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Computer Assisted Transmission LOine Corridor and Route Planning

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COMPUTER ASSISTED TRANSMISSION LINE CORRIDOR AND ROUTE PLANNING

A STATE-OF-THE-ART REVIEW

A Master's Project

presented by

HEDLEY GORDON EVANS

Submitted to the Graduate School of
the University of Massachusetts,
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Department of Landscape Architecture
and Regional Planning

Dept. of Landscape Architecture
and Regional Planning

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ABSTRACT

Computers have been used in a variety of ways for over ten years, in transmission line corridor and route planning. Significant advantages have resulted such as increases in the precision, speed and economy with which large amounts of spatial information can be managed, analyzed and clearly presented, to provide objective information for use in decision making.

This study reviews the state-of-the-art with an emphasis on North America. Included is a general introduction to the use of computers in transmission line planning. This includes an overview of the basic concepts involved and of the broader issues that typically need to be addressed in a broad review of different systems, or in selecting, adapting, or developing a system for a particular application.

Ten systems are profiled to give an overview of a representative range of planning systems. Each profile includes details on the system, the agency concerned, typical projects, the planning method, computer software and hardware used, and agency contact people. A case study describes in detail, the planning method of one of the comprehensive planning systems profiled.

Ten further organisations were identified as working with computer assisted transmission line planning research or project applications. These could not be profiled within the scope of the study. Their work is briefly reviewed and information is given on agency contact people.

There was considerable variation in the way that computers were used. Several systems profiled included transmission line planning as part of a larger facility planning process e.g. including consideration of power station, substation, access road and in one case, cooling water canal location. Several systems were comprehensive in the issues considered e.g. engineering, social and environmental, while others concentrated on one aspect such as landcover/landuse inventory using satellite image analysis, or visual simulation and/or visual assessment.

The study provides a means by which consideration given to the use of computers in transmission line planning, can be built on knowledge of a range of systems that have already been developed, and on research and development of systems that is ongoing elsewhere.

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ACKNOWLEDGEMENTS

This project has involved considerable cooperation from a large number of individuals, working with computer applications in transmission line planning. For the time they took to correspond and discuss their work and the state-of-the-art, I am most grateful.

I would like to give special thanks to my mentor and committee chairman, Dr Julius Gy Fabos, for his inspiration, guidance and ready availability throughout the project.

I would also like to thank Dr Meir Gross, our Department Head, for his participation and guidance as committee member.

To my former employer, New Zealand Electricity, a division of the Ministry of Energy, I am particularly grateful for the opportunity to undertake this research project as part of my program of graduate study.

CHAPTER I

INTRODUCTION

Purpose of Study

The purpose of this study is to provide an overview of the various ways in which computers are used in transmission line corridor and route planning. The emphasis of the study is on the analysis of potential environmental impacts, including visibility and visual impact assessment. The systems identified have largely been developed within North America.

Study Method

The following objectives were set:

1. To carry out a broad review of available literature and establish a bibliography of significant published material.

2. To carry out an in-depth review of material considered most relevent to the study.

3. To identify key organisations and individuals leading in this area, with an emphasis on USA and Canada, and what in broad terms their computer assisted transmission line corridor and route planning systems involve.

4. To select from the key organisations identified, a representative range of systems and develop overview profiles of each, where sufficient information could be

report.

Chapter III includes profiles of ten selected systems, chosen to illustrate a variety of ways in which the computer is used in transmission line planning. This chapter provides the most detailed information in the report, on a number of different systems developed. References directly relating to each profile are listed together with a contact person, address and phone number. Chapter IV illustrates in greater detail, one comprehensive planning system profiled in the previous chapter. Chapter V provides concluding comments on the study.

In addition to a bibliography of references cited throughout the text, a list of additional reference material that would be of use in further research, has been compiled. Appendix 2 lists the organisations not profiled, that were identified as having worked with computer assisted transmission line planning research or project applications. A brief description is given of the type of work involved, together with key reference material and contact information. Although it would have been a valuable addition to this report to have fully profiled many of the systems referred to, this was not feasible within the scope of this study.

CHAPTER II

A GENERAL INTRODUCTION TO THE USE OF COMPUTERS IN TRANSMISSION LINE CORRIDOR AND ROUTE PLANNING.

2.1 Introduction

The purpose of this chapter is to provide a general introduction to the use of computers in transmission line corridor and route planning. Matters which might need some clarification, that are referred to in the profiles of different systems in chapter III, in the case study in chapter IV and in the brief system reviews in appendix 2, are discussed.

2.2 The Planning process

Finding acceptable routes for transmission lines is becoming an increasingly complex task. The routing of transmission lines has in the past been a routine task, undertaken solely by transmission line engineers who made routing decisions based almost entirely on engineering related costs (Smith et al, 1979). The process of locating transmission line corridors, evaluating alternative corridors and routes, and selection of the final centerline route, has evolved over a period of several decades (White 1981, pg 8-1).

2.2.1 The Increasing Complexity Of Transmission Line

understood by agencies and the public (Howlet 1976, pg 36).

Because of such concerns and general pressures to increase the flexibility and comprehensiveness of the corridor and route selection process, a number of methods have been developed. These methods include extensions of the constraint mapping method published by McHarg in 1969, as well as a variety of computer orientated methods, which enable the storage and manipulation of the data required for an optimization approach.

2.2.2 The Conventional Transmission Line Planning Process

Smith et al 1979, divided the conventional transmission line routing process as practiced in most areas, into 5 major steps:

Step 1. Identification of the start and finish points of the proposed transmission line. A transmission line generally connects a generating station with a substation. If there is more than one substation termination location being considered, the problem becomes a multiple route selection and comparison planning proceedure. For each alternative termination point, steps 1 to 4 would need to be repeated.

Step 2. Selection and evaluation of alternative corridors. From the alternatives, the preferred corridor is selected.

Step 3. Alternative alignments are selected within the preferred corridor. Each segment of each alternative emphasised the involvement of the public (often through elected officials) and the incorporation of public values from the earlier stages of the route selection process. However, Smith et al (1979) found that the transmission line planning process can only effectively involve a broad spectrum of interests beginning at step 2. This is because of the difficulties experienced by anyone other than an electrical engineer, in conceptually envisaging the various transmission system alternatives.

Early public participation typically involves asking the public to comment on issues they consider should be dealt with. Representative methods of public participation, e.g. institutional representation, have often been found to have considerable advantages. Each individual involved has the opportunity to develop an in-depth understanding of the planning process and issues involved. When participating in the setting of objectives and criteria that lead to the results, the public often become supportive participants in the project. This helps avoid the unhelpful "I don't like it" type reaction sometimes encountered in wide open public participation.

Computer analysis assists in focussing attention on significant problem areas, and in the rapid generation of alternatives to assist with testing the outcome of alternative planning scenarios. There are a variety of different public participation techniques by which this process can continue, until consensus is reached. Methods areas assists in removing from further consideration, various parts of the study area. Thus the size of the study area may be reduced, or several corridors chosen for more detailed inventory (White 1981, pg 8-3).

The second phase typically starts with the selection of the various types of data which can be used to measure potential transmission facility impact. On the basis of this information, additional constraint maps are prepared. Graphic display of these variables is generally done by stratifying information according to pre-specified groups. Manual methods involve mapping this information on transparencies which are overlaid on a base map. The purpose of this overlay series is to define areas of environmental complexity and to identify areas where the location of a transmission line will have minimal effects. After manual or computerized overlay of all the constraint variables, or of selected constraint variables, alternate corridors and routes are manually determined (White 1981 pg 8-5). Profile 10 (Southern California Edison), provides an example of a project application.

The selection of variables used in a constraint mapping process, is usually limited by the complexity of the constraints in a region. In relatively homogenous areas with little environmental diversity, a manual constraint mapping systems can offer a quick and efficient method of identifying alternative corridors or routes. However as the number of variables increases, and as the requirement for of converting polygon data to grid data is usually done by computerized procedures. Refer to figure 3.2: "Engineering and Cost Constraints", (Ontario Hydro) in Profile 9, for typical single factor grid cell analysis. Composite constraint maps are understandably more complex.

2.4.3 Polygon Analysis

Here the planning procedure is similar to that for grid cell analysis, but data is entered as polygons and is analyzed in polygon form. Although there are geographic information systems capable of doing this, no transmission line planning systems have been identified in this study that use polygon analysis.

2.4.4 Network Analysis

Network analysis, which involves the selection of specific routes, provides an alternative to computerized corridor selection. The process begins with the standard constraint mapping technique. Typically, after several broad corridors are identified manually, specific routes are designated, field inspected and inventoried. Instead of assembling information for an entire region, only those areas directly affected by the alternative routes need to be inventoried. The data collected from the field inspections, is then coded for each link (i.e. for each segment of the transmission line route) in the network. The resulting measures of impact potential, are then used by the computer in selecting the route of least impact. This technique the transmission line is developed manually.

2.5 The Choice Of A Method

The choice of a method for selecting alternative corridors or routes depends on several factors (White 1981); the complexity of the region, the configuration of the system, the level of detail required and the need to explore alternative sites for related facilities (e.g. substations), in addition to alternative transmission line locations. It is difficult to establish general rules for specifying the approach to use.

2.6 Planning Related Issues

There are a wide variety of issues commonly considered in comprehensive transmission line planning studies. Although these vary somewhat between different studies, Smith et al (1979) note that these can usually be resolved into three primary issues:

- Environmental Sensitivity: The impact the transmission line would have on the existing ecosystems. Consideration of unique habitat areas, the presence of animal species and specific consequences of construction such as erosion and changes in runoff patterns.

-Cultural Sensitivity: Consideration given to changes in land use pattern, impacts on existing land use activities, such as agricultural operations (e.g. aerial spraying); issues relating to population proximity and

Consultants 1983) in that they involve; data capture, the editing and updating of data files, data manipulation, data analysis and retrieval of files, generation of a variety of output, including displays and statistical reports etc. The most significant difference between GIS's and other automated data systems, is in the spatial or geographic nature of the data. The data can be geo-referenced i.e. it is referenced to a specific location on the surface of the earth.

In traditional applications, the GIS is used to display information in a manner that is similar to map display e.g. as with soils, land use and land ownership. The real power of a GIS is realized when a variety of geographic data are manipulated so as to measure and show relationships that were not known beforehand, or were too complex to handle by manual means.

2.7.1 GIS Equipment

GIS's are comprised of hardware (the computer, data input and graphic output devices etc.,) and software (the computer programs). In the review of selected systems in chapter III, the basic computer system and peripheral items such as data input devices, graphic display and hardcopy output devices, are identified (where the information could be obtained), together with equipment characteristics, where appropriate.

2.7.2 The Basic Concepts Of A GIS

and update data, and to bring data gathered at various resolutions, scales and map projections, to a common format. Other utility functions enable selective access in a variety of ways, to any part of the data base. The data can typically be manipulated, checked and queried in various ways.

Data Manipulation: Sophisticated data manipulation functions are usually the most powerful aspect of a GIS. Such functions allow data to be manipulated and analyzed in ways that are often not feasible manually; for instance, overlay (e.g. to identify the co-occurrence of specified characteristics), aggregation (e.g. where a less detailed level of information is more appropriate), and statistical analysis.

Data Display: There is a wide range of data display and hardcopy output alternatives available for use with GIS's. Cathode Ray Tubes (CRT's) provide for temporary displays (or "softcopy") in black and white or color. There are a variety of sophisticated systems available for producing permanent (or "hardcopy") output on paper in both black and white, and color, including pen plots, dot matrix or electrostatic prints at any scale.

2.7.3 Further GIS Related Considerations In Reviewing Systems.

General System Capabilities and Limitations: In reviewing different systems, consideration should be given to the differences between methods, the circumstances under which

Data Base Integration: The problem of integration is present with any system. It is important that a data base is integrated, i.e. that all information is referenced correctly to the same place on the earth. In any given system, can data be transformed from other map projections and if so with what ease? How accurate is the data? (Does it for instance, round off to the nearest 100 feet on the ground? Does it conform to national map accuracy standards?) How flexible is the system to take advantage of a wide range of information?

Techniques For Weighting Data: How are features translated into quantified information? Each system has differences in the way the various types of judgements are integrated. Data can be weighted by setting weights through an interdisciplinary team, through the public, through public agencies concerned with transmission line location, or by all three working together (Howlet 1976, pg 37). Different methods of weighting data are referred to, in both chapters III and IV.

System Limitations: What is the maximum land area that can be accomodated by the system at different data cell sizes and the range of map scales at which it is used?

User Requirements: How easily is the system used? Is it a user friendly (menu driven) interactive operation?

Documentation Support: Is there a user guide and technical reference guide available? The better the documentation, the less important consulting type support becomes.

CHAPTER III

PROFILES OF SELECTED COMPUTER ASSISTED TRANSMISSION LINE PLANNING SYSTEMS

Introduction

The purpose of this chapter is to illustrate a variety of ways in which the computer is used in transmission line planning. From among those systems on which information could be obtained, a representative range of systems have been profiled. As would be expected, when all systems are dealing with transmission line planning, there is some overlap with the planning methods used. However, because of differences in emphasis between the different systems and in the detail of project applications, each study profiled is unique.

Each system is profiled according to the agency using the system. The profiles have been written to provide a brief description of each system including typical projects undertaken and a planning method overview. The description of system hardware and software, where available, summarizes the major components used, but often considerable flexibility exists in the choice of both software and particularly hardware, to achieve the same purpose. Typical output products are described to indicate the range of display (softcopy) and docomentation (hardcopy) available from each system for the project applications described.

PROFILE 1

SYSTEM DESCRIPTION

VISUAL APPRAISAL, INCLUDING VISIBILITY ASSESSMENT, VISUAL IMPACT ASSESSMENT AND VISUAL SIMULATION OF ALTERNATIVE ROUTES, GIVEN SPECIFIC TOWER LOCATIONS AND HEIGHTS

SYSTEM NAME

The four programs used in the system include BIBLE, VIEW, VISTA and LANDVU.

AGENCIES USING SYSTEM

Architecture and Building Aids Computer Unit Strathclyde (ABACUS),
University of Strathclyde,
Glasgow,
Scotland.

Turnbull Jeffery Partnership,
Edinburgh,
Scotland.

Consultant planners, architects, and landscape architects.

KEYWORDS

Transmission Line, Transmission Route, Visual Analysis, Visual Simulation, Geographic Information System, Siting.

TYPICAL PROJECTS UNDERTAKEN

Visual appraisal for transmission line routing studies for the South of Scotland Electricity Board.

the percentage and number of visible grid cells for each part of the tower, whole tower or whole route. This information includes adjustments for intervening trees and buildings, light refraction and curvature of the earths surface. The algorithms to carry out the terrain search are very fast and accurate.

There are other measurable factors that can be handled by the program. The most important of these is "backcloth". (The term backcloth in this case refers to that portion of the background to a view of a transmission line, that is below the skyline.) Program output shows those areas that can see the tower above the skyline (which can of course be seen more easily) and how much of the tower can be seen.

SOFTWARE

Four software packages form the basis of the planning method;

BIBLE (Buildings with Invisible Back Lines Eliminated); Generates monochrome wire line perspective drawings.

VISTA (Visual Impact Simulation Technical Aid); Generates colored, textured, shaded perspective drawings.

VIEW (A set of computer programs concerned with visual analysis; it is part of a larger suite dealing with land use and landscape planning problems. The key element is the dtm on which the various calculations are based.

LANDVU; is a perspective drawing program, using as input data, the gridded elevation data matrix (used in view)

Scotland,
United Kingdom.

Tel (031) 226-2797

REFERENCES

1. Whitleg T M. Gourlay J. Beaumont R D. Taylor P F. Aylward G M. Turnbull M. Environmental Assessment Methodology and Computer Aided Design. Techniques for the Visual Analysis of Transmission Line Routes. Paper Presented at the International Conference on Large High Voltage Electric Systems, Stockholm 1981. 6pp.

2. Purdie C L. Computer Aided Visual Impact Analysis. Proceedings of International CAD Congress: "Datinverarbeitung in der Konstruction '83". Association of German Engineers, Munich 1983 (pp 225 - 237).

3. Purdie, Cameron L. Computer Aided Visual Impact Analysis. PhD Dissertation. University of Strathclyde, Glasgow, Scotland. August 1983.

COMMENT

This sophisticated series of programs includes a variety of precise visual assessment techniques, all of which can be performed quickly and at a reasonable cost, in the testing of alternative ideas. Accurate perspective simulations and photomontages of alternative tower locations can be produced.

considered adequate given the size of the study area. The total number of grid cells was approximately 24,000. The program VIEWS was used to produce pseudo three-dimensional vistas of the study area. This program can show the area under study from any direction, at any altitude and at any scale. Plots were produced along 8 major compas points. Plots generated from an angle of 15 degrees above the horizontal produced an elevated representation of both the topography and the locations of the proposed transmission line corridors.

VIEWS output allows intervening hills and ridges to block the view of more distant landform, in the same manner as is experienced by a person looking upon the vista. However where linear features such as roads and alternative transmission line routes, are mapped, they are merely overlaid on top of the existing topography whether or not they are visible from a given direction.

The program EXPOSURE enables the analyst to define one or more observation points. The program determines which grid cells are invisible to the observer due to intervening high ground. It then plots a gridded representation of "exposed" and "unexposed" grid cells. Transmission line routes and specific tower locations were directly overlaid on the exposure output to determine their relative viewabilities. The exposure program examines only towers that are theoretically visible. Distance, time of day, color and background, which are not taken into account in

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REFERENCES

1. Clark County Department of Comprehensive Planning. Project Report: Viewshed of Proposed Power Line Through the River Mountains. December 1982. 29 pp.

COMMENT

This procedure is useful in determining the relative degrees of visibility of alternative transmission line locations. However the CCRIS system can not take account of the mitigating impact of physical background and lighting on the proposed lines. The system deals only with visibility and not with the issue of possible impacts on environmentally sensitive areas, nor with the comparative costs of constructing the lines along the various routes (1).

Department and the Western Regional Applications Program of the NASA/Ames Research Center. The project involved the preparation of a land use/ land cover inventory for four previously defined alternative corridors.

PLANNING METHOD OVERVIEW

Landsat digital data and image processing techniques, specifically a multidate supervised classification approach, were used to develop a landcover map for an agricultural area near Fresno California. Twenty six landcover classes were identified of which twenty were agricultural crops (1, pg i). High classification accuracies (greater than 80 percent), were attained for several classes, including cotton, grain and vineyards. A generalized version of the classification grouped the twenty six classes into thirteen categories. In addition, acreage summaries by cover type were obtained for the four corridors.

Portions of the two landsat scenes that covered the area were mosaicked together to create one image. Irrigated versus non-irrigated areas within the study area were mapped and acreages were estimated. This included information on which months or combination of months, land was irrigated.

Due to the complex nature of the study region, it was considered that multiple dates for digital analysis would provide a more accurate crop inventory. ("Digital analysis is a set of procedures and computer processes used to manipulate and interpret Landsat digital data into a useable classes described by the classification were grouped in two ways; a generalized (thirteen class) and a detailed (twenty six class) format.

The four alternative corridor boundaries were overlaid onto the final classification at a scale of 1:100,000. In addition, a sepatate overlay was generated to show the location of the one mile wide transmission line planning corridor and its centerline.

Acreage totals for each major crop type were generated to summarize the crops crops grown within each of the four corridors. These figures were provided for both the 200 foot wide corridor centerline and for the entire mile wide corridor.

At the conclusion of the project, computer compatible tapes containing the final classification and various transmission line corridor files, were provided by Ames Research Center to PG&E for future use. [The tapes were compatible with PG&E's in-house geographic software; Environmental Systems Research Institute's (ESRI) single-variable file format.]

SYSTEM HARDWARE/SOFTWARE

Because of the variety of computer systems at Ames, several different hardware/software systems were used during the course of project work. This gave the analysts the option of choosing the most appropriate system for each image processing procedure. The use of multiple systems is

USA.

Tel (415) 965-5912
FTS 448-5912

REFERENCE

1. Bergis V, Maw K, Newland W, Sinnot D, Thornbury G, Easterwood P, Bonderud J. Gates to Gregg High Voltage Transmission Line Study. NASA Report No; NASA TM-84314. December 1982. 143 pp.

COMMENT

With this transmission corridor study, obtaining accurate and up to date information for analysis was important because of the potential impact of a transmission line on the economy of the region. The San Joaquin Valley within which the line was proposed, is approximately 27,000 square miles in size and is 17 percent of the land area of the state of California. The major industry of the valley is agriculture. Important agricultural products are grapes, milk, beef, poultry and citrus. The total gross value of these products in 1978 was estimated at $5.065 billion

The study showed that the use of Landsat digital data for Land use/land cover inventories can be very useful in the planning and routing of transmission lines. Previously PG&E could not economically obtain land use information over large study areas. However, with the implementation of remote sensing techniques, large area inventories could become feasible and cost effective. This would allow for a more complete transmission line route evaluation and review of project alternatives by PG&E, with regard to agricultural

PROFILE 4

SYSTEM DESCRIPTION

CORRIDOR LAND COVER INVENTORY USING LANDSAT IMAGE ANALYSIS

SYSTEM NAMES

ERDAS 400, 2300 and 2400 systems.

AGENCY USING SYSTEM

Earth Resources Data Analysis Systems (ERDAS)
Atlanta,
Georgia,
USA.

ERDAS is a firm specializing in land management and resource analysis using state-of-the-art computer data base technology. ERDAS professional staff includes the disciplines of planning, landscape architecture, ecology, remote sensing, and electronics engineering (1, pg 2).

KEYWORDS

Transmission Line, Transmission Corridor, Remote Sensing, Image Analysis, Resource Assessment, Land Management, Data Base Development, Siting.

TYPICAL PROJECTS UNDERTAKEN

ERDAS was contracted by Tri-state Generation and Transmission Association Inc., to produce an 1,800 square mile transmission line corridor land cover inventory that

ERDAS has developed complete remote sensing and digital processing capabilities, which include all the necessary hardware and software for processing Landsat digital data. The computer system has the capability of producing a scale mapped product with acreage and percentage statistics for defined areas within the larger 185x185 km area covered by a full Landsat image. On this project, twenty six distinctive corridor segments were thus "windowed" out of the larger region (1, pp 11-12).

OUTPUT PRODUCTS

Color display (softcopy) and maps (hardcopy); black and white maps.

SYSTEM SOFTWARE

A large variety of ERDAS image analysis and GIS software is available.

SYSTEM HARDWARE

Each ERDAS system available, has a micro or minicomputer as a central processing unit, an intelligent terminal, a high resolution color monitor and a printer. Storage devices include any combinations of floppy or hard disc and tape drives.

CONTACT

Bruce Q Rado,
Vice President,

PROFILE 5

SYSTEM DESCRIPTION

CORRIDOR LOCATION BASED ON ECONOMIC, SOCIAL AND ECOLOGICAL IMPACT FACTORS

SYSTEM NAME

The corridor planning system is composed of five separate computer programs (system name not obtained).

AGENCY USING SYSTEM

Tennessee Valley Authority (TVA),
Norris,
Tennessee,
USA.

KEYWORDS

Transmission Line, Transmission Corridor, Geographic Information System, Siting.

TYPICAL PROJECTS UNDERTAKEN

Demonstration project designed to develop and evaluate a computer assisted method, to aid in locating transmission lines (1, pg i). The tested methodology was to be capable of determining potential transmission line routes based on optimisations of the combination of economic, social, and ecological impact factors associated with transmission line location, construction and operation. The methodology was being evaluated as a tool to be used in the initial stages of route planning and as a vehicle for documenting TVA

OUTPUT PRODUCTS

Black and white alphanumeric maps.

SYSTEM SOFTWARE

The corridor location system is composed of 5 separate computer programs which are executed in sequential order. 4 programs are written in FORTRAN IV language. One program is a general purpose utility program (1080X), resident on the TVA computer system.

SYSTEM HARDWARE

The programs are compatible with IBM 360 or 370 computers, operating under an OS of US operating system. Minimum peripheral requirements are; card reader, line printer (132 characters, 8 lines per inch), direct access disk (at least one drive; space requirements vary with data base size (1, Appx c).

CONTACT

Charles W Smart,
Program Manager,
&
E Bruce Rowland,
Projects Manager (Applications),
Geographic Information Program,
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impact statement. The complete delineation of the systematic decision making process becomes a public record and creates a very defendable position from the standpoint of presenting a proposed transmission line corridor for approval. The use of such a method shows an agencies willingness to examine all alternative actions as well as their potential impacts when planning transmission lines.

TVA now have an Intergraph turnkey GIS, that will enable both grid cell and polygon analysis and generates color output. This system which is more sophisticated than the grid cell system profiled, could be used in future transmission line planning studies.

PLANNING METHOD OVERVIEW

The study area extends over an area of 320 x 320 km and the grid cell size is one square km. The data base is gridded and includes topography, urban areas, existing roads, rivers, railway lines, areas of special management concern, ecologically important areas, water basins and others. Most of this information was input (digitized) from maps compiled by resource specialists. Topographic information was available from the U.S. Geological Survey in digital form. Some maps were combined to form single category maps e.g. routing constraints. Other maps used singly were processed to create intermediate models e.g. topography was used to create plume impingement, which was combined with others in the siting and routing constraints map. Topography also provided the basis for the slope gradient map, used in the corridor analysis model. Cost models were based on the proximity to rail lines for coal transport, and to water supply for cooling. This information was combined with siting constraints to provide alternative suitable sites, ranked by cost.

Transmission line routing constraints included several areas that could not be crossed by a corridor. Two cost measures were used. The first, cost of construction per kilometer, was calculated by slope. When slope exceeded 20 percent the cost per kilometer was "steep". When slope was less than 20 percent the cost was "flat". Each cell in the file was assigned one of the two levels of construction to work with many data types, including points, lines, polygons, cell attributes and surfaces. The programs are written in FORTRAN and Woodward Clyde Consultants has licensed the source code, so modification or enhancement can be made (2).

SYSTEM HARDWARE

PRIME 550 minicomputer with disc storage and tape drives for data storage and a high speed line printer for output. Alphanumeric computer terminals provide the main interface with the computer. The operating system is capable of communicating with numerous mainframe computers such as IBM, CDC and UNIVAC, as well as microcomputers (3, pg 9). Graphic equipment includes a Calcomp 8000 digitizing tablet, a Zeta 36535X pen plotter, a Tektronix 4027 color graphic CRT, high resolution Princeton graphic terminals and a Xerox 6500 color copier.

CONTACT

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USA.

Tel (415) 945-3000

REFERENCES

PROFILE 7

SYSTEM DESCRIPTION

COMPREHENSIVE ENVIRONMENTAL ASSESSMENT AS AN INPUT TO MANUAL IDENTIFICATION OF ALTERNATIVE CORRIDORS

SYSTEM NAME

COMPIS

AGENCY USING SYSTEM

Comarc Systems,
San Fransisco,
California,
USA.

KEYWORDS

Transmission Line, Transmission Corridor, Geographic Information System, Siting.

TYPICAL PROJECTS UNDERTAKEN

Tri-state Generation and Transmission Association Inc, Project Manager with several electrical utilities planning to route a 230 kV transmission line through a 2,600 square mile area in North Western Colorado, contracted with Comarc for assistance in the identification of several alternative corridors. Comarc applied a state-of-the-art computerized GIS to manipulate comprehensive and complex data inputs. They also successfully involved agency representatives, elected officials and lay public in planning decisions (1 pg 2).

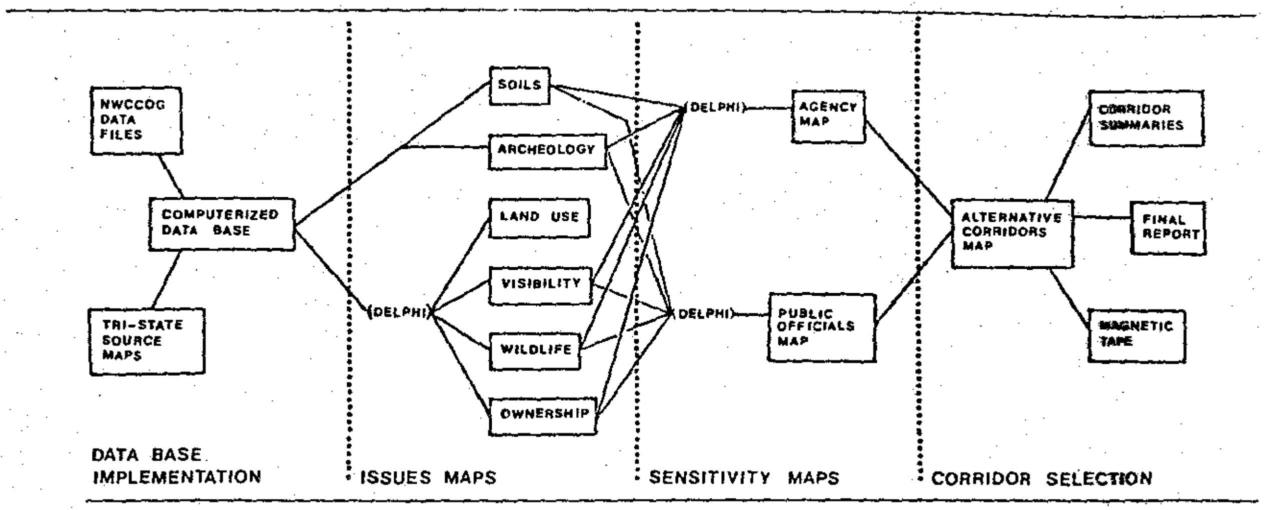

Figure 3.1 Tri-state Project Overview

<u>Phase II;</u> development of a series of issues maps. The issues maps have 3 characteristics.

a) The maps overlay diverse types of information in a composite fashion.

b) The maps are tailored to a particular type of development, in this case a transmission line.

c) The maps reflect subjective data, as well as objective data. Four of the six issues maps were generated by obtaining subjective evaluations of the importance of different types of data from the various agency personnel and county officials. This was achieved in a series of sessions using Comarc's modified Delphi technique. This is a rigorous discipline employed for obtaining objective decisions on qualitative issues. Because of percieved political considerations. Corridors likely to be highly controversial were thereby avoided.

OUTPUT PRODUCTS

Black and white plots.

SYSTEM SOFTWARE

The COMPIS package of programs.

SYSTEM HARDWARE

Alternative central processing units used are:

(1). IBM 4300 & 30XX series operating under a VM/CMS or a VMS/TSO operating system environment.

(2). Data General MV Series.

(3). DEC VAX Series under a standard VMS operating system environment.

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Comarc Systems,
150 Executive Park Boulevard,
San Fransisco,
California,
USA.

Tel (415) 467-1300
TLX II 910-372-7731

REFERENCES

1. Comarc Design Systems. Comarc Aids Colorado Utility in Transmission Line Routing. Comarc Commentary (on

PROFILE 8

SYSTEM DESCRIPTION

CORRIDOR LOCATION BASED ON ENGINEERING COST, ENVIRONMENTAL SENSITIVITY AND SOCIOECONOMIC SENSITIVITY.

SYSTEM NAME

Geographic Information Management System (GIMS).

AGENCY USING SYSTEM

Dames and Moore,
Los Angeles,
California,
USA.

A consulting firm with about 1100 employees and partners, providing a broad range of planning and economic, environmental, engineering, and geotechnical services (offices throughout USA and internationally).

KEYWORDS

Transmission Line, Transmission Corridor, Geographic Information System, Siting.

TYPICAL PROJECTS UNDERTAKEN

Consulting project applications.

PLANNING METHOD OVERVIEW

Dames and Moore have developed a sophisticated planning process that is described in detail as a case study in

Graphic output at various resolutions and of different types is available. Graphic equipment includes; alpha CRT's, TEKTRONIX graphic CRT's, plotters from Houston Instrument, Nicollet-Zeta and Calcomp, and both dot matrix and standard line printers. All of these devices are supported on the leased line network and by direct dial access. The most versatile and inexpensive display is produced on the line printer. Plotters and other graphic devices generate more sophisticated maps.

SYSTEM SOFTWARE

GIS Analysis and modelling is centered on Dames and Moores Geographic Information Management System (GIMS). This system has been developed over the last 10 years as an ongoing effort, in support of the firms consulting activities in multidisciplinary projects. Maximum flexibility in using GIMS has been a design objective, with major interfaces to various manufacturers equipment. The system enables input of data from existing digital sources e.g. machine readable digital terrain data available from the USGS. Information from original or published documents is input to the system via a variety of digitizers. All software is written in FORTRAN. Full documentation includes a comprehensive users manual.

SYSTEM HARDWARE

PROFILE 9

SYSTEM DESCRIPTION

ALTERNATIVE CORRIDOR/ROUTE IDENTIFICATION AND EVALUATION, BASED ON ENVIRONMENTAL, SOCIAL, ENGINEERING, & COST CONSTRAINTS

SYSTEM NAME

Computer Assisted Route and Site Selection (CARRS).

AGENCY USING SYSTEM

Ontario Hydro,
Toronto,
Ontario,
Canada.

KEYWORDS

Transmission Line, Transmission Corridor, Transmission Route, Environmental Assessment, Siting.

TYPICAL PROJECTS UNDERTAKEN

Environmental assessments for proposed generation and transmission facility location studies (power stations, transmission lines and substations). Ontario Hydro's first computer application for environmental assessment purposes, was developed in 1972 for the Bruce to Georgetown transmission line routing project. At that time, it became apparent that manual methods were inadequate, as they could not provide the planners the required flexibility or process the large amounts of data necessary to meet the requirements transmission lines in the general area between Sudbury and Thessalon, were evaluated in conjunction with alternative generating station sites.

In November 1982 an environmental assessment was completed that included both corridor and route selection studies for two 500 kV single-circuit transmission lines, approximately 210 km long, on a common right-of-way between Hanmer Transformer Station (TS) near Sudbury and Missisaggi TS northeast of Thessalon. The proposal also included the construction of associated terminal facilities on Hydro-owned property at Mississagi TS (4, pg 1).

This transmission line study has been chosen to illustrate a typical planning process. Following on from the study completed in 1978, a preferred transmission system alternative using 500 kv transmission lines was selected. Minor modifications were made to the corridors defined in the 1978 study, to make them more suitable for the preferred plan of locating a new transmission line between Hanmer TS and Mississagi TS. These corridors were presented to the public in 1979 and were accepted as a starting point for the route selection study.

The route selection planning process brought together all concerns related to all aspects of the environment (natural, social, engineering and cost), to enable identification and assessment of possible route locations within the corridors. The purpose was to recommend a route for government approval. The main steps in the route selection process (4, pg 5) are identified in figure 3.3: "Route Selection Process". (3, pg 5).

(1) Identifying the Study Area and Interested Public (January to June 1979): The study area (corridors from North Channel) was refined, environmental data was collected from a variety of sources and a community profile was carried out. Two citizens committees were formed.

(2) Identifying Constraints (August 1979 to January 1980): Potentially sensitive environmental features were

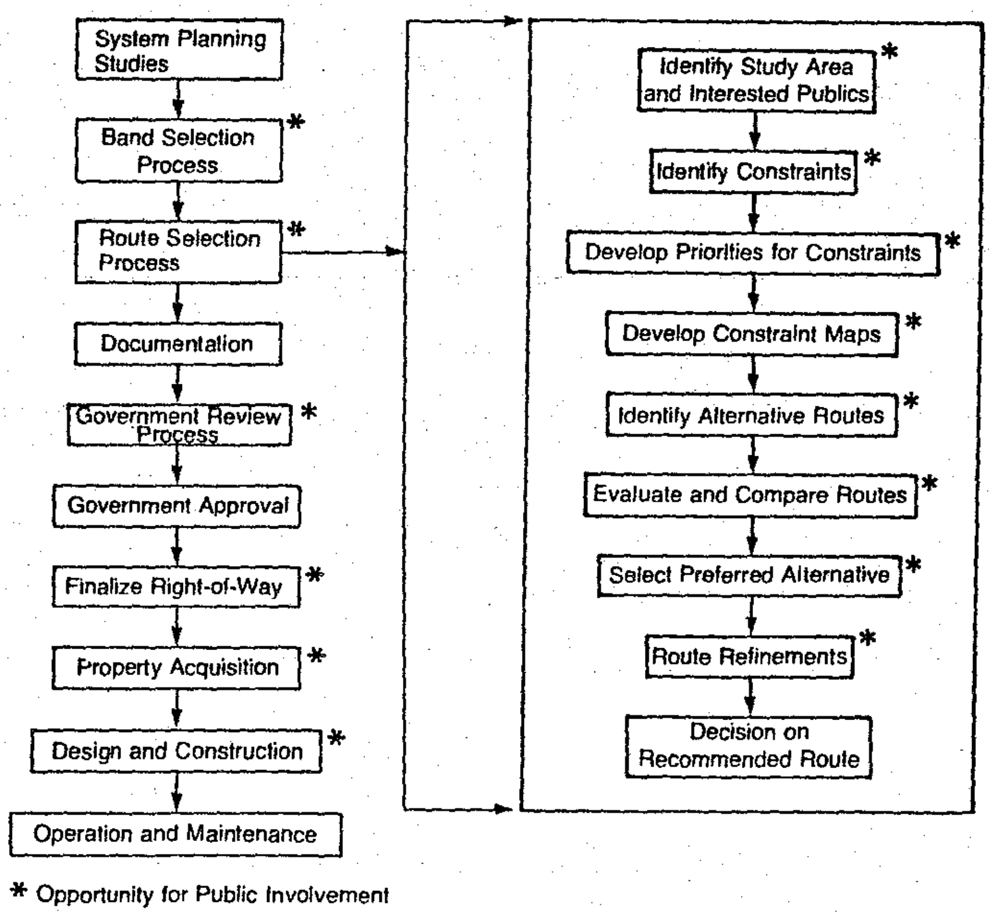


Figure 3.3 Route Selection Process (Ontario Hydro).

(5) Evaluating and Comparing Routes (November and December 1980): The six routes were evaluated on the basis of potential environmental, social, engineering and cost effects. For the environmental evaluation, 38 different types of environmental constraints (objective statements) were identified and assigned a priority (ranking). Each route was then analyzed to determine its potential effects on the constraints.

Construction cost was estimated for each of the six alternative routes. These mainly considered tower footing, access road and tower construction costs. Cost per kilometer was added to these, to cover costs associated with power losses, maintenance, purchase and stringing of conductors, all of which vary in direct proportion to length. There was an estimated construction cost difference of approximately six percent between the most and least expensive alternatives.

The social analysis of the alternative routes was based on an evaluation of their potential effects on population characteristics, the local economic base, and existing community structure and services.

(6) Selecting a Preferred Route (January to March 1981): The preferred route was then selected, based on the evaluation results and on public comment. Comments on the preferred route were then sought from both the citizens' committees, provincial and municipal government representatives and the general public, including

REFERENCES

1. Miller, Curtis. Nargis Jetha. Rod MacDonald. Classification of the Visual Landscape for Transmission Planning. In: G.H.Elsner and R.C. Smardon, eds. Proceedings of our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource, U.S. Forest Service General Technical Report PSW-35, Berkeley, CA. Pacific Southwest Forest and Range Experiment Station. 1979. 752 pp. (pp. 507-513).

2. Ontario Hydro, Computer Assisted Route and Site Selection System. Report No 80283, Land Use and Environmental Planning Department, August 1980.

3. Ontario Hydro, Hanmer Transformer Station to Missisagi Transformer Station. Outline of the Route Selection Phase. April 1979. 21 pp.

4. Ontario Hydro, Environmental Assessment Summary for Ontario Hydro's Hanmer Transformer Station to Mississagi Transformer Station Environmental Assessment. Report No 82219, Community Relations Department, Route and Site Selection Division, November 1982. 17pp.

5. Ontario Hydro, Environmental Assessment Hanmer Transformer Station to Missisagi Transformer Station. Report No 82059, Route and Site Selection Division. November 1982.

COMMENT

The CARSS system was developed to (2):

-"provide a mapped information handling tool that is efficient, understandable, and relatively accessible to the planner;

- provide for the input, manipulation, and output of large volumes of mapped information;

- function as a grid (cellular) system, yet maintain known and acceptable levels of data integrity for the recorded information;

- implement specific instructions for the synthesis of information;

- allow for the development of a variety of weighting and/or ranking schemes;

- allow for the evaluation of any cellular stored information using specifically developed packages;

PROFILE 10

SYSTEM DESCRIPTION

SITING METHOD FOR POWER STATION & ITS ACCESS ROADS, TRANSMISSION LINES & WATER PIPELINES, USING COST, ENGINEERING, ENVIRONMENTAL & HEALTH/SAFETY CRITERIA IN EXCLUSION SCREENING

SYSTEM NAME

GISS (The SCE Geographic Information Software System).

AGENCY USING SYSTEM

Southern California Edison (SCE).
Rosemead,
California,
USA.

SCE is the fourth largest privately owned electric utility company in the United States.

KEYWORDS

Transmission Line, Transmission Corridor, Generating Station, Siting, Geographic Information System.

TYPICAL PROJECTS UNDERTAKEN

A 100 mW solar thermal central receiver siting demonstration covering a 26,000 square km study area within the Mohave Desert; this involved selecting viable locations for both the generating station itself and its "umbilicals", i.e. the necessary access roads, transmission lines and in one scenario, a water pipeline. As a parallel effort, criteria were developed for other technologies of interest available in digital form (the Edison Mohave Resource Inventory - EMRI). Data layers were selected that were applicable to the siting of a 100 mW central receiver.

Phase 2: Regional screening. Exclusion screening was chosen because it was considered to be the most defensible method. After the set of explicit exclusionary criteria were applied to the study area, candidate areas remained. An example of a criterion used is that an acceptable candidate area must be more than 2.4 km from a residential area. The original criterion was 8 km, but it was found to be overly restrictive, as small parcels of land were scattered throughout the Mohave Desert. The 8 km distance, excluded the entire study area on a single criterion that reflected a desirable condition, but not a truly exclusionary one. The flexibility of the computerized technique was immediately apparent as the overly restrictive criterion was replaced. This emphasized the value of performing sensitivity analysis on the effect of individual criteria (1).

Eventually 24 criteria were retained for exclusion screening. These criteria were grouped into 4 issue themes; cost, engineering, environmental, health/safety. Criteria were applied to selecting viable locations for the generating station itself and its necessary access roads, transmission lines and in one scenario, a water pipeline.

Phase 3: For the purposes of this demonstration of system potential, candidate sites were selected within the

1. Myatt, Mona M. Utility Siting Decisions Using a Geographic Information System. Paper presented to the conference "Facility Siting and Routing '84, Energy and Environment. April 15-18 1984. Banff, Alberta, Canada.

COMMENT

Edison considered the study successful, both in terms of locating several regionally acceptable sites and in demonstrating how this technology can contribute to the site selection process (1).

1. ABACUS/TURNBULL JEFFERY	2. CLARK COUNTY	3. PG&E/NASA-Ames	4. ERDAS	5. TVA	6. WOODWARD-CLYDE	7. COMARC	8. DAMES & MOORE	9. ONTARIO HYDRO	10. SOUTHERN CAL. EDISON	
●		●	●		●	●	●			PROJECT PLANNING BY CONSULTANT
		●		●				●	●	PROJ. PLNG. BY POWER AUTHORITY
					●			●	●	TRANS. LINE PLNG. AS PART OF A LARGER FACILITY SITING PROCESS
				●	●		●	●	●	COMPREHENSIVE PLNG. (e.g., ENGINEERING, SOCIAL, ENVIRONMENTAL)
				●	●		●	●	●	INCLUDES ENGINEERING COST
					●				●	INCLUDES COSTS OTHER THAN ENGINEERING
				●	●	●	●	●	●	INCLUDES OVERALL ENV. ANALYSIS
				●		●	●	●	●	INCLUDES SOCIAL AND/OR CULTURAL AND/OR POLITICAL
		●	●							LAND USE/LAND COVER, CORRIDOR INVENTORY SYSTEM
		●	●					●		USE OF LANDSAT 3 IMAGE ANALYSIS
								●	●	CONSTRAINT MAPPING ANALYSIS
				●	●	●	●			GRID CELL ANALYSIS
										NETWORK ANALYSIS
●	●		●	●	●	●	●	●	●	VISUAL ANALYSIS
●										VISUAL SIMULATION
								●		CORRIDOR AND ROUTE PLANNING
		●	●	●	●	●	●		●	CORRIDOR PLANNING ONLY
●	●									ROUTE PLANNING ONLY
		●	●					●		IMPACT ASSESSMENT FOR MANUALLY DEFINED CORRIDOR
●	●							●		IMPACT ASSESSMENT FOR MANUALLY DEFINED ROUTE
				●	●		●			COMPUTERIZED "OPTIMUM" CORRIDOR SELECTION

Figure 3.4 Matrix - Planning System Characteristics

CHAPTER IV

CASE STUDY

Introduction

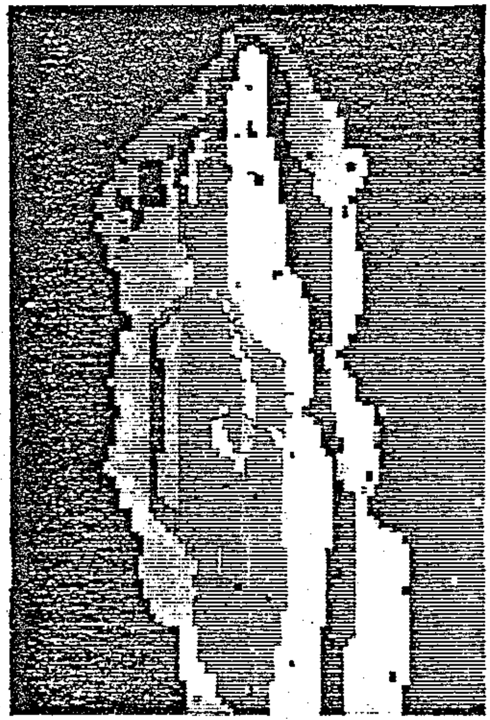
A case study has been included in this report to enable a typical computer assisted transmission line planning process to be described in greater detail than was feasible with the ten systems profiled. The Dames and Moore example was chosen because of the comprehensive nature of the planning process and the clarification of a typical comprehensive planning process that it provides.

Dames and Moore's "Geographic Information Management System" (GIMS).

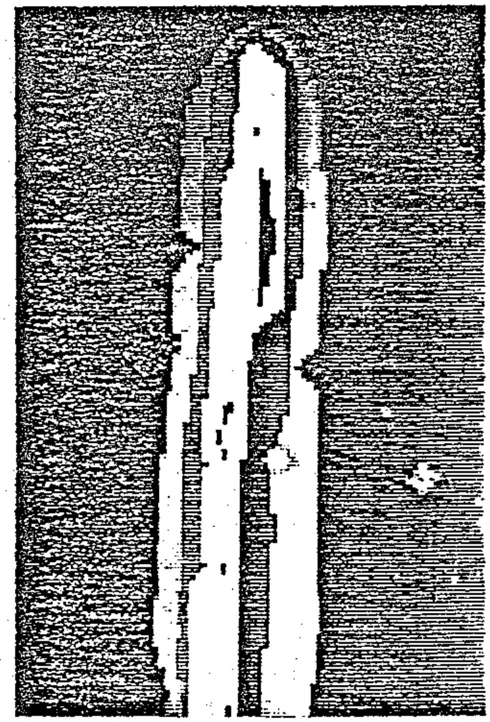
PLANNING METHOD OVERVIEW - FURTHER DETAILS

The planning method developed by Dames & Moore (profiled in chapter III), enables systematic evaluation of a given study region, using a set of logically defined criteria. The optimum transmission corridor is determined between any two points within the region under study. The technique is applied in two phases;

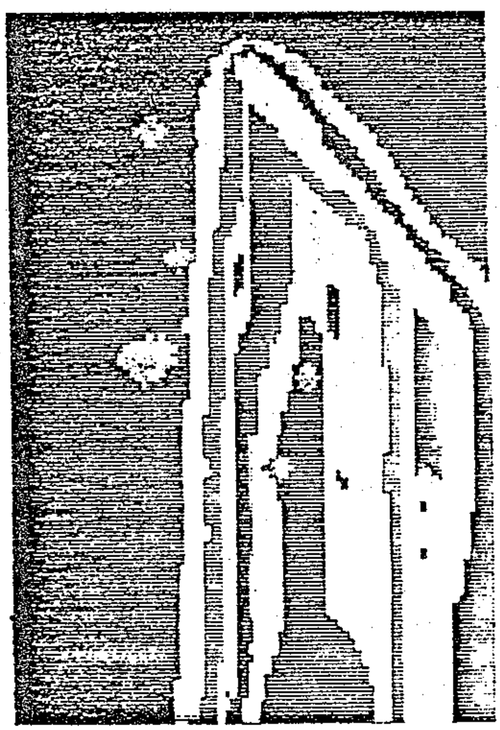
Phase I; using a geographic overlay process, areas of high to low suitability are identified, suitability being a measure of an areas ability to accept the introduction of a transmission line, with minimal impact.



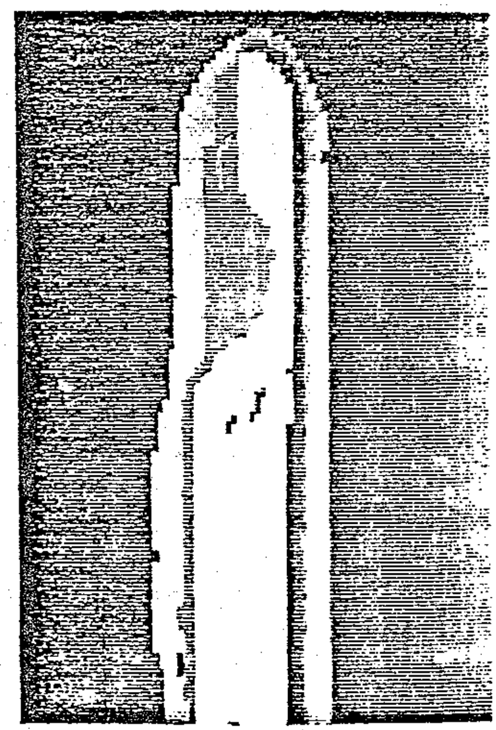
1 - Ecological Sensitivity Route



2 - Construction Suitability Route



3 - Cultural Sensitivity Route



4 - Composite Route

Figure 4.1 Primary Isues Maps & Composite Route Map

(Dames & Moore)

through the composite route map, from generating station to substation.

The issues maps can be formulated using a variety of group evaluation or decision making techniques. Whatever technique is used (i.e. Delphi, Preference Value Setting etc.,) the weights used in the formulation of the composite map should be considered normative values. Once the composite desirability map has been prepared, the routing algorithm is used to identify the optimum composite route. The composite route illustrated in figure 4.1 is narrow in some places. This indicates that the choice of routes is severely constrained (given the set of criteria used in the evaluation). Where the width of corridor is wider, there is a broader range of choices of transmission line alignment available, each having the same resultant cumulative impact. Areas of suboptimum corridor location, can be more easily identified in the original color map output, which was not able to be reproduced in this report. The width of these suboptimum envelopes also indicates the the degree of freedom of choice that is present on any given portion of the overall corridor. Once the final composite corridor has been developed, it is reviewed in detail and several comparisons are made to clarify the context of the results (1).

In the first comparison, the composite corridor is contrasted with each of the single objective corridors. Segments of the composite corridor that align with the

1. Public input is provided for through a systematic process that is carefully defined and documented, facilitating the focussing of public input on specific issues. This focus on specific issues rather than on specific parcels of real estate, defuses a significant stumbling block in the transmission line development process.

2. This computerized technique enables rapid analysis and experimentation with a variety of factors, to determine possible route locations under varying points of view and emphasis.

3. The entire region under study can be analyzed, showing optimum routes and their related suboptimal alternatives.

CHAPTER V

CONCLUSION

So what has been achieved with this study? The state-of-the-art of the use of computers in transmission line corridor and route planning has been researched, with an emphasis on the analysis of environmental factors, but also including engineering, economic, political, social, and cultural factors. The following has been documented.

1) A general introduction to the use of computers in transmission line planning (chapter II). This includes an overview of the basic concepts involved and of the broader issues that typically need to be addressed when reviewing different systems or in selecting, adapting or developing a system for a particular application.

2) A survey was conducted of agencies working in this area. From among those systems on which sufficient information could be obtained, a representative range of systems was profiled (chapter IV). The overview of each system included information on the agency contact people.

3) One comprehensive planning system which was profiled in chapter III, is documented as a case study in chapter IV. This was included to enable a more detailed explanation of a typical comprehensive planning process, than was possible in

BIBLIOGRAPHY

(Only those references used in compiling the profiles and otherwise cited throughout the report are included in this listing. A list of additional reference material follows.)

Arneson, Mary A. Blending Transportation Facilities into the Landscape Computer Style. Paper presented at the "Workshop for Automated Photogrammetry and Cartography of Highways and Transport Systems". April 28 to May 1, 1981. Portland, Oregon. American Society of Photogrammetry, Columbia River Region.

Bergis V, Maw K, Newland W, Sinnot D, Thornbury G, Easterwood P, Bonderud J. Gates to Gregg High Voltage Transmission Line Study. NASA Report No; NASA TM-84314. Moffet Field, California. December 1982. 143 pp.

Bisenius, Daniel J. Impact Analysis Methods - A Comparative Review. Method Study. Unpublished report. USDI, Bonneville Power Administration, Portland, Oregon. February 1981. 46 pp.

Bisenius, Daniel J. Marcotte, Jay G. Impact Analysis Methods; A Comparative Review. Paper presented at the Third Symposium on Environmental Concerns in Rights-of-Way Management, Islandia Hyatt House, San Diego, California, February 15-18, 1982. (Proceedings at press).

Blair, William G E. Gray, Brian A. Herbert, John A. Jones, Grant R. Visual Impact of High Voltage Transmission Facilities in Northern Idaho, Northwestern Montana, for USDA, Bonneville Power Administration, Jones and Jones Inc., Seattle, Washington, 1976. 157 pp.

Blau, David H. Siting of Major Facilities: A Regional Perspective. In: Regional Landscape Planning. Proceedings from Selected Educational Sessions. Paper Presented at the 1983 Annual Meeting of the American Society of Landscape Architects. 1983. 31 pp. (pp 11-15).

Carey, J B. G W Harju. A E Stevenson. Users Manual, MOSAIC/Photomontage. Berkeley: Pacific Southwest Forest and Range Experiment Station. 1976.

Castle, Gilbert H (III). Regional and Site Specific GIS Analysis. In: Regional Landscape Planning.

Engineers/Consultants, Reading, Pennsylvania. Unpublished Report. 1982.

Giles, Robert H Jr. Jones, A Blair III. Smart, Charles W. POWER: A Computer System for Corridor Location. Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Research Division Bulletin no 117. 1976. 30 pp.

Giles, Robert H Jr., Charles W Smart, A Blair Jones. POWER: A High Voltage Transmission Corridor Location System. In: R. E. Tillman (Ed.), Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, held at Mississippi State University, January 6-8, 1976. Published, Mississippi State University,1976. 335 pp. (pp 44-47).

Howlett, B. Environmental Selection of Transmission Line Routes with Maps and Computers. In: R. E. Tillman (Ed.), Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, held at Mississippi State University, January 6-8, 1976. Published, Mississippi State University,1976. 335 pp. (pp 36-41).

Hunter Cross, Richard (III), A Case Study of Computer-Aided Transmission Line Siting, from "Computer Mapping in Natural Resources and the Environment", Harvard Library of Computer Graphics, 1979 Mapping Collection, pp. 13-33.

Killpack, Charles. LANDSAT: Innovating Landscape Architecture. Landscape Architecture Technical Information Series 6, Vol. 4, No. 1, American Society of Landscape Architects, Washington D.C. September, 1979. 36pp.

Landscapes Limited. PERMITS Methodology: Process of Energy Routing to Minimise Impact from Transmission Systems. USDI, Bonneville Power Administration, 1974.

Lewis, Philip H. Bruce H Murray. Bernard J Niemann Jr. James A Wright. PERMITS Methodology - Phase 2. For USDI, Bonneville Power Administration. 2 Vols. Landscapes Limited, Madison, Wisconsin. 1974.

MacDougall, E. Bruce. Microcomputers in Landscape Architecture. Elsevier. 1983. 271 pp.

McHarg, Ian L. Design With Nature. Garden City, New York. Natural History Press. 1969.

Miller, Curtis. Nargis Jetha. Rod MacDonald.

Ontario. November 1982.

Purdie, Cameron L. Computer Aided Visual Impact Analysis. PhD Dissertation. University of Strathclyde, Glasgow, Scotland. August 1983.

Purdie, Cameron L. Computer Aided Visual Impact Analysis. Proceedings of International CAD Congress: "Datenverbeitung in der Konstruction '83". Association of German Engineers. Munich 1983. pp 225-237.

Robinette, Gary O. Energy and the Environment. Kendall/Hunt. 1973. 302pp.

Sherer, S.D. Embree, R.C. Photomontage Techniques for Siting Electrical Transmission Lines. Landscape Architecture and Planning. August 1983. Vol. 8, pp. 629-631.

Smart, Charles Willard. "A Computer-Assisted Technique for Planning Minimum Impact Transmission Right-of-Way Routes". Unpublished Doctoral Dissertation. Virginia Polytechnic Institute & State University, Blacksburg, Virginia. May 1976. 191 pp.

Smart, Charles W. E Bruce Rowland, and Larry E Beeman. Computer Interpretation of Soil Data for Rights-of-Way Management. In: R. E. Tillman (Ed.), Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, Held Mississippi State University, January 6-8, 1976. Published, Mississippi State University,1976. 335 pp. (pp 70-75).

Smith, Dennis R, Robinson, John H, Olsten, James C. Optimisation of Transmission Corridor Selection Using a Computerized Route Definition Technique. Paper presented at the 17th Annual Conference of the Urban and Regional Information Systems Association, August 19-23, 1979. San Diego, California.

Tennessee Valley Authority, Computer Assisted Transmission Corridor Routing Demonstration. Tennessee Valley Authority. 1982. Proceedings in press. 71 pp plus appendices.

Thor E C. MOSAIC II User's Guide. Berkeley, California. Pacific Southwest Forest and Range Experiment Station. 1980.

Travis, Michael R., Gary H Elsner, Wayne D Iverson, and Christine G Johnson. VIEWIT: Computation of Seen Area, Slope and Aspect for Land-use Planning. Berkeley, California. Pacific Southwest Forest and Range Experiment Station. USDA Forest Service Gen. Tech.

Astor, Peter H., Twine, Kevin P. Geographic Information in the Right of Way Management: The Status and Uses of Current Computer Technology. In: R E Tillman (ed). Environmental Concerns in Rights-of-Way Management. Proceedings of Second Symposium Held October 16-18, 1979, University of Michigan, Ann Arbor. Electric Power Research Institute. Palo Alto, California. Special Study Project WS 78-141. Proceedings March 1981. (pp. 3-1 to 3-13).

Bureau of Land Management. Visual Resource Management Program. Department of the Interior. Bureau of Land Management, U.S. Goverment Printing Office. 1980. 40 pp.

Bureau of Land Management. Visual Simulation Techniques. Department of the Interior. Bureau of Land Management, U.S. Goverment Printing Office. 1980. 40 pp.

Blair, William G.E.; Walters, David H; Mah, Edwin W.S.; Substation Visual Simulation Techniques, Report for Bonneville Power Administration by Jones and Jones Inc., Portland, Oregon. September, 1982.

Brown, Terry J. and Itami, Robert M; Landscape Principles Study: Procedures for Landscape Assessment and Management. -- Australia. Lanscape Journal. Vol. 1, No. 2. 1982. (pp. 113-122.)

Craik, K.H. and Feimer, N. Setting Technical Standards for Visual Assessment Procedures. In: G.H.Elsner and R.C. Smardon, eds. Proceedings of our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource, U.S. Forest Service General Technical Report PSW-35, Berkeley, CA. Pacific Southwest Forest and Range Experiment Station. 1979. 752 pp. (pp. 93-100.)

Dangermond, Jack. "Some Trends in the Evolution of GIS Technology" Paper read at the Harvard Computer Graphics Week, Cambridge, Ma. 1980.

Department of the Interior, Bureau of Land Management. A Summary: Visual Resource Management. July 1978.

de Waal Malefyt, S., J.J. de Waal Malefyt, and P.H. Astrom. An Ecological Methodology Used in the Selection of a 500 kV Transmission Line Route in the Southwestern United States. pp. 78-87. In: R. Tillman (ed.) Proc. of the First Nat'l Symp. on

Gumstrup, P.D., Meyer, M.P., Gufstfson, R.J., Hendrickson, E.R. Aerial Photographic Assessment of Transmission Line Structure Impact on Agrricultural Crop Production. Photogrammetric Engineering and Remote Sensing. Vol. 28, No. 8. 1982. (pp. 1313-1317.)

Hopkins, Lewis D. "Design Method Evaluation: An experiment with Corridor Selection". Socio-Economic Planning Science 7. 1973. (pp. 423-36.)

Huber, Dennis Lee. "Alternative Methods in Corridor Routing". Unpublished Masters Thesis, University of Tennessee, Knoxville. June 1980. 205 pp.

Huber, George. Andre L Delberg. Guidelines for Combining the Judgements of Individual Group Members in Decision Conferences. J. Acad. Management. 15 (2): 1972. (pp. 161-174.)

Hwang, Ching-Lai: Kwangson, Yoon. Multiple Attribute Decsion Making; Methods and Application: A State of the Art Survey. Publ. Springer-Verlag: Berlin Heidelberg, New York. 1981.

Killpack, Charles; Computer Mapping, Spatial Analysis and Landscape Architecture. Landscape Journal, Vol. 1, No. 1, 1982.

Law, Charles S. and Zube, Ervin H; Effects of Photographic Composition on Landscape Perception. Landscape Research. Vol. 8, No. 1, 1983.

McCannon, Dan. Public Participation in Routing Transmission Lines: What it means and why bother? In: R E Tillman (ed). Environmental Concerns in Rights-of-Way Management. Proceedings of Second Symposium Held October 16-18, 1979, University of Michigan, Ann Arbor. Electric Power Research Institute. Palo Alto, California. Special Study Project WS 78-141. Proceedings March 1981. (pp. 15-1 to 15-5).

Miser, Hugh J. Operations Research and Systems Analysis. Science, Vol. 209, 4 July, 1980. (pp. 139-146.)

Odening, Walter R., Kellog, Stephen D., Sicherman, Alan. Ecological Value Ranking and Utility Corridor Selection. In: R E Tillman (ed). Environmental Concerns in Rights-of-Way Management. Proceedings of Second Symposium Held October 16-18, 1979, University of Michigan, Ann Arbor. Electric Power Research Institute. Palo Alto, California. Special Study Project WS 78-141. Proceedings March 1981. (pp. 5-1 to 5-8.)

January, 1983. (pp. 83-84.)

Sheppard, Stephen R. J; Predictive Landscape Portrayals: A selective Research Review. Lanscape Journal. Vol. 1, No. 1, 1982. (pp. 9-14.)

Steinitz, Carl, Defensible Processes for Regional Landscape Design. Landscape Architecture Technical Information Series, Vol 2, No. 1, American Society of Landscape Architects, Washington, D.C. September, 1979.

Stevenson, A E. J A Cowley. J B Carey. A Computerized System for Portrayal of Landscape Alterations. In: G.H.Elsner and R.C. Smardon, eds. Proceedings of our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource, U.S. Forest Service General Technical Report PSW-35, Berkeley, CA. Pacific Southwest Forest and Range Experiment Station. 1979. 752 pp. (pp. 151-156.)

Stone, Edward H. II, Visual Resource Management, Landscape Architecture Technical Information Series, Vol. 1, No. 2, American Society of Landscape Architects, Washington, D.C., June 1978.

Thompson, Larry S. Probability and the Assessment of Impact Risk in Utility Corridor Siting. In: R E Tillman (ed). Environmental Concerns in Rights-of-Way Management. Proceedings of Second Symposium Held October 16-18, 1979, University of Michigan, Ann Arbor. Electric Power Research Institute. Palo Alto, California. Special Study Project WS 78-141. Proceedings March 1981. (pp. 4-1 to 4-8.)

Tillman, Robert E. (Ed). Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management. Held at Mississippi State University, January 6-8, 1976. Published by Mississippi State University. Proceedings 1976. 335 pp.

Tillman, R.E. (Ed) Environmental Concerns in Right-of-Way Management. Proceedings of Second Symposium Held at University of Michigan, Ann Arbor, October 16-18, 1979. Electric Power Research Institute. Palo Alto, California. Special Study Project WS 78-141. Proceedings March 1981.

Tlusty, Wayne. The Use of VIEWIT and Perspective Plot to Assist in Determining a Landscape's Visual Absorption Capacity. In: G.H.Elsner and R.C. Smardon, eds. Proceedings of our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource, U.S. Forest Service General Technical

1 Climate	1 System design improvements; avoidance
2 Topography	2 System design improvements; avoidance
3 Elevation	3 System design improvements; avoidance
4 Hydrology/water quality	4 Minimize erosion, sedimentation; avoid watershed and scenic river areas; avoid navigable waters; secure federal permit; provide suitable drainage and alteration of watercourses; create artificial wetlands; purchase other wetlands;
5 Soils/geology/seismicity	5 Avoid hazardous areas
6 Wildlife	6 Avoid; enhance habitat; provide compensatory habitat restoration
7 Vegetation	7 Low maintenance vegetation; reseeding; low growing vegetation; selective clearing, cuttings; minimize herbicide damage; avoid rare, sensitive, endangered vegetation; feather back the edges of ROW; clear for one year clearance; drop and lop; cut firewood size logs; aerial (helicopter removal);
8 Air	8 Construction dust suppression; herbicide use limitation and selective application
Social/Cultural Elements	
1 Historic/prehistoric resources	1 Recover resources before construction; avoid
2 Parks, landmarks, monuments, reserves	2 Avoid areas identified by USFS, USFWS, State Fish and Game agencies, etc.
3 Scenic resources (designated)	3 Avoid highly visible areas; underground facilities; maximize ROW sharing; when doubling up use same equipment; judicious tree removal
4 Public services	4 Avoid local public services and all major facilities
5 Economics	5 Relocate businesses; avoid economically healthy areas; minimize negative impacts on property values
6 Sense of community/comfort/convenien	6 Minimize breaks in community form (avoid corridors splitting neighborhoods); screen or treat noise
7 Urban design/visual quality	7 Avoid incompatible uses; avoid unsightly equipment; mitigate/screen unsightly equipment; use designated waste disposal areas
8 Health/safety	8 Provide operating manuals for equipment (flashover); design water sources near TL to minimize electrical discharge to animals drinking; alter height of lines; alter amount of line current
Manmade Elements	
1 Agricultural land uses	1 Joint productive use of ROW; avoid interruption of operations, crossing fields
2 Urban land uses	2 Joint use of ROW
3 Circulation/transportation facilities	3 Joint use of ROW
4 Public facilities	4 Avoid
5 Military installations	5 Avoid
6 Airports	6 Avoid
7 Existing transmission lines and pipeline:	7 Minimize overhang of TL (perpendicular); create buffers for adjacent lines; improve safety and emergency response techniques
Institutional/Regulatory Elements	
1 Land ownership	1 Avoid; purchase, eminent domain
2 Jurisdictions	2 Joint use
3 Land use plans and growth trends	3 Joint use; coordinate route planning with local planning agencies and vice versa; upgrade existing lines; (systems planning)
4 Land values	4 Coordinate route planning with local plan development; avoid high quality residential, office/industrial developments; underground
5 Funding/financing of electric power	5 Cancel, postpone project (negative action)
6 Environmental quality regulations	6 Minimize or avoid impacts
7 Federal, state regulations	7 Avoid USFS, USFW, Department of the Interior and BIA land, BLM lands and cooperate with licensing processes

Figure A.1: Ma

APPENDIX 2

ORGANISATIONS NOT PROFILED IN CHAPTER III, IDENTIFIED AS WORKING WITH COMPUTER ASSISTED TRANSMISSION LINE PLANNING RESEARCH OR PROJECT APPLICATIONS

BRIEF SYSTEM REVIEW: 1

SYSTEM DESCRIPTION

(1) VISUAL SIMULATION: (2) CORRIDOR LOCATION BASED ON ENVIRONMENTAL, VISUAL & SOCIOECONOMIC FACTORS

AGENCY/CONTACTS

Bonneville Power Administration (BPA),
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Portland,
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USA.

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&
Stephen Sherer, Tel (503) 230-3000

COMMENT

BPA has been working with computer assisted transmission line planning for over ten years. The first major application of a computer assisted method was with a study over the 1975-1978 period (6). The system had been acquired and was further developed. It was used to locate and evaluate approximately 1,200 miles of alternative corridors within an 8,000 square mile study region.

veiwing point chosen, one photomontage is produced for each alternative line route (7).

REFERENCES

1. Bisenius, Daniel J. Impact Analysis Methods - A Comparative Review. Method Study. Unpublished report. USDI, Bonneville Power Administration, Portland, Oregon. February 1981. 46 pp.

2. Bisenius, Daniel J. Marcotte, Jay G. Impact Analysis Methods; A Comparative Review. Paper presented at the Third Symposium on Environmental Concerns in Rights-of-Way Management, Islandia Hyatt House, San Diego, California, February 15-18, 1982. (Proceedings at press).

3. Carey, J B. G W Harju. A E Stevenson. Users Manual, MOSAIC/Photomontage. Berkeley, California. Pacific Southwest Forest and Range Experiment Station. 1976.

4. Landscapes Limited. PERMITS Methodology: Process of Energy Routing to Minimise Impact from Transmission Systems. USDI, Bonneville Power Administration, Portland, Oregon. 1974.

5. Lewis, Philip H. Bruce H Murray. Bernard J Niemann Jr. James A Wright. PERMITS Methodology - Phase 2. For USDI, Bonneville Power Administration. 2 Vols. Landscapes Limited, Madison, Wisconsin. 1974.

6. Murray, Timothy J. Daniel J Bisenius. Jay G Marcotte. Northwest Montana/North Idaho Transmission Corridor Study: A Computer Assisted Corridor Location and Impact Evaluation Assessment. In: G.H. Elsner and R.C. Smardon, eds. Proceedings of Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource, U.S. Forest Service General Technical Report PSW-35, Berkeley, California. Pacific Southwest Forest and Range Experiment Station. 1979. 752 pp. (pp. 470-476.)

7. Sherer, S.D. Embree, R.C. Photomontage Techniques for Siting Electrical Transmission Lines. Landscape Architecture and Planning. August 1983. Vol. 8, pp. 629-631.

8. Thor E C. MOSAIC II User's Guide. Berkeley, California. Pacific Southwest Forest and Range Experiment Station. 1980.

computerized capability to generate optimum transmission line routes according to user specifications of criteria from the data base, was developed.

This capability was used to select eight additional optimum routes, each reflecting a different set of value judgements. Each of the eight optimum routes, along with the Company and Citizens Group alternatives, was evaluated according to its potential effects on erosion, water quality, wildlife habitat, land use, critical resources, construction costs, views from residences and views from major highways.

Data processing technology was found to be a particular advantage in this case study, through increasing the speed, economy and precision in dealing with large amounts of spatial information, given the constraints of time and budget.

REFERENCE

1. Hunter Cross, Richard (III), A Case Study of Computer-Aided Transmission Line Siting, from "Computer Mapping in Natural Resources and the Environment," Harvard Library of Computer Graphics, 1979 Mapping Collection. pp 13-33

first study, undertaken in the early 1970's, involved the application of a geographic information system. This study was part of the Davenport power plant development project, for Pacific Gas and Electric (1,2 & 3). Here environmental, social and economic factors were considered in determining optimum transmission corridors.

In EDAW's Fort Collins office, a computer has been found to be an essential tool in the management and analysis of the large amounts of data that result from the application of weighted evaluation criteria.

In EDAW's Alexandria office, a modified form of the U.S. Forest Service's "Perspective Plot" program has been used to generate perspectives of transmission lines in a rural landscape. The plots were used to provide an accurate framework for the manual rendering of transmission line simulations on black and white photographs.

REFERENCES

1. Blau, David H. Siting of Major Facilities: A Regional Perspective. In: Regional Landscape Planning. Proceedings from Selected Educational Sessions. Paper Presented at the 1983 Annual Meeting of the American Society of Landscape Architects. 1983. 31 pp. (pp 11-15).

2. Robinette, Gary O. Energy and the Environment. Kendall/Hunt. 1973. 302pp.

3. Williams, Edward A. Massa, Allison K. Blau, David H. Schaal, Herbert R. Siting of Major Facilities - A Practical Approach. McGraw-Hill 1983. 314pp. (pp. 259-271).

Selecting a dam site from the five alternative sites identified by the applicant, required the evaluation of such factors as forest density, accessibility, soil composition and geologic character, for more than 9,200 hectares (23,000 acres). Determining the environmental impact of the proposed alternative transmission routes, required the mapping and analysis of approximately 3.7 million hectares (9.2 million acres). The extensive land area involved with the alternative transmission line corridors, was considered well suited to the large format of satellite imagery. Land use and vegetation cover data were unavailable, limited, or out of date for much of the area. The study was able to provide graphic and display materials for use in the project application hearing (1).

The study showed that Landsat 3 data could be used as an accurate and low cost data source, for the assessment of the impact of power projects on the environment. Also through having the remotely sensed data, FERC staff were able to recommend alternative routes and sites, in addition to the ones proposed by the project applicant (1).

REFERENCE

1. Christenson, Jerrold W. Anderson, Carrol. Gumbman, Phyllis. Environmental Assessment Using Remotely Sensed Data: Application of Remotely Sensed Data to Environmental Impact Studies for Transmission Line Routes. Intralab Project No 75-5. NASA. Undated (approximately 1976). 19pp.

Photogrammetry, Columbia River Region.

2. Nickerson, Devon B. Perspective Plot, An Interactive Analytical Technique for Visual Modelling of Land Management Activities: USDA Forest Service, Div. Timber Management, Pub R6-TM. 031-1980, Portland, Oregon. 1980. 145 pp.

3. Travis, Michael R., Gary H Elsner, Wayne D Iverson, and Christine G Johnson. VIEWIT: Computation of Seen Areas, Slope and Aspect for Land-use Planning. USDA Forest Service Gen. Tech. Report PSW-11/1975. 70 pp.

using computer assisted techniques, is the environmental impact statement for the Hot Springs to McNiel 500 Kv transmission line for Arkinsaw Power and Light Company.

REFERENCES

1. Gilbert/Commonwealth, Transmission Line Routing, Capabilities and Experience. Gilbert/Commonwealth, Engineers/Consultants, Reading, Pennsylvania. Unpublished Report. 1982.

2. White, Arlen D. Overview of Corridor Selection and Routing Methodologies. (8pp). In: R E Tillman (ed). Environmental Concerns in Rights-of-Way Management. Proceedings of Second Symposium Held October 16-18, 1979, University of Michigan, Ann Arbor. Electric Power Research Institute, Special Study Project WS 78-141. Proceedings March 1981.

BRIEF SYSTEM REVIEW: 8

SYSTEM DESCRIPTION

CORRIDOR LOCATION BASED MAINLY ON ENVIRONMENTAL ISSUES, WITH & WITHOUT OPTIMUM CORRIDOR LOCATION

AGENCY/CONTACTS

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USA.

Leon Simutis,
Associate Dean,
College of Architecture and Urban Studies.
Tel. (703) 961-5506

Robert H. Giles Jr.,
Professor,
Department of Fisheries and Wildlife Sciences.

COMMENT

Since more than ten years ago, both departments have been involved in independent programs of research, for different clients, on the development and application of computer assisted methods for transmission corridor planning.

The POWER system developed by the Department of Fisheries and Wildlife Sciences, was generalized for locating various types of corridors. This system deals mainly with environmental concerns. When an origin and destination is specified, the computer will locate an optimum corridor. The system was designed to run on an IBM mainframe computer. It was of interest to note that in one

April 15-18 1984. Banff, Alberta, Canada. Proceedings at Press.

2. Giles, Robert H Jr. Jones, A Blair III. Smart, Charles W. POWER: A Computer System for Corridor Location. Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Research Division Bulletin no 117. 1976. 30 pp.

3. Giles, Robert H Jr. Charles W Smart. A Blair Jones. POWER: A High Voltage Transmission Corridor Location System. In: R. E. Tillman (Ed.), Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, held Mississippi State University, January 6-8, 1976. Published, Mississippi State University,1976. 335 pp. (pp 44-47).

4. Smart, Charles Willard. "A Computer-Assisted Technique for Planning Minimum Impact Transmission Right-of-Way Routes". Unpublished Doctoral Dissertation. Virginia Polytechnic Institute & State University, Blacksburg, Virginia. May 1976. 191 pp.

Simple structural shapes can be plotted in perspective view. Elements such as transmission line support towers can easily be shown. At this point, software has not been written that would enable simulation of the conductors strung between the towers, although this is possible. The original software for the Perspective Plot program was written by Devon Nickerson while employed by the U.S. Forest Service. Since that time, the software (which being Government funded, is freely available to the public) has been considerably modified to meet the need of individual projects in his consulting work.

REFERENCE

1. Visual Simulations. Predicting the Impact of Land Management Activities. Brochure. Undated. 4 pp.

and J.E.Dooley. Additionally, the consultants made a research grant to R.T.Newkirk (as principal researcher) and M.J.Troughton at the University of Western Ontario (1, pp 147-148).

REFERENCE

1. Newkirk, Ross T. Environmental Planning for Utility Corridors. Ann Arbor Science Publishers Inc. 1979. 199 pp.

APPENDIX 3

WHY USE AN AUTOMATED SYSTEM?

[(From: Dangermond, Jack. A Classification of Software Components Commonly Used in Geographic Information Systems. In: United States/Australia Workshop on the Design and Implementation of Computer Based Geographic Information Systems. Hawaii, 1982. International Geographical Union, Commission on Geographical Data Sensing and Processing. 146 pp. (pp 70-91)].

Proponents of the automated geographic system technology point out a whole series of advantages which are enumerated in the literature. They include the following:

A. Data is maintained in a physically compact format (i.e., the magnetic file)

B. Data can be maintained and extracted at a lower cost per unit of data handled

C. Data can be retrieved with much greater speed

D. Various computerized tools allow for a variety of types of manipulation including map measurement, map overlay, transformation, graphic design, and data base manipulations

E. Graphic and non-graphic (i.e., attribute information) can be merged and manipulated simultaneously in a "related" manner

F. Rapid and repeated analytic testing of conceptual models about geography can be performed (i.e., land suitability/capability). This facilitates the evaluation of both scientific and policy criteria over large areas in short periods of time.

G. Change analysis can be efficiently performed for two or more different time periods