Cost-effectiveness of Different Herbicide and Non-herbicide Alternatives for Treating Transmission Rights of Way Vegetation

An Illustrative Guide

2012 TECHNICAL REPORT

Cost-Effectiveness Analysis for Comparing Vegetation Management Alternatives on Electric Transmission Line Rights of Way

An Illustrative Guide

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Product Description

This report is a guide to using cost-effectiveness analysis to compare different programs of vegetation management for electric transmission line rights of way.

Background

Cost effectiveness is an important economic measure for describing and comparing the relative acceptability of different vegetation management programs. Cost-effectiveness analysis is apparently rarely used in the utility industry. This might be related to its apparent complexity, but it can be made direct and accessible for use.

Objectives

The objectives of this report are 1) to define cost effectiveness, 2) to present a step-by-step method for using cost-effectiveness analysis, and 3) to model applications of cost-effectiveness analysis.

Approach

Objectives were met by reviewing the economic literature, recounting published steps for using cost-effectiveness analysis, and modeling a full, operational-scale application of the cost-effectiveness concept.

Results

This report provides definitions, steps, and illustrations to guide application of cost-effectiveness as a key economic means to make vegetation management decisions. New information was developed specific to the electric utility industry, including 1) important outcomes of vegetation management that are critical for fully evaluating effectiveness, 2) acceptable and unacceptable outcomes as part of a cost-effectiveness analysis, and 3) analysis of cost-effectiveness using existing, published values of both cost and effectiveness that should be useful as guides.

Applications, Value, and Use

Vegetation managers and other decision makers can use the report to assist in using cost-effectiveness analysis to guide vegetation management decisions.

Keywords

Cost-effectiveness ratio
Chemical and mechanical treatment methods
Herbicide treatments
Non-herbicide treatments
Mowing
Power line corridor

Abstract

Cost effectiveness is an important economic measure for describing and comparing the relative acceptability of different vegetation management programs. Cost-effectiveness analysis is apparently only rarely used in the utility industry. This may be related to its apparent complexity, but it can be made direct and accessible for use. Objectives for the reported research were to: 1) define cost effectiveness; 2) present a step-by-step method for using cost-effectiveness analysis; and 3) model applications of cost-effectiveness analysis. Accounting of key economic literature, recounting of published steps for using cost-effectiveness analysis, and modeling a full, operational-scale application of the cost-effectiveness concept were some of the steps taken to complete the work. This report provides these definitions, and steps and illustrations to guide application of cost-effectiveness as a key economic way of making vegetation management decisions.

Executive Summary

Vegetation managers could use a guide to applying cost effectiveness analysis of different vegetation management programs, including comparison of non-herbicide and herbicide alternatives for treating electric transmission line ROW vegetation. Such an analysis tool could be used to make informed decisions, better communicate the bases for treatment choices with various stakeholders, and direct research and development activities.

This report provides definitions, steps and illustrations to guide application of cost-effectiveness as a key economic way of making vegetation management decisions.

Objectives for the project were are, as follows:

- Objective No. 1: define cost effectiveness;
- Objective No. 2: present a step-by-step method for using cost-effectiveness analysis; and
- Objective No. 3: model applications of cost-effectiveness analysis.

Cost Effectiveness Defined

Cost effectiveness in electric transmission line vegetation management is an approach to decision making that can be used as a basis for choosing between two different programs for managing vegetation. Simply, cost effectiveness analysis is used to calculate the best alternative or activity that minimizes costs of achieving a desired result. What makes cost-effectiveness analysis different than other basis of decision making is empiricism. Cost-effectiveness analysis is based on measures that empirically combine monetary costs of a management action with outcomes produced from that management action that can also be quantified, but not using money-based values. A cost-effectiveness ratio – calculated as the cost per unit of outcome ($ cost / quantified outcome) – is the preferred method presented in the report.

The one complete example of cost-effectiveness analysis in the literature was presented in 1985. It was used to show that herbicide treatment methods were more cost effective than just hand cutting alone. There have been a few other published studies of cost effectiveness involving the electric utility industry, but these have been mostly conceptual and have not used the cost-effectiveness ratio method. The current study is the first in the industry to fully explore the use of cost-effectiveness analysis for vegetation managers responsible for electric transmission line rights-of-way.

A Step-by-Step Guide with Illustrations

A guide for the general application of a cost-effectiveness analysis was presented using a 10 step process adapted from the literature. These steps are generally described and specifically illustrated with an example using real vegetation management data related to the comparison of basal versus foliar approaches to controlling vegetation on powerline corridors. The illustration, or example, showed that cost-effectiveness was not acceptable for foliar treatments as associated with undesirable stems as the outcome when compared to basal treatment, but it was acceptable for foliar treatments as associated with desirable stem densities as the outcome. It was concluded that it would be up to the analyst to decide which is more important. Or, it may be that other outcomes are needed to judge the full cost effectiveness of basal versus foliar treatments. Finally, it may be that the cost effectiveness ratios were really not meaningfully different from each other once a series of sensitivity analyses were conducted, particularly replications of the analysis.

Two other examples of cost-effectiveness analysis were presented. Another step-by-step evaluation was conducted using various published sources of long-term, operational vegetation management. It showed that herbicides are the more cost effective treatment compared to mowing (based on undesirable tree stem densities as the outcome). A more conceptual analysis of a vegetation management program using a set of long-term operational costs and social and environmental outcomes showed that herbicides were more cost-effective than non-herbicide approaches (mowing) to managing vegetation on powerline corridor. However, it was possible to turn the conclusions around and judge that mowing was more cost effective if the emphasis was placed on more socially acceptable outcomes.

New information was developed specific to the electric utility industry in the process of the research, including: 1) a listing of important outcomes of vegetation management that are critical for fully evaluating effectiveness; 2) a unique treatment of acceptable and unacceptable outcomes as part of a cost-effectiveness analysis; and 3) three different, previously unreported analysis of cost-effectiveness using existing published values of both cost and effectiveness that should be useful as guides.

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Section 1: Introduction

Cost effectiveness is an important measure for describing and comparing the relative acceptability of different vegetation management programs. It had been used by research scientists working with the electric utilities in the past to compare treatment methods using measured levels of acceptability (Bramble et al. 1985; Nowak et al. 1992, Abrahamson et al. 1995). Before that, and much more commonly since, cost-effectiveness analysis has been used in the health care industry to help practitioners decide which treatments are best to apply to which patients to produce desired outcomes (Robinson 1993; Tan-Torres Edejer et al. 2003). It is expected that low use of cost-effectiveness analysis in the utility industry may be related to its apparent complexity but in many respects the concept and practice of using cost-effectiveness analysis can be made relatively simple and direct. It is the purpose of this report to help make cost-effectiveness analysis more accessible to vegetation management practitioners.

Vegetation managers could use a guide to applying cost effectiveness analysis of different vegetation management programs, including comparison of non-herbicide and herbicide alternatives for treating electric transmission line ROW vegetation. Such an analysis tool could be used to make informed decisions, better communicate the bases for treatment choices with various stakeholders, and direct research and development activities (focus R&D where the comparisons of different alternatives are interesting but weak on factual information).

Research Objectives

This report provides definitions, steps and illustrations to guide application of cost-effectiveness as a key economic way of making vegetation management decisions.

Objectives for the project were are, as follows:

- Objective No. 1: define cost effectiveness;
- Objective No. 2: present a step-by-step method for using cost-effectiveness analysis; and
- Objective No. 3: model applications of cost-effectiveness analysis.

These objectives were met by: accounting of key economic literature (Objectives 1 and 2); recounting of published steps for using cost-effectiveness analysis that include new, previously unpublished illustrations (Objectives 2 and 3); and modeling a full, operational-scale application of the cost-effectiveness concept (Objective 3). New information was developed specific to the electric utility industry, including: 1) a listing of important outcomes of vegetation management that are critical for full evaluation of effectiveness; 2) a unique treatment of acceptable and unacceptable outcomes as part of a cost-effectiveness analysis; and 3) three different, previously unreported analyses of cost-effectiveness using existing published values of both cost and effectiveness that should be useful as guides.

Section 2: Cost Effectiveness Defined

Cost effectiveness in electric transmission line vegetation management is an approach to decision making that can be used as a basis for choosing between two different programs to managing vegetation. Simply, cost effectiveness analysis is used to calculate the best alternative or activity that minimizes costs of achieving a desired result. What makes cost-effectiveness analysis different than other bases of decision making is empiricism. Cost-effectiveness analysis is based on measures that empirically combine monetary costs of a management action with outcomes produced from that management action that can also be quantified, but not using money-based values. When an outcome can be monetized, the analysis becomes cost-benefit.

Cost effectiveness analysis is used in two forms (adapted from Gittinger 1982):

1) the "constant effect" method, which uses least-cost analysis to determine the least cost alternative for meeting a stated level of outcomes, which is the same between programs, and

2) the "constant cost" method, which calculates the cost per unit of outcome, or the "cost effectiveness ratio", and requires that means exist for quantifying outcomes (but not by attaching a monetary price or economic value to the outcomes).

Both forms can be used in powerline corridor vegetation management work; however, the cost-effectiveness ratio method is presented in this report, as it is most commonly needed.

In vegetation management, the preferred program alternative in the cost-effectiveness ratio method usually minimizes or maximizes the discounted present value of cost per unit of outcome (the ratio of cost to some measure of outcome), depending on whether or not the outcome is desirable or undesirable. Discounting is normally done at the opportunity cost of capital. Section 3 of this report demonstrates how to discount costs and combine them via ratios, with quantified outcomes.

To date, the only published work that used cost-effectiveness ratio method in relation to vegetation management work on powerline corridors was by Bramble et al (1985). Other right-of-way studies have made reference to cost effectiveness (e.g., see Nowak et al. 1992; Abrahamson et al. 1995; Nowak et al. 2005), and even presented the components of "cost" and "outcomes" but did not combine them into ratios as needed in full cost-effectiveness analysis. Bramble et al. (1985) studied the effects of various vegetation management treatments on deer habitat. They noted that "The control of trees capable of interference with electric transmission formed an important part of this study, because to be of practical value, a ROW (right-of-way) treatment should have controlled trees before being evaluated for its impact upon nontarget plants that furnish wildlife food and cover." They compared the effects of five vegetation management treatment programs – hand cutting, summer basal herbicide, stem-foliar herbicide, ground-spread herbicide (pellets), and frill and squirt herbicide – and found that these treatments produced 23, 71, 73, 80, and 43 percent reductions in undesirable trees (>3 foot tall) 3 years post treatment, respectively. Relative costs were compared among these treatments on the basis of what they called a "cost-effectiveness quotient" (CEQ), which is principally similar to a cost-effectiveness ratio:

CEQ = (cost per 1000 stems in Year 1 / stem reduction percent at the end of the treatment cycle) x 100

A low CEQ was interpreted to indicate desirable cost effectiveness. It was clear from the Bramble et al. (1985) study that the herbicide treatments had more acceptable cost-effectiveness quotients compared to hand cutting (Table 2-1).

The Bramble et al. (1985) study is important as it reminds us that cost-effectiveness analysis can and should be used in the electric utility industry.

Table 2-1
Example of a cost-effectiveness analysis by Bramble et al. (1985) for different vegetation management treatment programs. The "cost-effectiveness quotient" is similar to a cost-effectiveness ratio, where application costs per 1,000 undesirable stems are divided by the percent reduction of undesirable stem density. The higher the quotient, the less acceptable the treatment.

Treatment	Application costs per 1000 undesirable stems ($)	Reduction of undesirable stem density (%)	Cost-effectiveness quotient
Stem-foliage	90	73	123
Summer basal	142	71	200
Pellet	239	80	299
Frill & squirt	143	43	333
Hand cutting	143	23	622

Section 3: A Step-by-Step Process for Using Cost-Effectiveness Analysis (after Cellini and Kee 2010)

Cost-effectiveness is seemingly simple, yet obtaining accurate estimates of costs and quantified outcomes can be extremely challenging. As Cellini and Kee (2010) note: "Every analysis requires a host of assumptions, sometimes complicated calculations, and ultimately, the careful judgment of the analyst." These challenges can be addressed by breaking down the cost-effectiveness analysis using a 10 step process (adapted from Cellini and Kee [2010]).

Step 1. Set the framework for the analysis;

Step 2. Decide what costs and outcomes should be recognized;

Step 3. Identify and categorize costs and outcomes;

Step 4. Project costs and outcomes over the life of the program;

Step 5. Monetize (place a dollar value on) costs;

Step 6. Quantify outcomes in terms of units of effectiveness;

Step 7. Discount costs to obtain present values;

Step 8. Compute a cost-effectiveness ratio;

Step 9. Perform sensitivity analysis; and

Step 10. Make a recommendation.

These steps are generally described, one-by-one, using paraphrased text from Cellini and Kee (2010) that has been tailored to the electric utility industry. Each step has a specific illustration – an example using real vegetation management data and other considerations – that carries through a cost-effectiveness analysis of two vegetation management programs – basal versus foliar approaches for using herbicides to control vegetation on powerline corridors.

Step 1: Set the Framework for the Analysis

In considering a program, a cost effectiveness analysis should start with the status quo: that is, recognizing the state of the company in the absence of the vegetation management program. This scenario sets the baseline for analysis. The only costs and outcomes that should be considered are those that are created above the normal routine of business, e.g., costs of vegetation management is only that associated with the field work – other administrative and institutional costs are usually part of the larger business. Outcomes are those directly produced by the vegetation management.

Cost-effectiveness analysis can be performed at any point in the management process: 1) when a program is being first considered (specifically, comparing alternative prospective programs aimed at a common management objective); 2) during implementation (such an analysis provides data on whether the program's current outcomes are worth the cost); and 3) upon the program's completion, such as at the end of a treatment cycle (commonly 4 years for vegetation management on powerline corridors) or strategic planning horizon (typically 15-20 years), with total program costs and outcomes. In the first and second points, the analysis will require estimations of costs and outcomes that are difficult to secure because they have not yet occurred. In these cases, the analysis may require a significant number of assumptions and may yield less accurate results than when cost-effectiveness analysis is conducted as compared to the third point. In the third point, at the end of the program, cost and outcomes are known and can be estimated accurately.

Step 1 Illustration

For this illustration, a suite of information from research and utility operations was combined with some base assumptions to produce an example of a cost effectiveness analysis. In this example, the status quo would be described simply as all regular utility activities and programs that occur during the new program implementations – the new programs are the applications of vegetation management treatment programs – basal versus foliar herbicide treatments to control powerline corridor vegetation. The analysis with this illustration will count the incremental changes in costs (costs associated with each treatment over a treatment cycle) and outcomes described by control over undesirable plants – trees that can grow tall enough to cause problems for the safety and reliability of transmitting electricity. Many other outcomes could have been used but for this analysis the focus was just on one.

Step 2: Decide What Costs and Outcomes Should be Recognized

Vegetation management programs can involve a broad variety of many stakeholders. In light of this, determining what costs and outcomes should count (or should have standing) is an important consideration in cost-effectiveness analysis.

A major issue for cost-effectiveness analysts is determining the geographic scope of the analysis, for example, should costs and outcomes be aggregated at the local (select electric transmission line) or program (state-wide) level? In addition to spatial considerations, costs and outcomes may need to be accounted at specific points (now and across this one treatment cycle), or across broader periods (across many treatment cycles, possibly to the end of the strategic planning horizon). Typically, analysts choose to define the jurisdiction according the right-of-way proper, and the adjoining landownership but other geographical distinctions could also be acceptable.

Step 2 Illustration

In a vegetation management program, utilities will likely want to consider costs and outcomes from their own and their stakeholder's perspectives. The analysts should therefore consider all the costs and outcomes of the program that accrue to the company, but are of interest to other stakeholders as well.

Step 3: Identify and Categorize Costs and Outcomes

In conducting a cost-effectiveness analysis as part of a project or program evaluation, the third step is to identify and categorize as many of the known costs and outcomes as possible. Even though all costs and outcomes cannot be known for certain, the analyst should make a reasonable effort to identify those that will have the most significant implications on management decision making. Not all of these cost and outcomes will require an evaluation in quantities (dollars for costs, amounts or other quantities for outcomes). Small or negligible costs and outcomes – those that will have little impact on the bottomline – are often ignored or just briefly discussed in the final analysis. Nonetheless, it is recommended that in early stages of analysis, cost and outcomes should be thought of comprehensively.

When discussing costs and outcomes it is common to classify all negative impacts of a decision as costs and all positive impacts as outcomes, whether these occur in implementation or as a consequence of a particular management choice. The analyst could, however, frame the analysis as comparing inputs to outcomes. In this case, both the inputs and outcomes could be either positive or negative but the same process of cost-effectiveness analysis applies.

Step 3 Illustration

A list of possible costs and outcomes for vegetation management work on electric transmission line rights-of-way is presented in Table 3-1 (see end of Section 3).

Step 4: Costs and Outcomes Over the Duration of a Project, or the Life of a Program

After identifying and categorizing possible costs and outcomes, this next step involves thinking about the time frame for analysis and how the costs and outcomes will change over time. Cost-effectiveness analysis may be conducted over any length of time. It is expected that cost-effectiveness analysis for powerline corridor vegetation management will have a time frame in the range of a few years to 15-20 years – these are the time frames associated with a treatment cycle (treat → vegetation responds → treat again at the end of the cycle, with the amount of time for a cycle depending on both the condition of the vegetation and the utility's perceptions on how that condition fits their management objectives), commonly around 4 years, and a strategic planning horizon (multiple treatment cycles applied across the management system over the course of 15-20 years – which coincides with the strategic planning cycle).

If the time frame includes more than one time period (e.g., multiple treatment cycles over the planning horizon), the analyst will typically start with the first year of the program and track down costs and outcomes that accrue in that year (placing dollar value on costs and the quantification of outcomes is discussed in subsequent steps). For a cost-effectiveness analysis where the project or program is being considered for the first time, the outcomes will need to be predicted over the life of the project or program: will each cost or outcome remain the same each year or will it increase, decrease or disappear in each subsequent year? If there are changes over time, will costs or outcomes increase smoothly (for example, at 4 percent per year) or change at irregular intervals. For cost-effectiveness analysis with programs that are completed, that is, at the end of a treatment cycle or strategic planning horizon, much of this information on costs and outcomes should be known.

Step 4 Illustration

In the illustrated example, costs are reported up-front – at the beginning of a treatment cycle. Direct costs were recorded for maintenance treatments that began 2 years after the transmission line was built with two treatment cycles – costs are available for 1984 (Year 1) and 1988 (Year 4). Outcomes were measured at the end of the two treatment cycles: 1987 and 1999. Two environmental outcomes were measured: 1) density of undesirable plants; and 2) density of desirable plants. The two cycles of treatment were combined to produce a program level analysis. Cellini and Kee (2010) recommend that the length of time should be used that is sufficient to capture most costs and outcomes of the program, and they point out that often it may be that cost accrue over a shorter period of time than outcomes. The illustration works on both recommendations – the use of treatment cycles and strategic planning horizons is logical for a utility in terms of capturing fully expressed costs and outcomes. And, costs are commonly absorbed at the beginning of the treatment cycle, and outcomes dependent on vegetation response taking longer to produce.

Step 5: Monetize (Place a Dollar Value on) Costs

After identifying all costs and outcomes and considering how they change over the analysis time period, the next step is to assign each cost a dollar value. Dollars are used to describe cost simply because having costs in the same, universally meaningful measure makes for easier addition and comparison. Because dollars are a common measure of value that people generally understand, they are preferred to other measures.

For each cost that the analyst seeks to place a dollar value on, it is important to clearly state its nature, how it was measured, and any assumptions made in the calculations. Those assumptions need to be made clear to decision makers and subjected to a sensitivity analysis (described in Step 9) to determine to what extent the outcome of the analysis is controlled by the assumptions made.

Step 5 Illustration

In the Nowak et al. (1992) study of cost and effectiveness, direct costs were presented for basal and foliar herbicides treatments (selective mode of treatment only) based on current year (1984 and 1988) contractor billing rates for labor, equipment and herbicide mix (materials). Labor and equipment use was measured by timing all activities associated with treating a right-of-way site. Treatment costs used only on-site productive time only; costs associated with mobilization, demobilization, or equipment maintenance were not included. Amount of herbicide formulation used to treat each site was measured using an in-line gauge.

Total cost for the basal herbicide treatment averaged $720 and $230 per acre for 1984 and 1988, respectively.

Total cost for the foliar herbicide treatment averaged $340 and $140 per acre for 1984 and 1988, respectively.

Step 6: Quantify Outcomes In Terms of Units of Effectiveness

In cost-effectiveness analysis, the analyst usually quantifies only the most important outcome to get the units of effectiveness. If more than one outcome is deemed important, separate cost-effectiveness ratios for an additional set of outcomes can be calculated and considered.

In general, for cost-effectiveness analysis, the task of quantifying outcomes is seemingly straightforward. The analyst must first identify the most important outcome by which the success of the project or program can be measured. Measures of effectiveness are idiosyncratic to each program. In all cases, they must be related to the objectives of the program. Because one of the key capacities of cost-effectiveness analysis is its ability to provide comparisons with other project- or program-level decisions, the measure of effectiveness should be an outcome that can have direct comparisons to other programs.

The task here is to quantify the outcomes in terms of units of effectiveness (see Table 3-1 for examples of such units). The idea is to quantify only the units of effectiveness that are attributable to the program, that is, the causal effects of the program over and above a status quo.

Step 6 Illustration

It is common in cost-effectiveness analysis for the analyst to use multiple measures of effectiveness that can serve as a surrogate for project or program success. In electric transmission line vegetation management work, those measures include the abundance of undesirable and desirable plants on a right-of-way site. A treatment that decreases the abundance of undesirable plants and increases the abundance of desirable plants is clearly effective (Bramble and Byrnes 1983; Nowak et al. 1992). In the illustrative example, the density (stems per acre) of undesirable tree and desirable tree and shrub stems was measured at the end of each of the two treatment cycles: 1987 (4 years post 1st cycle treatment) and 1999 (11 years post 2nd cycle treatment) (date taken from Nowak et al. [1992] and Ballard et al. [2002]).

Undesirable stem densities for the basal herbicide treatment averaged 2,420 and 1,100 stems per acre in 1987 and 1999, respectively.

Undesirable stem densities for the foliar herbicide treatment averaged 2,980 and 600 stems per acre in 1987 and 1999, respectively.

Desirable stem densities for the basal herbicide treatment averaged 2,470 and 4,850 stems per acre in 1987 and 1999, respectively.

Desirable stem densities for the foliar herbicide treatment averaged 2,630 and 2,670 stems per acre in 1987 and 1999, respectively.

Step 7: Discounting Costs to Obtain Present Values

The process of finding the present cost (or worth) of a value is discounting. Discounting permits determining the value today of an amount paid out in the future (Gittinger 1982). The idea is that even without inflation, $100 today is worth more to an organization than the same $100 promised to that organization 1 year from now, and much more than the same $100 promised to that organization for 10 years from now. The reason is that the money has an opportunity cost. People value costs and outcomes incurred or produced today more than those that they may incur or produce in the future.

In order to incorporate this concept, cost-effectiveness analysis includes the conversion of all monetary values to their present value, including costs – or their equivalent values at the beginning of the project or program, in Year 1. The discount rate (r) used to calculate the present value of costs is meant to reflect society's impatience or preference for consumption today over consumption in the future. The choice of a discount rate is important. The rate is usually based on current interest rates but can vary widely depending on the organization and the time frame of analysis. Cellini and Kee (2010) suggest that unless the organization specifies a specific interest rate, a base real discount rate of 2 to 3 percent should be used, while testing for sensitivity of the project to higher rates of 5 to 7 percent.

In cost-effectiveness analysis, the analysts usually take the present value of the costs of the program to use as the numerator in the calculation of a cost-effectiveness ratio. Costs are aggregated in each year, noting each year's cost as Ct, where t indicates the year from 1 to T (the last year of the analysis). Values in each year of treatment are converted to this Year 1 equivalent by dividing Ct by $(1+r)^t$. Summing the present value of the costs from each treatment year would be the present value of costs (PVC) for the whole project or program (example uses four treatment cycles each 4 years long):

$$\mathrm{PVC} = \mathrm{C}_1 + \frac{\mathrm{C}_2}{(1+\mathrm{r})^4} + \frac{\mathrm{C}_3}{(1+\mathrm{r})^8} + \frac{\mathrm{C}_4}{(1+\mathrm{r})^{12}} + \frac{\mathrm{C}_5}{(1+\mathrm{r})^{16}}$$

$$= \sum_{t-1}^{T} \frac{C_r}{(1+r)^{t-1}}$$

Step 7 Illustration

For this illustration, a 3 percent discount rate was used to obtain present value of costs. A change in discount rate is presented in Step 9 (sensitivity analysis). The following calculations were conducted using values presented in Step 5.

$$\mathrm{PVC}_{\mathrm{basal}} = 720 + \frac{230}{(1+0.03)^4} = \$924$$

$$\mathrm{PVC}_{\mathrm{foliar}} = 340 + \frac{140}{(1+0.03)^4} = \$464$$

Step 8: Computing Cost-Effectiveness Ratios

This step finally brings together the present value of costs and units of effectiveness to calculate a cost-effectiveness ratio, where single measures of program effectiveness are available for comparison among various treatment options for a project and program. Rather than use total costs, this ratio substitutes the present value of these costs:

$$\text{Cost-effectiveness ratio} = \frac{\mathrm{PVC}}{\text{Units of effectiveness}}$$

The result is expressed in "dollars per _____", with the "_____" being whatever the unit of outcome, or effectiveness, is.

Cellini and Kee (2010) present a caution for using cost-effectiveness ratios. When using cost-effectiveness analysis to compare treatment alternatives it may occur that ratios hide differences in scale. That is, if one treatment is 10 times the cost of another with roughly 10 times the units of effectiveness, the cost effectiveness ratios of the two treatments will look the same even though the actual costs and outcomes differ. In light of this, cost effectiveness analysis is most useful when comparing treatment of similar scope of costs and effectiveness.

Step 8 Illustration

Combining cost and effectiveness information from Steps 6 and 7 with the formula in Step 8 results in the following cost-effectiveness ratios for basal and foliar herbicides over two treatment cycles (NOTE: number of stems used in the ratio calculations were only taken from 1999 so as to produce a single effectiveness value for the herbicide programs).

Undesirable stem density as the unit of effectiveness:

Basal cost-effectiveness ratio = $924 / 1,110 = 0.84 (dollars per undesirable tree produced)

Foliar cost-effectiveness ratio = $464 / 600 = 0.77 (dollars per undesirable tree produced)

Desirable stem density as the unit of effectiveness:

Basal cost-effectiveness ratio = $924 / 4,850 = 0.19 (dollars per desirable stem produced)

Foliar cost-effectiveness ratio = $464 / 2,670 = 0.17 (dollars per desirable stem produced)

It could be concluded that the foliar treatment is more efficient at producing both undesirable and desirable stem densities. But, this outcome is really only desirable for desirable stems – that it costs less to produce a problem (undesirable stem density) is not acceptable. Judgment of cost-effectiveness ratios depends on the undesirable or desirable state of outcome (see Table 3-2 at the end of Section 3). Additionally, the cost-effectiveness ratios between basal and foliar treatments are likely close enough to judge them to be effectively equivalent. It might come down to the idea that the organization can then decide: *Do we want to pay more and get more, or pay less and get less, but on a per unit basis produce about the same outcome*? It would be useful to develop cost effectiveness measures in other situations and replicate the comparison of basal and foliar and then statistically compare the mean cost effectiveness ratio between treatments. This idea of replication is consistent with the recommended next step – sensitivity analysis.

Step 9: Perform Sensitivity Analysis

At the end of the previous section, it was noted that any one cost-effectiveness analysis could be replicated to determine variability in cost-effective ratio for a treatment. This is one kind of "sensitivity analysis" where effectiveness is examined for how sensitive it is to different treatment sites. As noted in earlier steps, it is important for the analyst to test the sensitivity of the analysis to particular assumptions.

Cellini and Kee (2010) present two main types of sensitivity analysis: 1) partial; and 2) extreme case. Although other, more sophisticated methods (such as Monte Carlo simulations) are available, partial and extreme case sensitivity analyses remain the methods of choice for most analysts.

Partial Sensitivity Analysis: The approach varies one assumption (or one parameter or number) at a time, holding all else constant.

Extreme Case Sensitivity Analysis: The approach varies all of the uncertain parameters simultaneously, picking the values for each parameter that yield either the best- or worst-case scenario.

Step 9 Illustration

In the basal versus foliar illustration, there is one key assumption – a discount rate of 3% for the calculation of present value of costs. When the discount rate was varied to include 2 and 4%, the cost-effectiveness ratios only change on average of 0.01 – this indicates that the cost effectiveness ratio for the basal and foliar treatments with undesirable and desirable stem densities as the unit of effectiveness was not sensitive to variation in discount rate.

Step 10: Make a Recommendation

The final step of cost-effectiveness, if appropriate, is making a management decision. In cost-effectiveness analysis, there is no clear decision rule when evaluating one project or program. The analyst makes his or her own judgment as to whether the cost per unit of effectiveness is sufficiently high or low to merit adoption.

Step 10 Illustration

On face value, cost-effectiveness was not acceptable for foliar treatments as associated with undesirable stems as the outcome but it was acceptable for foliar treatments as associated with desirable stem densities as the outcome. It would be up to the analyst to decide which is more important. Or, it may be that other outcomes are needed to judge the full cost effectiveness of basal versus foliar treatments.

Table 3-1
A list of possible costs and outcomes associated with cost-effectiveness analysis of electric transmission line rights-of-way vegetation management. Treatment costs are listed that can be monetized. Treatment outcomes are listed that can be quantified. NOTE: types of possible quantities are presented in parentheses.

Treatment Costs

Labor, equipment, and materials ($)

Treatment Outcomes

Safe and reliable transmission (number of ground-line faults)

Utility personnel and public health
- injuries (number of incidences; loss of personnel work days)

Public nuisance / annoyance associated with vegetation treatments
- aesthetics (amount of visible brownout -- percent cover)
- air quality (level of volatile organics)
- noise (decibels -- maximum, cumulative over time)

Stakeholder Interactions
- stakeholder feedback (number and nature of stakeholder correspondences)
- recreation (user days in passive recreation -- bird watching, hiking)

Environmental
- containment of undesirable plants (counts or other estimates of abundance)
- promotion of desirable plants (counts or other estimates of abundance)
- soils (degree of erosion, compaction)
- water (turbidity, chemistry, temperature)
- wildlife -- game (quality and quantity of harvested animals)
- wildlife -- non-game (abundance and vitality of organisms -- butterflies to songbirds)
- rare, threatened and endangered species (abundance and vitality)

Table 3-2
Acceptability of cost-effectiveness ratios (lower versus higher) associated with undesirable and desirable outcomes.

OUTCOME	COST-EFFECTIVENESS RATIO	
	Low	High
Undesirable / Detrimental	I less acceptable	II more acceptable
Desirable / Beneficial	III more acceptable	IV less acceptable

Section 4: Modeling a Full Cost-Effectiveness Analysis Using Multiple Outcomes

A common question for right-of-way vegetation managers is whether chemicals should be used, or if instead mechanical treatment of vegetation alone is best? An answer to this question is not simple as it can change with different management contexts and how a wide variety of social and environmental factors are considered. In the Section 3 illustration of cost-effectiveness analysis, only two cost-effectiveness ratios were considered, and they were closely related to each other. In this Section, cost-effectiveness analysis is more fully explored as might need to be done in an operation where the full gambit of administrative, social, economic and environment factors need to be evaluated before sound decisions about vegetation management can be made.

Working Cost-Effectiveness to Get an Answer: "Which is better – mechanical or chemical approaches to controlling vegetation on powerline corridors?"

Mechanical approaches to controlling right-of-way vegetation is commonly done with mowing; the common chemical approach is to use herbicides. Herbicides are regularly used to selectively, carefully remove undesirable plants (usually those tall growing plants that can grow into the transmission wire security zone) while minimizing disturbance to the low-growing, desirable plant community (Niering and Goodwin 1974; Bramble and Byrnes 1983). Mowing commonly leads to a right-of-way dominated by undesirable trees (Luken et al. 1991; Nowak et al. 1995; Ballard et al. 2002). Selective control of trees with herbicides creates diverse plant communities with mosaics of grasses, forbs, shrubs and short-trees (Bramble et al. 1991; Cameron et al. 1997; Podniesinski et al. 1997).

Vegetation management experience, coupled with a broad, deep understanding of published research, is available for cost-effectiveness analysis to fully compare mechanical and chemical approaches to managing right-of-way vegetation in New York State. A full evaluation of cost effectiveness based on using a set of outcomes, rather than just one or two (see, for example, the Section 3 illustration, and also Appendix A), is presented below where one outcome from each of the five categories presented in Table 3-1 – (1) "safe and reliable transmission", (2) "utility personnel and public health", (3) "public nuisance and annoyance", (4) "stakeholder interactions" and (5) "environment" – was used to calculate five cost-effectiveness ratios using the same base treatment cost. It was expected that a fuller analysis would reveal the greater complexity of operational analysis of cost effectiveness.

Treatment Costs

Labor, equipment and materials

Treatment costs of mechanical and chemical (herbicide) approaches were calculated in Appendix A as averaging $1,329 and $945 per acre for the mechanical and chemical treatment programs, respectively, when discounted over the course of four treatment cycles. It is this longer term cost value (compared to the first cycle treatment costs of $355 and $320 per acre for mechanical and chemical) that is used in this cost-effectiveness analysis.

Treatment Outcomes

Safe and reliable transmission

In this example analysis, only a professional opinion was used, but in an operational analysis this outcome data should come from monitoring. An analysis of reported outages from across the country over the last 10 years indicates that for many companies there have been no unplanned outages, and since it can be assumed that a wide variety of different mechanical and chemical treatment programs produced this positive outcome, effectiveness can be considered to be equivalent between mechanical and chemical treatment programs. In economic analyses, when the outcomes are the same the choice of one program versus another comes down to favoring the treatment with the least cost (which in economics parlance is referred to as "least cost analysis") – so in the case of this example, an herbicide program would be judged as most acceptable. A cost-effectiveness ratio was calculated using a constant outcome value of 1,000 units of effectiveness for both mechanical and chemical treatment programs, where 1,000 units is meant to convey the highest outcome possible. It is up to the analyst to decide what scale of unit to use, with opportunity to shift the size of the cost-effectiveness ratio up or down depending, for example, on the importance of the effect. With a 1,000 unit outcome, the cost-effectiveness ratio is 1.33 for mowing and 0.94 for herbicides – herbicides are most cost effective with safety and reliability of electrical service.

Utility personal and public health – injuries

Utility companies should have incident records of worker injuries when applying vegetation management treatments. A professional opinion was used to develop an assumption of injuries associated with mowing and herbicides could produce an outcome of a loss of 10,000 person-minutes per year for mowing, and 1,000 for herbicide. The cost-effectiveness ratios for mowing and herbicides were calculated to be 1.33 and 0.09 for mowing and herbicide programs, respectively, based on lost-time injuries as the outcome.

Public nuisance / annoyance—aesthetics

Aesthetics of herbicides can be less than that associated with mowing because the quantitative measure is one only degraded with herbicides – brownout, which is the dead standing tree with brown leaves. Many stakeholders do not desire to see the brown, dead trees. While there are ways to use herbicides to avoid brownout (e.g., use of cut stump treatments, or use of some chemicals that do not kill the plant until after the dormant season, e.g., fosamine ammonium treatments which do not kill leaves, but inhibit bud development). Since mowing does not produce many brown leaves, it was assigned an outcome value of 1000, whereas herbicides were assigned a number of 10,000. The cost-effectiveness ratios for mowing and herbicides were calculated to be 1.33 and 0.09 for mowing and herbicide programs, respectively, based on aesthetics as the outcome.

Stakeholder interactions—stakeholder complaints

The number and nature of communications from stakeholders with regards to vegetation management treatment should be recorded by the utility and summed over time as a measure of outcome or effectiveness. An assumption of more complaints being made with reference to herbicides versus mowing could produce outcome measurements of 1,000 calls per decade for mowing and 10,000 calls for complaints about herbicides. The cost-effectiveness ratios for mowing and herbicides were calculated to be 1.33 and 0.09 for mowing and herbicide programs, respectively, when based on stakeholder complaints as the outcome.

Environment—containment of undesirable plants

Cost effectiveness ratios are presented in Appendix A as 0.13 and 0.91 for the mowing and herbicide treatment programs, respectively.

Synthesis and Conclusion

In general, cost-effectiveness (cost/outcome) is generally more acceptable for the herbicide-based vegetation management program than the mowing-based program (Table 4-1). Herbicides produced outcomes with more acceptable cost-effectiveness ratios for safe and reliable transmission, utility personnel and public health, and the environment. Mowing produced more acceptable cost-effectiveness ratios for public nuisance and stakeholder interactions. In this example, and it is expected that in most cost-effectiveness analyses, the decision of one program versus another is not going to be clear – there will be tradeoffs in costs and outcomes. In the current example, and it is expected that with all attempts to answer the question: "*Which is More Cost Effective as a General Approach to Vegetation Management on Electric Transmission Line ROWs: Mechanical or Chemical Approaches?*", it will be left to the analyst, the vegetation manager and the company to decide how to weight the outcomes – what is more important, for example – social or environmental outcomes. What is the compromise so that it is not one or the other completely, but some combination? One compromise is to assign treatments not exclusively across a whole right-of-way system (i.e., one treatment approach everywhere), but to instead change the type of treatment to maximize cost effectiveness for parts of the right-of-way where either more social or environmental concerns are weighted more heavily, and produce for the whole system, the highest overall cost effectiveness possible.

Table 4-1
Cost-effectiveness ratios associated with different effectiveness measures between mowing and herbicide programs for treating electric transmission rights-of-way.

Effectiveness Measure	**Cost-Effectiveness Ratios**	
	Mowing program	Herbicide program
Safe and reliable transmission	1.33 less acceptable	0.94 more acceptable
Utility personnel and public health - injuries	0.13 less acceptable	0.94 more acceptable
Public nuisance / annoyance - aesthetics	1.33 more acceptable	0.09 less acceptable
Stakeholder Interactions - complaints	1.33 more acceptable	0.09 less acceptable
Environmental -undesirable plants	0.13 less acceptable	0.91 more acceptable

Section 5: Summary

Cost effectiveness is a formal process of evaluation, assessment and decision making where costs are definable in units of money, and effectiveness is definable in units of quantifiable outcomes. If outcomes can be quantified using money, then the analysis changes to "cost-benefit analysis". If two different programs produce the same outcomes, the analysis becomes "least-cost".

Cost effectiveness and other, related economic analyses are long-standing and important as they help ensure that decision making is as sound, complete and transparent as reasonably possible. Cost-effectiveness analysis has been commonly used in the health care industry for decades, but has only rarely been used in the electric utility industry. Given today's increasing complexity of vegetation management on powerline corridors, with a broad array of social and environmental factors needing to be considered in vegetation management program decision making, cost-effectiveness analysis is needed today.

Cost-effectiveness analysis results in a combination of cost / outcome – a ratio. Depending on whether the outcome is desirable or undesirable, a low or high cost-effectiveness ratio may be acceptable.

In most cases of vegetation management on powerline corridors, many outcomes need to be evaluated with cost-effectiveness analysis and then the collection of cost-effectiveness ratios artfully combined to produce an overall assessment of program alternatives. In right-of-way vegetation management, a broad array of social, economic, environmental and administrative factors need to be evaluated and lead to a complex of cost/outcome relations. These factors are considered via various risk (e.g., opportunity costs and discounting) and rewards (subject to varied levels of confidences in outcome measurements), increasing the complexity of analysis and making cost effectiveness analysis an art, as much as a skill, that requires knowledgeable professionals to produce useful analysis results, as a basis for sound decision making.

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Appendix A: Step-by-Step Analysis of Cost Effectiveness of Long-Term Mechanical Versus Chemical Approaches to Treating Vegetation on Powerline Corridors in New York State

Illustration of Cost Effectiveness as Related to Mechanical Versus Chemical Vegetation Management on Powerline Corridors

Between 1975 and 1995, a set of studies were completed in New York State that provide select information, which can be used to evaluate the cost effectiveness of general mechanical versus chemical approaches to vegetation management on electric transmission line rights-of-way across New York. These data were applied to the "10 steps of Cost-Effectiveness Analysis" from Section 3 of this report. The purpose of presenting another illustration is to show how data can be creatively collected and combined for a cost effectiveness analysis using published literature. Additionally, results associated with this illustration were used as part of Section 3 in this report, which presented how multiple outcomes could be combined to collectively assess many cost-effectiveness analyses for the same program.

Step 1: Set the Framework for the Analysis

The framework for this cost effectiveness analysis is vegetation management on New York State electric transmission line rights-of-way over the last nearly 40 years, including data collected from the mid-1970s through the 1990s on various aspects of cost and effectiveness. Given a focus on vegetation management, and specifically programs that used herbicides versus those that used mechanical treatment (mostly mowing, but also including some handcut plots), the utility company operations outside of vegetation management treatments are not included in the analysis. The analysis is essentially considered to be "upon the program's completion", that is, scenarios will be assembled and run for a normal strategic planning horizon – four 4-year treatment cycles, and the first year of treatment. While this is to be considered a retrospective assessment, because of the way the data was assembled, many assumptions were used to produce the analysis.

Step 2: Decide What Costs and Outcomes Should be Recognized

While all of the costs and outcomes, as listed in Table 3-1 should be recognized for this study, only chemical and mechanical treatment costs (essentially contractor billing rates for hourly, per acre work) and environmental effects measured by changes in undesirable stems densities are to be used to calculated cost effectiveness. Over the last 20 years, the electric utility industry has not reported much on monitoring, especially in the public arena. The only data available at an operational, state-wide scale is associated with tree density changes over time.

Step 3: Identify and Categorize Costs and Outcomes

Given the data available, the decision was made as to what measures of cost and effectiveness will have the most significant implications on management decision making. It is clear that the actual, contractor-based cost for treating the vegetation is the product of their labor rates, materials, etc. Changes in plant communities with treatment – both the abundances of undesirable and desirable plants – is probably the most important measure of effectiveness. Many of the other outcomes – ranging from aesthetics to wildlife habitat – are related to the types of vegetation that are a result of treatments. So while the identification and categorization of the costs and outcomes were set by the data available, these data are pertinent as examples and allow a reasonable answer to the starting question – *Is the selective technique of using herbicides to control electric transmission line vegetation more or less cost effective than the more coarse use of mechanical treatments, such as mowing?* – to be answered.

As noted earlier, the logical use of undesirable tree stem density patterns over time as the measured outcome causes a reverse in how effectiveness is judged. Instead of the judgment being that the most effective treatment is the one that produces the lowest cost per unit outcome, with undesirable tree stem density it is opposite – a treatment that costs more to produce an undesirable tree is the more effective treatment compared to one that costs less (see Table 3-2).

Step 4: Project Costs and Outcomes Over the Life of a Program

The time frame for analysis is matched to long-term data collected on tree stem density changes – 16 years, or four 4-year treatment cycles. Benefits may change over time (and in fact will – the number of trees at any one point over the 16 years would differ greatly from another time) but it is the end of the program condition that is available and possibly best to use as it reflects the accumulated effects of the treatments over time and space. The total density of trees after 16 years reflects the long-term effects of the treatments that occurred over that period.

Costs were adjusted by discounting (see Step 7).

Step 5: Monetize (Place a Dollar Value on) Costs

Treatment costs were assigned a dollar value using a study by Abrahamson et al. (1995). In that study, treatment costs were presented for New York State based on a mail and phone survey of the State's utility company. Average costs for mowing was found to be \$355 per acre, and the average cost of herbicides (selective foliar, selective basal, and cut stump) was \$310 per acre. Costs for mowing was assumed to not change over the duration of the program -- \$355 was applied to each of the treatment points (Years 1, 5, 9, 13 and 17). Cost for herbicides was assumed to be less over time due to an observed decrease in tree stem populations (see Finch and Shupe 1997): Year 1=\$320/acre, Year 5=\$280/acre, Year 9=\$240/acre, Year 13=\$200/acre, and Year 17=\$160/acre. The last, lowest value: \$160 per acre, is also the lowest cost value for herbicide treatments found in the same Abrahamson et al. (1995) study based on a literature review of treatment costs. NOTE: given the nature of the source of the data, all cost estimates are based on assumptions and should be subjected to a sensitivity analysis to determine to what extent the results of the analyses were controlled by the assumptions made.

Step 6: Quantify Outcomes in Terms of Units of Effectiveness

The units of effectiveness for this example were taken from a study by Nowak et al. (1995). They measured tree populations (>3 ft tall) on 58 large permanent measurement plots located on 21 electric transmission line rights-of-way across New York State in 1991, 16 years after the establishment of the plots. Each plot had a known operational vegetation management history, and so could be classed as mechanical (mostly mowing) or herbicide treated. Undesirable tree densities averaged 10,600 and 1,040 stems per acre for the mechanical and chemical treatment plots, respectively, in 1991.

Step 7: Discounting Costs to Obtain Present Values

Present value of cost (PVC) was determined using discounting. The discount rate used to calculate the present value of costs was assumed to be 4% percent.

For mechanical treatments:

$$\text{PVC} = \$355 + \frac{\$355}{(1+0.04)^5} + \frac{\$355}{(1+0.04)^9} + \frac{\$355}{(1+0.04)^{13}} + \frac{\$355}{(1+0.04)^{17}}$$

$$= \$1{,}329$$

For chemical treatments:

$$\text{PVC} = \$320 + \frac{\$280}{(1+0.04)^5} + \frac{\$240}{(1+0.04)^9} + \frac{\$200}{(1+0.04)^{13}} + \frac{\$160}{(1+0.04)^{17}}$$

$$= \$945$$

Step 8: Compute Cost-Effectiveness Ratios

Cost-effectiveness ratios (CERs) were calculated as follows.

For mechanical treatments:

$$\text{CER} = \frac{\$1{,}329}{10{,}400 \text{ undesirable stems per acre}} = 0.13$$

For chemical treatments:

$$\text{CER} = \frac{\$945}{1{,}040 \text{ undesirable stems per acre}} = 0.91$$

Step 9: Perform Sensitivity Analysis

A variety of key assumptions were made, essentially for all of the data – cost of treatments over time, whether or not stems densities were truly representative of New York State and relatable to the treatments (mechanical versus chemical), and a single discount rate. These assumptions were at least based on empirical studies, so were not contrived – but they are assumptions none-the-less. While sensitivity analysis was not conducted in this study, it should be for a full, operational-scale analysis of cost effectiveness.

Step 10: Make a Recommendation

Clearly, given this analysis and its assumptions, herbicides are the more cost effective treatment compared to mowing for the New York State scenario based on treatment costs and undesirable tree densities. Confidence in the conclusion, though, is low because of all of the assumptions needed to run the analysis. A thorough, robust sensitivity analysis would be needed that includes testing the effects of assumptions on all variables used in the analysis. If the result of the cost effectiveness evaluation still held up after sensitivity analysis, it may still not make sense to choose herbicides over mowing. It may be that some other measure of effectiveness is most cost effectively produced by mowing, making more complex the recommendation on which treatment to use (see Section 3). For example, a landowner may be adamantly opposed to the use of herbicide on his or her land, despite the information on cost-effectiveness. In this cost effectiveness analysis, having the numbers provides a strong foundation for discussion of the cost (or "cost effectiveness") of one choice versus another – cost-effectiveness analysis allows decision makers and other stakeholders a stronger opportunity of making informed decisions.

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