Rev 09 Sept.. 06, 2016

## UAA Utility Vegetation Managers Summit - White Paper

# Leveraging GIS for Vegetation Management Optimization

## Introduction:

Electrical utility vegetation managers face many challenges including:

- A vast utility network that requires treatment across varying terrain.
- Interaction with varying ecosystems, migratory species, land owners and customers.
- Evolving regulations, jurisdictions, and land use interest groups.
- The logistical challenges of contractor workforce management.
- The data tracking, auditing, compliance, budgetary and planning functions that accompany the complex task of managing a utility vegetation program.

These challenges have utility foresters trying to understand new technologies, and how to move towards a solution that best meets utility vegetation management needs. Many utilities already have some technology in place, such as a Geographic Information System (GIS), to spatially display utility asset and vegetation treatment information. Recent software development and the addition of Light Detection and Ranging (LiDAR) acquired point cloud data show promise for assisting with the planning and work management process. As well, utility foresters are exploring various vegetation management optimization strategies, where data is used to drive changes in maintenance cycle or work practice to leverage cost savings and reduce redundancy. Current and emerging technology plays a role in the ability to implement an optimized vegetation management program.

In 2015, the Utility Arborists Association (UAA) Utility Vegetation Managers Summit fostered significant discussion on “Vegetation Asset Management Strategies”. The result was a short-list of various ways that GIS platforms are being used to help vegetation managers. The 2016 summit topic was closely related and included “Emerging Technologies for Vegetation Management” and “T&D Maintenance Optimization Strategies”. The outcome from these two meetings is reflected in the following technical paper which explores GIS, LiDAR, and current vegetation maintenance strategies, and ties them together to bring focus to the emerging technique of “optimization”.

In the simplest sense, “optimization” may be thought of as the act of; refining the vegetation management strategy in current use for the purpose of improving operational efficiency, better managing risk, improving customer service, and potentially reducing costs. There is an industry optimization trend toward creating smaller management units, where specific environmental conditions or other drivers can be better addressed. The next step in optimization that was introduced at the UAA meetings was “Predictive Analytics”. Optimization can be looked at as a decision making process. Predictive analytics uses mathematics, algorithms, and computer software not only to sort and organize data, but to use that data to make recommendations faster and better than humans *(Sashihara 1).* Predictive analytics, or simply “optimization modelling”, is the next planning level solution that utility foresters can use to optimize vegetation management programs.

## Objective:

Today, there are new data sources and software options that are poised to dramatically change the planning, implementation, and tracking processes for vegetation management. This technical paper explores:

- How GIS is being used to support vegetation management programs,
- How vegetation management strategies are evolving,
- Where LiDAR fits in,
- Where utilities are heading with vegetation management optimization.

## 1.0 Using "GIS" for Vegetation Management

A Geographic Information System (GIS) is a computer-based tool that allows users to store, manipulate and visualize geographic information on a map. In a GIS, information about the real world is stored and collected as thematic layers. These layers are all linked by the same geography. Because we connect data with geography, we understand what belongs where**,** and we can see the data spatially, across the landscape and across time *(Williams 2).* In addition:

- GIS is the go-to technology for enhancing utility decision making, including route and corridor selection, and is widely used to optimize maintenance schedules and fleet movements;
- GIS-based maps are a visual language that improves communication between engineering, operations, senior management, legislators, regulators, land owners, municipalities and the public;
- GIS enables utilities to maintain authoritative records on vegetation treatments, herbicide applications, environmental mitigation plans, and about changing site conditions over time.

Vegetation management programs can benefit enormously from using GIS platforms, because almost everything is related to geography. GIS assists managers by displaying asset types by location, and can be overlaid with local conditions and restrictions. GIS can spatially display treatment history, use of contractor resources and cost history related to a point or points on a map. However, GIS does not actually prepare a plan. Managers must prepare the plan and use GIS to display the planned progression and history.

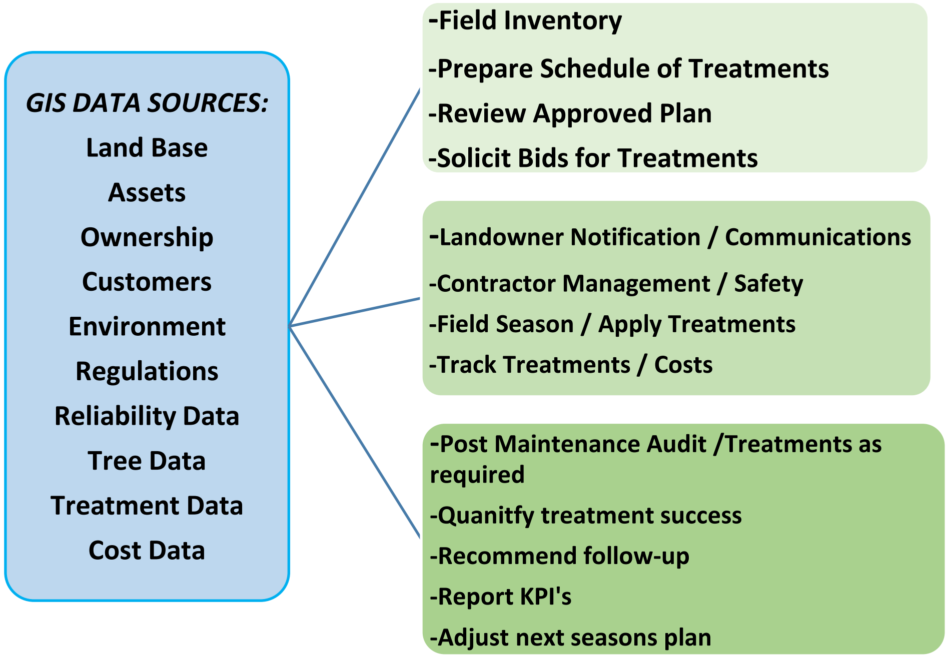
The implementation of an effective vegetation management program depends on answering the following basic questions with respect to planning:

- **Where** are we planning vegetation treatments?
- **When** are we scheduling vegetation treatments?
- **Whose** trees are going to be impacted?
- **What** regulatory, public, or environmental restrictions are we going to encounter?
- **What** did we learn from this process and are there any changes?

A GIS and its various data layers need to be designed to help managers easily address and display the answers to the above questions.

### 1.1 GIS Data Sources for Vegetation Management:

How vegetation managers use a GIS platform determines its ultimate value. The following chart identifies the primary data sources that can contribute to an effective utility vegetation management program. Utility foresters use these data sources to manage the administrative details of planning, implementing and reporting on vegetation treatments, which ultimately translate into field activities, summarized as follows:




Appendix 1 contains a summary of numerous data layers that were identified to be of value to vegetation managers, including a description, a comment on "*what the data layer tells us*", and the "*resulting vegetation management action".* This list is not all- inclusive, but can be used as a starting point by utility foresters, and expanded or modified according to local conditions.

In addition to the listed GIS data sources, there are many external "drivers" that influence vegetation management decisions and activities, including:

- Overall utility and vegetation program objectives
- State regulations or considerations
- Reliability statistics and NERC regulations governing reliability
- Environmental regulations
- Treatment types and timing
- Treatment costs
- Size of "management unit"

The following sections review how these external drivers influence vegetation program planning and why they should be considered in order to move towards an "optimized" vegetation program.

## 1.2 Utility and Vegetation Program Objectives:

Most electrical utilities have an overall objective to deliver *safe and reliable* power, at reasonable *cost*, while meeting the needs of c*ustomers*, following *regulations,* and respecting the *environment***.** Vegetation management is but one of the departments within the larger utility group which contribute to achieving overall reliability objectives. Each asset group within a utility may have vegetation control issues, but transmission and distribution have the most to manage due to linear corridors connecting generation to customers.

Utility vegetation management is required to meet four basic corporate objectives. These are translated into the following "typical" vegetation program "objectives and responses", which can be supported by various GIS data layers:

| Corporate Objective | Vegetation Program Objectives & Responses | GIS Layer |
|---|---|---|
| Improve Reliability | Minimize Vegetation Outages;<br>Increase Veg. Program Spend;<br>Implement "Reactive" maint. program | Track tree outages from OMS;<br>Show Reliability Stats by circuit |
| Ensure Worker & Public Safety | Minimize Tree Incidents;<br>Minimize Worker Injuries; | Track tree incidents;<br>Track safety incidents and history |

| | | |
|---|---|---|
| | Keep lines clear of vegetation for adequate visual line inspection and trouble identification;<br>Increase Veg. Program Spend | |
| Reduce Costs | Only perform VM work where required; Program funding reduction / or productivity improvements | Track cost history / treatment / year / circuit |
| Comply with Regulations | Minimize Regulatory violations (NERC Violations, Oil Spills, Water, Bird & Species Violations); implement training;<br>Increase Veg. Program Spend | Track tree removals and violations;<br>Track oil spills and watercourse crossings;<br>Track bird nests, restricted habitat areas, wetlands, rare flora and fauna |

Historically, the corporate objective of reducing costs was an opposing objective to improving reliability, meeting safety, and adhering to regulations. Today, the traditional vegetation program "response" to increase spending or implement more reactive cutting programs, is now forcing utility vegetation managers to consider treatment "optimization" as a NEW strategy to improve reliability *while* reducing costs.

Although both transmission and distribution vegetation programs may be aligned with overall corporate objectives, they often have different internal program objectives that result from differences in regulations, size of treatment areas, types of treatments, and customer density, as shown in the following example:

| **Vegetation Program Objectives - Differences Between Transmission & Distribution:** | |
|---|---|
| **Transmission** | **Distribution** |
| Manage Entire Lines | Manage 3-phase /1-phase & Protected Sections separately |
| NERC FAC-003-4 = NO Tree Caused Outages | Accepts Risk of Tree Caused Outages |
| Long-term Sustainable Plant Communities on R/W's -5, 10 or even 30yrs. | Urban 2yr / Suburban 3yr / Rural 6 yr. Cycle |

All of the above program objectives and differences translate into varying GIS data layers that drive objectives and constraints, affect program costs, and become essential data sources for vegetation program optimization.

### 1.3 Reliability and Vegetation Management:

For electrical utilities, "reliability" is the measure of how continuously electricity is delivered to a customer meter. Reliability is quantified using various statistical measures based on the quantity, duration, and types of interruptions that stop the delivery of electricity to customers. Utilities typically use SAIDI, SAIFI, CAIDI and CEMI as the primary reliability indices, to allow comparisons between utilities and to develop management priorities. Additional indices include CEMMI, CELID, MAIFI, and Index of Reliability. *(Please refer to relevant IEEE or CEA reliability indices and definitions).*

Reliability regulations vary considerably between transmission and distribution. Transmission lines over 200kV comply with NERC FAC-003-4. When it comes to budget allocation NERC regulations have the effect of placing higher priority on funding of transmission vegetation maintenance, over distribution, due to fines for violations.

GIS data can be used to track Transmission compliance for each of the following NERC requirements:

- Manage vegetation to ensure no encroachments into the Minimum Vegetation Clearance Distance (MVCD)
    - LiDAR layer confirming no encroachments along Rights-of-Way (R/W) boundaries
- Immediately notify the controlling authority of impending vegetation conditions
    - GIS layer showing annual off R/W danger tree removal locations plus any tree violations
- Annual inspection and completion of treatments for 100% of lines over 200kV
    - GIS layer showing annual cut plan (scheduled & implemented) plus historical and future plans by year

Distribution networks are not currently subject to federal regulations but many are subject to state regulations. For example, New Hampshire regulates the clearance at the time of pruning and cycle length. California requires a minimum clearance of 18 inches on Distribution lines, with additional clearance required during fire season in certain areas. Other states have approached regulation in a variety of ways.

From the perspective of vegetation management:

- Trees are typically one of the most frequent causes of electric interruptions and as such the highest contributors of reduced electrical reliability as measured by frequency and duration of tree caused outages. (e.g., trees cause 35% of distribution outages at NBP - 5 yr. avg. SAIFI).
- Frequency (SAIFI) of tree caused outages is an indicator of tree proximity, health and mortality. It allows utilities to prepare "reactive" treatment plans to target areas of poor reliability, and respond to evolving tree and forest conditions.
- Utility vegetation programs need to consider using reliability statistics to prioritize tree maintenance, preferably at the circuit and protected section level.
- Utilities would benefit from consistent use of standardized definitions, calculations, and tracking of reliability statistics.
- GIS can be used to spatially display reliability data over time on a circuit or more granular basis, to assist with maintenance prioritization.
- Ideally, utilities need to create multi-department reliability targets that ensure all customers receive quality service in terms of reliability. These vegetation management component targets then need to be translated into achievable milestones for the vegetation management team. GIS data and analysis of past reliability improvement from historic VM work can help to set realistic goals.

## 1.4 Environmental Regulations Affecting Vegetation Management:

Ecosystem attributes relevant to vegetation management include land use, topography, watercourses and wetlands, rare, threatened and endangered species, and forest stand types. Many regulating authorities have attempted to protect at risk ecosystem attributes with laws and regulations. These environmental regulations tend to translate into restrictions on site access and timing of treatments, which ultimately affect costs. This can be detrimental to a VM program if not planned for or anticipated in advance. Maintaining GIS layers for the growing array of environmental restrictions will help ensure compliance as well as accurate cost tracking and forecasting.

For a transmission utility with thousands of miles to manage across various ecosystems, land uses, watercourses and vegetation species mixes, the above information is important for selecting appropriate herbicide treatments, implementing sustainable vegetation management programs, and managing fire risk.

Distribution vegetation programs, because of extensive urban and suburban R/W's, deal to a limited extent with water, herbicides and migratory birds, and more with individual tree inventories, customer information, mechanical prescriptions and access restrictions.

Examples of GIS data layers for environmental regulations include:

- Protected Species – turtles / owls / osprey / bats, etc.
- Wetlands / watercourses / watercourse crossings / vernal pools
- Parkland designation
- Migratory species corridors / nesting sites / raptors
- Pollinators
- Fire sensitive sites / fuel loading
- Insect infestation / outbreak management
- Aboriginal land use

Regulations translated into GIS data layers can be extremely valuable. One example is the "Clean Water Act", dealing with all watercourse issues in New Brunswick, Canada. This regulation requires a 30-foot (9m) management buffer along all watercourses, and a 16-foot (5m) restricted access at water's edge. This statement, once loaded onto GIS, translates into a visible 16-foot (5m) buffer along all streams, lakes, rivers, and wetlands. This in turn can be translated into actual locations and areas where power lines cross a watercourse. Five meter buffers require hand cutting, no machine crossing without a bridge, and potential sediment control, which translates into site specific cost attributes along each span. This level of detailed span attribute data can be created for every GIS layer and regulation, which then becomes essential data for budgeting, cost forecasting and operational optimizing for both Transmission and Distribution.

## 1.5 Tracking Treatment Types and Timing:

Tracking of treatment types and timing of applications is essential for compliance and valuable for program optimization. For transmission, treatments such as herbicides are sensitive to season of application, site conditions, species mix, density, and vegetation age. Detailed records of success or poor efficacy, help to fine-tune future applications, and are essential data for herbicide program optimization.

For Distribution, cutting, mowing and pruning are the dominant treatments. Tracking this unit work data is helpful in further refining prescriptions, treatment units, and negotiating future service provider contract rates.

### 1.6 Treatment Costs:

Every activity that is undertaken to ensure that vegetation is managed *costs money*. One of the most important data layers for budget forecasting is tracking treatment costs. This data has historically been tracked outside of GIS in a spreadsheet, and captured in aggregate form (ex: $100,000 spent on 50miles circuit 7450). This however is not sufficient to understand the impact of changing site conditions and restrictions, and may not be useful if the utility wants to optimize treatments and reduce costs. Ideally, cost data needs to be captured at a work unit level, and associated with local site conditions and restrictions, as per the following examples:

- Aerial bucket prune – Heavy = 60m = A$/meter
- Slope +40%; require hand cutting = B $/meter
- Designated Wetland; required hand cutting & removal of brush = C $/meter
- Avoided nesting raptor; delay & return at hourly cost = D $
- Customer restriction; gates, access, no herbicides, etc., requires offsetting actions = E $
- Inaccessible backlot climbing = $F/meter

Ideally, GIS can be used to track all treatments based on GPS X and Y coordinates, including actual field costs, and site conditions or restrictions. This data is then ideal for budget forecasting and optimization modelling.

### 1.7 Size of Management Unit:

Historically, utility foresters have managed entire transmission “lines”, or distribution “circuits”. This management approach has been used more due to the work districts that a utility is divided into, for the ease of managing contractor resources., or for reliability-related reasons. Typically, these lines were managed on a “fixed cycle”, with entire lines or circuits being treated. This “entire line and circuit-on-cycle” approach is less flexible and provides less granularity, especially when utilities can have thousands of lines totaling tens of thousands of miles. As utility managers have attempted to improve program efficiency and recognize that not all trees represent a risk at the same time, utility foresters have had to consider managing smaller units.

Some distribution utilities have adopted “segments” of a circuit, which are significantly smaller line or circuit sections that exist between two distribution protective devices. The circuit “segments” or “sections” recognize that when a tree falls, it only takes out the power between the two protective devices, plus all downstream segments. Managing by segment, allows for the treatment of a smaller unit of work, and has the added benefit of allowing work prioritization by customer quantity, type of load, and risk. The identification of distribution circuit segments, and shorter sections of transmission corridor, is an essential exercise for utilities as they consider optimization modelling.

### 1.8 Data as GIS Attributes:

In summary, all of the aforementioned data sources can become “GIS data attributes” that apply to vegetation management and the utility network, but only if they are tied to exact geographic locations. All data, is either an attribute that exists within a GIS area polygon, or, it is an attribute that has distinct GPS X and Y coordinates. This is important for utility GIS staff as they incorporate data onto maps, and is essential for utility foresters as they define, gather and store data for use in a GIS and for optimization modelling.

## 2.0 <u>Electrical Utility Vegetation Management</u>

“Vegetation” is the mosaic of plant communities across the landscape. The “types” of vegetation that exist, are a result of the combined influence of climate, organism types, topography, soil parent material, and interventions over time. *(Boreal Research Institute 3.)*

Vegetation management is the technique of encouraging or discouraging certain plant species from occupying a site. For electrical utilities, vegetation management is the process of removing, pruning or controlling the growth of trees and brush along transmission and distribution corridors. Utility foresters are expected to keep transmission and distribution Rights-of-way (R/W's) clear of vegetation, and manage off R/W risk from trees that could fall into power lines. How utility foresters remove or control vegetation is dependent on the many variables surrounding asset type, location, tree conditions, utility objectives, customer objectives, regulatory requirements and available treatment options.

Transmission vegetation management is considered of higher priority due to:

- Serving direct connected industrial loads and municipal utilities, as well as all distribution customers
- More stringent regulations (NERC FAC-003-4) with potential fines

Distribution vegetation management is considered the more complex program to implement with a higher volume of work, extensive customer permissioning and communication, greater public visibility, shorter treatment cycles and limited use of herbicide and other work restrictions.

## 2.1 Vegetation Management Strategies:

Various strategies are employed by utilities to manage vegetation. A sustainable R/W should be the ultimate objective for all transmission and distribution vegetation programs, and can include:

- Using herbicides as part of an "Integrated Vegetation Management (IVM)" program, to encourage low growing plant communities
- Landscape changes – grubbing and contouring
- Power line re-routing and underground installation
- Planting of low growing species
- Allelopathy or other manipulation of plant communities naturally? Other IVM biological control?
- Encouragement of other cultural control with communities?

Distribution vegetation management strategies focus less on herbicides and more on cycle based tree pruning and removals. For transmission, a sustainable R/W could mean many years between cycles. The same could be true for rural off-road distribution R/W's.

The following table presents six basic vegetation maintenance strategies historically and currently used by electrical utilities, and identifies where "optimization" fits into the overall picture;

| Summary of 6 Basic Utility Vegetation Maintenance Strategies | | | | |
|---|---|---|---|---|
| **Apply To:** | **Maintenance Strategy** | **Technique** | **Positive** | **Negative** |
| **D** | **Corrective Maintenance** | -Hotspot pruning as required<br>-Treatment cycle based on outages | -Easy to Plan and Implement<br>-Low expense<br>-Small workforce | -Overwhelms System quickly<br>-High susceptibility to storms<br>-High Indirect cost over time<br>-Potentially low reliability<br>-High Customer dissatisfaction<br>- Limited visibility of work<br>(Hard to plan for which could result in unbalanced levels of work and crews throughout a year, resulting effects on work force or reliance on transient work force) |
| **T&D** | **Fixed Cycle** | -T&D / Urban / Suburban / Rural<br>All Circuits Same Fixed Cycle (ex: 4 yrs.) | -Easy to Plan and Implement<br>-High reliability | -High Budget required to maintain 100%<br>-Potentially cutting trees NOT yet a risk<br>- Does not recognize slower growing trees which could be managed on a longer cycle |
| **T&D** | **Variable Cycle + Mid Cycle Hotspot of Cycle Busters** | -All Circuits Variable Cycle (2-6 yrs.)<br>-T&D / Urban / Suburban / Rural<br>- 4&6 / 2 / 4 / 6 yrs.<br>-Treatments Deferred or Triggered by proximity of trees into lines, Risk to Customer, Line voltage (3-ph vs 1-ph) | -High reliability if budget allows<br>-More flexibility<br>-Potentially lower cost<br>-Potentially Higher reliability | -More challenging to Implement<br>-More data intensive |

| | | | | |
|---|---|---|---|---|
| **T&D** | **Condition Based Maint. (Optimized Cycles)** | -D-Circuits Ranked by Risk<br>-Inspection triggered by Outage stats<br>-D-Circuits treated by protected section | -Focused on Reliability<br>-Focused on Customer Risk<br>-Potential lower Long-term cost<br>-Potentially Highest reliability<br>Potential increase in tree health with avoided unnecessary pruning?? | -MOST challenging to Implement<br>-MOST data intensive<br>-Field data +GIS + Optimize Modelling<br>- Potential poor reliability if modeling is inaccurate |
| **T&D** | **Sustainable R/W** | -T-Lines 10-30 yr. cycle<br>-IVM Herbicide Program | -Long-term plant communities<br>-Long-term Lower Cost<br>-Lower impact to adjacent customers | -Requires data collection and monitoring to implement<br>-Higher initial cost to implement with both mechanical and herbicide |
| **T & D** | **Off R/W Hazard and/or Danger Tree Removal** | -Annual rotating program as required<br>-ID & Remove all suspect trees to criteria | -Easy to implement<br>-Direct reliability impact that is trackable | -Requires data collection and monitoring to implement<br>-Expense needs justification thru saving indirect costs<br>-Large customer education requirement and impact from customer restricted work on private trees |

As per the above table, complexity to implement a vegetation management program appears to increase as a utility moves from “corrective” to “optimized” strategies. At the same time, there appears to be an increase in reliability, and long-term cost stabilization, perhaps due to an increase in data review and more timely application of treatments.

At the early stages of establishing a utility network, trees were not necessarily present along power lines and it was sufficient to react to outages and address tree issues as they grew into the lines. Once it became obvious that more was needed due to frequent direct tree-power line contact, utilities evolved into fixed cycle programs. Utilities are now exploring variable cycle programs that recognize that not all locations have the same conditions, and not all trees grow at the same rate, nor require the same cycle *(UAA 4.)* Today, utilities are starting to “optimize” treatment programs based on site specific conditions. However, this is where terminology needs to be clarified. Some utilities are using the term “optimization” to mean “condition based maintenance” programs that have adjusted the size of management unit, and deferred treatments some years into the future. This attempt to optimize has little comparison to the new software techniques which use “predictive analytics” and mathematical modelling to produce “optimized” maintenance schedules.

Additional observations include:

- Transmission vegetation programs need to consider both on R/W and off R/W tree management strategies to improve reliability and meet regulations.
- Distribution programs need to consider classifying urban, suburban, and rural circuits separately, and optimizing treatment timing based on field conditions, customer expectations, customer densities, risks, probability of failure (POF), consequences of failure (COF), and reliability indices such as SAIFI, SAIDI, and CEMI for each circuit or smaller management unit.
- If utility foresters only plan annually they may never see the horizon with potential workload peaks, resulting in challenges with workload leveling, budget forecasting, and critical risk consequences.

## 3.0 <u>LiDAR for Vegetation Management</u>

LiDAR is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. LiDAR defines objects as distinct “points” in space, defined by X, Y, Z coordinates, thus creating what is known as a “point cloud”. The main benefit of LiDAR is that it allows easy calculation of distance between known points, and can be used to calculate changes over time such as tree growth. LiDAR is the current “best data capture” technology for use on GIS platforms, capturing the relative position of trees and objects, with high accuracy, across large areas.

For vegetation management, one-time LiDAR acquisition allows for considerable data collection, including:

- Detailed snapshot of the complete utility network
- Delineation of accurate power line R/W boundaries, and pole and tower center-lines

- Confirmation of extent of tree cover across the entire network
- Confirmation of proximity of tree branches relative to power lines
- Confirmation of tree height under conductor to confirm NERC compliance, including No “In R/W violations”, “Off R/W Fall-In Trees”, T-R/W narrowing, or post–cut violations
- Confirmation of watercourse buffers and land use boundaries
- Data source for infrastructure inspection, building location, encroachment and under-build
- Potential data source for species identification, tree health monitoring of dead and dying trees, disease clusters, and insect outbreaks

One of the challenges of LiDAR is that it is a “one-time” snapshot of conditions. Changes over time require periodic, 1-5 year re-flights to track changes. Data re-capture is currently expensive, and does not project changes 5, 10, or 20 years into the future. Multi-year flights allow for additional benefits, including:

- Confirmation of tree growth rates, location of fast growing species, and “cycle-busters”
- Data source for change detection from land development, seismic events, flooding, fire and landslides
- Confirmation of NERC compliance

Challenges with LiDAR include:

- Initially expensive to capture the entire utility network
- Potentially long time to process data (6-12 months for large networks)
- Must be captured accurately and processed properly, resulting in extremely large, yet valuable data sets
- Potentially short lifespan for data (1-5 yrs.)
- Evolving NERC compliance may insist on this technology for annual confirmation of no violations
- Potential increase in liability if utilities do not act on known tree violations, as identified by LiDAR

### 3.1 Using LiDAR and GIS to Improve Utility Reliability:

A GIS can spatially display an infinite variety of information including LiDAR, but it does not make decisions for current nor future operations. New software developments called “Predictive Analytics” have taken GIS data layers and vegetation program objectives and constraints, and combined them to “optimize” the impact of each data layer, and produce an “optimized” schedule over time.

Predictive analytics and optimization modelling can:

- Grow trees over longer time horizons
- Select optimum treatments and schedules
- Define budget requirements over time
- Manage multiple objectives and risks

Predictive optimization modeling requires a current snapshot or inventory of the asset being modeled. LiDAR capture of vegetation and infrastructure conditions can provide one of the most accurate inventories with high confidence of input data, which increases the confidence level of optimization modeling. *(Jones, 5)*

## 4.0 <u>Optimization Modelling for Utility Vegetation Management</u>

The definition of “Optimization” is the process of making a design, system, or decision as fully effective as possible, and to determine the best “compromise” given multiple objectives and constraints. *(Webster 6.)* Some utilities are currently trying to optimize treatment cycles with mid-cycle hot-spotting, condition based maintenance, and managing by smaller protected segments instead of circuits, in an attempt to address different tree growth rates and to reduce costs.

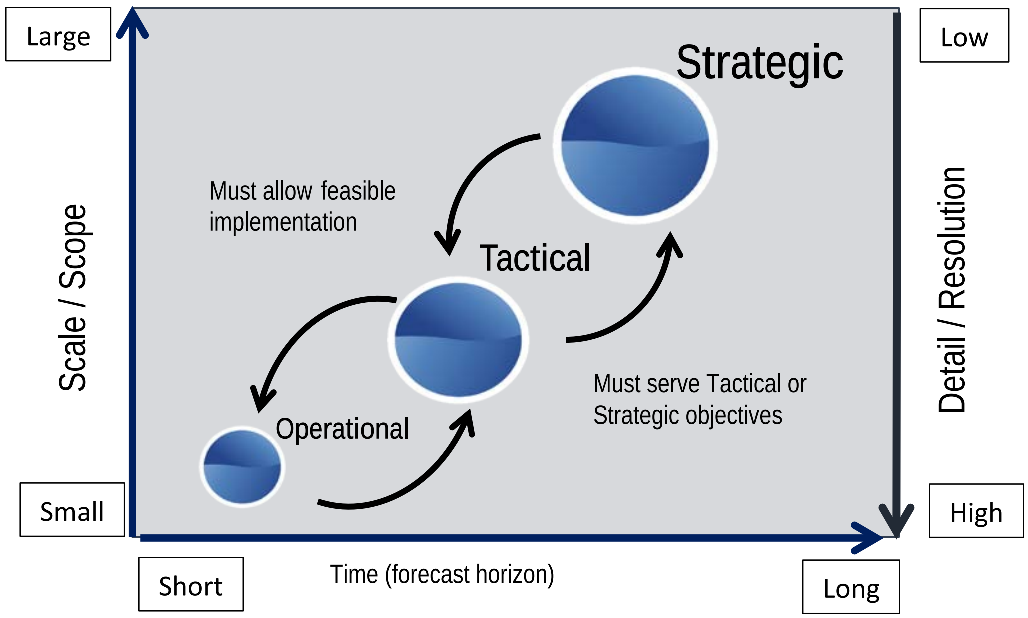
“Predictive Analytics” is optimization taken several steps further to include mathematics, statistical algorithms and computer analyses, to arrive at the mathematically optimum solution. Software companies have adapted existing analytical tools to assist the utility vegetation management planning function. The model uses a utility’s real world asset situation, objectives, constraints, and costs, to calculate the optimum schedule and budgets, to reach a desired objective, or confirm that a utility’s budget is insufficient.

Optimization modelling is:

- An “asset management” strategy with a systematic approach that applies economics, engineering, forestry and business principles.
- Improved decision making by using factual data, is performance based, defendable and transparent.
- A “planning exercise” with multiple levels and multiple scenarios that a utility forester performs in software external to GIS.
- An ideal fit for asset intensive utilities.

Optimization modelling has 3 levels of detail:

- **Strategic;** long-term plans (10-30yr.), capital forecasting + external issues, objectives & constraints
- **Tactical;** mid-term plans (1-5yrs.), capital forecasting + contractor capacity
- **Operational;** seasonal production and crew scheduling, and budgeting




## 4.1 Why Utilities Need to Optimize:

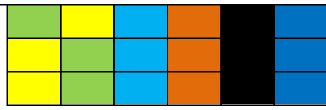
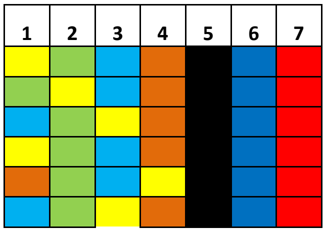
In terms of vegetation management, “optimization” is all about:

- **WHEN** we treat
- **WHERE** we treat
- **WHAT** resources we use to treat…all working toward meeting specific objectives, one of which can be; **REDUCING** total treatment cost

Predictive optimization modelling will calculate the current state, and predict the future condition of the asset relative to vegetation. As well, it will identify the prescriptions and associated cost over time required to achieve the desired future state of the asset. *(Jones 5)*

It is relatively simple to build a “prioritization” model that defines sections that absolutely should be done first. But it becomes increasingly difficult to define what to do next, when all the variables are the same, or when there are thousands of choices. The following table uses an “over simplified” example to illustrate how optimization affects treatment scheduling and ultimately program costs, as compared to typical cycle based maintenance strategies:

| Effect of Optimization on Scheduling Compared to Cycle Based Maintenance | | |
|---|---|---|
| **Maintenance Strategy** | **Action** | **Variables** |
| **Cycle Based Maintenance**<br>Ex: 5 yr. Cycle<br>1 2 3 4 5 | **Inspect** | 1/5th of lines every year |
| | **Treat** | 1/5th of lines every year |
| | **Where** | 1/5th of all lines |
| | **Cost $** | “A” $/Hr or “B” $/unit |
| **Condition Based Maintenance**<br>Ex: 5-6 yr. Cycle<br>Extended Cycle<br>1 2 3 4 5 6 | **Inspect** | 1/5th of lines every year |
| | **Treat** | 25% Ahead 1 yr. / 10% Defer 2 yrs. |
| | **Where** | 65% Cut / 35% Defer |
| | **Cost $** | (“A” $/Hr or “B” $/unit) x 65% |

| | | |
|---|---|---|
|  . | | |
| **Optimized Maintenance**<br>No Fixed Cycle<br> | **Inspect** | 1/5th of lines every year |
| | **Treat** | 30% Defer 1 yr. / 15% Defer 2 yrs. / 15% Defer 3 yrs.<br><br>Bring ahead 10% & cut 2 yrs. early |
| | **Where** | 40% Cut / 60% Defer Cut over next 3 yrs. |
| | **Cost $** | ("A" $/Hr or "B" $/unit) x 40% |
| | | Lower Cost over long-term OR Higher Production |

*"The potential outcome of optimization is that the "treatment unit" gets smaller over time, treatments are applied only when necessary, and costs are reduced or levelized. The necessity for accurate tracking of treatments and storm disturbances gets more important."*

## 4.2 Data Requirements for Optimization Modelling:

Optimization modelling requires detailed site and power line attribute data. Utilities can start with available GIS data layers, and use historical and/or field derived data for infrastructure and vegetation as input for modelling. Data quality and accuracy can then be expanded and improved over time, including newly acquired LiDAR data. The following table summarizes suggested attribute data for optimization modelling:

| Data Type | Description | Data Defines : |
|---|---|---|
| **Land base** | Geography, Hydrology, Topography | Treatment Options |
| **Site Characteristics** | Slope / Hydrology / Seasonal access | Treatment & Equipment Options |
| **Asset** | Voltage Class by Location + Protected sections + # of customers served | Priorities |
| **Ownership** | Contact & communications / access / restrictions | Treatment Options |
| **Customer** | Type / Location / Consequence of Failure | RISK & Priorities |
| **Environmental** | Rare & Endangered Species / Wetlands / Riparian zones | Treatment & Equipment Options |
| **Regulations** | NERC / Environmental / Operational / Road Safety / Work Safety | Treatment & Equipment Options |
| **Vegetation** | Species / Growth Rates / Extent or density of Trees across network<br>Proximity of Tree Branches to lines (LIDAR) | RISK & Priorities<br>*Probability of Failure* |
| **Reliability** | SAIDI / SAIFI by Circuit | Priorities |
| **Treatments** | Type / Cost / Realistic Production / Operability Rules | Treatment Options |
| **Objectives** | Business Rules / Constraints | Priorities |

## 4.3 Advantages of Optimization:

The reality for utility vegetation managers is that trees grow at different rates and are a risk at different times and locations along power lines. In addition, even though trees are maintained periodically, storm damage, unexpected growth, and other events results in unplanned cutting. All of which are continuous factors that undermine the ability to plan and budget. Electric utilities looking for a "better" vegetation management strategy, might consider adding optimization modelling to the planning process. The process of modeling starts a utility down the path of gathering appropriate data, defining risks and setting objectives. It provides a formal framework to gather relevant data and increase data value.

The advantages of optimization modelling include:

- Provides a complete network perspective over a longer planning horizon than one cycle.
- Allows utilities to leverage greater value out of their LiDAR investment.
- Combines simulation and mathematical optimization. Predictive models can generate optimal network management strategies that maximize an objective while meeting business constraints. (It does this by generating multi-year treatment schedules.)
- Allows utilities to stop annual planning based on "addressing the worst circuits first".

- Takes pole-to-pole span attribute data, adds tree proximity data to define probability of failure, customer data to define consequence of failure, plus all costs, constraints and objectives, and projects risk into the future.
- Simulates tree growth and proximity to wires over time, so that risk of tree contact can be calculated across the network over time.
- Supports planning and scheduling at any level of “granularity”, from long-term strategy, to multi-year operational, to annual or site specific tactical planning of maintenance crews.
- Allows utilities to project outcomes of current strategies, and allows budget justification to senior management.
- Automates multi-year scheduling and annual plan updates based on actual cut versus planned cut.
- Allows utilities to determine budget levels for desired reliability levels, by circuit or network, over time.
- Allows utilities to test the impact of cutting a line ahead of schedule for political purposes, demonstrating the long-term negative impact to budget, or, the impact of injecting additional funding to potentially reduce long-term budget trends.
- Allows utilities to compare the value of treatment costs across the system.
- Uses actual treatment costs to forecast future budgets, and can be configured to calculate Net Present Value (NPV) financial comparison of treatment options.
- Allows budget forecasting over any time horizon, with automatic updates to future budgets based on imposed changes.
- Supports potential for reduced costs over time, or, increased production with the same budget.
- Provides extensive maps, charts and data to allow drill-down to data source to understand data significance and potential drivers.

Some of the challenges with optimization modelling include;

- A commitment to data sourcing, and processing data into what is essential for modelling.
- Ideally requires capture of changes in annual tree conditions due to cutting or storms, using LiDAR or other means.
- Potentially requires a full-time analyst to remain familiar with modelling functions, to gather and manage input data, and to perform detailed queries or analyses.
- A system or tool to display and perform the optimization?

In summary, predictive analytics uses mathematical modelling to identify the right schedule of activities at the right cost, in areas of greatest risk, where it can have the largest impact on customer reliability, based on available budget, corporate objectives, regulatory requirements, and tree risk.

## 5.0 Conclusions:

The implementation of an effective vegetation management program depends on answering the following basic questions:

- **Where** are we planning vegetation maintenance?
- **When** are we scheduling vegetation maintenance?
- **Whose** trees are going to be impacted?
- **What** regulatory, public, or environmental restrictions are we going to encounter?

Utility vegetation management programs benefit enormously from using GIS platforms by helping managers easily address and track the answers to the above basic questions. GIS-based maps are a visual language that improves communications, and enables utilities to maintain authoritative records on vegetation treatments. But a GIS does not actually prepare a plan. Today, utility foresters must prepare the plan and use GIS to display the planned progression and history.

The primary data sources that contribute to an effective utility vegetation management program include;

- Land base, asset, property ownership, customer, environmental restrictions
- Reliability data, tree, treatment, and cost data

The newest mechanism for data capture of vegetation and infrastructure conditions, is LiDAR. LiDAR data provides one of the most accurate inventories, can assist with compliance, confirms vegetation extent and proximity around power lines, and is the best data source for optimization modelling.

Utilities are looking for a "better" vegetation management strategy to improve reliability without increasing budgets. The implementation of "predictive analytics" and "optimization modelling" may provide the decision support that utility foresters are looking for.

Optimization modelling relies on;

- Accurate pole-to-pole attribute data as provided by GIS and historical data
- LiDAR data to confirm extent of trees and proximity of branches to power lines
- Treatment cost data
- Clearly defined objectives and constraints

Optimization modelling provides;

- Budget development, forecasting and defense
- Prioritization of treatments and schedules, to where and when they are needed
- Reduction of risk (infrastructure, compliance, financial, wildfire, environment, reliability)
- Ability to model tree growth over time
- A true condition based maintenance strategy
- Ability for managers to measure consequence of actions
- Potential cost reductions

References:


1) Sashihara, Steve (2015) The Optimization Edge
2) Williams, Robert (1987), Selling a geographic information system to government policy makers. Paper from 1987 Annual Conference of the Urban and Regional Information Systems Association. Last modified: July 4, 2015
3) BoreaLResearch Institute (2011) Principles of Vegetation Management
4) UAA White Paper (2014) – Scheduling, Optimum Cycle and the Cost of Deferring Maintenance
5) Jones, Doug (2016) Optimization Modelling
6) Webster Dictionary – Definition of Optimization