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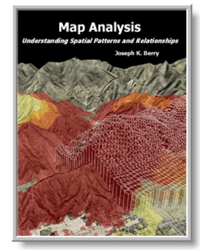
A Consensus Method Finds Preferred Routing



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A Consensus Method Finds Preferred Routing

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Introduction

Determining the best route through an area is one of the oldest spatial problems. Meandering animal tracks evolved into a wagon trail that became a small road and ultimately a superhighway. Although this empirical metamorphosis has historical precedent, contemporary routing problems involve resolving complex interactions of engineering, environmental and social concerns.

Previously, electric transmission line siting required thousands of hours around paper maps, sketching hundreds of possible paths, and then assessing feasibility by "eyeballing" the best route. The tools of the trade were a straightedge and professional experience. This manual approach capitalizes on expert interpretation and judgment, but it's often criticized as a closed process that lacks a defendable procedure and fails to engage the perspectives of external stakeholders in what constitutes a preferred route.

Selection of preferred routes--and the prerequisite choice of broad, generalized routing called corridors--is a growing source of public controversy and regulatory scrutiny throughout the United States. The electric industry has responded with many initiatives, including a new GIS-based system that could radically change the way electric utilities evaluate and select transmission line routes.

The GTC/EPRI Project

The Electrical Power Research Institute (EPRI) and Georgia Transmission Corp. (GTC) are developing a prototype GIS tool that integrates satellite imagery with layers of statewide GIS datasets. In addition, standard business process and site-selection methods are being created in the hopes of developing new industry standards. The GTC/EPRI Transmission Line Siting

Methodology Research Project is an example of how geotechnology can be used to improve productivity and help address a critical industry-wide challenge.

GTC, provider of electric transmission for 39 electric cooperatives, is sponsoring the EPRI project that's being developed with the participation of utilities, government agencies, elected officials and community stakeholders from Georgia and neighboring states. Transmission lines carry bulk power from generating facilities to local distribution systems that, in turn, carry electricity to homes and businesses. EPRI is a nonprofit energy research consortium that provides science- and technology-based solutions for the world's energy industry.

GIS Needed

Although the exact set of factors to be considered may change in different parts of the country, most transmission line routing requires attention to *environmental* (e.g., wetlands and flood plains), *community* (e.g., existing neighborhoods and historic sites) and *engineering* (e.g., slope and access) factors.

GISs are explicitly designed to manage and combine large amounts of spatially distributed data. In fact, transmission line siting can be thought of as a special case of land suitability analysis that drove much of GIS' early development.

Authority to use land is critical for electric transmission lines. GIS siting methodology attempts to use sound science and technology to expedite approvals, getting projects built on time and at lower costs. The National Environmental Policy Act (NEPA) and best-management practices require documentation that constrains project siting. The purpose of documentation isn't to generate reams of paperwork, but to foster excellent siting decisions. However, the site selection process can take years and millions of dollars, and it often disenfranchises affected parties.

The documentation process doesn't mandate a standard routing procedure or particular substantive results. It does require, however, a thorough study of consequences of proposed actions. It requires proponents to look at the effects of alternatives as well as articulate satisfactory explanations, including rational connections among facts found and choices made.

Adopting GIS methodology streamlines the decision documentation process and promotes consistent, quantitative and defensible "standards" for examining data, articulating explanations and demonstrating connections among facts and choices. GIS siting procedures help proactive companies implement strategies that anticipate critical land-use issues affecting transmission line placement.

Approach Overview

The EPRI Transmission Line Siting Methodology is analogous to a funnel into which geographic information is input and a preferred route emerges (see Figure 1). Geographic information is calibrated and analyzed in phases with increasing resolution. Proceeding down and through the funnel, the suitability analysis process continuously refines the corridor(s) most suitable for transmission line construction.

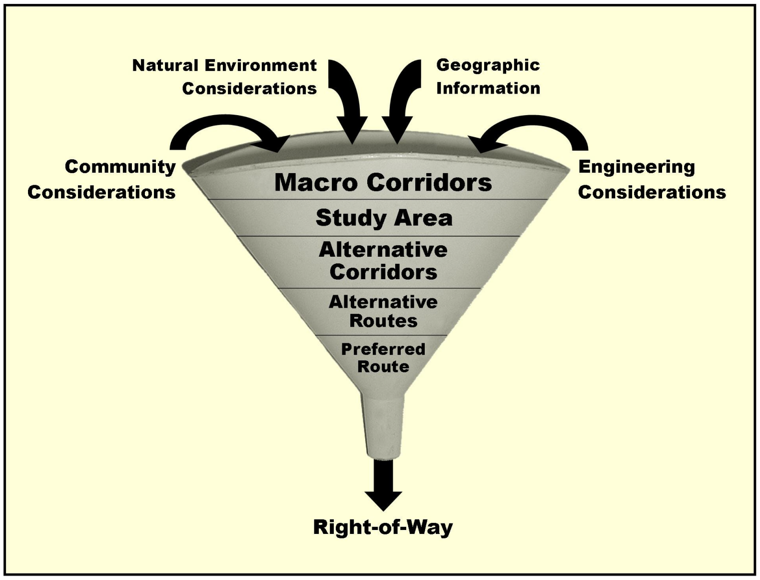

Figure 1. The route-selection process can be conceptualized as a funnel that successively refines potential locations for siting a transmission line.

For example, at the macro corridor level, statewide data based on 30-meter satellite imagery are used to identify the study area, whereas at the alternate-routes step, four-meter grid cells are used to capture highly resolved information such as the position of buildings to identify preferred routes.

Geographic features are organized by scale (resolution) and discipline. To rank individual features by suitability and weight feature groups by relative importance, internal and external stakeholder input is gathered using the "Delphi Process" that builds consensus as well as the "Analytical Hierarchical Process" (AHP) for pair-wise comparison. Four separate suitability surfaces are created, placing more decision-making preference on the following:

1. Optimizing engineering considerations
2. Built environment consequences
3. Natural environment impacts
4. Averages of preference factors

After the four preference surfaces and a map of areas to avoid (e.g., airports, large water bodies) are available, Photo Science Inc.'s Corridor Analyst software is used to measure the accumulative preference for all possible routes connecting the endpoints. The total accumulative preference surface from the start and endpoints is classified to delineate the top 3 percent of all possible routes. The process results in four alternative corridors reflecting the routing preferences contained in the suitability surfaces (see Figure 2).

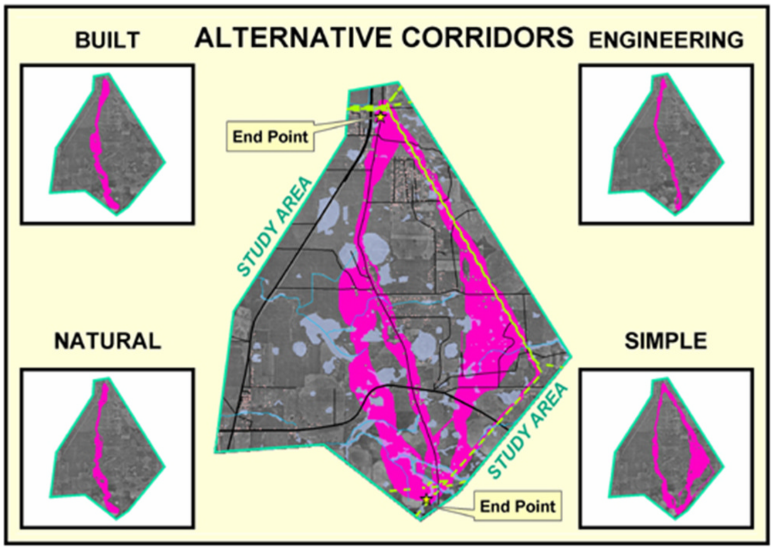

Figure 2. Alternate routes are generated by evaluating the siting model using weights derived from different group perspectives.

Adding Data

Within the alternative corridors, additional data are gathered (e.g., buildings and property lines), and a team of routing experts define a network of alternative route segments for further evaluation (see Figure 3). Statistics, such as acreage of wetlands affected, number of streams crossed, number of houses within close proximity, etc., are automatically generated for each of the alternate route segments.

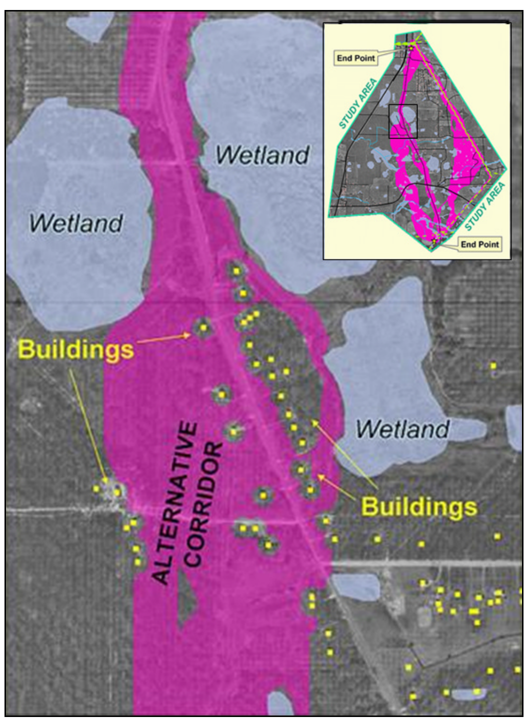

Figure 3. Within the alternate corridors, additional data are gathered such as exact building locations from aerial photography.

Segments with connectivity are defined, and segment statistics are summed to create alternative route statistics. Based on spatial data and other factors, the siting team uses AHP pair-wise comparison to assign weights to the alternative routes, resulting in a relative ranking of each route alternative. The highest-ranking route identifies the preferred route corridor (see Figure 4).

Detailed field surveys are conducted along the preferred route (collecting data using Global Positioning System, photogrammetry, light detection and ranging, and conventional surveying techniques) to map cultural, ecological, topographical and physical features. Engineers make slight centerline realignments and then design the final pole placements and construction estimates based on the information.

Input for determining the calibration and weighting of routing criteria was gathered from subsets of the stakeholders appropriate for the group's focus, whether engineering, natural environment or built environment.

Preference values were assigned based on a standardized process predefined by the model-development team. For each of the engineering layers (slope, linear features and selected land uses), individual stakeholders valued each feature (from 1 to 9) for a range of opportunities. The value 1 indicated the most-preferred feature in the map layer, while 9 was assigned to the least preferred. For example, 0-15 percent slopes identified the best conditions, 15-30 percent was moderate, and greater than 30 percent identified the worst conditions.

A modified Delphi Process was used to gain consensus for preference values. The values assigned by group participants to each category were averaged, and the standard deviation was calculated. If the deviation of the individual preference values for a particular feature was small, the group agreed that there was consensus and assigned the average preference value for the feature. If the deviation for a feature was large, the group proceeded to discuss the range of values and developed consensus through a sequence of re-evaluations.

Engineering Considerations

Those participating in the engineering analysis included engineers and scientists from utilities and state infrastructure agencies involved with site selection for transmission lines. The group was selected to provide specific knowledge regarding the collocation of power lines with other linear features, including transmission lines, roadways, railroads and other utilities.

After all the layer features had been evaluated, the selected preference values for all features were used to create a raster surface of preferences for the individual engineering layers. The AHP process was used to weight the map layers to reflect relative importance, and a weighted average was calculated to derive the overall engineering preference surface. This procedure for calibrating and weighting map criteria also was used for assessing the project effect on the natural and built environment perspectives.

Natural Environment

Numerous federal and state laws such as the Endangered Species Act, the Clean Water Act, National Pollution Discharge Elimination System, and wetlands and riparian buffer regulations drive the selection of environmental criteria. Many of the rules require obtaining permits from regulatory agencies and often require mitigation of impacts. Additional environmental criteria have been established as part of GTC's business policies, such as avoiding lands with private conservation easements as well as state and federally owned lands.

The natural environment stakeholder group included members of the regulator community such as the U.S. Army Corps of Engineers, U.S. Environmental Protection Division and Georgia Department of Natural Resources as well as local representatives from non-government organizations in the environmental community.

For the most part, the group reached consensus for factors that had good regulatory foundations. For criteria without regulatory rules, such as public-land issues and other land-use categories, it was more difficult to reach group agreement. A few of the factors initially considered by the environmental group, such as intensive agriculture and small water-retention ponds, turned out to be better considered by the engineering or built groups.

Built Environment

NEPA and various state-level policies require consideration of aspects of the built environment, such as historic sites. However, the most important obstacle to siting new transmission lines has been opposition from homeowner and community groups. An effective transmission line siting method can't be blind to community and neighborhood preferences.

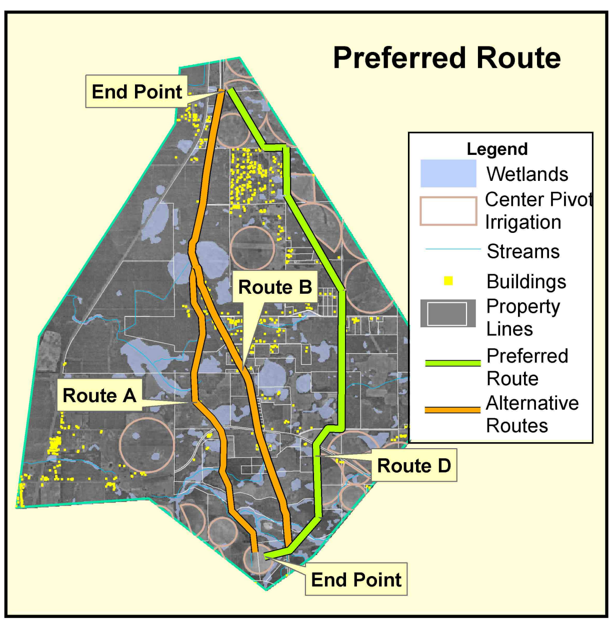

Figure 4. A GIS-generated preferred route is adjusted as necessary based on detailed field information and site-specific construction requirements.

The built environment stakeholder group provided input on community concerns for appropriate calibration and weighting of preference surfaces. The group included professionals in historic planning, regional planning, community development and local government as well as representatives from homeowner and neighborhood organizations. The stakeholders first calibrated the scale for each measure and then determined the importance weighting for the following built environment layers: proximity to buildings, proximity to cultural resources, building density, proximity to proposed development, visual vulnerability and proximity to excluded areas.

Actual buildings were handled as avoidance areas, and a fairly high level of consensus was reached. The same process was conducted with a group of utility professionals, and similar results were achieved.

Lessons Learned

In January 2004, a workshop was held with transmission line siting professionals from 10 utility companies. The professionals were asked to review and comment on the methodology described in this article. The GTC/EPRI methodology is generally similar to the processes that other utilities currently are using. All were using some type of GIS-based system, and most used a process that focused on more-detailed data as siting alternatives were narrowed.

Most utility representatives thought that this new methodology was more organized, comprehensive and consistent than their current practice, and most thought the methodology would produce consistent routing based on sound and documented science. Particular interest was expressed in the efficiency of the macro corridor analysis technique to guide the collection of successively more-detailed data.

Probably the most important difference among utilities was in how they handled public involvement. Some utilities ask stakeholders to identify criteria and weight them for each project; others develop alternative routes and ask stakeholders to select from that set; still others rely on an internal siting team with little involvement from the public.

Our experience found that asking citizen stakeholders to work directly with weights and criteria among group perspectives didn't produce a viable model. Citizens tried to "game the system" in setting weights to favor their perspective, often producing unintended results. Our final approach combines the criteria and weights identified by citizen stakeholders with those identified by professionals. This process incorporates public opinion and professional experience to create a consistent model that can be used on a range of projects.

In addition, we found that stakeholders often confused proximity measures with the feature itself. When stakeholders set large proximity zones around features they considered valuable, they would inadvertently force the route into other valuable areas. We also found that it was important to include data about land use in the model.

In an effort to reduce cost, the research team initially considered all buildings the same regardless of use. It became evident that it's necessary to have the model distinguish among residential, commercial and industrial buildings. Most stakeholders considered residential buildings more sensitive than commercial and industrial structures, and the model needed to be able to resolve at least this crude level of land-use distinction.

GTC intends to apply the methodology for all future transmission projects. The structure and rigorous procedure is no substitute for the judgment, values or perspectives of the stakeholders, and it depends--more than ever--on the skill and experience of the professional staff involved.

The GTC/EPRI routing methodology provides a structure for infusing diverse perspectives into siting electric transmission lines. Traditional techniques rely on expertise and judgment that often seems to "mystify" the process by not clearly identifying the criteria used or how it was evaluated.

The GIS-based GTC/EPRI approach is an objective, consistent and comprehensive process that encourages multiple perspectives for generating alternative routes, and it thoroughly documents the decision process. The general approach is readily applicable to other siting applications of linear features such as pipelines and roads.

Authors' Note: *For more information on routing and optimal path procedures, visit the Web at* ***http://www.innovativegis.com/basis/MapAnalysis****, select Topic 19, Routing and Optimal Paths. Links to further discussion of Delphi and AHP in calibrating and weighting GIS model criteria are included.*

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