THE ECONOMIC IMPACTS OF DEFERRING ELECTRIC UTILITY TREE MAINTENANCE

by D. Mark Browning and Harry V. Wiant

Abstract. A study was conducted to examine the economics of deferring line clearance tree pruning. The cost of pruning a tree was found to increase significantly as it grows closer to, and beyond, the conductors. The amount of biomass, and thus disposal cost, also increases with the length of time a tree is allowed to grow. Predictive models were developed for three utilities to provide a means of projecting the total impact of postponing line clearance work on crew time and costs associated with pruning trees. For every routine maintenance dollar deferred, substantially more than one dollar must be spent in subsequent years to re-establish the preferred cycle. The specific amount of this increase is utility dependent and is affected by production costs, tree growth rates, site characteristics (dbh and type of pruning), etc. An additional adjustment would be necessary to allow for an increase in disposal costs resulting from a larger amount of biomass removed. If funding reductions are not offset with larger expenditures in subsequent years, tree maintenance cycles are rapidly extended. Modeling a 20 percent annual funding decrease resulted in extending one utility's cycle from 5 years to 9 years over a 12-year period. These estimates do not take into account the impact that deferred line clearance work has on service reliability, service restoration costs, and the amount of time spent on hotspotting and responding to customer requests for unscheduled maintenance.

Electric utility line clearance programs typically approach tree management through a program of maintenance cycles where trees are pruned at regularly scheduled intervals. Unfortunately, many utilities fund their programs in such a way that trees are not pruned in time and they begin to overgrow the conductors.

The impact of deferring utility tree maintenance is generally evaluated in terms of service reliability. Anecdotal evidence suggests that deferred tree maintenance also impacts a utility's maintenance costs. One implication is that the cost to prune trees on a more frequent basis (i.e., when implementing a shorter pruning cycle) may be offset by reduced per-tree costs. Another implication is that when utilities reduce line clearance funding, there is a disproportionate impact on the cycle. Understanding these relationships would enable utility arborists to better identify and justify the optimum line clearance cycle in their service area.

The International Society of Arboriculture Research Trust provided funding in an effort to better understand the economic impacts of the widespread practice of deferring utility tree maintenance. The study was conducted on three utility properties in the United States by Environmental Consultants, Inc. (ECI). The three utilities that participated in the study are Northern States Power Company (MN), Puget Sound Power & Light Company, and West Penn Power Company.

Study Methodology

Each utility was responsible for selecting 5 areas or circuits last pruned during the dormant season 2, 3, 4, 5, and 6 years prior to the study. The sites were similar in terms of the following criteria:

- Accessibility to a lift truck
- Tree density
- General age of the tree population
- Type of pruning required (e.g., percent top trims)
- Species composition
- Voltage, number of phases, and construction type.

Each site contained between 50 and 80 trees. All of the sites were located in urban/suburban areas on 3-phase circuits accessible to a lift truck. Over 1,000 trees were included in the study.

The utilities began pruning the study trees in the spring of 1996. Pruning was performed in a manner consistent with the utilities' normal line clearance operations. The following data was collected by the crews completing the work:

- Time (years) since last pruned
- Type of work completed
- Tree diameter class
- Time and equipment to complete the work
- Clearance prior to pruning
- Clearance obtained
- Weight of chipped debris.

Study Results

The data collected by the crews were analyzed to determine how deferring line clearance work impacts the cost of tree pruning. The amount of tree-to-conductor clearance prior to pruning, the average branch length removed, diameter at breast height (dbh), and work type (top or side trim) were included in the analysis. The weight of each load of chipped debris was also determined and tracked by study site.

Factors Affecting Maintenance Cost

Years since last pruned. The utilities selected five study areas based on the number of years since the trees at the site were last pruned. Figure 1 illustrates the relationship between the average time required to prune trees for line clearance and the reported number of years since they were last pruned by one of the utilities. A highly significant, positive curvilinear relationship was found to exist between the number of years a tree is allowed to grow and the amount of time required to prune it. As the period of growth is lengthened, the amount of time required for maintenance increases.

Pre-work clearance. Figures 2, 3, and 4 show the average labor time (worker-minutes) required to prune a tree based on the proximity of the trees to the conductors. As shown, an inverse relationship exists between proximity of the branches to the conductors and the average time required to complete line clearance work. As the amount of pre-trim clearance decreases, the average labor time required for tree pruning increases.

The correlation coefficients (r) between pre-work clearance and the time to prune the trees are -0.30 for utility A, -0.51 for utility B, and -0.55 for utility C. In all cases, the relationship is highly significant at the 0.01 level.

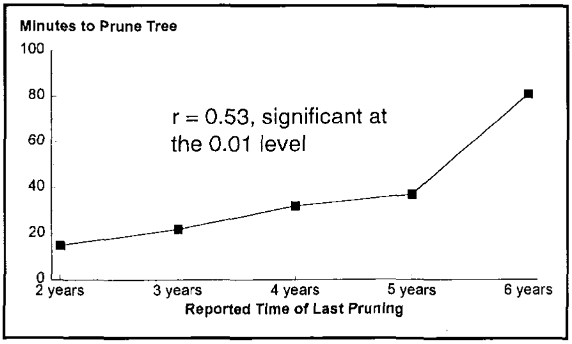

Figure 1. Average worker-minutes to prune trees by the number of years since they were last pruned.

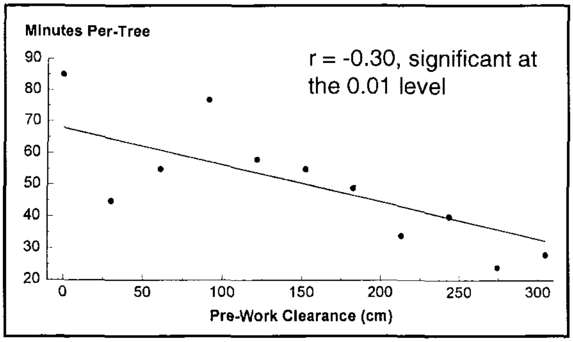

Figure 2. Relatinship between proximity to the conductors and time (worker-minutes) to prune trees at utility A.

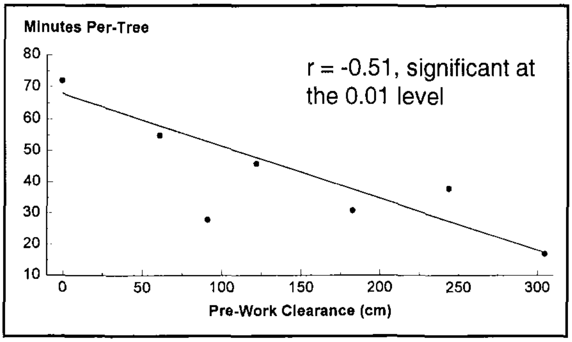

Figure 3. Relationship between proximity to the conductors and time (worker-minutes) to prune trees at utility B.

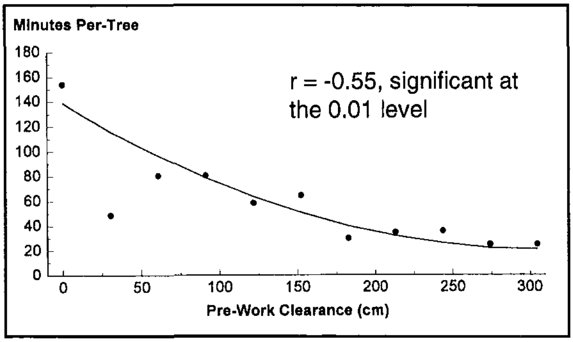

Figure 4. Relationship beetween proximity to the conductors and time (worker-minutes) to prune trees at utility C.

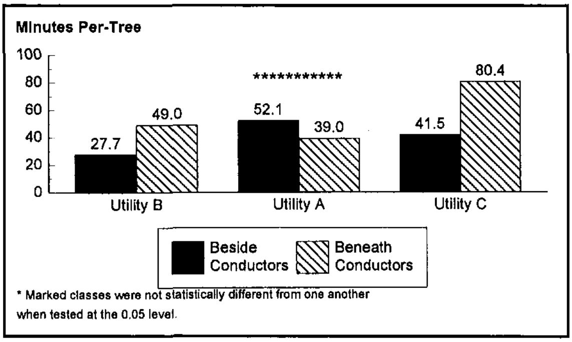

Figure 5. Average time (worker-minutes) to prune trees based on their location.

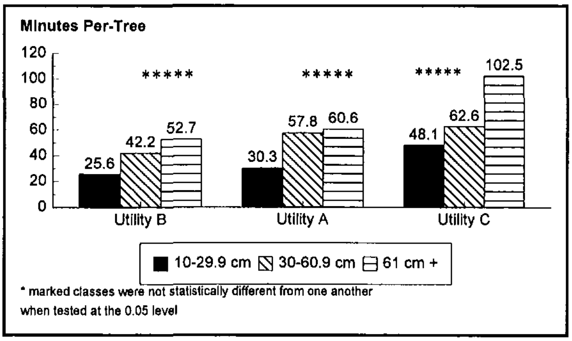

Figure 6. Average per-tree pruning time (worker-minutes) by diameter class.

Branch length. The average branch length removed from a tree is also correlated to the time and cost of line clearance tree pruning. The data from all three utilities showed a strong positive correlation between the average branch length removed and the time required to prune the tree. The correlation coefficients (r) were 0.57 for utility A, 0.47 for utility B, and 0.44 for utility C. All correlations were significant at the .01 level.

Type of pruning. Electric utilities frequently categorize line clearance tree pruning by tree location. Trees located beneath the conductors are typically referred to as requiring "top" pruning while those beside the conductor require "side" pruning. Figure 5 shows the relationship between tree location and the average time needed to complete the work. The time required to prune a tree located beneath the conductors is significantly greater than the time needed for trees beside the conductors at utilities B and C, 1.77 and 1.94 times greater respectively. At utility A, trees beside the conductors took longer, on average, than those beneath the conductor. The difference, however, was not statistically significant at the 0.05 level.

Tree diameter. Three size categories were used to classify the study trees based on their diameter at breast height. The three diameter classes were 10 to 29.9 cm (4 to 11.9 in), 30 to 60.9 cm (12 to 24.3 in), and 61 cm (24.4 in) and larger. The amount of time required to prune trees varied significantly by diameter class at all three utilities (Figure 6).

Impact of Deferred Maintenance on Cost

Pruning costs. Regression analysis was used to develop predictive models for worker-minutes (Y) of pruning time for the participating utilities. Variables (X1, X2 , ..., Xn) and interactions of variables were screened using stepwise regression techniques to determine which significantly contributed to the model. Each variable, each significant interaction, and each variable in the significant interactions were used to develop the final regression models. Regression coefficients and the model correlations are provided in Table 1. The form of the model is as follows:

$$Y = B0 + B1X1 + ... + BnXn$$

These models can be used to project the economic impact of allowing trees to grow longer than the optimum cycle. Since tree diameter, type of pruning, and clearance are each significant factors, it is clear that the impact will vary for different sites. Any specific set of site conditions can be modeled using the data presented in Table 1.

One of the study sites which met this criteria was chosen as a model site. This provided a specific set of conditions for comparing the cost of pruning at different points in time. The results are presented in Table 2, which shows the projected impact of deferring maintenance at each of the utilities.

Table 3 shows the relative impact of deferring maintenance in terms of dollars at each of the utilities. As an example, if utility B's tree population, growth rates and clearance standards indicate that the optimum cycle length is 5 years, deferring pruning past 5 years will have a substantial impact on line clearance costs. Each dollar "saved" by not pruning trees at the appropriate time (year 5) will have to be replaced with $1.21 (plus inflation adjustment) one-year later in order to get back on schedule. If trees are allowed to grow past the conductors for 2 years, it will cost $1.39 for every $1 of pruning which was deferred.

Table 1. Regression coefficients for models to predict average time to prune trees based on significant variables and interactions.

Variable Number	Variable/Interaction	Regression Coefficients (B_n) Utility A	Utility B	Utility C
	Intercept	156.105	95.739	135.044
X_1	Pre-work Clearance	-11.399	-7.928	-14.078
X_2	(Pre-work Clearance)^2	-0.160		0.262
X_3	Length Removed	4.275	-2.431	
X_4	(Length Removed)^2	0.059	-0.052	-0.113
	Tree Diameter*			
X_5	1 if Small, else 0	-84.144	4.234	-68.852
X_6	1 if Medium, else 0	-4.819	5.064	-40.995
	Pruning Type*			
X_7	1 if Side, else 0	-22.220	2.021	2.166
	Interactions			
X_8	$X_1 * X_5$	7.056		8.910
X_9	$X_1 * X_6$			3.803
X_{10}	$X_2 * X_5$			-0.263
X_{11}	$X_2 * X_6$			0.039
X_{12}	$X_2 * X_7$	0.290		
X_{13}	$X_3 * X_5$	-3.628	5.852	
X_{14}	$X_3 * X_6$		3.804	
X_{15}	$X_4 * X_5$	-0.172		
X_{16}	$X_4 * X_6$	-0.222		
X_{17}	$X_4 * X_7$		-0.222	-0.213
Model Degrees of Freedom		12	9	11
Error Degrees of Freedom		327	330	328
Correlation Coefficient		0.63	0.63	0.64

*Categorical data was coded as either a 1 or a zero

Table 2. The impact of deferred maintenance on the average time to prune trees for line clearance as projected by the regression equation.

		Average Time (Worker Minutes) To Prune Trees At A Site That Is:				
Utility	Length of Optimum Line Clearance Cycle	At The Conductor*	1-Yr. Past Optimum	2 Yrs. Past Optimum	3 Yrs. Past Optimum	4 Yrs. Past Optimum
A	5 Years	68.9	84.9	98.7	109.6	116.2
B	5 Years	56.9	68.8	79.2	87.1	93.2
C	6 Years	43.4	50.5	56.3	60.8	64.0

* Optimum time is based on the industry standard of 10-15% maximum tree-to-conductor contact, referenced in this table as "At The Conductor".

Biomass. Chipped debris obtained by tree pruning was collected by utility B to gain insight into the relationship between the age of branch regrowth and the amount of biomass removed from a tree. The weight of chipped debris was not obtained for individual trees. Rather, the total weight of chipped biomass was determined for each site and an average per-tree weight of biomass was calculated. As shown in Table 4, the average weight of chipped biomass rises significantly with time. The average weight of chipped debris increased from about 7.5 kilograms per-tree for the 2-year old site to over 129

Table 3. Projected impact of deferred maintenance on the average cost of pruning trees for line clearance.

			Relative Cost* To Prune Trees At A Site That Is:			
Utility	Length of Optimum Line Clearance Cycle	At The Conductor**	1-Yr. Past Optimum	2 Yrs. Past Optimum	3 Yrs. Past Optimum	4 Yrs. Past Optimum
A	5 Years	$1	$1.23	$1.43	$1.59	$1.69
B	5 Years	$1	$1.21	$1.39	$1.53	$1.64
C	6 Years	$1	$1.16	$1.30	$1.40	$1.47

* Excludes an adjustment for inflation.

** Optimum time is based on the industry standard of 10-15% maximum tree-to-conductor contact, referenced in this table as "At The Conductor".

Table 4. Weight of biomass removed by the number of years since last pruned for trees at Utility B.

Last Pruned	Number of Trees	Total Weight (kg)	Weight Per-Tree (kg)
2 yrs.	63	463	7.4
3 yrs.	73	1,488	20.4
4 yrs.	76	3,892	51.2
5 yrs.	80	4,944	61.8
6 yrs.	65	8,410	129.4

kilograms per-tree for the 6-year old site. Figure 7 illustrates the close relationship found between the average weight of the biomass removed and the average time required to prune a tree.

Discussion

The time and cost associated with pruning a tree to maintain safe and reliable clearance from the electric system increases as it grows toward and beyond the conductors. Every dollar of spending deferred until a later date must be replaced with more than one dollar in order to restore the program to the original cyclical maintenance schedule. How much more depends on the characteristics of the tree (dbh and type of pruning), the specified clearance standards, tree growth rates, and the number of years that pruning is deferred. For Utility B, each dollar withheld from the pruning budget would need to be replaced with $1.21 (plus inflation) the following year in order to get back on schedule. A 2-year delay in pruning would increase this to $1.39. Similar results were obtained from the models developed for utilities A and C.

Postponing maintenance beyond the optimum time also results in increased disposal costs. Data from Utility B showed that the site pruned on cycle (i.e., after 5 years) produced an average of about 62 kilograms of pruning debris per tree. The site which had been allowed to grow 1-year longer produced approximately twice the amount of debris.

Many utilities that reduce their line clearance budget do not replace the funds in subsequent years. Therefore, it is important to know the long-term impact of funding reductions. This can be also assessed using the models presented in Table 1.

For example, assume that Utility B, which has an optimum 5-year cycle, undergoes a 20 percent reduction in its annual budget for tree pruning. Initially, it would appear that the cycle length would merely increase by 20 percent, from 5 years to 6.25 years. The impact, however, would actually be much larger. One year of reduced funding would allow 4 percent of the trees to grow beyond the optimum scheduled maintenance time (5 years). After 4 years of a reduced budget, over 21 percent of the trees will have grown for more than the optimum 5 years.

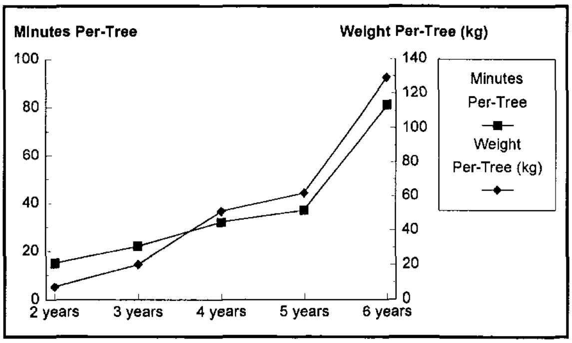

Figure 7. Comparison of time (work-minutes) to prune a tree and the biomass removed by the number of years since trees were last pruned at Utility B.

Some trees will have 7 years of regrowth. After 12 years, nearly one-half of all the trees on the system will have gone more than 5 years without receiving maintenance, and some will not have been pruned in 9 years.

This example, which is illustrated in Figure 8, shows how a 20 percent reduction in funding would result in an 80 percent change in cycle, moving the utility from a 5-year cycle to a 9-year cycle (i.e., 4 years over cycle) in just 12 years. It is important to note that this change is likely to be accelerated as service reliability declines and hotspotting and responding to customer requests becomes more common, further reducing the funds available for scheduled, cyclical maintenance.

A decline in service reliability also results in lost revenue while service is down, and an increase in the amount of time spent on service restoration. Although service restoration is not a vegetation management cost, it can still be directly related to vegetation conditions and should therefore be considered when making decisions on deferring the maintenance of scheduling units.

Deferred maintenance can also alter the vegetation conditions of scheduling units beyond increasing the amount of regrowth on the trees. Longer intervals of maintenance can allow hazardous trees and limbs to develop, further jeopardizing system reliability. In addition, deferring the maintenance of brush allows it to mature and become a more expensive and often permanent part of the workload.

In terms of service reliability and safety, it is imperative to maintain vegetation on a schedule that minimizes the number of trees that have the potential to contact the conductors. Deferring maintenance allows trees to grow into and beyond the conductors, which decreases the reliability of the system and significantly affects future maintenance costs.

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Project Manager
Environmental Consultants, Inc.
520 Business Park Circle
Stoughton, WI 53589

Professor Emeritus, Division of Forestry
West Virginia University
113 Scenery Drive
Morgantown, WV 26505

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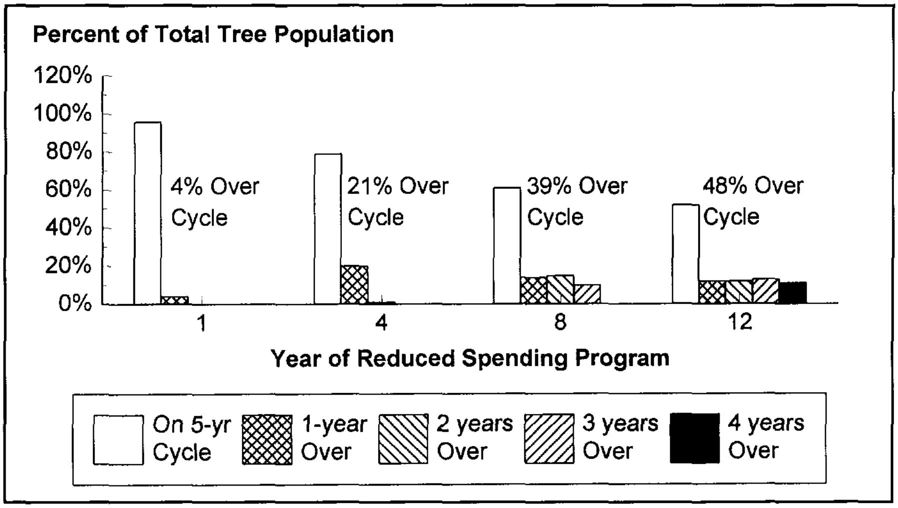

Figure 8. Projected impact on a 5-year cycle of a 20 percent annual funding reduction.

Résumé. Le coût d'élagage de dégagement d'un arbre s'accroît significativement lorsque l'arbre pousse de plus en plus près et au-dessus des fils électriques. Le volume de biomasse, et par conséquent les coûts de disposition, augmentent eux aussi avec la période de temps où il est permis à l'arbre de croître. Des modèles de prédiction ont été développés pour projeter les coûts associés à un report du dégagement des fils électriques. Pour chaque dollar de dépense dans l'entretien cyclique qui est reporté, c'est substantiellement plus d'un dollar qui doit être dépensé au cours des années suivantes pour réétablir le cycle préférentiel de dégagement.

Zussammenfassung. Die Kosten für das Freischneiden von Bäumen steigen deutlich an, wenn die Bäume dicher heran und über die Leitungen hinaus wachsen. Die Menge an Biomasse und die Entsorgungskosten steigen ebenfalls mit der Zeit, in der die Bäume ungestört wachsen können. Es wurden aussagekräftige Modelle entwickelt, um die Kosten für die verzögerten Maßnahmen zum freischneiden der Leitungen zu demonstrieren. Für jeden zurückbehaltenen Dollar für die Routinepflege muß demzufolge mehr als ein Dollar in den Folgejahren aufgegeben werden, um den gewünschten Kreislauf wiederherzustellen.