
Group	PA	NADF	PA	NADF	PA	NADF
Arborist	16.00	15.89	13.78	14.16	7.82*	8.59*
Builder	18.26	18.39	13.92	14.67	6.10*	8.80*
Designer	17.58	18.12	12.38*	14.35*	6.78*	7.98*
Total	17.02	17.07	13.23*	14.30*	7.12*	8.39*

[z]Maximum score = 25.
[y]Maximum score = 30.
[x]Maximum score = 15.
*Indicates significance at the .05 level of difference between Pennsylvania (PA) and NADF surveys.

Table 2. Knowledge versus use of tree preservation practices by arborists, builders, and designers. Percentage who answered "very helpful" or "helpful" for knowledge statements, "strongly agree" or "agree" for self-knowledge statements, and "always" or "frequently" for use statements.

		Arborist		Builder		Designer	
Code	Statement	Knowledge %	Use %	Knowledge %	Use %	Knowledge %	Use %
KU	Conduct tree inventory[z]	99.6	37.0	81.3	61.3	97.7	53.2
KU	Erect protective fencing[z]	100.0	43.2	78.5	28.8	97.3	51.4
KU	Store soil out of root zone[zy]	96.9	40.3	82.3	59.5	95.9	64.8
KU	Geotextile + wood chips[zy]	90.4	19.7	55.7	0.1	69.1	11.2
KU	Enforce tree protection zone[zy]	96.5	31.9	57.9	27.5	88.3	29.6
K	Avoid traffic on wet soil[z]	94.1		60.0		82.3	
K	Avoid bulldozer takedowns[z]	86.3		32.0		67.3	
K	Preserve topsoil in root zone[z]	96.9		68.0		95.4	
K	Preserve leaf litter[z]	93.0		40.8		73.3	
K	Pave to minimize compaction	83.8		84.6		86.9	
SK	Knowledge of soils[z]	96.2		58.2		78.0	
SK	Knowledge of preservation[z]	93.1		34.2		65.8	
SK	Knowledge of tree biology[z]	97.7		48.1		66.2	
U	Avoid trenches in root zone[y]		53.3		63.8		58.5
U	Cluster utility trenches		32.5		61.5		48.6
U	Design space for trees[y]		31.3		61.3		53.2
U	Avoid cuts/fills in root zone[y]		35.4		57.5		63.9
U	Restrict traffic on the site[y]		47.5		56.3		58.6
U	Cement washout site[y]		24.0		46.8		31.8
U	Off-site parking		30.6		32.9		31.0
U	Equipment with tracks[y]		15.4		30.7		0.1
U	Inform workers[y]		27.2		26.8		20.4
U	Retaining wall[y]		19.4		26.6		34.1
U	Use boring under trees[y]		12.6		12.7		12.1
U	Post construction care[y]		28.2		12.5		21.7
U	Install signs		14.4		11.3		12.0
U	Raised foundations[y]		0.1		0.1		0.1
Mean percentage		**93.8**	**34.4**	**64.1**	**35.4**	**85.4**	**42.0**

[z]Indicates statements retained after factor analysis in the final three knowledge factors.
[y]Indicates statements retained after factor analysis in the final three use factors.
K indicates a statement used to measure knowledge.
SK indicates a statement used for a self-evaluation of a respondent's knowledge.
U indicates a statement used to measure use.

Table 3. Relative utility of selected methods for promoting the use of tree preservation in construction projects (mean scores, 5-point scale) by survey and group.

	Survey			Group				
Method	PA n = 275	NADF n = 372	F value	Arborist n = 268	Builder n = 75	Designer n = 204	F value	Total n = 647
Education	4.66	4.72	1.42	4.75 a	4.65 a	4.66 a	1.49	4.69
Technical help	4.37	4.47	2.40	4.57 a	4.20 b	4.38 b	7.80	4.43
Local ordinances	3.71*	4.16*	20.87	4.08 a	2.89 b	4.16 a	34.46	3.97
Govt. incentives	3.78	3.94	2.43	3.94 a	3.67 a	3.83 a	1.50	3.87
State laws	3.36	3.49	1.35	3.57 a	2.49 b	3.55 a	19.64	3.44

Between surveys, an asterisk indicates means are significantly different at $p < .05$; d.f. = 1, 645.
Among groups, means within a row followed by the same letter are not significantly different at $p < .05$; d.f, 2, 544.

Table 4. The most important reasons for preserving trees, by survey and group (mean scores representing the percentage of projects in which respondents selected a single reason why trees were preserved).

	Survey			Group				
Reason why trees were preserved	PA n = 226	NADF n = 358	F value	Arborist n = 246	Builder n = 69	Designer n = 202	F value	Total n = 585
Professional's awareness	3.82	3.75	0.40	3.63 a	4.17 b	3.89 ab	5.31	3.76
Owner awareness	3.15	3.24	0.58	3.17 a	3.84 b	3.02 a	11.28	3.20
Unusually valuable trees	2.59	2.73	1.88	2.56 a	2.91 a	2.74 a	2.65	2.68
Laws or ordinances	2.21*	2.94*	32.13	2.62 a	1.91 b	2.91 a	10.93	2.66

Between surveys, an asterisk indicates means are significantly different at $p < .05$; d.f. = 1, 582.
Among groups, means within a row followed by the same letter are not significantly different at $p < .05$; d.f, 2, 514.
A score of 5 indicated that the item was the most important reason for preserving trees in 76% to 100% of projects, 4 indicated most important in 51% to 75% of projects, 3 indicated most important in 26% to 50% of projects, 2 indicated most important in 1% to 25% of projects, and 1 indicated not important in any projects.

Table 5. Perceived costs and benefits of preserving trees in construction projects, by survey and group (mean percentages of respondents who indicated that statements represented their perceptions accurately or very accurately).

	Survey			Group				
Statement	PA n = 255	NADF n = 366	F value	Arborist n = 252	Builder n = 78	Designer n = 215	F value	Total n = 621
Customers willing to pay a premium	78.04*	86.07*	6.84	86.11 a	74.36 a	81.40 a	3.05	82.77
Primary cost is the extra time needed	51.37	49.18	0.29	59.13 a	50.00 ab	40.00 b	8.72	50.08
Cost is passed on to property owner	78.82	74.32	1.68	76.19 a	79.49 a	75.35 a	0.27	76.17
Unnecessarily slows down construction	16.08*	6.01*	17.12	7.54 a	24.36 b	9.30 a	9.46	10.14
Contributes little to energy conservation	5.49*	2.19*	4.82	0.10 a	10.26 b	4.65 b	8.23	3.54
Wooded lot is not important to buyers	5.49	3.83	0.97	3.97 a	1.28 a	6.51 a	1.20	4.51

Between surveys, an asterisk indicates means are significantly different at $p < .05$; d.f. = 1, 619.
Among groups, means within a row followed by the same letter are not significantly different at $p < .05$; d.f, 2, 542.

Table 6. The most important reasons for not preserving trees, by survey and group (mean scores represent the percentage of projects in which respondents selected a single reason why trees were not preserved).

Reasons why trees were not preserved	Survey			Group				Total
	PA n = 212	NADF n = 340	F value	Arborist n = 230	Builder n = 71	Designer n = 190	F value	n = 553
Site constraints	3.27	3.42	1.45	3.00 a	4.00 b	3.64 b	20.02	3.34
Insufficient knowledge	2.36	2.38	0.02	2.90 a	1.66 b	1.90 b	33.56	2.43
Costs too much	2.50*	2.25*	4.55	2.60 a	2.20 ab	2.09 b	8.27	2.37
Too much time	2.14	1.94	3.39	2.30 a	1.66 b	1.76 b	13.55	2.03
Building codes	1.67*	1.92*	6.98	1.87 a	1.72 a	1.81 a	0.51	1.85
Deadlines	1.85	1.82	0.07	1.95 a	1.51 b	1.74 ab	4.99	1.85

Between surveys, an asterisk indicates means are significantly different at $p < .05$; d.f. = 1, 550.
Among groups, means within a row followed by the same letter are not significantly different at $p < .05$; d.f, 2, 488.
A score of 5 indicated that the item was the most important reason for not preserving trees in 76% to 100% of projects, 4 indicated most important in 51% to 75% of projects, 3 indicated most important in 26% to 50% of projects, 2 indicated most important in 1% to 25% of projects, and 1 indicated not important in any projects.

Table 7. Mean scores for Knowledge Factor 1 (self-assessment of knowledge concerning tree biology, soils, and tree preservation practices), Knowledge Factor 2 (knowledge of procedures that might damage trees), and Knowledge Factor 3 (knowledge of practices that can be used to preserve trees). A score of 5 represented the highest level of knowledge, and a score of 1 represented the lowest for each statement.

Group	Knowledge factor 1[z] mean score		Knowledge factor 2[y] mean score		Knowledge factor 3[x] mean score	
	PA	NADF	PA	NADF	PA	NADF
Arborist	13.28	13.58	22.47	22.56	18.86	18.70
Builder	9.63*	10.91*	15.41*	18.56*	14.53*	16.82*
Designer	10.72*	11.48*	19.92*	21.09*	17.21*	18.10*
Total	11.69*	12.28*	20.44*	21.46*	17.59*	18.21*

[z]Maximum score = 15.
[y]Maximum score = 25.
[x]Maximum score = 20.
*Indicates significance at the .05 level of difference between Pennsylvania (PA) and NADF surveys.

Table 8. Comparison of scores on self-assessment of knowledge with scores on knowledge of damaging procedures and knowledge of protective practices (Table 7) for arborists, builders, and designers, adjusted to percentages of the maximum scores of the scales.

Knowledge factor	Arborists (%)	Builders (%)	Designers (%)
Self-assessment	90	68	75
Damaging procedures	90	68	82
Protective practices	94	78	88

Table 9. Perceived benefit of having an improved knowledge of selected subjects (mean scores, 5-point scale) by survey and professional group.

	Survey			Group				
Subject	PA n = 256	NADF n = 367	F value	Arborist n = 261	Builder n = 76	Designer n = 212	F value	Total n = 624
Tree health	4.34*	4.49*	4.54	4.55 a	3.99 b	4.44 a	13.67	4.43
Soil conditions	4.32	4.43	2.87	4.50 a	3.84 b	4.45 a	19.31	4.38
Tree preservation	4.36	4.40	0.33	4.49 a	3.97 b	4.38 a	10.93	4.38
Cost of preservation	4.20	4.34	3.59	4.41 a	3.91 b	4.23 ab	8.92	4.28
Benefits of landscape	3.95	3.93	0.03	4.04 a	3.55 b	3.89 ab	5.90	3.94

Between surveys, an asterisk indicates means are significantly different at $p < .05$; d.f. = 1, 621.
Among groups, means within a row followed by the same letter are not significantly different at $p < .05$; d.f, 2, 546.

Table 10. Importance of selected sources for education on the topic of preserving trees in construction projects (mean scores, 5-point scale)) by survey and group.

	Survey			Group				
Sources of education	PA n = 237	NADF n = 337	F value	Arborist n = 243	Builder n = 71	Designer n = 194	F value	Total n =576
Professional organization	4.27	4.16	1.51	4.45 a	3.52 c	4.19 b	25.09	4.23
Trade organization	3.83	3.67	2.15	3.95 a	3.48 b	3.55 b	7.27	3.75
Cooperative Extension	3.59	3.57	0.03	3.65 a	2.94 b	3.67 a	11.73	3.59
NADF	2.89*	3.89*	10.41	3.51 a	3.49 a	3.38 a	0.61	3.51
In-house training	3.32*	3.55*	3.97	3.76 a	2.82 c	3.32 b	15.26	3.46

Between surveys, an asterisk indicates means are significantly different at $p < .05$; d.f. = 1, 572.
Among groups, means within a row followed by the same letter are not significantly different at $p < .05$; d.f, 2, 505.

Résume. Deux enquêtes auprès de trois groupes de professionnels impliqués dans la préservation des arbres durant les projets de construction (professions reliées à l'entretien des arbres, le design du site et la construction) ont révélé leur degré de connaissance et d'utilisation de pratiques pour la préservation des arbres, et a aussi permis d'identifier certains des incitatifs et des barrières à la préservation des arbres. Plusieurs pratiques de préservation des arbres ont été employées peu fréquemment, et ce en dépit du fait qu'elles sont peu coûteuses et efficaces. Une vaste majorité de répondants croient que les consommateurs vont accepter de payer un supplément pour une propriété où des arbres matures et en santé sont présents. Les constructeurs font certaines tentatives pour préserver les arbres sur seulement la moitié de leur projet; les arboriculteurs et les designers ont, néanmoins, apparemment peu d'opportunités même là. Plusieurs arboriculteurs constatent qu'ils ont généralement été appelés pour des conseils trop tard dans le processus de construction. Le *Séminaire sur construire avec des arbres*, commandité par la Fondation Nationale du Jour de l'Arbre (National Arbor Day Foundation), a apparemment accrû la connaissance et l'utilisation de pratiques pour la préservation des arbres. La connaissance de la valeur des arbres une fois le projet complété constituait la raison la plus importante du pourquoi des mesures de préservation des arbres avaient été adoptées. La législation locale ainsi que celle de l'état étaient perçues comme moins importantes, notamment par les constructeurs. Les contraintes de site étaient citées comme la barrière la plus importante à la préservation des arbres, malgré qu'elles ne furent pas identifiées comme telles. Les arboriculteurs sont ceux qui ont obtenu le résultat le plus élevé sur l'échelle quant à la connaissance des pratiques de préservation des arbres. Pour les constructeurs et les designers, il y avait une corrélation faible mais positive entre la connaissance et l'utilisation de mesures pour la préservation des arbres. Des efforts d'éducation et de promotion auprès des propriétaires, des designers de site et des professionnels de la construction pourraient augmenter la quantité d'arbres qui survivraient au processus de construction.

Zusammenfassung. Zwei Umfragen unter Einzelpersonen aus drei Berufen der Baumpflege und –erhaltung auf Baustellen (Baumpflege, Landschaftsgestaltung und Landschaftsbau) offenbaren hier ihren Wissensstand und Anwendung von Baumerhaltungsmaßnahmen und nennen einige der Anreize und Grenzen in der Baumpflege. Viele Baumpflegemethoden sind mit geringer Frequenz angewendet worden, obwohl bekannt war, dass sie effektiv und preiswert waren. Eine große Mehrheit der Befragten glaubten, dass Kunden eine Menge bezahlen würden für ein Grundstück mit gesundem, ausgewachsenen Baumbestand. Landschaftsbauer machten den Versuch, wenigstens auf der Hälfte ihres Objekts die Bäume zu schützen, Baumpfleger und Designer haben da weniger Chancen. Viele Baumpfleger bemerkten, dass sie im fortschreitenden Bauprozeß zu spät um Rat gefragt wurden. Seminare unter dem Titel „Gebäude mit Bäumen", die vom National Arbor Day Foundation gesponsort wurden, vergrößerten das Wissen und die Anwendung von Baumpflegemaßnahmen. Bewusstsein über den Wert von Bäumen in Relation zum fertiggestellten Gebäude ist der wichtigste Grund, warum Baumpflegemaßnahmen genutzt werden. Staatliche und Kommunale Verordnungen werden als nicht wichtig angesehen, insbesondere bei Landschaftsbauern. Standortfragen wurden als größte Barriere gegenüber Baumpflege betrachtet, obwohl diese nicht weiter erörtert wurden. Die Baumpfleger bewerteten das messbare Wissen über Baumpflegepraktiken sehr hoch. Die Designer und Landschaftsbauer gab es eine positive, aber schwache Korrelation zwischen Wissen und Anwendung von Pflegemaßnahmen.

Resumen. Dos estudios con personas de tres profesiones en preservación de árboles en proyectos de construcción (profesionales relacionados con el cuidado de los árboles, diseño del sitio y construcción) revelaron su nivel de conocimiento y uso de prácticas de preservación de los árboles, e identificaron algunas de las iniciativas y barreras para preservar los árboles. Muchas prácticas de preservación de los árboles han sido usadas con poca frecuencia, a pesar de ser efectivas y poco costosas. Una gran mayoría de encuestados creyeron que los clientes deberían pagar una prima extra para propiedades que tengan árboles maduros y saludables. Los constructores hicieron algún intento para preservar árboles en solamente la mitad de sus proyectos; los arbolistas y diseñadores aparentemente tienen aún pocas oportunidades. Muchos arbolistas comentaron que ellos han sido consultados demasiado tarde en los procesos de construcción. Los "Seminarios de Construcción con Árboles", patrocinados por la National Arbor Day Foundation, aparentemente incrementaron el conocimiento y uso de las prácticas de preservación de los árboles. La inconsciencia acerca del valor de los árboles para un proyecto terminado fue la razón más importante de por qué deben ser usadas las prácticas de preservación de los árboles. Las leyes estatales y locales fueron vistas como menos importantes, especialmente por los constructores. Las limitaciones del sitio fueron citadas como las principales barreras para la preservación de los árboles, a pesar de que no fueron identificadas. Los arbolistas tuvieron la calificación más alta en una escala que midió el conocimiento de las prácticas de preservación de los árboles. Para los constructores y diseñadores, hubo una positiva pero débil correlación entre el conocimiento y el uso de las prácticas de preservación de los árboles. Los esfuerzos educativos y de mercado, apoyados en los propietarios, los diseñadores del sitio y los profesionales de la construcción, podrían incrementar el número de árboles saludables que sobrevivan los procesos de construcción.