VISUAL IMPACT ANALYSIS : A CASE STUDY OF A COMPUTER BASED SYSTEM

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ABSTRACT

A system for Computer Aided Visual Impact Analysis (CAVIA) has been developed. The system can be considered as having Landscape Data, Man-Made Object Data, Visibility and Visualisation Sub-Systems. A case study of the application of the system to the evaluation of alternative transmission line routes illustrates the techniques used for data collection, visibility and visualisation. The integration of a Digital Terrain Model and associated derived data with Landsat satellite data to guide design work and construction planning is described. Validation of visualisation and other aspects of the technique based on the constructed lines and current and future developments such as image mixing are discussed. The need for the system as an aid to planning and design problems is explained.

CAVIA

Over a number of years the Turnbull Jeffrey Partnership, a firm of Planners, Architects and Landscape Architects, and ABACUS, a research unit in the Department of Architecture and Building Science at the University of Strathclyde, have been collaboratively engaged, with support from the South of Scotland Electricity Board, on the development of a system for Computer Aided Visual Impact Analysis (CAVIA). The system can be considered as having four main sub-systems:

<u>Landscape Data</u>
Integration of digital terrain models with land use information and satellite data to generate plans, sections and perspective views of the landscape

<u>Man-Made Objects Data</u>
Modelling, in plan, section and perspective and, if required in colour, of any man-made objects - electricity pylons, buildings, bridges, forests etc

<u>Visibility</u>
Accurate measurement of the degree of visibility of man-made objects in the landscape and the complementary measurement of 'dead ground'

Visualisation

Mixing 'frame-grabbed' images of the site with computer generated images of man-made objects and displaying the resulting visualisation. Generation of images of landscape and man-made objects, in line or colour form, suitable as visualisations on their own, as montages with black and white or colour photographs or as video by mixing with 'frame-grabbed' or live images.

Techniques used for Visibility and Visualisation

Five principal programs are involved in the process of determining the visibility of objects or features in the landscape and these are briefly described below. In addition, many other programs were needed in support for the purposes of data checking, manipulation, analysis and display. All programs operated on the same DTM and object data. The principle of intervisibility is fundamental to the program methodology in identifying the locations in the landscape where a person would see a transmission tower.

The program VIEW1, based on this principle considers only topography as defined by a DTM. The visibility of an object established by the application of this program results in the worst possible case since no allowance is made for any screening which may result from trees, buildings or other features in the landscape. In some landscapes such features may reduce visibility considerably. The height of the object may be set as required, thus if the height of the object is set as the top of a transmission tower, the visibility of the whole tower can be investigated. All the simulations take into account curvature of the earth and refraction of light which can be significant when view distances over one kilometre are involved. VIEW1 also allows the investigation of invisible areas, that is dead ground. This is important in routing considerations since the visibility or invisibility of an object placed in an area of dead ground can be immediately determined.

The VIEW2 program can be used to analyse views of transmission towers from specified viewpoints. This program can: modify a DTM to allow for the screening effect of features such as trees or buildings; identify those towers visible from a specified viewpoint; detail the percentage of the tower visible; identify the occurrence of background including the percentage above the horizon; and identify the visibility of the features from the viewpoint. This program can take into account whether a viewpoint, such as a road, is in a cutting or on an embankment. An additional program VIEW3 can identify the influence of features such as trees or hedges in screening of towers. The results of the VIEW1, VIEW2 and VIEW3 programs are represented in two dimensional form, either as maps, computer print-out, computer line drawings or as tables and diagrams. By using additional programs, VIEWER and LANDVU, it is possible to produce an accurate perspective drawing of the visible towers in the landscape from a given viewpoint. This is important in demonstrating the visibility of the towers and their scale in the landscape.

The VIEWER program is a three point perspective drawing procedure providing 'wireline' drawings with hidden lines removed of objects for photomontaging. VIEWER processes a three dimensional geometrical description of an object, in this case transmission towers and/or a DTM treated as an object, and outputs a three point perspective view of it. This view is fully corrected and adjusted to accurately depict the exact object as viewed by an observer from any viewpoint location in the study area.

The LANDVU program produces a computer generated three point perspective of the DTM from a specified viewpoint in the form of a 'wireline' drawing with hidden lines removed.

Using this data and the appropriate viewing parameters recorded during the site photography, properly established perspective views can be drawn by the computer replicating exactly the viewpoint and direction of view on the ground. To prepare a photomontage, these perspectives are printed onto transparent sheets and overlaid on the enlarged colour site photographs. An exact registration between the photograph and the computer drawing is achieved by means of control points. These points are known and visible features in the site photographs, and are modelled in the computer views to ensure an accurate match in the montage.

CASE STUDY : TORNESS TRANSMISSION LINES

The CAVIA system has been put to use on various projects as it has been developed and is to some extent project led. The Torness Lines Study is one of a considerable number of projects undertaken, but was the first in which the majority of the system was used.

Transmission lines are constructed to transmit electrical power from the source of generation to load centres and carry power on conductors suspended at regular intervals from towers of lattice steel construction some forty-five to fifty metres high.

The Torness Transmission Lines study involved the detailed visual assessment of two alternative transmission line routes in the south east of Scotland in the Berwickshire and Ettrick and Lauderdale Districts of Borders Region, centred on the Lammermuir Hills which rise up to 500 metres and separate the fertile and populous plains of East Lothian in the north and the Merse and Upper Tweed Valleys in the south. In scenic terms, the Lammermuirs have an open treeless appearance characteristic of much of the upland scenery of southern Scotland south of the fault line from Dunbar to Girvan. At a regional level the Hills are subject to environmental policies contained within the structure plans of Lothian and Borders Regional Councils, designed to protect the ecology and the scenic nature of the area.

Visibility : General Considerations

In conducting a study of the potential visibility of a transmission line, it is first of all necessary to make some judgement about the area from which the transmission towers will be visible. Distance is a very important factor when viewing a transmission line in the landscape. Apparent height in the landscape varies inversely with distance and generally, the smaller the apparent size of the transmission tower, the less significant its visibility. In many instances, the overall visibility of a transmission line will be limited by surrounding topographic features. Where this is not so, experience has indicated that the most significant views are likely to be experienced within a distance of five kilometres from the transmission towers. Longer distance views can be significant, particularly where a transmission line is viewed above the horizon, ie on the skyline. Accordingly, a study area extending beyond five kilometres from the routes was defined to accommodate such longer views to towers. This larger area was selected by examining the topography surrounding the immediate study area in Borders Region.

Use of a computer in visibility studies rather than field studies has distinct advantages:

1 to given levels of accuracy, the visibility of objects in the landscape can be simulated and recorded by analytical techniques which could be impossibly long to undertake manually

2 after data acquisition and simulation, different alternatives can be evaluated quickly and easily.

Data Collection

A 30km x 30km area of the Lammermuirs mainly within Borders Region was identified for analysis. Although a square study area was chosen, this is not a requirement of the techniques. The DTM is prepared from Ordnance Survey 1:25000 series maps by Laser-Scan Laboratories Limited of Cambridge, using specially developed equipment and computer programs. The process involves following the contours with a laser and recording in digital form the location of all points where the contour lines change direction. The data is then transformed to National Grid co-ordinates, interpolated to the specific grid of 25 metre and verified using contoured drawings and three dimensional representations of the data. Before the DTM of the study area was prepared, four trial areas, typifying the different topographic features of the study area, were tested to determine the most appropriate grid interval for the DTM and the levels of accuracy required. Roads and woodlands were also digitised and the information converted for use at a 25 metre grid.

Application and Interpretation

Initially the entire area of 30km by 30km was studied using a DTM with a 200 metre grid generalised from the 25 metre grid to assess the overall visibility of alternative routes. The VIEW1 program produced visibility maps for each of forty transmission towers and amalgamated these to produce 'contours of visability' for each route in total (Figure 1). This level of analysis was used to identify broad patterns of visibility and to highlight areas for further detailed study.

The results showed that both of the proposed routes exhibited a similar pattern of visibility. Both cross a high upland section of the Lammermuir Hills at a height of approximately 400 metres. In the area, the local population resides in villages and farm steadings which for the most part lie in lowland areas along valley floors. With the exception of one stretch of trunk road, the same conclusion applies to the major roads in the area. The results demonstrated that the resident and road using population are entirely screened by intervening topography from either of the transmission routes considered in the study.

Subsequently, a smaller area of 22km by 22km was analysed using a 100 metre grid to give a greater level of accuracy. The area chosen was based on the 'contours of visibility' map produced using the 200 metre grid. The analysis of information generated by the VIEW1 program when run using the smaller data set, validated the general conclusion and permitted certain more detailed conclusions to be drawn about the similarities and differences in visibility for each of the proposed lines.

Once the main areas of visibility had been defined a more accurate visual assessment was undertaken from selected viewpoints within these areas. Clearly not every potential viewpoint is of equal importance and a selected list of viewpoints was identified by field observation and from the results of the VIEW1 program.

The visibility from individual viewpoints was assessed using the VIEW2 program. This analysis generated a range of detailed information for each viewpoint. In this way, valuable data was obtained to assist with the assessment of the visibility, particularly in respect of the extent of visibility of particular towers above the skyline.

Whenever possible, the results of the computer studies were correlated with a parallel exercise of field observation recording the nature of the view, type of landscape and vegetation, important buildings, and recreational activities. The height of a transmission tower can be estimated roughly in the field by employing a yardstick device and estimates of visibility can be recorded by a simple method of classification. The computer results can then be combined to construct an analysis of visibility in the contaxt of landscape setting and type. The VIEW3 program was used to define 'critical areas' where the existence of a feature, such as woodland or a building, of a stated size would make the difference between visibility and invisibility. It was then possible to examine maps and aerial photographs to establish if trees or buildings occurred at these critical locations.

Visualisation

The visualisation stage of the study was undertaken using VIEWER and LANDVU computer perspective programs. It was originally intended to prepare a photomontage from each of the viewpoints with a view of the alternative lines (Figure 4). However, bad weather precluded the possibility of obtaining photographs from all but one of the viewpoints and a perspective view of the landscape from these viewpoints was generated using the LANDVU program. The results of this program were correlated with the results of the VIEW2 program and from the photomantage process obtained for the one possible montage permitted by the weather.

Outcome of Case Study

A Public Inquiry proved to be necessary to resolve the issues associated with the transmission routes. The computer assisted techniques proved to have certain key advantages:

1 the quantification of the extent of visibility associated with the alternative routes and the exploration of the detailed pattern of change in the visibility by reference to an overlay of maps. This is not normally possible and directed debate away from speculation about what may or may not be seen, and instead focussed on interprepation of patterns of visibility and the implications of these for the landscape of the area

2 the production of accurate photomontage and perspective views of the landscape from selected viewpoints showing the representation of the landscape before and after the transmission towers had been erected. In some cases these proved particularly interesting since the towers were screened entirely from view where field observation had indicated that some parts of some towers may be visible. Once again, debate could be focussed on the interpretation of visual images rather than on their accuracy.

Access Tracks

Although the Public Inquiry found in favour of the SSEB's proposed route, the method of construction, the access tracks for construction and maintenace of the lines were subject to further planning submissions to ensure that their impact on the environment was minimised.

It was therefore decided to prepare a detailed land use map to identify ground cover habitats along 12 kilometres of the most sensitive terrain on the route and to advice on the most appropriate construction techniques and ground reinstatement.

The practical objective was to provide good quality ground cover data to ensure accurate and prompt drawings for Planning Permission outlining proposals for a proper and full landscape and ecological reinstatement and for subsequent contract documents. In addition to the planning submission, this information was used in design work and as an outline guide in construction planning, and in discussion with relevant conservation bodies to assure them of adequate landscape reinstatement. Finally, the maps with a distribution of ground cover habitats were linked to prescribed components of landscape advice detailed techniques of construction and reinstatement practice to be employed in association with particular habitats.

The distribution of ground cover habitats was prepared by remote sensing techniques based on LANDSAT satellite imagery. In this case the use of LANDSAT data was selected due to the short timescale before construction work began. Traditional methods using published maps of soil and land use classifications linked to a time consuming site survey would have limited the scope and extent of the study particularly in the ability to examine the distribution of ground cover habitats at a variety of scales.

The satellite interpretation work was carried out by the Environmental Remote Sensing Applications Centre (ERSAC) Limited using an image processing computer system. The interpretation was validated by on-site checking of selected areas. The ground cover data available at the end of this process was held in the form of a classification at 50 metre grid intervals for an area of 22km x 22km.

After the interpretation and field-checking process a final ground cover interpretation was prepared as follows: woodland, water, heather dominant, heather grass/burnt mix, upland grass, improved grass, bracken dominant, cropland.

The data derived from the satellite imagery was analysed and then combined with elevation data at a 25 metre grid and data on the location of woodlands and roads (Figure 2). Additional data was derived from the DTM: slope at specified gradients (Figure 3); drainage direction; aspect; elevation at specified contour intervals.

This derived data was then integrated with the ground cover data to produce maps combining ground cover distributions such as heather etc with physical characteristics such as slope, elevation etc. An interesting correlation was observed between certain classes of slopes and heather moorland on deep peat.

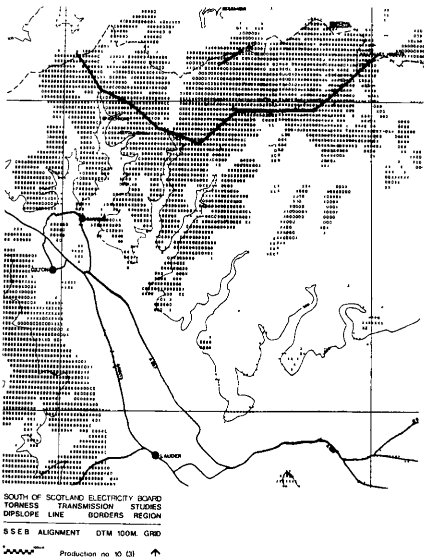

Figure 1 Contours of Visability

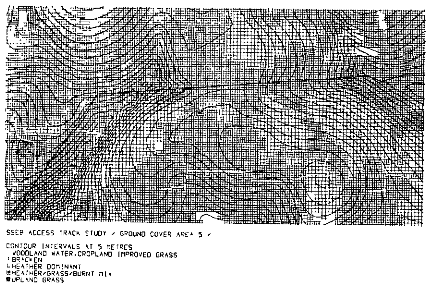

Figure 2 Ground Cover Map

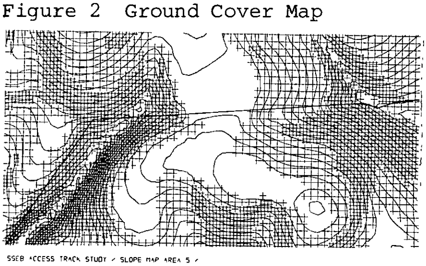

Figure 3 Slope Map

Figure 4 Photomontage of proposed transmission towers

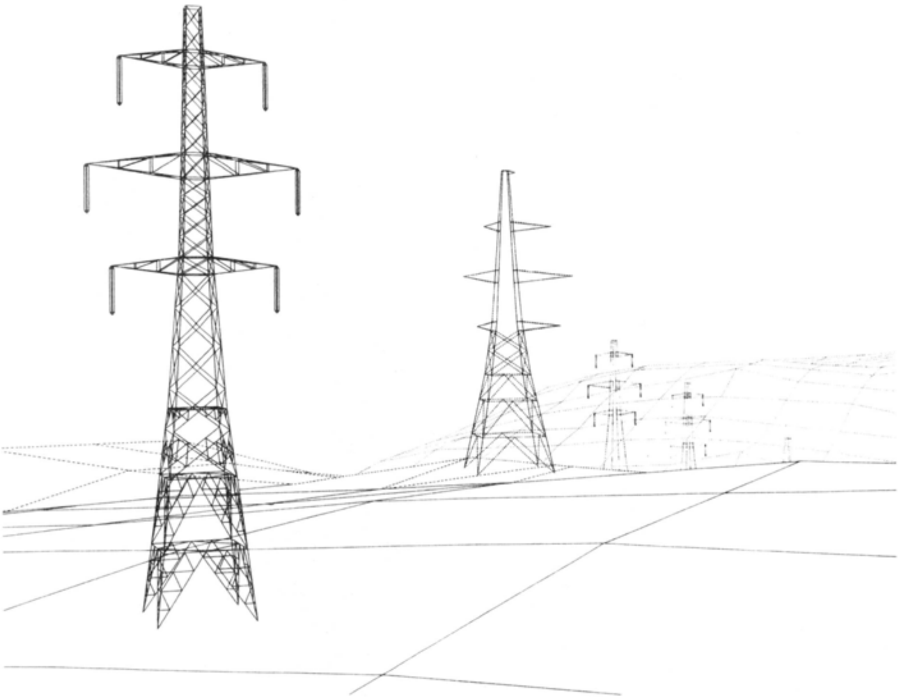

Figure 5 Perspective of towers using pen plotter to give distance effect

CURRENT AND FUTURE DEVELOPMENTS

Since the completion of the transmission line and access tracks extensive validation of the techniques has been undertaken.

Validation of Visualisations

The visualisations produced before the line was constructed have been compared with the actual line and any differences investigated. The performance of software has been evaluated and the programs used for the study assessed against their current versions.

Transmission Towers

Various construction towers have been modelled in detail. Modelling of conductors and wires is well advanced. Methods of dealing with distance have been investigated both in terms of line drawing output and colour (Figure 5).

Photographs for Montaging

Until now it has been necessary to use professional surveyors to locate photographic viewpoints and control points to the accuracy required for montaging computer images with photographs. Considerable effort is going into accurately calculating viewpoints from identifiable features in the photographs.

Hidden Line Elimination

The specification for appropriate hidden line elimination software which can handle complex scenes is being developed. Such software which will use plotters for output will be able to handle the required quantity of DTM and object data with no restrictions on viewpoint/target locations and no restriction on mutual intersection of bodies.

Image Mixing : The Effects of Climate

Climatic conditions affect the visibility of middle-ground and distant objects via varying lighting conditions and atmospheric pollutants (water vapour etc). In order to mix computer generated images with video images of natural landscape it will be necessary to model in software the effects of distance under varying weather conditions. The approach adopted will be to photograph, for example, receding pylon lines under extremes of visibility and by image processing to establish the degree of atmospheric visual attenuation to apply to the computer generated images.

Image Mixing : Separation of Foreground and Background

Realistic visualisation of a building often requires viewing from a position which locates the building between a background (eg hills) and a foreground (eg trees): conventional 'cut and paste' techniques of mixing the images, although feasible, are laborious and seldom adequate. It is intended to automate the mixing process using the frame grabbing and buffering capabilities of the PLUTO II imaging system so that separate parts of the landscape and building images can be successively superimposed to produce the required composite image.

Output Display : Hardcopy

The choice of hardcopy medium depends on the use: presentation to clients for design purposes, high quality presentation for public inquiry etc. The study will examine and if possible counteract, using software methods, the limitation of current copy devices: for example, plotters in terms of pen thickness and range of colours, and colour printers in terms of resolution and range of colours.

Output Display : Video

The main issue to be investigated is the cost-effectiveness of producing dynamic images of design/planning proposal. It is already possible to generate a 'walk-through' of buildings and of neighbourhoods but only by the expensive and time consuming process of frame-by-frame filming. The advanced IRIS 2400 workstation offers the possibility of real time dynamic viewing, video recording and manipulation of a model, in either wire-line or fully coloured modelling. The remaining problem is then to ensure colour constancy from designer's materials to screen view to video record.

CONCLUSION

The natural and man-made environment is under increasing stress. We are entering a phase when the exploitation of energy resources is likely to cause a dramatic acceleration in our rate of impact on the natural environment; in particular there is cause for serious concern regarding the damaging visual impact of energy related developments - oil terminals, dams, power stations, transmission lines, open cast mining - on remaining areas of relatively unspoilt rural landscape. At the same time the need to renew our inner cities places enormous responsibilities on architects and planners who seek to integrate - elegantly and economically - the new with the old.

The political will exists to address the problem: a recent EEC directive recognises landscape and, by implication, visual impact, as an issue within environmental impact analysis. What is lacking is the means to appraise and compare the visual impact of alternative proposals objectively, economically and, above all, in a manner which is understandable to the range of interests involved in the design and planning process. CAVIA is a computer aided system which attempts to meet these requirements.

Computer techniques such as CAVIA are now beginning to be recognised to have an increasingly important role in aiding in the resolution of planning and design problems. The challenge is to integrate a diverse range of techniques from several disciplines into one system.

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