SURFACE MINE PLANNING & DESIGN IMPLICATIONS AND THEORY OF A VISUAL ENVIRONMENTAL QUALITY PREDICTIVE MODEL[1]

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Abstract: Surface mine planners and designers are searching for scientifically based tools to assist in the pre-mine planning and post-mine development or surface mine sites. In this study, I present a science based visual and environmental quality predictive model useful in preparing and assessing landscape treatments for surface mine sites. The equation explains 67 percent of respondent preference, with an overall p-value for the equation <0.0001 and a p-value < 0.05 for each regressor. Regressors employed in the equation include an environmental quality index, foreground vegetation, distant non-vegetation, people, vehicles, utilities, foreground flowers, foreground erosion, wildlife, landscape openness, landscape mystery, and noosphericness (a measure of human disturbance). The equation can be explained with an Intrusion/Neutral Modifier/ Temporal Enhancement Theory which suggests that human intrusions upon other humans results in landscape of low preference and which also suggests that landscape containing natural and special temporal features such as wildlife and flowers can enhance the value of a landscape scene. This research supports the importance of visual barriers such as berms and vegetation screens during mining operations and supports public perceptions concerning many types of industrial activities. In addition, the equation can be applied to study post-mining landscape development plans to maximize the efficiency and effectiveness of landscape treatments.

Additional Key Words: landscape architecture, landscape planning, environmental psychology, landscape reclamation, landscape design

Introduction

Environmental scientists have been interested in assessing the properties of the landscape in order to evaluate the impact of proposed treatments upon the landscape, including surface mine reclamation planning and design projects. Investigators and practitioners are engaged in applying research based predictive models to study the effects of specific landscape planning, design, and management treatments upon built and natural environmental settings. These predictive models can connect a multiplicity of environmental issues such as biological diversity, spatial function, and aesthetic quality into general spatial models as illustrated by Burley (1993) and McHarg (1969). In this paper, I present the historical development of these predictive models, describe a recently developed prediction model, and discuss the implications of this model for surface mine visual management.

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Literature Review

In many respects, Elwood Shafer and colleagues, with the publication of their visual quality equations started the modern era of landscape visual preference research (Shafer 1969, Shafer *et al.* 1969, and Shafer and Tooby 1973). They employed contemporary social science research methods to numerically obtain a perception based evaluation of landscape photographs. They then measured various properties of the photographs and statistically related several of the properties with the preferences of the respondents. Shafer's equation was then demonstrated in a forest management situation to illustrate the application of the work (Brush and Shafer 1975). Shafer's model was heavily criticized by Bourassa (1991), Wienstein (1976), and Carlson (1977), especially because the equation seemed unlinked to any formal, predictive theory to explain the relationships between the variables measured in the photographs and the preferences of respondents. Essentially their criticisms are valid; yet in some respects I believe Shafer and colleagues were somewhat unfairly denounced because engineers, ecologists, economists, and agronomists often gain wide acceptance for developing statistical relationships between variables without having a single theory to explain the relationships-- developing a theory is not a prerequisite for developing an equation. Nevertheless, Shafer's

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equation was difficult for some social scientists to accept and investigators examined other directions in environmental landscape preference research.

In contrast to Shafer's approach, there have been a series of normative theory based visual quality analysis procedures. The normative theory approach is different than a formal theory approach, because normative theories are actually principles or rules for the designer and planner to follow; but the normative theory does not predict and explain behavior or phenomena, it only directs the behavior of the designer (Lang 1987). This approach has been called the expert approach by Taylor *et al.* (1987) because the methodology employs experts to apply normative theory to derive heuristically based procedures to evaluate visual quality without any empirical evidence. The Bureau of Land Management (1980) and the United States Forest Service (1973 and 1974) have employed this approach to evaluate the visual quality of landscape treatments. In the absence of predictive models, this "best guess" approach could be acceptable but not desirable. Consequently, visual quality investigators have made advancements in visual quality prediction that render the expert approach undesirable and inappropriate. Today, the United States Forest Service suggests that a combination of science based predictive models with the application of some expert opinion about environments is preferred.

Since Shafer's first investigations, researchers have explored an ever expanding range of variables to predict visual quality. They have primarily employed photographs or slides to conduct their preference surveys. Investigators have discovered that black and white photographs and color slides are reasonable substitutes for the real landscape and that respondents' perception of the images presented by these media are strongly correlated to the real landscape; however drawings of landscapes do not covary with the respondents' perception of the real landscape and thus drawings cannot be used in preference surveys (Smardon *et al.* 1986, Boster and Daniel 1974, and Zube 1974). Predictive preference equations have been developed primarily by employing physical attributes and landscape cover types in the photographs to assess scenic quality based upon insect damage (Buhyoff *et al.* 1982), special resource applications (Vining and Stevens 1986), air pollution (Latimer *et al.* 1981, Malm *et al.* 1981), general forested landscapes (Arthur 1977, and Daniel and Schroeder 1979), and riverine settings (Brown and Daniel 1991). While Shafer's specific equation has been discarded, investigators have employed his general technique to produce equations related to management features of the landscape and to variables that may seem to be more associated with intuitive constructs. Fisher *et al.* (1984) note that this general approach seemed to have scientific merit and seemed to perform well to predict landscape quality. In addition, the methodology for this equation building approach has been studied and refined (Pitt and Zube 1979, Daniel and Bolster 1976, Brown and Daniel 1990, and Brown *et al.* 1990). Furthermore, the research approach has demonstrated some cross-cultural agreements (Zube and Mills 1976) and consistency within a culture (Anderson *et al.* 1976), but these cultural areas require more investigations to test consistency and cultural agreement. In contrast to the predictive models, some investigators have examined a broad range of variables in order to define general categories associated with visual quality and to increase conceptual understanding concerning visual quality. These investigators suggest that there are other key informational and experiential variables beyond simply measuring the physical attributes of the landscape or the cover type of an area. Kaplan and Kaplan indicate that landscape legibility, coherence, mystery, and complexity are informational variables concerning the landscape that may be important in predicting visual quality (1989). In 1989, Kaplan *et al.* reported upon an investigation examining physical attributes, cover types, informational attributes, and a class of variables they called perception based: openness, smoothness, and locomotion. Brown describes the difficulties and procedures to employ these more complex variables in predictive modeling (1994).

Since Shafer's first published model, these studies comprise the fundamental effort in predictive visual quality modeling. Case studies and descriptions concerning these procedures can be found in Smardon *et al* (1986), Taylor *et al* (1987), and in Smardon and Karp (1993). Most models focus upon biospheric landscape types and often ignore evaluating the landscape types encountered in the noosphere; although recent studies by Sullivan (1991) and Wolf (1993) suggest a renewed interested in the built landscape. In addition, investigators have been exploring techniques to interpret vast areas of the landscape with spatial modeling tools (Bishop and Hulse 1994, Crawford 1994, and Orland 1994). The cumulative efforts of these works imply that investigators wishing to study landscape treatments along transportation corridors may find a series of notable scientific tools that are perception based and predict with some degree of reliability the visual quality effects of these treatments. Richard Kent's scenic quality work along transportation corridors in Connecticut is indicative of this quantitative effort (1993).

Visual quality has been an issue in surface mine reclamation planning and design. The late Norm

Dietrich (1986) published a paper in the 1986 American Society for Surface Mining conference proceedings describing visual landscape treatments for limestone quarries. Essentially he placed vegetation buffers along key viewing points to screen visually unappealing landscape features. His approach was an expert opinion method relying upon the scholarly normative traditions of a design profession. Burley and Brown (1992) and Paulson and Scott (1993) described technological applications in visual quality assessment and applications.

A Recent Model

Methodology. As an environmental scientist, landscape architect, and ecologist, I was interested in this body of work to see if I could develop an empirical prediction equation that was somewhat broad and universal in application for North American settings. Therefore I developed a study plan and executed the initial study. I had considered this study as my primary inquiry for a PhD; however, instead I chose to continue some work that I had conducted concerning the development of predictive equations for surface mine soil reclamation. Nevertheless, I also took courses related to environment and behavior and pursued the environmental quality prediction work as a second avenue of study. In 1997, I reported upon a study (Burley 1997) in which I selected 250 landscape images in color slide format. The photographs represent locations from Canada and the United States, ranging from the American Southeast, to the American Midwest, the American Great Plains, the American West, the American Southwest, and the Canadian West. The images contain physical attributes such as buildings, automobiles, boats, people, wildlife, water, roads, fire, smoke, clouds, flowers, vegetation, and non-vegetated substrate across prairie, woodland, wetland, agricultural, urban savanna, and cliff detritus cover types. In addition, I employed an environmental quality index similar to the index presented by Smyser (1982). Burley (1997) presents the list of independent variables selected for the study. I followed Shafer's general methodology to record information from the photographs by dividing the image into a 6.35 mm by 6.35 mm grid composed of 30 rows and 38 columns. Each variable was then measured and recorded.

To generate a dependent variable, 50 images were randomly selected and presented to a respondent in sets of 10 images. For each set the respondent ranked the image for scenic beauty relative to the other nine images. No image could receive the same score. A 10 represented poor visual/environmental quality and a 1 represented better scenic/environmental quality. Once a respondent had completed a set of 50 slides, another 50 slides were selected without replacement and presented to a new respondent. Once the complete set of 250 slides had been assessed, the 250 slides were combined to randomly select another 50 slides. This process was completed twelve times. Six sessions were completed in the summer of 1990 at Pingree Park, a research and education facility supported by Colorado State University on the north boundary of Rocky Mountain National Park, Colorado. The other six sessions were completed in the summer of 1991 at the University of Michigan's Biological Station, near Pellston, Michigan. At both locations, respondents were composed of male and female adults attending the facility as staff, students, visitors, and instructors, for a total of 60 respondents. The sum of the score for each photograph across all twelve sessions represented the scenic beauty/environmental quality score for each photograph. While the number of respondents may seem small, the Kaplans from the University of Michigan often use small respondent groups to study the relative importance of potential predictor variables to draw general conclusions. Obtaining random samples from large representative groups is expensive and thus almost all visual/environmental quality preference work has been accomplished with small, not necessarily randomly selected respondents. Eventually, studies examining larger randomly selected respondents will need to be investigated.

In my original study I examined main effect regressors, squared terms, and two variable interaction terms. This comprised a large set of possible regressors; thus I employed a screening procedure in SAS (SAS 1982), RSReg, and selected the most promising variables with low p-values ($p<0.10$). The selected pool of independent variables were regressed against the dependent variable in a Maximum R-squared Stepwise procedure (SAS 1982). The most promising equations from this process contain Type II Sums of Squares for each regressor with a p-value of less than 0.05, an overall regression p-value of less than 0.01, and the largest multiple coefficient of determination possible. In addition, the equation should not stray too far from C-plot collinearity diagnostic requirements.

My study generated a single best equation which explained sixty-seven percent of the variation in the data (which is comparatively quite good). The equation was highly significant with a p-value of less than or equal to 0.0001. The significant regressors in the equation included an intercept, the environmental quality index, perimeter of foreground vegetation, area of distant non-vegetation, vehicles, humans, utilities, wildlife, openness, mystery, noospheric features, an interaction term between flowers and perimeter of intermediate non-vegetation, several squared terms associated with main effect regressors. and an interaction term between noospheric features and mystery. The coefficients associated with the terms are presented by Burley (1997) and no regressor contained a p-value greater than 0.0358. In this study, dependent variable scores in the forties indicate images with exceptional scenic beauty and environmental quality. Scores in the nineties and one-hundreds indicate exceptionally non-scenic and low environmental quality images. In this study, regressor variables with Beta coefficients that have a negative sign indicate regressors that directly increase scenic beauty and environmental quality; positive Beta coefficients decrease scenic beauty and environmental quality.

General Interpretation. In the original equation that I developed, there is a set of regressors negatively associated with visual/environmental quality, regressors with a positive Beta coefficient. These regressors include the presence of vehicles, the presence of humans, the presence of utility structures, and an overall noospheric features regressor. In addition, according to the regression study, if the environmental quality index is negative, this regressor also reduces visual quality. I interpret these regressors to be negative intrusions upon the landscape as perceived by the respondents. This means that the more humans, vehicles, buildings, pavement, polluted air, polluted water, eroded land, and related environmental factors are present in an image, scenic quality is diminished. Each of these features can be considered undesirable environmental effects imposed upon an individual by another person-- the undesirable environmental effects are perceived as intrusions.

In contrast, there is a set of regressors positively associated with visual/environmental quality, regressors with a negative Beta coefficient. These regressors include the presence of perimeter foreground vegetation, distant non-vegetation, the presence of wildlife, openness, and the presence of flowers. I interpret these regressors to be positive enhancements upon the landscape as perceived by the respondents.

There is a third set of variables that is important to consider. I classify these variables as neutral modifiers. These variables are not significant in the regression equation, but they affect the presence or absence of both intrusions and enhancers. I place foreground herbaceous vegetation, intermediate ground vegetation, distant vegetation, sky, clouds, sun, moon, water, ice, and snow in this set. The more area these variables occupy in an image, the greater the impact of these non-significant variables, because they reduce the opportunity for both intrusions or enhancements to be present. These variables tend to generate landscape images with scores close to a neutral range, somewhere near 70.00.

Discussion

Theoretical Explanation

I believe that the equation can be explained with a general theory. I call the theory, "Biospheric Preference Theory." In this theory, I postulate that the respondents have a preference for biospheric surroundings, meaning plants, wildlife, flowers, distant views to landforms, clean air, clean water, and related features. Conversely, the respondents have a dislike for noospheric surroundings.

In many respects, this theory makes sense. For example, consider either an urban or rural setting in North America. Which residential properties have increased the most in value? Ideally, these properties contain a commanding distant view, are next to trees, contain some wildlife like songbirds, have a low density of nearby houses, contain quiet streets with few automobiles, have relatively few people, and have fresh air and clean water. Therefore, the results derived from my equation are not surprising and may corroborate some basic values associated with the normative visual/environmental quality preferences of many North American residents.

Implications for Surface Mine Visual Management

Environmental planners and designers are often attempting to minimize the impact of these intrusions by incorporating roadside vegetation, screening undesirable views, adding noise walls, maintaining environmental diversity, and sensitively fitting new built features into the landscape. The published equation (Burley 1997) suggests that these efforts are indeed important. However, with the equation it is now possible to quantitatively study and measure the effects of specific spatial treatments. One can compare various images by constructing a plot of the predicted mean score for the statistical equation and then calculating the ninety-five percent confidence tables for these mean scores. A graph can be constructed of these confidence plots. To use the graph, one can compute a visual/environmental quality score and enter the graph on the y-axis at the location of the computed visual quality score. Move horizontally to the right until one encounters the 45 degree line, labeled the "Visual Score" line. Moving vertically up and down from any point on the Visual Score line, one can then encounter the " Upper Limit" line and the "Lower Limit" line. These intersections are the ninety-five percent confidence tails for any visual scores

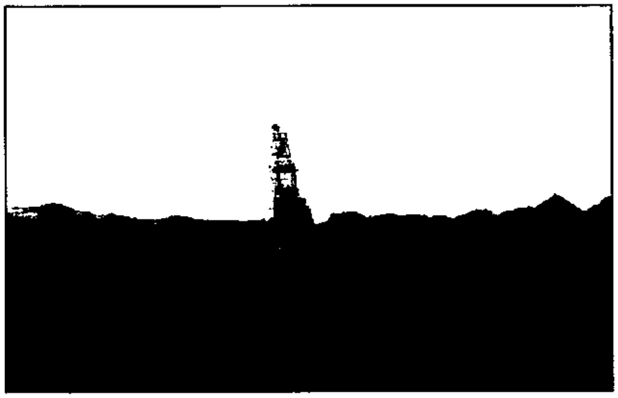

Figure 1. An image from a North Dakota surface mine (© Jon Bryan Burley 1983, all rights reserved)

Figure 2. A multiple family housing construction site in Minnesota. (© Jon Bryan Burley 1980, all rights reserved)

"Lower Limit" line. These intersections are the ninety-five percent confidence tails for any visual scores computed with the published equation (Burley 1997). Comparisons between scores from different images are made horizontally by determining whether there is an overlap between the two tails. Besides examining existing conditions, a planner/designer/land manager can study various landscape treatments to improve visual quality. This type of analytical approach may be helpful in assessing the visual quality merits of various surface mining planning, design, and management proposals. Keefe and Burley (1998) describe in detail a methodology to accomplish such an assessment task.

To understand the implications of the model, it is helpful to examine photographs and their visual quality scores. I have chosen five images from the original 250 image study. The original study contained images of surface mine activities and industrial

Figure 3. An image from the floodplain on the Red River Valley of the North. (©Jon Bryan Burley 1988, all rights reserved)

activities as well as other disturbances. The first image (Figure 1), is a scene from a surface coal mine in North Dakota. Notice the image contains equipment, filling a fair amount of the scene. Some of the image is comprised of exposed substrate, but not in the foreground, and the rest of the image contains sky and herbaceous vegetation. By following the procedures in my paper (Burley 1997:59), the score for the image is 71.72. While this score is ranging upwards (the larger the score the lower the visual/environmental quality), this is not an ugly image, and it is actually not significantly different than a neutral image composed of herbaceous vegetation, sky, and water. Here is a case where the surface mine image is not perceived to be predictably different than a North Dakota prairie/cropland landscape. In addition, another scene (Figure 2) of a disturbed landscape during site construction for a housing project has a score of 67.65. In contrast, the image presented in Figure 3 is a scene from a Red River Valley of the North floodplain, comprised of woody plants and herbaceous materials. The score for this scene is 52.51 and is significantly different than the images in figure 1 and figure 2, but not significantly different from a neutral scene with a

Figure 4. Wildflowers along a New Mexico roadside. activities as well as other disturbances. (© Jon Bryan Burley 1990, all rights reserved)

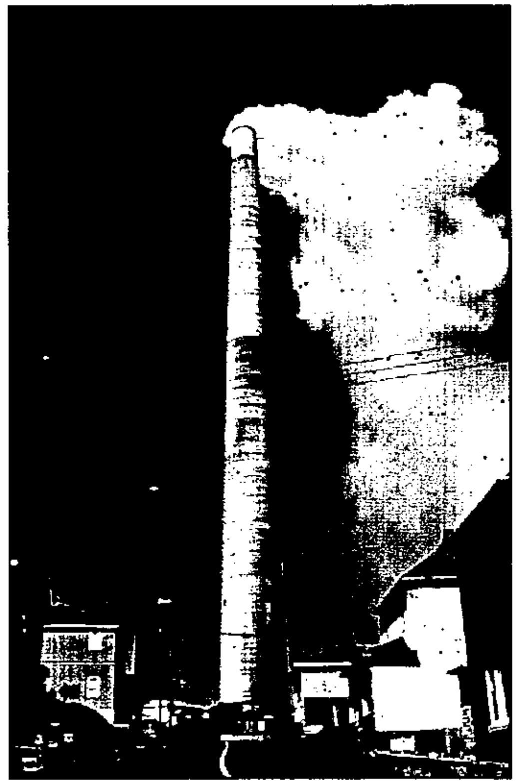

Figure 5. A view of Sudbury, Ontario. (Cambrian Color Slides).

score of 61.9. The fourth scene (Figure 4) is a roadside landscape from northern New Mexico, containing many flowers. The score for this image is 40.33. This image is significantly different from the neutral scene and the floodplain scene. Finally, figure 5 is an image from Sudbury, Ontario, and scores 102.73. This image is significantly different than all the other images (Figure 6). By examining these slides through the visual/environmental quality model it is apparent that various images can be separated into categories of scenic/environmental quality. This approach has some merit for assessing surface mine landscapes and in the planning and design stages for a surface mine.

Essentially, some of the contents of a surface mine, such as exposed soil, roads, buildings, equipment, and infrastructure are viewed negatively by the respondents. However, it takes a substantial amount of these features to make an image significantly different from a neutral landscape composed of herbaceous plants, sky, and water. Therefore, the visual impact of a small great plains surface mine distant from a public road, may be minimal. Conversely, a mine that removes woody plants or has exposed soil, roads, buildings, equipment, and infrastructure close to a

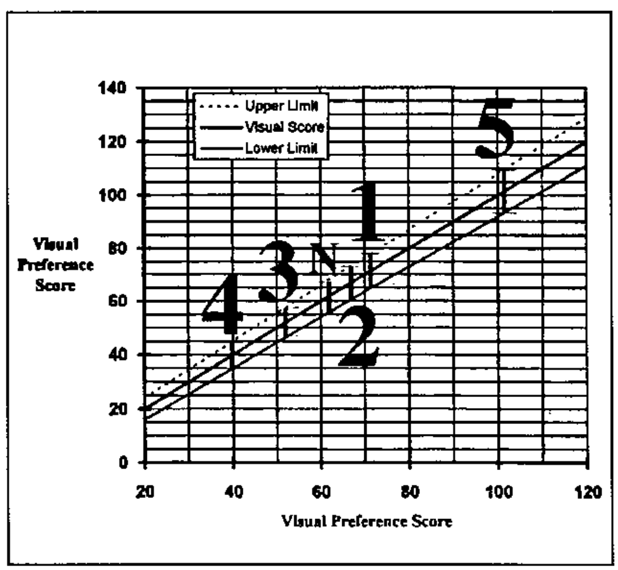

Figure 6. The model scores and 95% confidence scores for Figures 1-5, and the location and tails of the neutral scene (N).

viewing area will often be significantly different than the pre-mining landscape. In conclusion, the use of carefully placed softscape screens (vegetation and berms) as heuristically applied by Dietrich (1986) has scientific merit and in the future, visual/environmental quality prediction models may be useful tools to assess landscape disturbed by surface mining and to prescribe landscape treatments .

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