SIMULATING THE ENVIRONMENTAL IMPACTS OF A HIGH VOLTAGE TRANSMISSION LINE

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ABSTRACT

A system called POWER has been developed for the optimal location of high voltage power lines. The system employs a Dijkstra network-search algorithm, a type of modified dynamic programming. An optimal corridor, based on a least-cost criterion, is selected from all grid cells between the specified origin and destination of the line.

By using the optimum route as a standard, it is possible to study the likely consequences of routes if placed in other corridors, between other points, or over certain line segments, such as across a national park.

INTRODUCTION

In the past 5 years I have worked with an energetic team of students to develop a state environmental information system and an optimal corridor location system for high voltage lines (Jones 1976, Smart 1976). We acknowledge the support of the Virginia State Corporation Commission, the U.S. Fish and Wildlife Service, and Virginia Polytechnic Institute and State University. We now have a system of 1.1 million cells, each of 1/9th km^2 (27 acres), in which we have at least 40 variables. The system was created to provide third-party inputs to public court proceedings prior to granting permission to an electric company to construct transmission facilities. We have been largely successful.

METHODS

Since the methodology is reported elsewhere (Smart 1976, Jones 1976, Giles 1976, Giles et al. 1976a, 1976b), it will not be detailed here. Generally, however, the environmental cost of a tower and line being in a cell are computed. Then working out from the origin, the costs of moving into each cell around the cell are computed and stored. The process is repeated along minimum-cost sequences of cells, the computer storing all costs of all least-cost pathways. The pathways extend like root-hairs in all directions from the origin, proceeding rapidly across low-cost areas, going slowly in high-cost areas. When a union is established with the destination, it can be demonstrated to be the global optimum.

Estimating costs is a major problem and is solved as follows. There are 12 dimensions of impact (Table 1). There are not exclusively "land use types" as in similar systems but include all major categories of cost including construction costs and offenses to visual aesthetics. Each dimension of impact is a function of one or more critical characteristics (Table 2). For example, the conspicuousness of a tower of a specified height in a cell is defined as a function of the presence of roads and historic sites (i.e. many viewers), elevation of adjacent cells, and a viewing distance of about 3 miles (in all directions of a cell having a road). Impacts to agricultural lands are, for example, a function of the slope of the land.

TABLE 1

Cost Categories or Dimensions of Impact Used in Powerline Corridor Analysis and Evaluation

1. Economic costs to the rate payer
2. Scenic and visual impacts
3. Vegetative change
4. Wildlife community impacts
5. Aquatic community impacts
6. Recreation utility
7. Historic impact
8. Residential use impact
9. Agricultural use impact
10. Forestry impact
11. Institutional use impact (schools, etc.)
12. Industrial use impact

In addition to 12 dimensions of impact and 40 critical characteristics possible for each cell, many critical characteristics may have ecological or other changes over 30 years (the economic life of the proposed line). Change in such factors as a function of time are included in the system.

Each dimension of impact is weighted, by the decision-making group. Where they are unwilling or unable to assign such weights for the 12 dimensions, three sets of weights are assigned by the project staff to represent their perceptions of the weights of a simplistic society of (1) profit maximizers, (2) all-around altruist, and (3) ultra-perservationists. The entire system is run three times to determine corridors for such hypothetical societies.

In one sense, we simulate the value systems of societies to determine the optimal corridors.

TABLE 2

Critical Characteristics Employed Singly or in Various Combinations in Computing Dimensions of Impact Over Time

1. Total present-valued land acquisition, construction, and maintenance costs
2. Cell observability
3. Large streams
4. Small streams
5. Lakes and ponds
6. Swamps
7. Wooded marsh
8. Submerged marsh
9. National Forest
10. Miscellaneous forest
11. State-owned natural resources
12. Orchards
13. Agricultural field
14. Residential area
15. Urban area
16. Slope class 5-15 degrees
17. Slope class greater than 15 degrees
18. Registered historic sites
19. Recommended historic sites
20. Proposed historic sites
21. Existing public parks
22. Potential public parks
23. Existing public natural areas
24. Potential public natural areas
25. Existing private non-commercial recreation areas
26. Potential private non-commercial recreation areas
27. Existing commercial recreation
28. Potential commercial recreation
29. Existing scenic easements
30. Potential scenic easements
31. Potential recreation resources
32. Existing major hiking trails
33. Proposed trails
34. Existing boat landings
35. Existing beaches
36. Potential beaches
37. Erosion prone soil type - High
38. Erosion prone soil type - Moderate
39. Erosion prone soil type - Low
40. South-facing slopes
41. Southwest-facing slopes
42. Ridge tops

In the weighting process there is power to evaluate the cost dimension relative to environmental or pseudo-environmental factors (such as visual impact). Assigning all dimensions with the exception of cost to have values of zero, a minimum construction and maintenance cost line results. Assigning construction cost a value of zero results in an "environmental" analysis system.

RESULTS

Early in problem analysis we discovered that there was no good place or best place to put a powerline. There are only bad corridors; the problem is to select the least-bad route.

We also discovered, based on the above, that the decision to build a transmission facility requires two decisions before a solution can be implemented. The first is that demand must be established and a decision made to build a transmission facility. The second is the question of where.

In multiple runs of the system we have found that corridors with different weights are identical over much of the distance (> 50%) because of the interactive constraints and costs of steep slopes, valley locations that are both economical and tend to hide the line, and the presence of existing roads and transmission facilities.

We were surprised, though perhaps we should not have been, that the corridors did not take on exotic shapes with zigs-and-zags but have been relatively straight. Each cell, no matter what its characteristics, incurs costs. The fewer the cells, the more minimal the cost of the route. Never the less, no routes have yet been of the ruler type.

We discovered that the computer's answer to how to minimize the impacts of a line across southern Virginia was to "put it in North Carolina." We viewed this as humorous validation of the system.

We have discovered a reluctance by decision makers to change weights or to revise the criteria for the analysis, though, throughout, the system has been developed as a "playing board" or the means for considering changes. For example, the public was notably distressed when the system routed the line across a recreational lake (it was low, non-visible from many roads, away from agricultural and residential areas, and there would be no erosion or wildlife impacts). Rather than add lake cells to the roads and historic-site cells which were the viewing points for determing potential conspicuousness or visibility, the methodology was ignored for a particular project (although it was subsequently used).

Similarly, the system selected a preferred route through a small community - one with existing power lines (thus no further visual impact), highly industrial, low residential, no historic or similar sites, and surrounding cells that would be highly impacted. The valley was selected in all three value systems. The valley result was surprising, but, on examination, the reasons were clear. Even though the costs of going through the community were high, the summation of hundreds of low-impact cells nearby counter-balanced those costs and made it conspicuously a lower-cost total route than any other. Over long distances the optima are much more difficult to discriminate.

The political forces in the community arose and there was no further positive discussion of the computer-selected route. The lessons are at least (1) citizens over a broader area than a proposed corridor might become involved in such decision making processes, and (2) if there are known constraints for the system that are not included in the data base (e.g. a senator's house, a person prone to filing suits, a volatile social group), then these can (and probably should) be included in the analysis by those asking for a decision aid from the POWER system. At least, the system can be used to show the routes if "X" is included or deleted.

AN APPLICATION

Even though parks connote wildness and low disturbance, they are continually being modified by those who see them as useful for military, communication, criminal and a host of other public facilities. Their undeveloped nature makes them targets for development, places where the conflicts and costs over private property can be avoided.

The National Environmental Policy Act and related state laws have now changed that somewhat. Almost every major facility must now have an impact statement prior to construction. I view these as highly desirable (though I shall comment later on the present methods used). They are needed because (1) Costs for construction and maintenance increase; optimal locations are needed; (2) More and more people are influenced by facilities, both on- and off-site. The disproducts of facility location are more likely to influence more people.

Suppose the system is used to locate a corridor across a 3-county area, say over 50 miles. That route crosses a national park, as does the route proposed by the utility applicant. In Table 3 are shown the relative impacts of a line in northern Virginia. When only the park is considered, as it might be by a federal agency or a special-interest group, the impact to the park of the optimal route will be 2.4 times *greater* than that of the utility company route. However, when taken as a whole, i.e. over the entire corridor, the total impacts of the optimal corridor are 3.6 times *less* than those from the proposed route.

TABLE 3

Relative Impacts of a High-Voltage Powerline Across Northern Virginia

Powerline Corridors	Total Corridor Impacts	Corridor Impacts to Park Only
Corridor proposed by Utility Company	3.60	0.42
Optimal Corridor Selected by POWER System	1.00	1.00

For the operations research expert, the problem of scale is a well known one. However, the system, as employed above, suggests that environmental impacts are also important to consider from several scales or perspectives. Here the question for the park manager is made difficult. Shall he argue for park protection or for the total overall public good from the siting decision?

DISCUSSION

POWER is an operational system and available for the cost of a computer tape. It has been distributed to over 25 agencies, universities, and companies. It is a functional system that can be used in many ways for research, managerial decision making, and futuristic endeavors.

POWER like other computer systems used in a simulation mode can become (and in my opinion should become) dominant methods in the creation and presentation of environmental impact statements (EIS). Rather than discard the EIS process, as some argue, it seems far more sound to develop general purpose information systems, develop sophisticated ecological and environmental models, and then apply optimization to select "best" practices. Simulation can then be done and their results presented as the EIS. Fundamentally, NEPA proposes that society answer before it acts: *What if* this act is taken or this facility is built? What will be the consequences?

LITERATURE CITED

1. Dijkstra, E. W. 1959. *A note on two problems in connection with graphs*. Numerical Mathematics 1:269-271.
2. Giles, R. H., Jr. 1976. *Siting high-voltage powerlines in Virginia*. Industrial Veg. Mgmt. 8(3):14-19.
3. Giles, R. H., Jr., A. B. Jones III, and C. W. Smart. 1976a. *Power: a computer system for corridor location*. Office of Biological Services, U.S. Fish and Wildlife Service, Washington, D.C. 30 p.
4. Giles, R. H., Jr., C. W. Smart, and A. B. Jones III. 1976b. *Power: a high voltage transmission corridor location system*. First Right of Way Symposium, Mississippi State Univ., Mississippi State, Miss. Jan 7-9.
5. Jones, A. B. III. 1976. *Power: a computer information system for land use decisions*. M.S. Thesis, VPI&SU, Blacksburg, Va. 194 p.
6. Smart, C. W. 1976. *A computer-assisted technique for planning minimum impact transmission right of way routes*. PhD Diss., VPI&SU, Blacksburg, Va. xiii + 192 p.