Evaluation of Tree Planting Practices in The Urban Landscape

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INTRODUCTION

During the 1970s and 1980s the explosion of urban landscape architecture resulted in plazas and paved spaces punctuated by groves of trees. The growth and survival rates of these trees, however, was significantly lower than trees planted in more open situations. As streets were widened and new development was initiated at higher densities, utility requirements increased the demand for available sidewalk space above and below ground. Simultaneously, the technology of construction changed; heavier and more efficient machinery, capable of moving larger volumes of earth and making deeper cuts, resulted in soils at construction sites that were highly disturbed and compacted. To add insult to injury, there was also a significant erosion in environmental quality; beyond the obvious air pollution problems, trees were now required to withstand a variety of chemicals, including de-icing salts, cleaning fluids, and lawn chemicals. As a result, the trees at many projects often experienced poor recovery from initial transplant shock, early decline and death, higher maintenance, and differential growth rates. These problems ultimately compromised the original design intent of the projects and severely limited their positive contribution to the urban environment.

The landscape design profession has not responded adequately to these changes. Trees are still being planted using installation details and procedures developed for suburban sites or handed down from an era prior to these changes in the urban environment. This paper is part of an emerging effort to restructure the way we use trees in urban designs. Based on a series of comparative case studies of existing urban landscapes, this paper demonstrates the need for new directions in design by identifying patterns of success or failure.

The limited scope of this project, and its use of case studies as a data source, primarily serves to identify problems and suggest solutions. The ultimate conclusion is a series of recommendations for further research projects that must be undertaken if we are serious about the long-term survival of trees in the urban landscape.

CASE STUDY PROJECT SELECTION

All the projects selected for study exhibited classic urban design problems currently facing today's designers and all had sufficient history to allow comparative study. Selected project trees all grow in tree pits within the pavement and are at least 10 years old (median age is 17 years). A total of 13 sites were selected which include over 1,300 trees in 34 distinct groups of species or planting situations. The case study projects are:

1) Allentown Mall, Allentown, PA
2) Charlottesville Mall, Charlottesville, VA
3) Chelsea Center City, Chelsea, MA
4) Chestnut Street Mall, Philadelphia, PA
5) Christian Science Center, Boston, MA
6) Constitution Plaza, Hartford, CT
7) Dock Square, Boston, MA
8) Federal Reserve Bank, Philadelphia, PA

9) Independence Mall, Philadelphia, PA
10) Library/Gallery Place, Washington, DC
11) Paley Park, New York, NY
12) Pennsylvania Avenue, Washington, DC
13) Visitor's Center, Philadelphia, PA

PROJECT EVALUATION CRITERIA

The 13 projects were each evaluated to establish a standard data base and allow comparison between projects (table 1). The trees were evaluated by field observation, interviewing key personnel involved with the project, and study of the contract documents. The criteria are as follows:

Size was taken from the contract documents and confirmed by interview, if possible.

Average growth rate/year was calculated by subtracting the average trunk diameter (D.B.H.) from the caliper size at installation. When a caliper size is given as a range, the smaller size was used. Because of the difference between caliper and D.B.H., this figure is not a true representation of actual growth, rather a statistical figure for comparison.

Tree Condition for each tree was evaluated in the field using the following standards. When it was unclear into which category a tree belonged, the lower category was used. Each category was assigned a numerical value from 1 (excellent) to 7 (dead). The rating methodology:

1) **Excellent.** No noticeable problems, even branching, normal leaf size and color.
2) **Good.** Full grown with no tip dieback; may have minor bark wounds, thinner crowns, slightly smaller leaf size, or minor infestation.
3) **Fair.** One or two of the following: minor tip or crown dieback less than 10 percent; small, chlorotic or disfigured leaves; thinner crown; significant trunk wounding; recent large branch removal that minimally affects crown shape; or large insect infestation. Problems should be able to be repaired or maintained with no long-term impact on tree health.
4) **Poor.** Any of the following: crown dieback 10 to 25 percent; significantly smaller, chlorotic or disfigured leaves; branch removal that affects crown shape in a significant way; or trunk wounding that will have a long term impact on the tree.
5) **Very poor.** Any problem that is so significant that it grossly affects the shape or health of the tree (25 percent or more). Trees that have little hope of long-term survival.
6) **Replace.** Trees that still have some green but should be replaced immediately for aesthetic and safety reasons.
7) **Dead.** Trees that are dead or have less than 10 percent of the crown with leaves. Tree pits with no tree or that have been paved over. Tree pits with trees that were obviously not part of the original planting.

Soil Volume was taken from the contract documents and confirmed in the field.

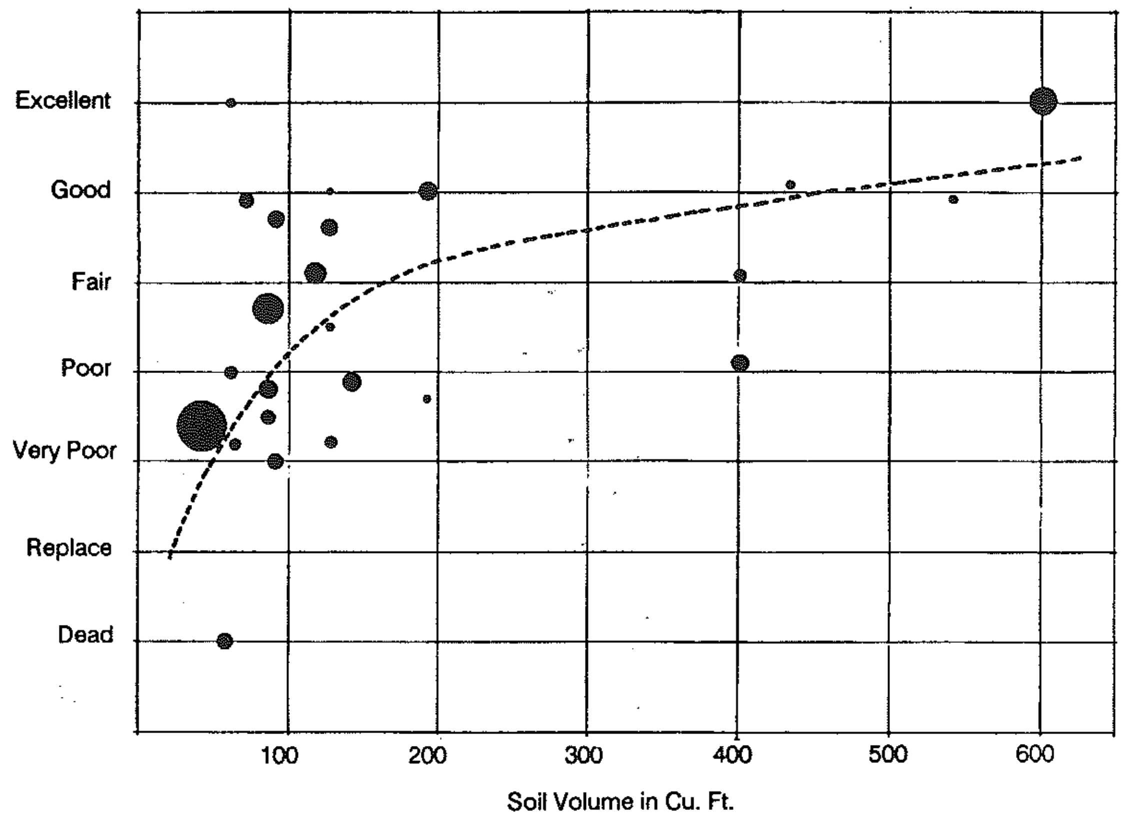
Maintenance Level was assigned to each project based on key maintenance tasks according to the following criteria:

1) **Very High.** Regular pruning, regular disease and insect control, watering beyond the initial transplant period.
2) **High.** Regular pruning, regular disease and insect control.
3) **Medium.** Pruning once or twice during project life, disease and insect control as required.
4) **Low.** Emergency pruning only. Number of trees at planting was determined by the actual count of trees, including empty tree pits or tree pits that had been paved over since initial construction.

PROJECT EVALUATION

Current Average Tree Condition Compared to Soil Volume. The condition of each tree was ranked using a numerical system (1 to 7) to allow graphic comparison to other factors (figure 1). When compared to soil volume, there is a continuous increase in overall tree performance as soil volume increases. This increase is dramatic at lower soil volumes (40 to 100 cubic feet) and flattens above about 150 cubic feet. This flattening can be explained by the following theories: (1) The trees with larger soil volumes are younger and have not filled the area provided; (2) Given the wide range of species in the study, different species

Figure 1. Tree Condition--Soil Volume



are reacting differently to soil volume and other site factors; and (3) Other urban stresses may account for a large portion of exhibited tree condition.

One tree group shows an average condition which seems to be inconsistent with other data results; the red oaks of the Christian Science Project are in one of the smallest soil volumes yet scored an average of "excellent." This site has three important factors that contribute to its success: (1) The surrounding sidewalk has subsided, indicating poor compaction in the area; (2) The project site has good drainage; and (3) there is a large irrigated lawn area adjacent to the planting.

Maintenance as a Factor in Tree Condition. In plotting maintenance levels against tree condition, no obvious relationship could be established (figure 2). It suggests that levels of maintenance are not critical in the tree's performance expectation. However, this is inconsistent with other observations. A study with tighter controls and targeted on this issue should be undertaken to resolve this conflict.

ADDITIONAL OBSERVATIONS

In addition to the evaluation of the numerical data, further observations were made during the course of the study:

Clustering of Successful and Unsuccessful Trees. Stands of similarly planted trees, even healthy stands such as the one found in Charlottesville Mall, almost always responded as a cluster to condition variations. Rarely was a single specimen in a healthy state found surrounded by unhealthy trees, or a dead tree found surrounded by healthy trees. The trees usually responded to environmental change gradually. This was more consistent on sloped sites than flat sites, indicating water as a key element in the relationship.

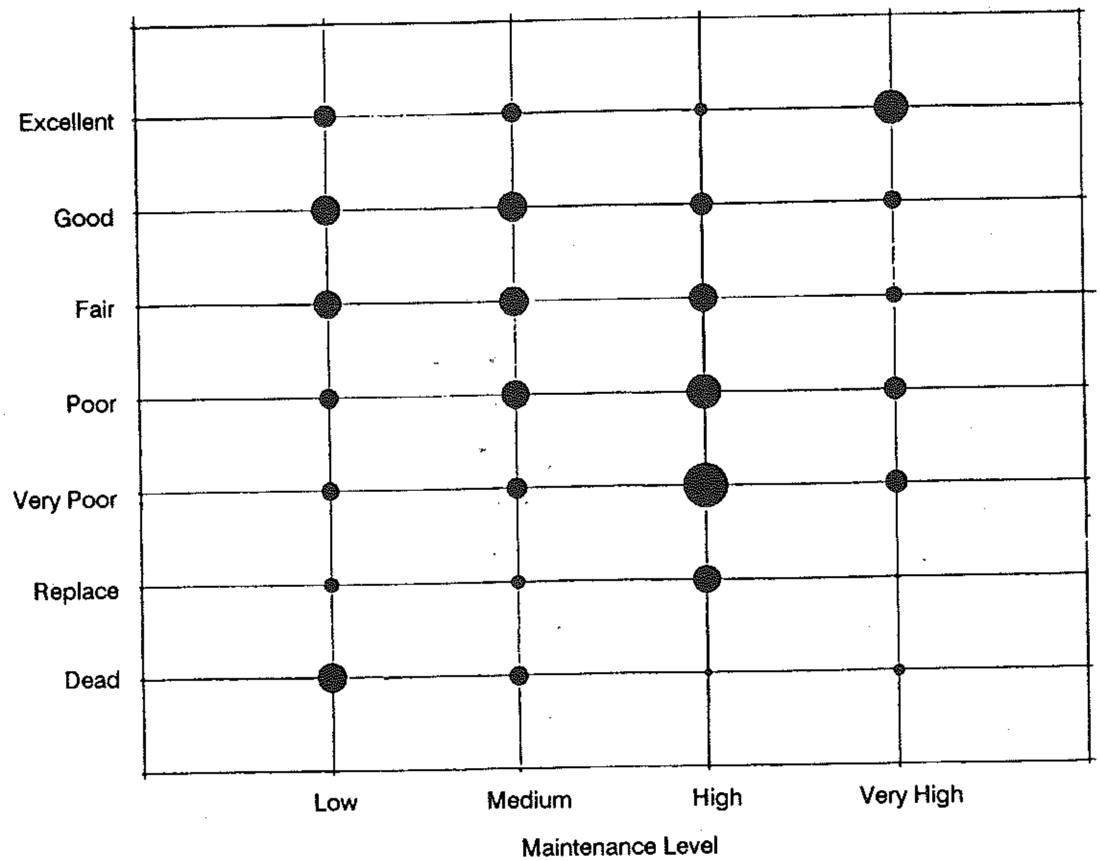
Table 1. Project Data Summary

Projects	Age in Years	Main-tenence Level	Planting Site Soil Volume-- Cu. Ft.	Avg. Growth/Yr.	Avg. Condition	Number of Trees by Condition Level						
						Excellent	Good	Fair	Poor	Very Poor	Dead	Replace
Allentown Mall												
Honey Locust	16	L	126	.27	2.0	1	3	1	–	–	–	–
London Plane	16	L	126	.35	3.5	2	4	1	–	1	–	1
Norway Maple	16	L	126	.17	4.8	1	–	6	4	1	4	6
Red Oak	16	L	126	.24	3.2	6	14	12	7	8	4	–
Charlottesville Mall												
Red Maple	14	M	192	.16	4.3	–	–	–	7	3	–	–
Willow Oak	14	M	192	.51	2.0	14	17	8	3	–	–	–
Chelsea												
Green Ash	11	M	86	.08	4.5	–	1	12	6	2	3	9
Linden	11	M	86	.18	3.3	4	25	14	9	10	5	3
Red Maple	11	M	86	.23	3.2	2	4	5	7	–	–	1
Red Oak	11	M	86	.16	3.3	2	13	18	11	6	3	1
Zelkova	11	M	86	.29	4.1	–	2	7	11	4	–	3
Bradfrod Pear	11	M	86	.27	4.2	1	10	6	4	4	1	10
Chestnut Street												
Cherry	13	L	56	–	7	–	–	–	–	–	–	13
Linden	13	L	56	–	7	–	–	–	–	–	–	4
Red Maple	13	L	56	–	7	–	–	–	–	–	–	4
Sweet Gum	13	L	56	–	7	–	–	–	–	–	–	4
Crabapple	13	L	56	–	7	–	–	–	–	–	–	14
Chinese Dogwood	13	L	56	–	7	–	–	–	–	–	–	13
Christian Science												
Red Oak (M.A.)	21	L	60	.26	1.0	12	2	–	–	–	–	–
Red Oak (H.A.)	21	L	60	.081	4.0	–	5	7	6	2	2	4
Linden	21	VH	600	.16	1.0	121	–	–	–	–	–	–
Constitution Plaza												
Sugar Maple	27	VH	90	.17	5.0	1	2	4	6	3	2	12
Dock Square												
Linden	24	L	72	.40	2.1	13	17	3	2	0	0	2

Table 1 continued. Project Data Summary

Projects	Age in Years	Main-tenence Level	Planting Site Soil Volume–Cu. Ft.	Avg. Growth/Yr.	Avg. Condition	Number of Trees by Condition Level						
						Excellent	Good	Fair	Poor	Very Poor	Dead	Replace
Federal Reserve												
Red Oak	23	M	540	.25	2.1	3	3	4	–	–	–	–
Zelkova	23	M	432	.32	1.9	3	3	2	–	–	–	–
Independence Mall												
Red Oak	27	H	140	.14	4.1	–	8	10	17	13	4	4
Honeylocust	27	H	40	.10	4.6	–	–	48	110	190	56	–
Library/Gallery Place												
Red Maple	24	L	400	.16	3.9	–	8	15	5	12	5	1
Bradford Pear	24	L	400	.42	2.9	–	11	6	5	–	–	1
Paley Park												
Honeylocust	22	VH	62	.03	4.8	–	–	–	15	–	–	3
Pensylvania Ave.												
Willow Oak (3rd-4th)	11	VH	115	.22	2.8	1	6	7	4	–	–	–
Willow Oak (14th-15th)	10	VH	115	.29	2.9	1	7	3	1	3	–	–
Laurel Oak	10	VH	115	.25	2.8	3	11	8	6	2	–	–
Visitor's Center												
London Plane	24	H	91	.36	2.3	11	24	7	2	–	–	3
Totals or Averages for all projects	17	–	149	.23	3.9	202	200	214	248	264	94	116

Figure 2. Tree Condition--Maintenance Level



Association with Structures. When examining the clustering of successful or unsuccessful trees, often the clusters were found in association with architectural or engineering structures (walls, foundations, vaults, footing, etc.). Generally, these items had a positive effect on the health or condition of the tree. Back-filling around architectural footings, a process frequently done by hand or small tools, may create more rooting opportunities than larger expanses of paving compacted by machine. This also suggests that there is a compaction rate that satisfies the engineering requirements of the structure while also being adequate for root growth. More research into this area is needed.

Association with Adjacent Open Spaces. Trees in proximity to open lawn or garden spaces were always healthier than trees planted toward the centers of paved areas. This is consistent with the concept of root "breakout."

Tree Guards and Tree Grates. Under most circumstances, tree grates and tree guards were damaging the trees or had been removed. The damage caused by tree guards and tree grates cannot be overstated.

Paving Details. Of the various paving systems included in the study, large granite cobbles set in sand at Boston Dock Square and The Visitor's Center in Philadelphia seemed to provide the best rooting surface. Both sets of trees scored well and there was little evidence of root disruption of the area. However, at the third block of Independence Mall, where a flexible unit brick paver was set in sand, the trees scored poorly and the pavers were torn apart by the tree roots. In areas where the paving was either concrete, or pavers set on concrete, the results were varied, and it is difficult to determine if the paving system was influential in the results.

CONCLUSIONS AND RECOMMENDATIONS

The overall conclusion of this study is a confirmation that using current approaches to theinstallation of trees in the urban landscape will result in unpredictable outcomes, and that the average condition of trees in the landscape after 10 to 20 years will be disappointing; the average condition of the case study projects was 3.7, between poor and fair. The studies, however, also indicate a number of areas for improvement or where further research may reveal significant improvement possibilities.

Soil Volume. Trees respond favorably to an increase in soil volume available to their roots. The following direct relationships are apparent when studying the data collected.

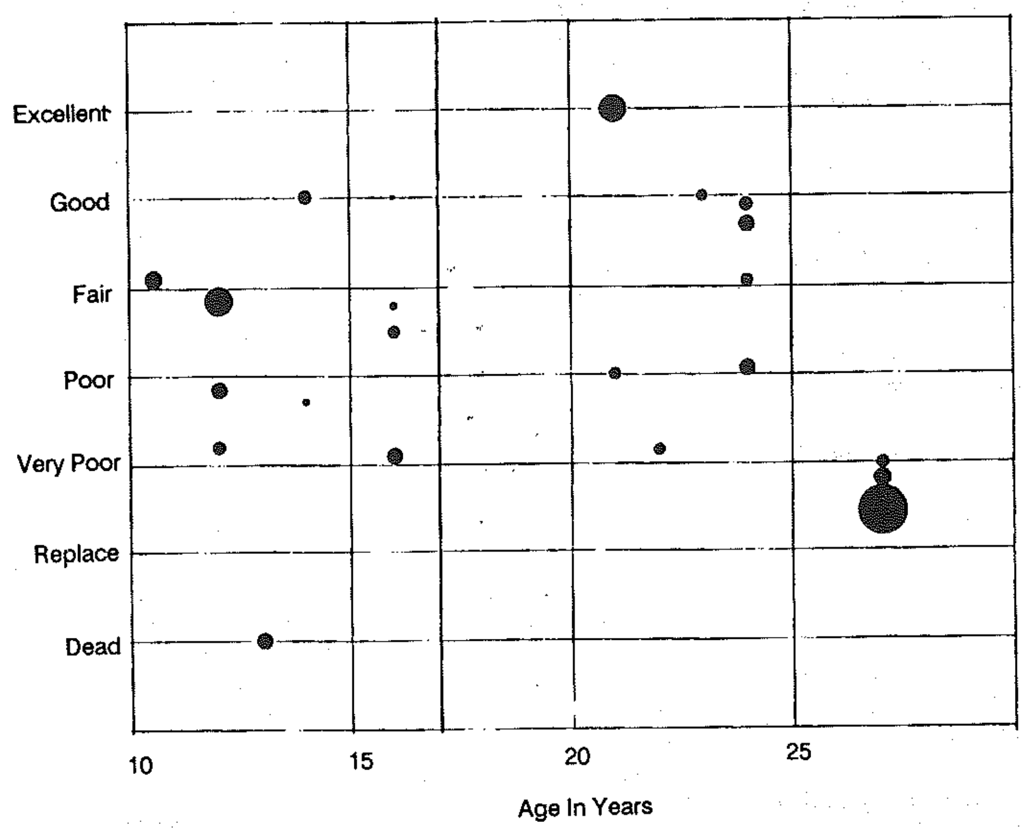
1) Increasing the size of the actual hole dug for the root ball increases the performance of the tree and the consistency of tree health within the stand. This is especially true for the first 100 to 200 cubic feet. After this level, the data is less convincing. Exactly what is the proper planting site size, is still a subject for debate. But any planting site with less than 100 cubic feet cannot sustain long-term tree growth.
2) There is strong evidence that the majority of successful trees in this study have found some alternative source of rooting space outside their designed areas. These spaces are called "breakout" spaces. Because of the haphazard distribution of breakout spaces in the urban landscape, haphazard distribution of tree health within the design often occurs. Breakout space should be designed into the urban landscape, both below the pavement and beside it. All potential breakout spaces should be identified during the design phase, and a determination should be made as to whether they should be increased, redistributed to enhance regulated consistency of the stand, or in some cases, eliminated to avoid irregularity in future tree growth.
3) Designers should, whenever possible, begin to design trees in open lawn areas adjacent to paved areas, rather than in tree pits. Red oaks and sugar maples planted outside the paving at Constitution Plaza, and willow oaks planted behind the sidewalk at Pennsylvania Avenue, have all more than doubled the growth rates of similar trees planted at the same time in confined tree pits. At Constitution Plaza, the difference is particularly obvious with 20-inch diameter trees, nearly all in excellent condition, contrasted by dead or dying street trees.

Paving Systems. No single paving system seems to be superior. Examination of paving types and conditions in relation to tree condition indicates that there must be a combination of sub-base compaction and paver design that is suitable to support the pavers without dangerous amounts of settlement or bucking, while still providing an acceptable growing medium for tree roots. This balance has obviously been obtained around many of the trees studied where healthy trees are surrounded by smooth uncracked paving and no other obvious breakout space available. The factors that need study are the soil type, compaction rates, drainage availability, and paving design. In the final analysis, however, healthy trees were more often associated with failed pavement either from settlement (poor compaction during construction) or lifting (roots growing in the thin air zone just below the pavement). Since failed paving is not an acceptable way to grow trees, alternative systems must be found.

Symmetry of Plan Design and Consistency of Tree Growth. Rarely were the grand schemes of the designer realized. In every project studied, the design process appears to have stopped at the plan review. One or two typical details for tree planting were expected to guide the entire construction process. When designing symmetrical landscapes, designers should calculate the soil volume available to each tree and develop a scheme so that each tree in the planting has access to approximately the same quantity. This can be done by a combination of restricting larger rooting areas or expanding smaller ones. Difference in rooting areas will result in differences in tree appearance within 10 years or less.

If the project control or budget to balance the rooting area is not available, then asymmetrical designs should be considered. This new technical requirement will have a profound effect on the design process. It essentially requires the designer to understand, at the beginning of the design process, the potential limitations of scope, budget, and schedule, which now have a larger impact on the final design.

Figure 3. Tree Condition--Age



Species Selection. The case study did not look specifically at species selection, but two conflicting results are apparent. Within individual projects, species selection seems to be very important. In the few projects where multiple examples of similar species occurred, however, species selection does not appear to be as important in relation to other factors. General observations and other research indicates that speciesselection is extremely important. A balance must be struck between using the best species for each situation and keeping a high degree of diversity within the overall urban landscape. Species selection should continue to be a matter of the highest importance to designers, and further research into this area must continue at the highest funding levels available. At the same time, the design community must expand their knowledge of tree types in order to be able to select the right tree.

Age of the Planting. It appears that project age is not a limiting factor in tree health (figure 3). Conclusions of this study suggest that these projects are performing only slightly better than the typical urban street tree. National estimates vary from 10 to 25 years as the average life expectancy of a street tree in intensively developed urban areas. The trees at Christian Science and the trees in open planters at Constitution Plaza, however, demonstrate that age does not have to be limiting and that, after over 25 years, complete stands of healthy trees are possible.

Trunk Diameter Growth as an Indicator of Tree Health. The study revealed a consistent relationship between trunk diameter growth and general tree health. This finding is consistent with forest practices, however, no base-line data exists for urban trees. The large number of trees included in this study could be the beginning of such a performance base line and should be useful to urban foresters in determining the health of specific urban trees. Trunk growth rates is an easier and faster way to evaluate large stands of trees. By monitoring this one number, a quick overview of the trees' performance could be taken. Since a slowdown in trunk growth often precedes the appearance of other manifestations of tree problems, this measurement could predict tree problems.

Tree Grates and Tree Guards. Use of tree grates and tree guards should be discontinued or redesigned to assure that they will not injure the tree. This one simple act would save thousands of urban trees and reduce the cost of tree installation. The cost of a typical tree grate ($500 to $1,000) could fund most of the cost of the additional soil called for in this report.

Irrigation. The data does not suggest that irrigation is a significant factor in tree health. While it may improve the health of trees in marginal planting sites, it is probably not necessary if sufficient soil volumes are available to the tree. The ability to get supplemental water to the soil zone during times of extreme drought appears to have some benefit, however, this conclusion is based on observation of other projects not included in this study. More research in this area is necessary.

Maintenance. One of the more perplexing findings of this study was a lack of relationship between the level of maintenance and tree health. It appears that beyond simple and occasional pruning and dealing with specific insect infestations, other factors (e.g., soil and species selection) seem to outweigh maintenance. Since this finding is not consistent with other observations, it should be the subject of further research.

Proceedings of the Fourth Urban Forestry Conference

ST. LOUIS, MISSOURI
OCTOBER 15-19, 1989

Edited by:

Phillip D. Rodbell

To Jim
your exceptional contributions
to Urban Forestry will carve
a niche of responsibility
for all LAs ...
Keep moving + shaking
Phillip

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