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DESCRIPTORS IN SCENIC LOW-VOLUME ROADS ANALYSIS THROUGH VISUAL EVALUATION

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ABSTRACT

This paper analyzes the problem of the inclusion of road infrastructure in the present environment; in fact many international and national studies and research have been carried out to address this aspect of road infrastructure construction. Although many approaches to this type of problem exist, now there are two main procedures to solve it: a) the surrounding environment seen from the road (i.e. from the perspective of the driver's eye), and b) the whole surrounding environment observed from off the road (the point of view external to the road). The experimental analysis presented here shows a predictive model to assess the beauty of a scenario in which the road is introduced from the road. The model has been developed thanks to experimental investigation using a sample of 200 non-expert judges asked to express an opinion on 32 different scenes in conventional photographs selected from *low-volume roads* within the Province of Salerno. The coefficients of the resulting model have significance greater than 95% and the equation has a coefficient of determination equal to 0.86. By comparing the measured values with those derived from applying the predictive model, the effectiveness of the model is clear: the maximum error is less than 10%.

Keywords: landscape, visual impact, environment, linear regression.

INTRODUCTION AND LITERATURE REVIEW

The inclusion of road infrastructure in the surrounding environment is one of the most important parts of road design [1-6]. Not surprisingly, even before the proposal of the preliminary level of the project, in many countries, standards obliged designers to evaluate the effects produced by the road infrastructure [7] on the environment and the landscape.

A particular aspect, which, however, is taken into consideration in only some countries is the appreciation of the landscape after road building, using procedures to assess the landscape from the road (i.e. from the perspective of the driver's eye) and procedures that assess the whole landscape from off the road (the perspective external to the road).

Many studies have been carried out over recent years in support of various International programs on these issues [8]. The main approaches used for these types of studies refer to two different philosophies of research: one based on a sample of experts called to evaluate the features of a landscape usually assessed from photographs, and another based on samples of non-expert judges who have to evaluate the features of the same landscape using the same photographs. In the U.S., many programs have been developed since the 50's, and much literature has been produced based on these two different approaches.

The BLM [9] (Bureau of Land Management) adopts a system of landscape evaluation basing on seven different factors: morphology, vegetation, water, color, landscapes near the road to be evaluated, rarities and cultural aspects. Based on these parameters, experts carry out a qualitative assessment of its level of diversity and the harmony of the landscape.

ADOT [10] (Arizona Department of Transportation) uses a method of analysis that consists of two consecutive phases. The first step involves the discretization of the entire landscape through mapping operations which divide the examined landscape into many individual units (landscape units). The second phase develops as follows: using three descriptive variables (vividness, integrity and unity) the relative appropriate level for each landscape unit derived from the discretization is assessed to determine its visual quality. The sample evaluation is always based on expert judges' opinions.

The state of Washington has adopted its own specific system to assess the landscape [11] which requires to the Planning Departments "to provide road users incessant opportunities". This method, like the previous procedure, requires the division of the whole examined landscape into landscape units. Later, the expert judges use the unity, integrity and vividness factors as indicators of the visual quality of the landscape, assigning o each factor a numerical value between 1 and 7 to assess the visual quality of each individual landscape unit.

The California Department of Transportation has adopted a system to analyze the visual quality of the road landscape called "Visual Impact Assessment for Highway Projects" [12], based on a criterion provided by the FHWA (Federal Highway Administration). The main assumption is that "higher levels of integrity (therefore fewer intrusions) produce a higher visual quality in a landscape after the impact generated by the road infrastructure building." This criterion is based on the expert judges' sample.

The SBE (Scenic Beauty Estimation) model, which is based on a sample characterized by non-expert judges, starts from the assumption that beauty, and so the visual quality of a landscape, is an "interactive" concept. Beauty is understood as something to be inferred through the opinion expressed by observers in response to the perception of the surrounding environment. This way of evaluating visual quality makes it possible to appraise the estimates of the observers as the result of a combination of

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their perception of the beauty of the landscape and their measure of evaluation.

The perceived visual quality of an environment is then represented, in this model, by a specified value which is the result of the combination of the effects caused by various different properties shown on the landscape.

If, for example, the observer has to express an opinion based on only two assertions ("I like", "I don't like"), he needs to establish a single criterion that functions as a single threshold value. In the case where the respondent is asked to give an evaluation based on only two assertions, subjects may be involved in more complex situations, where they are required to judge the photographs using scales with scores at various levels, for example a 5-point scale.

Many researchers have produced several works on these issues over the past decades.

Dixon and Wolf [13] reviewed the many issues surrounding the urban roadside environment: they summarized both the quantified effects of roadside landscape and proposed researchable questions that could aid communities in pursuing the balance of transportation quality and urban livability. Topics include urban forest benefits in communities, studies of trees and traffic safety, landscape effects on traffic calming, self-enforcing streets, and street design. The authors provided a multidisciplinary perspective on this topic; one represents traffic engineering and the second is active in urban forestry planning and design. They collectively presented the diverse issues concerning the placement of living, fixed objects adjacent to the urban roadway. The goal is 1) to report the best available science on this often controversial topic, 2) to offer suggestions for ways to evaluate the safety impact of urban trees and landscape, and 3) to suggest workable solutions for tree and landscaping placement to address the safety concerns of transportation professionals and integrate the interests and values of urban communities.

Lu *et al*. [14] developed procedures and models for the evaluation of the freeway green landscape. The main evaluation indices considered in the evaluation procedures and models are anti-glare capability in median areas, the enhancement of soil stability in slope embankment areas, and the protection of the ecology in roadside areas. In addition, the quality of the landscape scenic view is another important factor that affects green landscape quality. The main purpose of the models is to convert evaluation indices into an overall measure of quality that can represent the overall quality of the freeway green landscape. The conversion is based on multivariable regression models and expert opinion survey models. Field data were collected by field surveyors, who collected index data and a panel that provided subjective ratings of the green landscape in the median, slope embankment and roadside areas. Both data sets were used for regression analysis and modeling purposes. Conversely, an expert opinion survey was conducted to obtain subjective opinions on the model weights. The models developed were validated by objective [15-19] and subjective [20, 21] methods. The validation results show a strong correlation between the subjective and objective evaluations: the models are effective and reasonable.

Flannery *et al*. [22] compared drivers' assessments of the performance of urban streets with objective measures of performance, including level of service (LOS). The purpose of the study was to test the ability of the LOS to predict drivers' perceptions of service quality. Seventy-seven automobile drivers rated the service quality of half-mile segments of urban roads as depicted on videotaped scenes from the driver's perspective. Drivers rated 12 to 15 video segments on a six-point scale ranging from very satisfactory to very unsatisfactory. After rating all segments, the drivers selected and ranked the three factors that they considered the most important in providing quality from a list of 36 factors. The results showed that the mean driver rating had statistically significant correlation ns with operational and design characteristics and a esthetics, including the following variables: travel time, average travel speed, number of stops, delay, number of signals, lane width, the presence of trees, and the quality of the landscaping. The LOS, calculated using the Highway Capacity Manual methodology, predicted 35% of the variance in mean driver rating. This finding suggests that the LOS does not completely represent drivers' assessments of performance because drivers perceive the quality of urban street segments in several dimensions, including travel efficiency, sense of safety, and aesthetics.

De la Fuente de Val *et al*. [23] analyzed the relationships between the landscape spatial pattern and the rating of visual aesthetic quality. Eight landscape photographs were evaluated for 11 visual attributes by 98 respondents. The scores obtained for these 11 attributes were subjected to principal components analysis in order to summarize the qualities important to the respondents and thus determine their visual preferences. For each photograph, three window sizes were defined (with respect to a land cover map) to cover the different areas corresponding to the visual field (foreground, mid-ground and background). The landscape spatial structure for each window was analyzed using spatial metrics. The correlation between each dimension and the spatial pattern indices of the landscape was then calculated.

Positive correlations were obtained between visual aesthetic quality and a number of landscape pattern indices. The results suggest that landscape heterogeneity might be an important factor in determining visual aesthetic quality. Public participation is desirable and it is a component of most programs to assess the scenic quality of a landscape [24, 25].

Jankauskaitė and Veteikis [26] have provided an original method of distributing the landscape sample areas in Lithuania, differing from most methods based on a random choice of sample areas, though a thorough analysis of the analogous methods in other countries was performed. According to the spread of different natural landscape types (such as clayey plains, hills, sandy plains, etc.), a set of 100 sample areas (2.5 km^2 each) distributed throughout Lithuania was selected. Thus, the largest number of sample areas was assigned to the wide clayey

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plains, and the smallest number to sandy coastal plains. In order to find a concrete place for each sample area within the landscape type, a computer program [27-30] was employed and the highest representation principle applied. Several tens of thousands of possible positions of the sample areas were tested in order to find the best to represent land cover structure.

In another study Dell'Acqua *et al*. [31] show the application and the verification of detailed methodologies used by international agencies to assess the Scenic Quality of a landscape. Three variables were chosen to analyze a series of selected Italian landscapes, i.e., Vividness, Intactness and Unity. Photographic inventories were created for different landscapes. Pools of landscape architects judged the slides for each landscape using a 7-point scale for each of the three indicators. Identical slides were then shown to untrained dob servers comprising 201 students who used a 10-point scale to evaluate Scenic Beauty for each picture. The students' opinions were then compared with the expert evaluations. The results indicate that vividness is most correlated with Scenic Beauty, which has a much weaker correlation with intactness.

In this study we propose a procedure to assess the beauty of a landscape seen from a road (i.e. from the perspective of the driver's eye). The study uses using a sample of 200 non-expert judges who assigned a score from 1 to 5 for32 photos representing landscapes observed from *low-volume roads* in the southern of Italy [32-38].

DATA COLLECTION

The impact on the driver is not only one of visual [39] pleasure. A pleasant sight makes the driver to feel at ease, thus improving road safety [40]. It is reasonable to imagine that scenery with an open prospect, a road located in a flat area, on segments of tangent and with no lateral obstructions, will be appreciated by driver sand they will drive better. It is evident that when these situations (taken alone or combined with each other) are lacking, comfort tends to diminish and, in general, driving becomes [41] more tense (stress).

So if the surrounding environment perceived by the driver, seen from the road, is fairly well represented by a picture, then it is permissible to assert that some geometric features contained in the photo can be directly related to the pleasantness of the scene. The model presented in the following paragraphs has been developed on the basis of this assumption.

The data were obtained from four different areas of study all located in the south of Italy [42-49]. Table-1 shows the characteristics of the examined areas.

Table-1. Landscapes analysed.

Types of road	Length of roads (km)	Total number of photos	Number of photos chosen for the analysis
Rural LVRs	20	22	9
Rural LVRs	25	21	9
Rural LVRs	22	18	9
Rural LVRs	21	25	9

SURVEY PROCEDURE AND PHOTO SAMPLE

The photos were taken using the procedure illustrated in the next paragraph, with a high-resolution camera (*Nikon "Coolpix" S225 12 MP*) set on a tripod especially constructed for the experiment. To properly simulate the scenario perceived by the driver, the "optical parameters" of the cameras were set as close as possible to the conditions of human perception. In addition, the camera lens was placed on the axis of the road lane normally corresponding to the line of sight of the driver. Figure-1a, below, shows the position of the camera and Figure-1b shows some of the standard conditions in which the photos were taken.

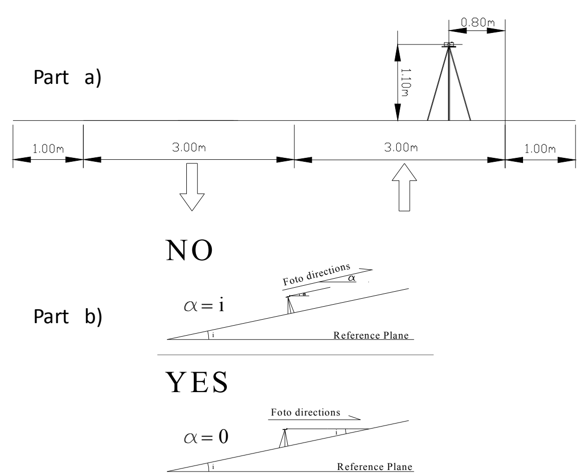

Figure-1. (a) Scheme of the position for the camera. (b) Reporting framework of the scene.

INTERVIEWS WITH NON-EXPERT JUDGES

The photographs were subsequently submitted to the evaluation of a sample of 200 non-expert observers who participated on a voluntary basis, to assess the features in terms of the beauty of the surrounding environment. The sample of non-experts used in the study was structured as follows:

- Aged between 18 and 70 years, uniformly distributed;
- Resident in southern Italy;
- 30% students;
- 50% had never driven on these roads;
- 50% females (50% males);
- 100% driver's license.

Before showing the pictures to the observers, we provided some information on the landscapes and the purpose of the investigation. We subsequently asked them to express an opinion from the point of view of an observer looking at the landscape from inside a moving car. The opinion of the landscape, depicted in photos, had to be formulated on a 5-score scale as follows:

1 = very bad;
2 = poor;
3 = sufficient;
4 = good;
5 = excellent.

Figure-2. Example of a photograph shown for assessment.

Table-2 shows an excerpt of the database built after the interviews with 200 subjects comprising the non-expert judge sample.

Table-2. Database from interviews with a sample of 200 non-expert judges landscapes analysed.

Landscape	photos	interview1	interview2	…	interview200
1	1	3	3	...	2
1	2	4	4	...	3
1	3	2	3	...	1
…	…	…	…	...	…
…	…	…	…	…	…
4	31	2	2	...	3
4	32	3	4	...	4

Table-3. Frequency of assessment obtained for each photo.

Photos	Frequency of value 1	Frequency of value 2	Frequency of value 3	Frequency of value 4	Frequency of value 5
1	34	84	62	19	1
2	5	56	74	53	12
3	33	80	62	24	1
…	…	…	…	…	…
…	…	…	…	…	…
31	11	41	76	55	17
32	23	79	65	30	3

For each photo we calculated the mean, mode, median and standard deviation. Table-4 shows an excerpt of the results obtained.

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Table-4. Extract of database for mean, median, mode and standard deviation values.

Landscape	Photos	Mean Value	Median	Mode	St.Dev.
1	1	2.35	2	2	0.889
1	2	3.06	3	3	0.941
1	3	2.4	2	2	0.919
…	…	…	…	…	…
…	…	…	…	…	…
4	31	3.13	3	3	3
4	32	2.56	2	2	2

DATA ANALYSIS

To make the surrounding environments in the photographs comparable (taken according to the standard procedures set out above), we started from the intuitive model shown in Figure-3.

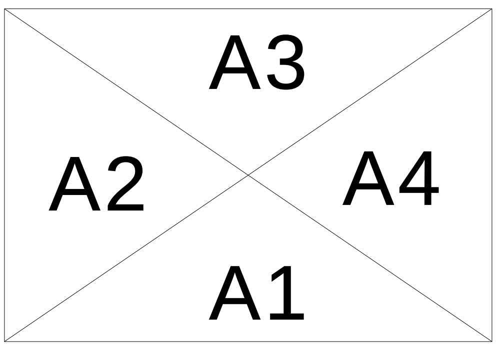

Figure-3. Intuitive model to assess the photos.

Each photo was divided into 4 areas as shown in Figure-3: this division, obtained by marking the main diagonal, identifies the following areas:

- A1 = area occupied by the road;
- A2 = area located on the left side obstacles;
- A3 = area with open horizon;
- A4 = area located on the right side with the presence of some obstacles.

Clearly, given the way the model was constructed and set out, and by using photographs of the same size, the sum of the areas (A1 + A2 + A3 + A4) is constant. Based on these assumptions, which were verified by the data obtained from the experiment, the areas that tend to lead to positive opinions are A1 and A3, while the other two, namely A2 and A4, tend not to be.

For these reasons, the following equation is used to represent the quality of the landscape:

$$A_{tot}= A1+(1-A2)+A3+(1-A4) \quad (1)$$

The color of obstacles is also taken into account in Equation-1. If the obstacles are gray (or grayish) or green (or greenish) it is necessary to correct A2 and A4 as follows:

$$A2= \mathbf{l}_1 * A_{gray\_left} + \mathbf{l}_2 * A_{green\_left} \quad (2)$$

$$A4= \mathbf{l}_1 * A_{gray\_right} + \mathbf{l}_2 * A_{green\_right} \quad (3)$$

where:
$\mathbf{l}_1$= 1.0 and $\mathbf{l}_2$= 0.75.

In addition, to make the photographs comparable, the characteristics shown in Figure-4 were applied to each one:

- H_{left}= H_{right};
- L/B= 1.238;
- pixel number per photo = 11megapixels.

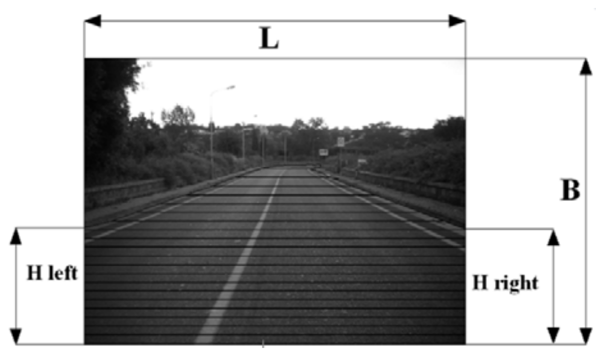

Figure-4. Definition of the characteristics of the photographs.

The parameters [50-53] used to create the theoretical model illustrated above, are due to greater appreciation corresponding to an increase in horizon area (A3) as well as an increase in road area (A1). This tendency, reflected in the opinion sex pressed in the experiment, is probably linked to the fact that seeing an area of road and wide horizon without lateral obstructions increases a feeling of comfort and safety in drivers.

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On the contrary, a closed landscape with lateral obstructions and little open horizon causes tense driver behavior. During the experiment, the presence of lateral obstacles showed the tendency to differentiate the obstructions by color. It was found that the negative effect caused by green obstacles (trees, hedges, etc.) is approximately 75% less than the effect caused by gray lateral obstacles for these reasons; the above corrective factors were used.

RESULTS

The experimental model to assess the quality of the surrounding landscape in which the road is placed was created using a linear regression with the following parameters:

- **Var1:** A_{tot} obtained according to the procedure illustrated in the previous paragraph; for each photo the A_{tot} variable was calculated using Equation-1;
- **Var2:** mean value of the opinions expressed for each photo.

To make the data comparable, normalization in a space of 1-norm was carried out before implementing the regression, with the following Equation-4:

$$x_n^i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \quad (4)$$

where:

- x_n^i is the normalized index;
- x_{max} is the maximum value of the index to be normalized;
- x_{min} is the minimum value of the index to be normalized.

The normalized data, for the “Var1” and “Var 2” variables were then grouped into 6 classes.

Table-5 shows the data assembled into classes. The last two columns refer to A_{tot} and the mean value of the judgments.

Table-5. Data assembled into classes.

Class	Number of elements	A_{tot_mean}	MR (Mean value of rates)
1	2	1.49	0.07
2	3	1.72	0.27
3	7	1.97	0.39
4	8	2.07	0.58
5	5	1.99	0.72
6	7	2.61	0.92

A linear regression between A_{tot_mean} (independent variable) and MR (dependent variable), gave the following Equation-5:

$$MR= 0.761*A_{tot\_mean}- 1.011 \ (r^2 = 0.86) \quad (5)$$

The significance of the coefficients of the model (5) is shown in Table-6.

Table-6. Significance of the coefficients of the model (5).

	Coefficient	Standard deviation	t-Student	Significance
Constant	1.011	0.125	11.269	<0.05
A_{tot_mean}	0.761	0.221	5.130	<0.05

As can be seen from the last column in Table-6, the significance of the coefficients of the model is acceptable. To test the ability of the prediction model, the following validation was carried out: Equation (5) was applied to 4 photos belonging to the 4 sites mentioned above that were not used in the calibration phase. Table-7 shows the results of the validation procedure.

The prediction model can only be applied for A_{tot_mean} values between 1.328 and 2.643 where the model returns 0 and 1 respectively. It should be noted that the model is more reliable for values in the middle of this range.

Table-7. Results of the validation for model (5).

Photo	A_{tot_mean}	Values obtained by assessments	Values obtained applying prediction model (5)	Residual (%)
A	2.20	0.60	0.66	9.5
B	2.32	0.72	0.75	4.6
C	2.50	0.81	0.89	9.1
D	1.96	0.53	0.48	9.3

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CONCLUSIONS

The road infrastructure's position in the landscape is a very important question in the road design [54-56].

In many countries, Standard obliges road designers during the feasibility study to the assessment of the effects produced by the plan on the environment and landscape [57, 58].

Main component of this study topic is the acceptance of the landscape as a result of the infrastructure building both assessing the landscape from the road (i.e. from the point of view of the driver) and assessing the whole landscape (point of view out by the road). This type of analysis is already carried out in some Countries.

The paper presented here was addressed to the procedure definition and application for the assessment of the satisfaction of a landscape from the driver's point of view.

The procedure was developed by an experimental investigation using a 200 non-expert users sample who have expressed a score on 32 different landscapes presented in pictures that were acquired with adequate photographic equipment under standard conditions.

The prediction model has a confidence-level equal to 0.99 with adjusted determination coefficient equal to 0.86. The difference between predicted and observed values shows a good fit of the model and a correct reliability simulation giving a max residual of less than 10%.

Therefore, the procedure here presented can have general validity and can be considered a useful support to quantify the "*acceptance of the landscape from the point of view of the driver*" variable to be placed in the array of environmental assessment.

The procedure is also useful in the roadsides design phase [59-67] because it allows to evaluate on driver behavior the influence of the visual appearance of the marginal elements (retaining walls, trees, safety barriers, natural retaining walls, vertical signs, etc..).

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