# BENEFIT-COST ANALYSIS OF MUNICIPAL DUTCH ELM DISEASE CONTROL PROGRAMS IN COLORADO

**by Stephen C. Sherwood and David R. Betters**[1]

**Abstract.** Dutch elm disease is a serious problem for many municipalities throughout the United States. Several disease control alternatives have been applied to help reduce elm losses, but seldom have the economic costs and benefits been addressed. A benefit-cost methodology is presented which can be used to analyze the economic efficiency of control alternatives. The approach is developed and then applied to selected municipalities in Colorado. The results indicate that the methodology can be easily applied and that, given the application here, benefits of certain Dutch elm disease control alternatives exceed the costs.

Municipalities throughout much of the country are faced with the possibility of losing a large proportion of their American elm trees (*Ulmus americana*) to Dutch elm disease (DED). Elm trees in the United States are primarily important for shade and ornamental purposes. There are few, if any, viable substitutes for the ornamental elm, and the public, in general, has not been willing to accept the loss of the elm trees and the environmental amenities associated with them.

In Colorado alone expenditures for DED control programs amounted to over 1.5 million dollars in 1979. Considerably more is spent annually in the eastern states. Yet the economic efficiency aspects of these DED control programs have received only limited attention. The most extensive treatment regarding the economic aspects of DED control are those presented by Cannon and Worley (2) and Cannon et al. (3). Both the types of control programs needed and the expected benefits and costs of specific control programs are difficult to ascertain, and so they have generally not been considered in detail. The purpose of this article is to present a methodology for performing a benefit-cost analysis (BCA) of municipal DED control programs. An application is shown in order to illustrate the methodology and demonstrate its usefulness in analyzing public investment in DED control. The theoretical aspects of BCA are discussed in several books such as Krutilla and Fisher, Mishan, Pearce or Peskin and Seskin (7, 8, 10, 12).

### Methods for Valuating Benefits

The benefits of a DED control program are primarily related to maintaining live elms in an area. These benefits can be determined by assigning a dollar value to the individual trees saved by the control program. Total benefits would then be the number of trees saved multiplied by the value per tree. There are methods available that attempt to valuate such goods, even though the majority of benefits are of an esthetic and seemingly "intangible" nature. Several methods are available for placing a value on the elm tree. These are:

1) The value of a tree as a marketable commodity in the commercial wood product market.
2) Opportunity costs in terms of the cost savings of not having to remove diseased and dead trees.
3) Valuation of trees based on tree maintenance expenditures.
4) Opportunity costs in terms of preventing loss in property value given expected DED losses.
5) Willingness-to-pay values based on what individuals would spend to save the elms or go without them.
6) The replacement value of the trees.
7) Values determined by the use of the "Guide

[1] Stephen C. Sherwood is a former graduate research assistant, Department of Forest and Wood Sciences, Colorado State University; now research forester, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. David R. Betters is an associate professor, Department of Forest and Wood Sciences, Colorado State University, Fort Collins, Colorado.

The authors wish to acknowledge the USDA Forest Service funding support for this study and the assistance of Mr. John G. Laut, Insect and Disease Division, Colorado State Forest Service.

for Establishing Values of Trees and Other Plants" prepared by the Council of Tree and Landscape Appraisers (CTLA) (4).

All of these techniques have shortcomings, and some are more legitimate for use in this case than others. For example, the value of the tree for commercial wood products 1) is a market value. But this value neglects to account for the elm's esthetic qualities which normally provide the majority of the benefits. Tree removal cost savings 2) and tree maintenance expenditure 3) are appealing in that they are based on actual expenditures. However, both are supply oriented analyses in which demand has not received consideration. Loss in property value 4) has merit but is very difficult to apply. The difficulty in using loss in property values is that many other factors influence the value of property, including its location, size, and various types of improvements other than the elms. These other factors make it difficult to separate out the contributions of the trees themselves. Nevertheless, property values have been used to estimate values of residential tree losses (9).

Willingness-to-pay values 5) could be useful in valuing tree benefits. This is, however, an extremely difficult process involving many problems such as eliminating biased estimates. For example, an individual with a large number of elms within his immediate neighborhood may purposely over estimate his willingness-to-pay for a control program. He would do so if he anticipates paying a small portion of the actual costs. In the case of a municipal program financed by tax revenues, the bulk of the control program costs would be distributed among other residents within the municipality. This would result in an inflated value being placed on the individual trees by individuals having the elm trees. Further, in using this approach it would be necessary to determine an individual's willingness-to-pay for various levels of control, because his willingness-to-pay could vary depending, in part, upon the number of elms that would be saved at each control level. In a practical sense, determining such values would not be an easy task. It has also been argued that the hypothetical nature of the willingness-to-pay question results in hypothetical responses that are not totally relevant to the world situation and should not be compared to values (benefits and/or costs) which have been determined in the market (1, 5, 11). However, most economists would recommend the use of willingness-to-pay values whenever they can be accurately developed.

The final methods, the replacement costs 6) and CTLA formula guide 7) can also be used to estimate tree value. In the absence of accurate willigness-to-pay values, these are the methods used to measure tree value in this article. Replacement costs have generally been accepted by the courts, Internal Revenue Service, and insurance adjusters as an estimate of tree value for calculation of casualty losses. A tree is at least as valuable as the cost incurred in replacing it. Replacement costs can normally be determined for trees up to 12 inches in diameter and can be used as a proxy for benefit value if the tree lost is, in fact, replaced by a tree of the same size.

The CTLA formula has been adopted by the International Society of Arboriculture, American Society of Consulting Arborists, National Arborist Association and the American Association of Nurserymen. It is an "ad hoc" procedure for deriving tree value. Given the difficulty in developing willingness-to-pay measures these type procedures can be used to estimate value. Ad hoc procedures have also been used to define value in other areas. For example, the "modified unit day" method (6) of valuing recreation is conceptually the same approach as the CTLA formula.

The CTLA formula allows consideration of four characteristics in placing values on individual trees. These characteristics are tree size (diameter), condition (poor to excellent), location, and species. The formula, in general form, is as follows: Basic value (in dollars) × species classification (0-100%) × condition rating (0-100%) × location factor (in percent) = Value of the tree.

The CTLA formula determines the basic value of a tree based on size and average replacement costs. Estimates of replacement cost are easily determined for trees up to 12 inches in diameter, after which replacement becomes unfeasible. For trees beyond replaceable size, the basic value is again based on the replacement cost value for smaller trees but is then adjusted upward in order to account for the larger tree sizes. Smaller tree values are adjusted after employing a Delphi approach in which a large sample of professional plantsmen were questioned regarding large tree values[1]. In part, their evaluation was based on what individuals were willing-to-pay to not have a large tree removed or actually moved for new developments such as roads or buildings. By using replacement costs as the cornerstone for large tree values, an element of willingness-to-pay is retained throughout the calculation of final tree value. This is essential when estimating the social benefits attributable to DED control programs.

While the CTLA formula is appealing in many respects, there are several shortcomings inherent in the formula that require attention. The first concerns the element of subjectivity involved in establishing the final value of individual trees. It is important to realize, first, that basic values are based on the replacement cost values discussed earlier. Second, no given set of rules will apply in all cases. The formula approach, in each instance, would have to be augmented by an onsite appraisal by a qualified professional plantsman.

Two other shortcomings of the CTLA formula are best expressed through the following two questions: 1) How does the CTLA formula handle the "substitute" problem? 2) Can it handle a situation where the number of trees differs on a particular property? With regards to the first question, the CTLA formula indirectly addresses the substitute question by using replacement cost values as the starting point in calculating a tree's value. These replacement costs represent the cost that would be incurred if one desired to substitute for the elm tree some other species of ornamental tree. Sustitutes are definitely possible, but it takes substantial time and investment to grow a tree that is, for example, 25 inches in diameter.

The location categories listed in the *Guide* allow for consideration of the number of trees present on a given property. In using the formula, basic tree value is adjusted downward according to its location, which for a given tree is described in the *Guide* in one of several ways, including: 1) feature or historical trees, 2) average residential landscape trees, 3) malls and public area trees, 4) city streets and boulevards, 5) native, open woods trees, and 6) dense forest trees. Examination of these location categories indicates that the number of trees present does receive some consideration in establishing tree vaues. This is evidenced by the fact that a tree found in a densely forested area receives a final value well below a tree of the same species, size, and condition located in a mall or public area.

Given the strengths and shortcomings of the CTLA formula, and the absence of accurate willingness-to-pay figures the method seems to be the most appropriate, flexible, and practical method to use. For a more complete discussion of the CTLA formula, the reader can obtain a copy of the *Guide* by writing to the address presented in the Literature Cited section. Finally, an example of how the formula works is presented in Table 1. These values represent American elm tree values for an *average* elm placed in Species Class II, located on city streets and boulevards, and in fair to good condition.

**DED Program Costs**

The costs of a DED control program include not only the monetary outlays or accounting costs but also the opportunity costs associated with the use of a municipality's limited resources. In the case of long term projects that require a constant and continuous supply of resources, the sum of the opportunity costs associated with use of those resources can be substantial. This is especially applicable to DED control programs which will typically be in operation for several years until losses have been reduced to a level where they can be handled by the existing tree care maintenance program. When evaluating a DED control program, the opportunity cost of the resources utilized in the project are accounted for through the discount rate. The discount rate, or opportunity cost, represents the rate of return which could be realized if the resources were put into their next best alternative use, whether it be

[1]Personal communication with Dr. L.C. Chadwick, Director Emeritus of the International Shade Tree Conference, Inc., Columbus, Ohio.

another pubic project or a project in the private sector (8). In the private sector, if an individual's best alternative use of capital is a savings account yielding 8% annually, this is his/her discount rate or opportunity cost. If funds are invested today in DED control, it is assumed that this investment will generate benefits in the future. If the amount and timing of these benefits are known or estimated, they are discounted to the present using the appropriate discount rate. Upon discounting, if the present value of the benefits exceeds the present value of the costs, the investment has returned benefits at a percentage rate of return at least equal to the discount rate. In this case, the project is deemed worthwhile.

The debate over the proper discount rate that should be applied to public projects, such as a DED control program, is far from resolved, and it is beyond the scope of this work to promote a particular viewpoint. A 7% discount rate is used here. This rate is close to that recommended by the Water Resources Council for evaluating federal investments in fiscal year 1979.

The individual tree cost data presented in Table 2 are based on actual costs incurred by various Colorado municipalities in 1978 and 1979. Cost data from 1978 were adjusted for inflation, using the index of average hourly earnings for construction wages paid to common labor.

**Table 1. American Elm Tree Values (in 1979 dollars).**

| *Diameter class* | *Basic value* | *Species classification (X80%)* | *Location (X85%)* | *Condition (X80%)* | *Final value of average tree* |
|---|---|---|---|---|---|
| 5-10.9" | $ 905[1] | $ 724 | $ 615 | $ 492 | $ 492 |
| 11-15.9" | 2,389 | 1,911 | 1,624 | 1,299 | 1,299 |
| 16-20.9" | 4,581 | 3,665 | 3,115 | 2,492 | 2,492 |
| 21-25.9" | 7,479 | 5,983 | 5,086 | 4,069 | 4,069 |
| 26-30.9" | 11,084 | 8.867 | 7,537 | 6,029 | 6,029 |

[1]Value based on replacement costs

**Table 2. Annual Costs (in 1979 dollars)**

| | *Alternative B* | | | *Alternative C* | | | *Alternative D* | | |
|---|---|---|---|---|---|---|---|---|---|
| *Cost Category* | *Number of trees first year* | | *Cost per tree* | *Number of trees first year* | | *Cost per tree* | *Number of trees first year* | | *Cost per tree* |
| Survey Cost | 1000 | × | $ .012 | 1000 | × | $ .012 | 1000 | × | $ .012 |
| | | **$12** | | | **$24** | | | **$36** | |
| Tree Removal Cost[1] | 34 | × | $85.40 | 34 | × | $85.60 | 34 | × | $85.60 |
| | | **$2,910** | | | **$2,910** | | | **$2,910** | |
| Pruning Cost[3] | | | | 333 | × | $35.47 | 333 | × | $35.47 |
| | | | | | **$11,812** | | | **$11,812** | |
| Insecticide Spray Cost[2, 3] | | | | | | | 1000 | × | $5.02 |
| | | | | | | | | **$5,020** | |
| Total Cost, First Year (Year 0) | | **$2,992** | | | **$14,734** | | | **$19,754** | |

[1]It is assumed that prompt tree removal does not cost any more than "removal at convenience"

[2]Based on the use of methoxychlor.

[3]Cost estimates include equipment costs.

## The Methodology

There are five steps that should be followed in performing a benefit-cost analysis of DED control programs. These are as follows:

*Step 1.* Determine average annual projected losses of an uncontrolled DED outbreak.

*Step 2.* Determine projected tree losses under the various levels of control.

*Step 3.* Determine the net number of trees saved by implementing a control program for each control alternative and assign a value to these benefits (benefit or value data used here will be that presented in Table 1).

*Step 4.* Determine the costs of operating various alternative control programs, including no control (cost data used here will be that presented in Table 2).

*Step 5.* Calculate net benefits and benefit cost ratios for each alternative.

Net benefits or net present value (NPV) measures total net worth of the program, including present and future costs and benefits. In general, it indicates whether a project is worth undertaking. The benefit-cost ratio (B/C) expresses the return per dollar invested in a control alternative. In comparing strategies, one project may be ranked higher in a certain measure and lower in another.

## Benefit-Cost Analysis: An application

For purposes of the application, four alternative control strategies have been defined. These four alternative programs are defined as follows:

*Alternative A.* No control. Diseased and dead elms are removed in order to prevent personal injury or property damage caused by falling branches or downed trees. No efforts are made to promptly remove and treat broodwood before mature beetle populations emerge to inoculate healthy elms.

*Alternative B.* Inconsistent sanitation. One tree survey is made each year. Tree removals are not consistently performed within the desired time limit. Overall control efforts are inconsistent from year to year.

*Alternative C.* Consistent sanitation. Two surveys are made each year. Tree removals are performed promptly. Deadwood pruning is performed on a majority of elms as needed.

*Alternative D.* Consistent intensive sanitation. Multiple tree surveys are made each year. Tree removals are performed promptly. Deadwood pruning and insecticide sprays (methoxychlor) are applied to the majority of elms.

The methodology will be illustrated using data from existing control programs, similar to ones described above, in Rocky Ford, Greeley, Fort Collins, and Aurora, Colorado. It is necessary to point out that there are several limitations inherent in the data concerning DED losses under the various control programs described above. First, only eight years of data were available in order to determine the average loss figures presented under Step 1 below. Data from a larger number of years would have helped to increase the accuracy of the calculations. Second, it is assumed that differences between percentage losses is due to the control programs alone and non-DED caused mortality is negligible. Third, the annual elm tree losses and rate-of-spread occurring in each of the municipalities are unique to Colorado and cannot be applied to other areas. There are numerous biological and physical reasons for this. For example, there is little or no pressure on the rate-of-spread coming from outside the municipalities studied. This is due to the relative isolation of the study areas. In addition, the climate within the area of study is unique, especially when compared to the mid-western and eastern states where DED has had such a tremendous impact.

Rocky Ford's data will be used to estimate elm losses occurring with no control program (Alternative A). The Greeley program is representative of an inconsistent sanitation program (Alternative B), Fort Collins represents a consistent sanitation program (Alternative C), and Aurora typifies Alternative D. These four municipalities were selected on the basis of similar elm population sizes and the available data collected over a period of eight years by the Colorado State Forest Service.

*Step 1.* In the municipality exercising no control (Alternative A) an average of 3.41 percent of the elm population was lost annually. This percent loss figure is the average of annual percentage losses over the years 1972 through 1979. This average value will be used in Step 3 for calculating estimates of the number of trees saved by implementing Alternatives B, C, and D. Average values seem the most appropriate to use. Normally it takes a certain amount of time for the control program benefits, in terms of losses prevented, to become established. The long term averages are the best estimate of the long term annual benefits in losses prevented.

There was a good deal of variation in percentage losses from year to year. To a certain extent this is expected since there are numerous other factors influencing the rate-of-spread besides the control program. In the case here, without an ecological/pathological rate-of-spread model, these long term averages are the best estimates of losses prevented. Additional data, collected over a longer period of time, would have probably helped to reduce the amount of variation from the average annual elm loss figures.

*Step 2.* Average annual percentage losses for Greeley, Fort Collins, and Aurora (Alternatives B, C, and D, respectively) are calculated in the same manner as for Rocky Ford. Tree loss data from 1972 through 1979 are used so that the number of years analyzed for all alternatives is the same.

The average annual percentage loss for each alternative is as follows:

| | |
|---|---|
| Alternative B | 3.34 percent |
| Alternative C | 2.78 percent |
| Alternative D | 1.72 percent |

*Step 3.* In this case, benefit and cost estimates for Alternatives B, C, and D will be computed for a 10-year period. The analysis could easily be extended to estimate costs and benefits as they would occur over a greater number of years.

Calculations here will be based on a total initial elm population of 1000 trees. A municipality performing its own BCA would simply substitute its actual total elm population for the 1000 used in this application or adjust the 1000 unit figures proportionally.

The initial step in computing benefit values is to estimate the number of trees saved annually due to the different control alternatives B, C, and D. For example, the loss with no control is 3.41 percent or 34 trees, based on an elm population of 1000. The loss under Alternative D is 1.74 or 17 trees. Thus the trees saved the first year of Alternative D's control program is 17 (34-17). As time goes on the residual population is decreased and, therefore, the number of trees saved becomes somewhat less. Estimates of trees saved were calculated in a similar manner for Alternatives B, C, and D for each year of the ten-year period.

Benfits can now be expressed in monetary terms by multiplying the number of trees saved by an elm tree value taken from Table 1. A value of $4,069 per tree is used for this application. This is the value for an average American elm in the 21 to 25.9 inch diameter class. In this case only one average value per tree is used to simplify illustration of the approach. No one single value needs to be used in the analysis. Several values may be used by a municipality, depending on the numbers of elms in various categories of size, species, location and condition.

*Step 4.* Estimates of total annual costs for Alternatives B, C, and D have been calculated, using an initial elm population figure of 1000 trees. For purposes of this application with Alternatives C and D, it is assumed that each tree is pruned once every three years or that one-third of the residual population is pruned each year. A municipality using the methodology would compute pruning costs based on its own estimate of the number of trees that require pruning in any given year. Total annual costs for each year are the sum of survey, pruning, insecticide spray, tree removal and administrative costs. Table 2 presents each alternative's initial annual costs disaggregated by technique. Using these costs and tree loss figures, the annual costs for year 0 through year 9 were calculated.

*Step 5.* Annual discounted benefits and annual discounted costs are summed and used to derive net discounted benefits and benefit-cost ratios (B/C) for each alternative. These figures, as well as total discounted costs and trees saved, are presented in Table 3. As stated earlier, the discount rate used here in 7% per year. The alternatives can be compared according to total discounted cost (for 10 years), net discounted benefits, trees saved, and benefit/cost ratios. Other evaluation criteria outside the normal scope of a BCA might also be included here, for example, distributional or social aspects regarding the alternatives. It is important that the comparison of the alternatives be based on an equal initial population size and an equal time span.

From Table 3 it can be seen that costs are almost seven times greater for Alternative D than for Alternative B. On the other hand, the estimated number of trees saved by each alternative also increases by a factor of 19. The figures also indicate that the change in benefits is greater than the change in costs when moving to more intensive control program alternatives. For example, in moving from Alternative B to Alternative C costs increase by $45,076, while benefits increase by $76,910. In changing from Alternative C to Alternative D costs and benefits increase by $67,848 and $213,697, respectively. The analyst should also consider these aspects in making an alternative selection.

Although the CTLA formula was used in this application, the cost data in Table 3 can be used to place a value on the elm tree. As pointed out earlier, cost approaches such as removal cost savings and tree maintenance expenditure methods can be used to derive an estimate of value. For example, using program costs and tree losses prevented, the elm tree value would have to be $2467 per tree to justify the total expenditure in Alternative B. In the case of Alternative C, the tree value would need to be at least $1574; for Alternative D at least $1191 per tree. On the average, the elms would have to be worth at least these amounts to justify the alternative programs costs.

**Table 3. Results of the BCA**

| *Alternative* | *Total discounted cost* | *Trees saved* | *Total discounted benefits* | *B/C ratio* |
|---|---|---|---|---|
| B | $15,328 | 8 | $18,970 | 1.24 |
| C | 60,416 | 54 | 95,880 | 1.62 |
| D | 128,276 | 152 | 309,577 | 3.41 |

## Conclusions

While considering the limitations imposed by the loss data, the results of this BCA indicate that DED control programs in selected Colorado municipalities do generate benefits that exceed their costs. More intensive program alternatives exhibit higher net benefits and benefits per dollar invested. In moving from less intensive to more intensive control alternatives, the change in benefits exceed the change in costs. More intensive control programs seem justified from an economic standpoint.

The methodology presented in this study allows for the economic comparison of alternative DED control programs in an urban environment. The results of the benefit-cost analysis can be used as part of the input necessary to make decisions. Recommendations, however, should be made only after proper consideration of other factors, including biological and environmental circumstances, budget constraints, and social, distributional, and political aspects of the problem.

## Literature Cited


1. Beardsley, W. 1971. *Bias and non-comparability in recreation evaluation models.* Land Economics 42(2): 176-180.
2. Cannon, W.N., and D.P. Worley. 1976. Dutch elm disease, performance and costs. USFS Forest Service Research Paper NE-345. 7 pp.
3. Cannon, W.N., S.H. Banger, and D.P. Worley. 1977. Dutch elm disease control: The economics of intensive sanitation. USDA Forest Service Research Paper NE-387. 28 pp.

4. Chadwick, L.C., and D. Neely, et al. 1979. Guide for establishing values of trees and other plants. Int. Society of Arboriculture, P.O. Box 71, Urbana, Illinois. 42 pp.
5. Cocheba, D.J., and W.A. Langford. 1978. *Wildlife evaluation: The collective good aspect of hunting.* Land Econ. 54(4): 490-499.
6. Dwyer, J.F., J.R. Kelly and M.D. Bowes. 1977. Improved procedures for valuation of the contribution of recreation to national economic development. Urbana, Ill.: Report #128. Water Resources Center, U. Illinois.
7. Krutilla, J.V., and A.C. Fisher. 1975. The Economics of Natural Environments. Johns Hopkins Press. 292 pp.
8. Mishan, E.J. 1976. Cost-Benefit Analysis. Praeger. 454 pp.
9. Payne, B.R., W.B. White, R.E. McCoy and R.R. McNichols. 1973. Economic analysis of the gypsy moth problem in the Northest, II: Applied to residential property. Upper Darby, Pennsylvania. USDA Forest Service Research Paper NE-285.
10. Pearce, D.W. 1971. Cost-benefit Analysis. Macmillan Press, Inc. 80 pp.
11. Pearce, D.W. 1977. Environmental Economics. Longman, 200 pp.
12. Peskin, H.M., and E.P. Seskin. 1975. Cost-Benefit Analysis and Water Pollution Policy. The Urban Institute. 370 pp.

## ABSTRACTS

COOK, ALAN D. 1981. **Experts discuss new findings, technology to diagnose trees.** Weeds, Trees & Turf 20(1): 28-29, 44.

Tree diagnosis and evaluation has become a technical scientifically based profession. Electronic equipment, pathologic expertise, and a total knowledge and background of trees has replaced any "I guess . . ." or "It looks like . . ." comments from the professional. Experts presented a thorough review of factors affecting health and monetary value of trees at the Tree Diagnostic and Evaluation Workshop in Columbus, Ohio. Speakers came from 11 states to address an audience of more than 100, representing 21 states and Canada.

ANONYMOUS. 1981. **Prevention of tree diseases includes root graft barriers.** Weeds, Trees & Turf 20(3): 59.

Preventative measures remain the dominant control method for many diseases of trees and ornamentals. Selecting resistant varieties, removing diseased individuals, and planting many varieties in low proportions at safe distances apart are a few of the preventative measures used today. Another preventative measure, not quite as common but equally important, is blocking transmission of disease by root grafts. This can be an effective measure where susceptible species are planted within root range of each other, generally within 35 to 50 feet. A mechanical or chemical barrier must be created between infected and healthy trees. Groundskeepers have two options available for severing root grafts. Mechanically a trench 30 inches deep can be dug midway between diseased and healthy trees. There are many instances when a fumigant may be preferred. The fumigant soaks into the soil and kills tree roots in the immediate area. Thus, the underground root graft is broken and disease-causing sap cannot spread to healthy trees.