Numerical Modeling of Eastern Connecticut's Visual Resources[1]

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Abstract: A numerical model capable of accurately predicting the preference for landscape photographs of selected points in eastern Connecticut is presented. A function of the social attitudes expressed toward thirty-two salient visual landscape features serves as the independent variable in predicting preferences. A technique for objectively assigning adjectives to landscape scenes is also discussed. This Landscape Preference Model has received field application in parts of eastern Connecticut for evaluating the effects of human activities on scenic quality.

INTRODUCTION

Among other objectives, the National Environmental Policy Act (NEPA 1970) of 1969 provides guidelines for the assurance of ". . . safe, healthful, productive, and aesthetically and culturally pleasing surroundings . . ." for all Americans. Landscape assessment, which reflects the social and psychological perceptions of natural and man-made environments, is an essential tool for measuring the direction and magnitude of the impact of human activities upon the visual resource. Landscape assessment can be described as a procedure for identifying preferred landscapes and their visual components (Kaplan 1975). Landscape assessment utilizes the evaluation of visual qualities or characteristics within a series of landscapes to determine the relative relationships between those landscapes (Laurie 1975).

A number of the many landscape assessment and scenic assessment models developed have been collectively reviewed (Arthur and Boster, 1976; Bagley *et al.* 1973). Many of these techniques provide planners with information on the preference for visual landscape resources.

The sophisticated methods developed by landscape specialists should be applied with caution. Involvement with numerical indices, social attitude values, or other quantitative measures should not become so extreme that the user becomes alienated from the sensitivity necessary to appreciate visual landscape phenomena.

LANDSCAPE ASSESSMENT: A BRIEF REVIEW

In the past decade, there has been a variety of approaches developed to assess the visual environment. One of the earliest techniques was a methodology for classifying roadside scenery (Burke *et a1.* 1968). A similar technique (Sargent 1966) provided a model with which the landscape analyst uses a cardinal scale, of 1 to 10, to rate the scenery of interest. There are a number of other comparable subjective, and sometimes graphic, approaches to the art of visual landscape assessment (Laurie 1975, Litton 1968, Litton 1971, Palmer 1973, Tandy 1967) each having its own level of validity and appropriateness.

Recognizing that objective measures of visual quality are necessary to certain environmental decision-making processes, a number of researchers have developed landscape assessment methods in which the rating reflects statistically derived preference responses. Rigorous

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mathematical approaches such as factor analysis and multiple regression have been applied to sets of rank ordered landscape photographs in order to produce these predictive models (Shafer *et al.,* 1969, Shafer and Mietz, 1970, Pitt 1976). Some investigators have tested the real-world applicability of their models by conducting on-site studies of landscape scene preference (Zube *et al.* 1974).

Another approach in objectively quantifying visual resources has been the use of the Delphi Method, which uses an iterative-feedback questionnaire. Such a survey was conducted of professionals in landscape architecture, environmental design, and related disciplines to generate value functions to be used in a comprehensive environmental impact assessment strategy for water resources planning (Dee *et al.* 1972, Dee *et al.* 1973). Aesthetics, consisting of seventeen parameters, was one of four major components of the impact evaluation system. The visual assessment aspect of this model has been transformed from its original graphic representation into a computer program version (Civco 1975).

A conclusion repeatedly reached in many of these landscape assessment and scenic quality evaluation studies is that each model is highly region-dependent. Visual landscape composition varies from one locale to another as do the attitudes toward and preferences for these landscapes. Therefore, landscape assessment models should be applied in the specific geographic area in which they were developed, or in regions with highly similar physiographic, cultural, and socio-economic characteristics. The objective of this particular study was to construct a numerical model of preference for salient visual landscape resources, specifically of selected parts of eastern Connecticut.

THE STUDY

Most of the landscape scenes used in this study were in or near the town of Mansfield, Connecticut, located in the northeastern hills region of the state. Mansfield typifies much of eastern Connecticut in terms of physiography and visual landscape composition. The landscapes investigated were representative of those types frequently encountered in eastern Connecticut. Further, the compositions of these landscapes depicted, in varying degrees, thirty-two of the landscape features identified by other researchers (Zube *et al.* 1974) as being significant visual resource components. These included:

lakes and streams	ground cover
broadleaf trees	man-made clearings
mixed trees	edge of clearings
evergreen trees	shrubs
rocks and ledges	walls
hills	tilled fields
mountains	roads
valleys	farm buildings
plains	houses and buildings
slopes	shopping areas
ridges	factories
shorelines	fences
pastures	power lines
skyline	signs
wetlands	gas stations
natural clearings	suburban development

Fifty 35mm high speed Ektachrome color photographs were taken of different landscape continua. Using the criteria of landscape-representativeness and photographic quality, this initial sample of fifty landscape continua was reduced by a class of landscape architecture students at The University of Connecticut. The thirty landscape photographs most frequently chosen were used for inclusion in the study. This final sample was then randomly sorted into two groups: one of twenty photographs, for the experimental procedures in the formulation of the landscape assessment model, and one of ten photographs for the test of the, model. While the two sets of photographs were taken from the same general region, each scene depicted a distinct landscape.

Phase I: Survey Technique and Data Gathering

The initial phase of the study involved the determination of scenic quality as portrayed in the first set of color landscape photographs (n=20). Interviews were conducted with 200 study participants on an individual basis. These interviews took the form of a detailed questionnaire consisting of three sections: collection of pertinent demographic data, landscape feature evaluation, and landscape scene rank ordering.

Using a modified Q-sort method (Stephenson 1953), which assured uniform sampling stratification, subsets of the twenty photographs were formed. Each participant was given a set of four landscape photographs and was instructed to rate each of the thirty-two landscape features in terms of its contribution to or detraction from the overall scenic quality of the landscape. The scale graduated from 1 (strongly detracts) to 7 (strongly contributes), with a value of 4 indicating neutrality. If a landscape feature was not present in a scene, the participant recorded a value of 0 (absent) for that respective landscape feature.

Again, with sets of photographs having been selected using a modified Q-sort method, each participant was given a set of ten landscape photographs and was requested to rank them in descending order of scenic quality (*i.e.*, 9=most scenic, 0=least scenic). As a result of staggering (modified Q-sort) the observations, each of the twenty landscape photographs was "feature evaluated" forty times and rank ordered one hundred times after all 200 participants had been interviewed.

Phase II: Scenic Quality Adjective Assignment

Realizing that numerical indices are not always the best way in which to describe the scenic quality of a landscape continuum (*e.g.*, some people prefer to communicate in common language rather than mathematical expressions), correlations were made between visual appeal adjectives and the rankings of the landscape photographs. To provide the data to make this comparison, another sample of fifty participants was selected and each was instructed to sort the twenty original landscape photographs into seven "scenic quality" piles. The possible categories included: extremely scenic, scenic, slightly scenic, neutral, slightly non-scenic, non-scenic, and extremely non-scenic.

Phase 111: Test of the Landscape Preference Model

In order to provide data to test the strength of the preference prediction model, the second set of landscape photographs (n=10) was rank ordered by another sample of fifty observers. In this instance, each participant examined the entire set.

DATA ANALYSIS

In the first phase of this investigation, the rank ordering procedure produced a set of arithmetic mean values ($\overline{Y}_j$), which were derived from the data of the rank orders of the twenty photographs. Therefore, each photograph was assigned its mean rank value (or relative preference) and whole number rank order (Y_j).

A test of the consistency of the rank order procedure and the associated mean rank value ($\overline{Y}_j$) was performed using the Chi-square statistic (Ostle 1963). The concept of consistency involves uniformity in the participants' assignment of rank orders to the photographs. It was expected that the mean rank value of the least preferred landscape and that of the most preferred landscape would be in the ratio of 20:1. Expected mean rank values ($e\overline{Y}_j$) were calculated for all twenty rank order positions based upon this distribution theory.

The determination of landscape feature valuations involved statistical averaging of the mean landscape feature value for each feature (n=32) in each individual photograph (n=20), as well as for each feature considering the set of photographs as a whole. These resultant values were considered to be representative social attitude values demonstrated toward a particular feature (xi) and a representative example of that feature (Xi).

Model Formulation

The approach used to generate a mathematical model capable of predicting preference for visual landscape resources involved feature reduction and description of the entire landscape continuum (as represented by the photograph) by a single index. This single value is different for each photograph and is equal to the sum of each particular photograph's representative landscape feature valuations (X_i) divided by the number of landscape features present in the continuum. Therefore, the new variable $\overline{X}_i$, is an unweighted index illustrative of a landscape photograph's composition as a whole.

After having expressed the landscape feature composition of a landscape continuum as a single value ($\overline{X}_i$), it was necessary to find the relationship between this independent variable and the dependent variable, mean rank value or $\overline{Y}_j$. The statistical procedure used was polynomial regression analysis. The general form of the type of polynomial used was:

$$\overline{Y}_j = a + b_1\overline{X}_i + b_2\overline{X}_i^2 + b_3\overline{X}_i^3 + \ldots b_k\overline{X}_i,$$

where $\overline{Y}_j$ represented mean rank value, *a*, represented the X-axis intercept, $\overline{X}_i$ represented mean photographic content, *b* the coefficients, and *k* was the degree)f the exponent of the independent variable. In order to be accepted, the prediction equation had to result in a coefficient of at least 0.85 in terms of both mean rank (Pearson's) and absolute rank order correlation (Spearman's).

Phase II of this study involved the assignment of adjectives describing the visual quality of landscape continua to their respective photographs. Adjectives were given values of from 1 (extremely scenic) to 7 (extremely non-scenic).

The adjective ratings for each of the twenty experimental photographs were averaged, and these values were identified as a new dependent variable, mean adjective score. Regression analysis was applied to the photographs' predicted mean rank values ($\bar{Y}_j$) and the adjective scores.

Test of the Model

The observed mean rank values, and the absolute rank orders, of the set of ten test photographs were calculated from the data gathered during Phase III. The prediction preference model was applied to these ten landscape photographs as described by their feature composition (mean feature valuation or $\bar{X}_i$). Both predicted mean rank order and absolute rank orders were calculated. These predicted values were compared with the observed values by using Pearson's correlation coefficient and Spearman's rank order correlation coefficient.

The predictive model had to produce correlations of at least 0.85 at the one-percent significance level in order to be accepted and adopted for use in modeling eastern Connecticut's visual landscape resources.

RESULTS AND DISCUSSION

Landscape Photograph Rank Order

A high degree of uniformity was observed in the way in which the twenty original landscape photographs were rank ordered (Table 1) by the initial 200 study participants. The most preferred landscape, Photograph Number 2, consisted mainly of a rocky stream lined with coniferous trees, and was consistently, highly ranked (σ=0.76). The most consistently (•=0.27), least preferred landscape, Photograph Number 19, depicted a typical 1960's shopping center. Scene Number 17 was noticeably ranked inconsistently, and was primarily composed of two visually contrasting landscape features--a factory and a stream.

Table 1--Rank Order Parameters for Twenty Experimental Photographs

Photograph Number	Expected Mean Rank Order, $e\bar{Y}_j$	Observed Mean Rank Order, $\bar{Y}_j$	Standard Deviation (σ)	Absolute Rank Order
1	4.68	3.59	0.86	11
2	0.45	1.23	0.76	1
3	0.90	1.77	1.21	2
4	2.97	3.25	0.98	7
5	1.26	2.07	0.82	3
6	3.42	3.33	1.63	8
7	5.58	4.97	1.01	13
8	3.87	3.35	0.69	9
9	5.13	4.88	1.72	12
10	2.61	3.08	1.64	6
11	1.80	2.09	2.12	4
12	6.03	4.99	0.56	14
13	8.10	7.97	1.56	19
14	4.23	3.43	1.29	10
15	7.74	7.94	1.16	18
16	6.39	5.38	1.52	15
17	2.16	2.86	2.22	5
18	6.84	7.13	0.89	16
19	8.57	8.77	0.27	20
20	7.29	7.92	0.63	17

Landscape Feature Evaluation

The direction and magnitude of visual impact imparted by salient visual resources were determined by the valuation of the thirty-two landscape features. These results are presented in Table 2. The data can be considered as social attitude indices of the representative contribution of each visual landscape feature toward scenic quality (conditioned, of course, by the range of landscapes and the participants used in this study). Features with a value of greater than four have a positive visual impact, while those less than four have a negative visual impact. A value of four indicates visual neutrality. It is evident that water, trees, landforms and other apparently natural features have a significantly positive impact on the visual environment, while many man-made features, such as shopping areas, gas stations, and signs, have a definite negative impact.

Mathematical Model

A fourth-order polynomial regression equation, with mean landscape feature content ($\bar{X}_i$ or $\Sigma X_i/n$) as the independent variable was found to be able to predict accurately the preference for the twenty experimental landscape photographs. Mean landscape feature content ($\bar{X}_i$) is determined, as described previously, by averaging the social attitude indices (X_i), given in Table 2, for all the features present in a landscape scene.

Table 2--Landscape Feature Valuations

Landscape Feature	Mean Social Attitude Value, X	Standard Deviation (σ)	Number Times Observed
Lakes and Streams	6.2	.562	240
Broadleaf Trees	5.8	.748	760
Mixed Trees	5.8	.618	480
Rocks and Ledges	5.8	.931	240
Hills	5.8	.681	440
Mountains	5.6	.283	80
Natural Clearings	5.4	.277	120
Farm Buildings	5.4	.954	40
Valleys	5.2	.890	440
Evergreen Trees	5.2	.812	520
Wetlands	5.2	.481	80
Plains	5.2	.071	80
Pastures	5.2	.392	160
Slopes	5.0	.676	440
Ground Cover	5.0	.530	680
Skyline	5.0	.659	760
Shorelines	4.8	.786	240
Ridges	4.8	.925	400
Edge of Clearings	4.8	1.005	600
Walls	4.6	1.010	40
Shrubs	4.6	.747	360
Tilled Fields	4.4	.467	120
Roads	3.8	1.019	360
Man-made Clearings	3.4	1.149	640
Houses and Buildings	3.2	.691	200
Shopping Areas	3.0	1.145	80
Factories	3.0	.909	160
Fences	2.8	1.358	160
Power Lines	2.4	.876	320
Signs	2.2	1.333	240
Gas Stations	2.2	.521	40
Suburban Development	1.8	.936	120

The actual form of the Landscape Preference Model is:

$$\bar{Y}_j = 920.754807 - 840.5848039\ \bar{X}_i + 288.2842356\ \bar{X}_i^2 - 43.5473328\ \bar{X}_i^3 + 2.4349968\ \bar{X}_i^4$$

where $\bar{Y}_j$ represents predicted mean rank order and $\bar{X}_i$ represents mean landscape feature content of a particular landscape photograph. When applied to the sample of twenty photographs, the model produced a correlation between observed and predicted mean rank order of better than 0.90.

Adjective Assignment

Linear regression analysis, applied to the mean rank order of each of the twenty experimental photographs and its corresponding adjective numeric, produced a correlation of 0.98. This significant relationship indicated that this sample of observers could consistently describe the landscape photographs with similar adjectives. Further, since mean rank order and the adjective numerics are directly associated, descriptors of scenic quality can be assigned to a series of landscape photographs.

Test of the Model

The resultant Landscape Preference Model, represented by the fourth-order polynomial, was applied to the second set of landscape photographs (n=10) from selected points in eastern Connecticut. The observed mean rank values and absolute rank orders were determined during Phase III of the experiment and served as the basis for evaluating the preference prediction equation. The observed and predicted parameters are shown in Table 3. Additionally, the predicted adjectives of scenic quality are presented. It can be seen from these results that the model produced accurate predictions; Pearson's correlation of mean rank value was 0.88, and Spearman's rank order correlation was 0.93, both significant at better than the one-percent level.

Figures 1*and 2*depict two landscape photographs used in the design of the preference prediction model. Figure 1*represents the second most highly preferred scene, both observed and predicted, and was described as "scenic" by the study participants. Figure 2*illustrates a "non-scenic" landscape photograph, being one of the least preferred scenes.

Examples of the scenes used to test the model are shown in Figures 3*and 4*. The first of these scenes was the most highly preferred, as observed and as predicted by the model, and can be described as "scenic to extremely scenic" within the context of eastern Connecticut's visual resources. The second scene (Figure 4*) was the least preferred and is representative of a "non-scenic" landscape.

APPLICATIONS OF THE MODEL TN EASTERN CONNECTICUT

The Landscape Preference Model has received field application in parts of eastern Connecticut.

Table 3--Observed and Predicted Rank Order Parameters for Ten Test Photographs

Photograph Number	Mean Feature Content, $\bar{X}_i$	Observed Mean (Absolute) Rank Order	Predicted Mean (Absolute) Rank Order	Scenic Quality Score	Scenic Quality Adjective
1	5.05	3.08 (3)	3.05 (3)	2.76	slightly scenic to scenic
2	5.69	1.18 (1)	1.08 (1)	1.62	scenic to extremely scenic
3	5.02	3.40 (4)	3.26 (4)	2.87	slightly scenic to scenic
4	5.27	1.84 (2)	1.83 (2)	2.05	scenic to slightly scenic
5	3.78	4.28 (6)	7.59 (9)	5.37	slightly non-scenic to non-scenic
6	3.71	8.02 (10)	7.73 (10)	5.45	non-scenic
7	4.46	6.88 (8)	6.27 (7)	4.61	slightly non-scenic to neutral
8	4.93	3.82 (5)	3.83 (5)	3.20	slightly scenic to scenic
9	4.80	4.90 (7)	4.62 (6)	3.66	neutral to slightly scenic
10	4.01	7.60 (9)	7.27 (8)	5.18	slightly non-scenic to non-scenic

*See color illustration on page 390.

As a member of the eastern Connecticut Environmental Review Team, the author has used the model on several occasions to determine the scenic character of specific projects. These evaluations have been used to rate the visual effect and suitability of development activities ranging from an industrial park to housing subdivisions to outdoor recreation facilities.

Currently, the Landscape Preference Model is being modified to be made compatible with a computerized mapping program under development. This spatial data analysis program is being applied to a section of eastern Connecticut scheduled for a planned highway relocation and extension. One of the policy determinants for computer-assisted highway corridor siting is the "minimization of impact to visual landscape resources." A version of the Landscape Preference Model will supply the baseline information necessary for such a determination.

SUMMARY

The numerical analysis of visual landscape resources, as depicted by color photographs from selected points in Eastern Connecticut, demonstrated that there are noticeable tendencies in observers' preferences and dislikes for these scenes. Statistical studies showed that landscape features were perceived similarly by different individuals and that the visual importance of these elements could be expressed in terms of a social attitude index. A mathematical function performed upon a reduction of the values of the landscape features composing a given landscape photograph continuum was found to be able to predict the preference both numerically and descriptively. A ranking of a number of these landscape photographs has shown the relative preference for each and permitted the overall evaluation of the landscape photograph sample.

It should be noted that this model is directly applicable only in situations where the conditions approximate those set forth in this study. If a similar approach were to be tried elsewhere, the landscape-type compositions and population socio-economic factors should be considered and the results qualified accordingly.

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