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Visual Landscape Quality as Viewed from Motorways in Spain

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Abstract: Motorways are large infrastructures that alter the environmental resources in a territory, while constituting an important element through which the individual comes into contact with the landscape. Motorways are integrated in the landscape through their layout design and construction, the aesthetic details of minor structures (design and building materials) and the treatment of embankments and landscape planting. In this paper, we test the following hypotheses: motorway elements are related to the perception of landscape quality—from the point of view of the road users—and the aesthetic characteristics of minor infrastructures and planting affect the quality of the landscape perceived from the roads. These research questions were tested by comparing the visual quality of the landscapes captured in 128 photographs taken from sections of motorways in Spain. We compared the results obtained from (a) a photo-based method, and (b) the public's landscape preferences determined using a survey of 737 people. The results show a correlation between the landscape quality values obtained using the model and the landscape preferences expressed by the public. We also found that the presence of the motorway elements and their aesthetic characteristics are significant in the users' perception. These results can be applied in the decision-making process for potential investments to integrate new and existing motorways in the landscape.

Keywords: landscape aesthetics; visual quality; motorways; public preferences

1. Introduction

The visual connections people make with the environment are crucial in landscape planning and management [1]. The importance of landscape management is due to its relevance as a natural resource for nature conservation and recreation, and its heritage value. Visual landscapes are an intrinsic part of the cultural perception of the environment and people's attachment to the territory and their quality of life [2,3]. Due to their aesthetic, recreation and heritage values, visual landscapes play a key role in cultural ecosystem services—benefits provided by ecosystems that contribute to making human life both possible and worth living [4,5]. The goal of landscape planning and management is to combine ecosystem conservation and protection with maintaining visual landscape quality, as a reflection of the ecosystem's informative function, its environmental structure, and its role in satisfying people's needs and valuation of places [6,7]. The European Landscape Convention (ELC) [8] incorporates the importance of the relationship between human perception and the environment in its definition of landscape as "the territory perceived by people, whose character is the result of the action and interaction of natural and/or human factors". The ELC envisages management and monitoring of every part of the territory [9], and highlights the importance of outstanding as well as every day landscapes [8]. The definition mentions the "character" of the landscape, which—according to [10]—is "the presence, variety and arrangement of landscape features, which give a landscape a specific identity and make it stand out from surrounding landscapes".

Transport networks play different and crucial roles in landscape character and in the interaction between people and the landscape. Large linear infrastructures such as motorways alter the territory's environmental resources, structure and functions. The effects of transport networks (together with urbanization and globalization) are among the main forces driving the intense and irreversible changes in landscapes and the emergence of new landscapes since the second half of the 20th century [11,12]. However, during this intense period of anthropization of the territory, roads have led to another way of perceiving the environment. These transport routes increase the opportunities of access, but are also a resource through which people come into contact with the landscape [13–15]. Due to the importance of roads in everyday life, the assessment of landscapes seen from roads is an important part of the landscape management.

The literature on landscape assessment is abundant and includes a wide range of methods. Among them, approaches based on public perception have been used extensively in landscape assessment studies, since they complement approaches based on experts' opinions and are consistent with the ELC [16–19]. Visual landscape quality is often assessed by assigning specific and easily identifiable and valuable attributes or descriptor variables to the territory or scene using photographs as substitutes for the landscape [20–22]. The literature contains various publications on landscape assessment that focus on the relationship between landscape and roads [15], including the following notable examples. Ref. [23] studied the descriptor variables used in scenic highway analysis, identifying four variables—naturalness, vividness, variety and unity—that were common in state and federal highway documents in the U.S. [24] reported that visual landscape quality in transport developments could be quantitatively evaluated using the following physical attributes as variables: vegetation, views, relief, land use, presence of water and flowers, and lack of maintenance. In the Mediterranean area, it is worth mentioning the photo-based method proposed by [25], which includes the evaluation of 14 physical, aesthetic and psychological landscape attributes in photographs. It has been demonstrated to be useful in assessing landscapes seen from roads in several studies, and was used by [26] to capture the value of the landscape along roads in Spain. Ref. [18] adapted the full method, taking into account four of the 14 descriptors to measure landscape quality from rural roads in Spain. Recently, Martín et al. [15] applied it to assess landscapes seen from highways, combined with GIS indicators of landscape character.

However, there are fewer studies that consider the effects on the perception of landscape quality of the aesthetic characteristics of the minor infrastructures of a road (such as overpasses and tunnels), and the landscape integration measures carried out in the project and maintained throughout the operation of the infrastructure (such as planting and embankment restoration) [27]. Few characteristics of road design have been studied with regard to their empirical perception [14]. Ref. [13] demonstrated the importance of road materials in the public's perception of the landscape. Ref. [28] developed a model to study the effects of specific landscaping treatments used in the design of transport infrastructures, and concluded that efforts to minimize this impact, such as incorporating vegetation on the verges, screening unattractive views, sound barriers, etc. have a positive effect on perceived landscape quality. Ref. [29] studied whether ecologically treated slopes influenced the quality of the landscape perceived by the users, while [30] reported that the presence of large trees in groves on road verges significantly affects landscape perception and notably improves the appreciation of the landscapes seen from the highway. Ref. [27] studied the effectiveness of a set of landscape integration measures frequently recommended in road design manuals in determining the landscape quality perceived by the public (motorways users).

In this paper, we test the following hypotheses: (1) landscape quality seen from Mediterranean motorways can be measured using the photo-based method proposed by [25]; and (2) motorway elements affect the perception of landscape quality—from the point of view of the road users—and the aesthetic characteristics of minor infrastructures and planting are relevant to the quality of the landscape perceived from motorways. These research questions were tested by comparing the visual landscape quality in photographs taken from sections of motorways in Spain. We compared the visual landscape quality obtained using the photo-based method and the public's landscape preferences determined using a survey.

2. Data and Methods

The method involves evaluating the visual quality of the landscapes in 128 photographs taken from motorways using a photo-based method [25]. The results are compared to the public's preferences for the same landscapes expressed in a survey of 737 people. Following the methodology in [31], a linear regression is performed to analyse the model's predictive capacity, and multiple linear regressions are used to study the attributes with the greatest influence on public perception. The aesthetic characteristics of motorway elements such as minor infrastructures, planting etc., are added to the multiple linear regression model in the form of dummy variables in order to study their influence.

2.1. Evaluation of Visual Landscape Quality: Photo-Based Method

A photo-based method of assessing visual landscape quality was used to evaluate the landscape shown in each photograph. This method is an adaptation of the one proposed by [32] to Mediterranean landscapes [21], and was previously validated through surveys of experts and the general public [31].

The landscapes are sorted into different categories by assessing 14 factors in the photographs, classified into physical, aesthetic, and psychological attributes:

- Physical attributes: water, form of the terrain, vegetation, snow, fauna, land use, views, cultural resources and alterations.
- Aesthetic attributes: form, colour, texture.
- Psychological attributes: unity and expression.

Each attribute considered in the assessment has a specific numeric value. The final value of the landscape quality in each photograph is established as the sum of the scores assigned to each attribute. The score is set from 0 to 100 and the landscapes are classified as poor (<20), deficient (20–32), mediocre (32–44), good (44–56), notable (56–68), very good (68–80) and excellent (>80). A complete description of the method can be found in [25,33].

2.2. Survey of Landscape Preferences Expressed by the Public

The public's landscape preferences are determined from data from a 2009 survey consisting of five questionnaires (or series) containing 25 or 26 photos, taken from the point of view of a road user (driver or passenger). Each respondent was shown a single series. All photographs were in colour, with a resolution of 254 ppi and dimensions of 18 × 24 cm (2400 × 1800 pixels). The photographs in the questionnaires were taken from an inventory of the landscapes observed from various Spanish motorways taken between May and June 2009 (more information on the inventory is available in [27]). The roads travelled and photographed during the photographic inventory are shown in Figure 1.

In the survey, done either on a website or face-to-face in motorway service areas, the respondents were selected randomly and were asked to assess their preference for the landscapes shown on a scale of 1 to 5 (1 = very poor; 5 = very good). They were shown a total of 128 photographs of landscapes that can be seen from the motorways (divided in 5 sets), and answers were obtained from 737 people. The initial simple size estimated for each series was 89 people. To obtain it, the simple random sampling technique was used.

$$n_0 = \left(\frac{\sigma \cdot z_{(1-\frac{\alpha}{2})}}{d}\right)^2$$

where:

n_0 is the sample size.
σ is the standard deviation, the σ value used to estimate the simple size was 0.48 [31].
d is the sampling error (0.1 was the value considered).
$z_{(1\,-\,\alpha/2)}$ is the value of the standard normal variable (1.98 with a confidence level α = 95%).

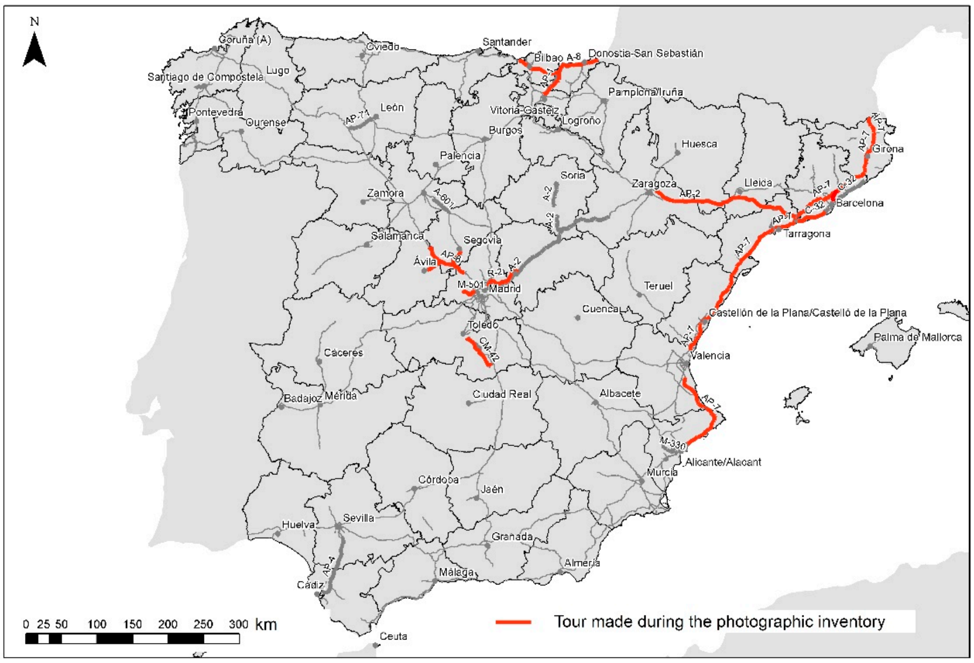

Figure 1. Tour made during the photographic inventory of the landscapes seen from the motorways. Source: [27].

2.3. Statistical Analysis

The goodness of fit of the model for predicting the respondents' preferences was determined using simple and multiple linear regressions. The proposed models explain the respondents' average score in each photo (dependent variable) based on assessments obtained with the photo-based method. In all cases, contrasts are used on the model coefficients estimated (contrast of the t (α = 0.05)) to determine whether the variables in the models are significant. In these contrasts, the null hypothesis is that these coefficients are 0. To determine atypical values, the Grubbs test was used.

A diagnosis was performed on all the models by comparing the starting hypotheses of the regression, namely that there was no autocorrelation between the residuals. This was done using the Durbin-Watson statistic (DW) (α = 0.05).

The percentage of variability of the observer's preferences that explains each model is expressed using the R^2 and adjusted for degrees of freedom R^2 statistic, which is better suited to comparing models with a different number of independent variables. The larger these statistics, the better the respondents' preferences explain the model.

The number of variables studied increases progressively in the proposed models as proposed by [31].

2.3.1. Simple Linear Regression

The first regression model proposed is a simple linear regression where the dependent variable is the mean score given by the respondents to each photograph, and the independent variable is the result of the landscape value for each photograph obtained using the photo-based method. The model is as follows:

$$Y = \beta_0 + \beta_1 X + U$$

where:

Y is the mean score for each photo in the survey.
X is the score obtained by applying the photo-based method.
β_0 and β_1 are the estimated coefficients in the regression model.
U is the random variation of the model.

2.3.2. Multiple Regression with Groups of Attributes

In this case, the physical, aesthetic and psychological attribute groups are considered as the explanatory variables for the preference, and the independent variable is the result of the landscape score for each photograph. The proposed model is therefore:

$$Y = \beta_0 + \beta_1 \text{ Physical} + \beta_2 \text{ Aesthetic} + \beta_3 \text{ Psychological} + U$$

where:

Y is the mean score for each photo in the survey.
Physical, aesthetic and psychological are the assessments using the photo-based method, corresponding to physical, aesthetic and psychological attribute groups respectively.
β_0, β_1, β_2 and β_3 are the estimated coefficients in the multiple regression model.
U is the vector for the random variation of the model.

2.3.3. Multiple Regression with Each Attribute Separately

A multiple regression model is also proposed, considering each attribute separately as independent variables.

$$Y = XB + U$$

where

Y is the vector of the mean scores awarded to each photograph by the respondents.
X is the matrix of scores awarded by the photo-based method to each attribute.
B is the vector of the coefficients.
U is the vector for the random variation of the model.

2.3.4. Multiple Regression Considering the Motorway Elements

Finally, it was studied whether the presence of the road and its integration in the landscape—that is, the aesthetic characteristics of the motorway elements and its minor infrastructures—influence the perception of the landscape and could be included in the model.

This analysis was done using two dummy variables in the regression model described above to represent three alternatives: (1) the road is present in the photograph; (2) the road is present and defects can be identified in its integration in the landscape; and (3) the road is present and sufficient efforts have been made to integrate it. The following variables were introduced in the model:

$$X_m \begin{cases} 1, \; if\ the\ motorway\ can\ be\ seen\ in\ the\ photograph,\ and\ is\ identified\ as\ being\ poorly\ integrated \\ 0, \; in\ all\ other\ cases \end{cases}$$

$$X_b \begin{cases} 1, \; if\ the\ motorway\ can\ be\ seen\ in\ the\ photograph,\ and\ is\ identified\ as\ being\ well\ integrated \\ 0, \; in\ all\ other\ cases \end{cases}$$

The photographs were classified according to the X_m and X_b variables following the study by [27], which examined the efficacy of landscape integration measures on Spanish motorways in improving landscape perception. It was considered that X_b is equal to 1, that is, there is good integration if the photographs where the motorway is present show evidence of the actions present in the list in

Table 1. If defects are detected in the integration of the road in the landscape in the photographs, X_m is considered to be equal to 1. Some examples of these photographs are shown in Figure 2.

Table 1. Summary of effective landscape integration measures. Source: [27].

Embankments	Geographic correction of levels and slopes to adapt to the topography.
	Revegetation treatments for embankments
Tunnels	Treatment of the tunnel mouth and design of the vault to adapt to the slope
	Use of colours that blend with the landscape
	Revegetation treatment for the tunnel mouth
Planting (verges and central reservation)	Concealment of elements that alter the landscape: vegetation screens.
	Enhancement of the road landscaping features
	Visual orientation of the layout and reduction of glare
Retaining walls	Concrete walls with different sections
	Walls made from "natural" materials: gabions, jetties, etc.
Noise barriers	Prefabricated screens: transparent, opaque, prefabricated barriers and hillocks
	Use of colours that blend with the landscape
	Noise barriers in combination with planting
Overpasses and walkways	Use of colours that blend with the landscape
	"Light" designs, with pillars and beams that do not obscure the views as far as possible
	Incorporation of vegetation to improve the motorway's aesthetic quality
	Search for designs with forms similar to those predominant in the area

Figure 2. *Cont.*

Figure 2. Examples of the photographs included in the survey. On the left column defects of integration in landscape can be found, the value assigned to Xm in these photographs is 1. On the right column those defects are corrected according to the recommendation in Table 1, so the value assigned to Xb is 1. More information about the set of photographs used can be found in [27].

3. Results

The scores obtained with the photo-based method and the mean score given by the respondents to each photograph are represented in two frequency histograms in Figure 3. In both graphics, landscape preference is represented in a 0–100 scale for a better interpretation. The photo-based method provides a more asymmetric left-skewed histogram, containing more photographs in the classes below 50 than the histogram that represents the score given by the public. This indicates that the landscape preference provided by the photo-based method is lower than preference revealed in the survey. Concerning the presence of outliers in the respondents' average score, the Grubbs test discarded (p-value = 1).

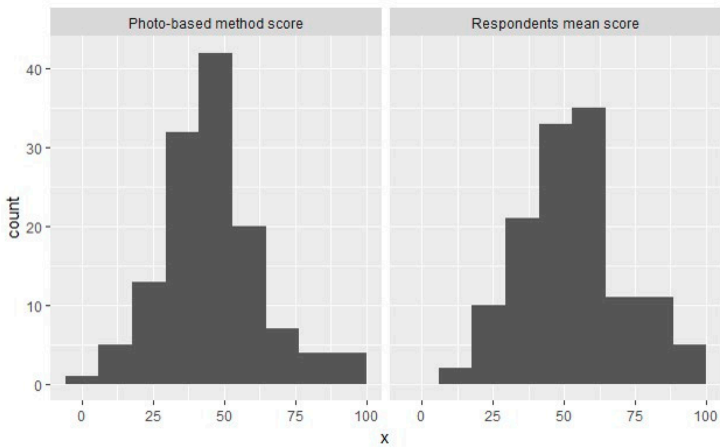

Figure 3. Frequency histograms of the landscape quality (0–100 scale) obtained using the photo-based method and the respondents' mean scores in the survey.

Regarding the models proposed, the first one is a simple linear regression where the dependent variable is the respondents' average score in each photograph, and the independent variable is the result of the landscape score for each photograph obtained using the photo-based method.

Table 2 shows the results of the contrasts on the estimated coefficients β_0 and β_1 in the model (contrast of the t). The p-value for both coefficients is less than 0.05, indicating that the null hypothesis is rejected; that is, that the coefficients are 0. There is therefore a statistically significant linear relation between the respondents' preference and photo-based method, with a confidence level of at least 95%.

Table 2. Results of the estimated linear regression model.

Parameter	Estimate	Standard Error	*t*-Value	*p*-Value
β_0	13.21183	2.44798	5.397	0.0000
β_1	0.86659	0.04991	17.364	0.0000

Correlation coefficient = 0.83980; Residual standard error: 9.965 on 126 degrees of freedom (d.f); R^2: 0.7053, Adjusted for d.f. R^2: 0.7029; F-statistic: 301.5 on 1 and 126 DF, *p*-value: $<2.2 \times 10^{-16}$; DW = 1.8182, *p*-value = 0.1499.

The magnitude of the relation between the two variables, expressed through the R^2 statistic, indicates that the adjusted model explains 70.53% of the variability of the preferences expressed in the survey. The correlation coefficient is 0.84, indicating a moderately strong relation between the variables.

The DW statistic was used to complete the analysis, which in this case discards the serial autocorrelation in the residuals (with a confidence level of 95%).

Table 3 shows the result of the model considering the physical, aesthetic and psychological attribute groups as explanatory variables for landscape quality preference.

Table 3. Results of the estimated model considering the physical, aesthetic and psychological attribute groups as explanatory variables.

Parameter	Estimate	Standard Error	*t*-Value	*p*-Value
Constant β_0	1.432095	0.108341	13.218	0.0000
Physical β_1	0.040067	0.003404	11.772	0.0000
Aesthetic β_2	0.026544	0.004545	5.84	0.0000
Psychological β_3	0.037291	0.005517	6.759	0.0000

Residual standard error: 0.3948 on 124 degrees of freedom (d.f.); R^2: 0.7155, Adjusted for d.f. R^2: 0.7086; F-statistic: 103.9 on 3 and 124 d.f., *p*-value: $< 2.2 \times 10^{-16}$; DW = 1.805, *p*-value = 0.1255.

The three independent variables are statistically significant based on the contrasts for the estimated coefficients in the model, with a confidence level of 95%.

The R^2 statistic indicates that the model adjusted in this way explains 71.55% of the variability of the preferences expressed in the survey. The R^2 adjusted for d.f. statistic, the most suitable for comparing models with a different number of independent variables, is 70.86%. The DW statistic confirms that there is no indication of serial autocorrelation in the residuals, with a 95% confidence level.

The R^2 values obtained are slightly greater than in the simple linear regression (Table 2). The variability of the preference is best explained by considering the physical, aesthetic and psychological attributes separately than considering the final result of the model as the sole independent variable. The weight given by the regression model to each group of attributes (coefficients β) is very similar for the physical and psychological attributes (0.040 and 0.037, respectively). The value of the estimated coefficient for the aesthetic attributes is lower, so their weight in the estimation of the preference is somewhat less.

Thirdly, a multiple regression model is proposed considering each attribute separately as independent variables. The result is shown in Table 4. There is a statistically significant relation between the independent and dependent variables, with a 95% confidence level. The fit is even better than in the previous case, as the value of the adjusted R^2 statistic increases to 77.42%. This implies that the attributes-based model better fits the structure of the individuals' preference if each variable is analysed separately. The result of the analysis of residuals is a *p*-value in the DW statistic of over 0.05, so no serial autocorrelation can be detected in the residuals, with a 95% confidence level.

However, the examination of each variable reveals that the results of the contrasts on the estimated coefficients β in the models indicate that three of these variables could be eliminated from the regression model. The result of the contrast gives a number over 0.05 as a *p*-value, so the hypothesis that they are different from 0 can be rejected (α = 0.05). These attributes are views, form and unity, corresponding to the physical, aesthetic and psychological groups, respectively.

Table 4. Results of the estimated model considering each attribute separately as explanatory variables for the preference. Bolded texts indicate *p*-values higher than 0.05.

Parameter	Estimate	Standard Error	*t*-Value	*p*-Value
Constant β_0	1.985620	0.170505	11.645	0.0000
Water β_1	0.034057	0.012028	2.832	0.0055
Landform β_2	0.037026	0.012805	2.892	0.0046
Vegetation β_3	0.024411	0.008999	2.713	0.0077
Snow β_4	0.074602	0.025454	2.931	0.0041
land uses β_5	0.033975	0.006535	5.199	0.0000
Fauna β_6	0.108313	0.053909	2.009	0.0469
Views β_7	−0.004720	0.012384	−0.381	**0.7038**
Cultural resources β_8	0.098051	0.022681	4.323	0.0000
Alterations β_9	0.058132	0.010519	5.527	0.0000
Form β_{10}	0.026454	0.014535	1.820	**0.0714**
Colour β_{11}	0.016873	0.007542	2.237	0.0272
Texture β_{12}	0.023618	0.009084	2.600	0.0106
Unity β_{13}	0.007529	0.009492	0.793	**0.4293**
Expression β_{14}	0.047288	0.007597	6.225	0.0000

Residual standard error: 0.3475 on 113 degrees of freedom (d.f.); R^2: 0.7991, Adjusted for d.f. R^2: 0.7742; F-statistic: 32.11 on 14 and 113 d.f., *p*-value: $< 2.2 \times 10^{-16}$; DW = 1.8563, *p*-value = 0.1824.

The results of the three regressions showed that the photo-based method is a good predictor of the preferences selected, at least with the photographs used in the survey.

Finally, it was studied whether the presence of the road could have a notable influence on landscape perception and whether landscape integration—that is, the management of the operation and conservation of the motorway and the integration efforts made during the project—would influence landscape perception and could be included in the model.

When each separate variable and the dummy variables are taken as the independent variables, the result of the regression model (Table 5) is better than when the attribute groups are considered separately. This improvement can be expressed again in terms of the adjusted R^2 adjusted for d.f. which goes from 77.42% (Table 4) to 80.58%. The coefficients of the variables X_m and X_b are significant and indicate that the presence of the motorway and the lack of integration measures may represent a deterioration in observers' perception of landscape quality, which is reflected in the negative sign of the estimated β coefficients. It is also worth noting that these two coefficients are of a greater magnitude than all the others, and therefore have a significant weight in the perception of landscape quality. X_m also has a greater absolute value than X_b, so the presence of the road with poorly integrated elements causes a greater decline in the quality perceived by the observers than the presence of the road with good integration practices.

However, not all the variables used in this model were ultimately significant. The variables corresponding to the attributes for fauna, views, form and unity, as the *p*-value for each one is greater than or equal to 0.05, are not statistically significant, with a confidence level of 95% or greater, so it may therefore be advisable to eliminate them from the model.

Table 5. Results of the estimated model considering each attribute separately and the presence of the road as explanatory values for the preference. Bolded texts indicate *p*-values higher than 0.05.

Parameter	Estimate	Standard Error	*t*-Value	*p*-Value
Constant β_0	2.247229	0.169771	13.237	0.0000
Water β_1	0.024347	0.011361	2.143	0.03431
Landform β_2	0.037553	0.011879	3.161	0.00203
Vegetation β_3	0.026058	0.008356	3.119	0.00232
Snow β_4	0.053794	0.024083	2.234	0.02751
land uses β_5	0.045427	0.006571	6.913	0.0000
Fauna β_6	0.032490	0.053031	0.613	**0.54135**
Views β_7	−0.008100	0.011588	−0.699	**0.48602**
Cultural resources β_8	0.082544	0.021375	3.862	0.00019
Alterations β_9	0.051663	0.009925	5.205	0.0000
Form β_{10}	0.021448	0.013562	1.581	**0.11662**
Colour β_{11}	0.022563	0.007232	3.12	0.00231
Texture β_{12}	0.020441	0.008523	2.398	0.01814
Unity β_{13}	0.002355	0.008884	0.265	**0.79141**
Expression β_{14}	0.03159	0.007925	3.986	0.00012
Xm β_{15}	−0.461266	0.106851	−4.317	0.0000
Xb β_{16}	−0.392413	0.096719	−4.057	0.0000

Residual standard error: 0.3223 on 111 degrees of freedom (d.f.); R2: 0.8302, Adjusted for d.f. R2: 0.8058; F-statistic: 33.93 on 16 and 111 d.f., *p*-value: $< 2.2 \times 10^{-16}$; DW = 1.9013, *p*-value = 0.2495.

4. Discussion and Conclusions

The first aim of this paper was to investigate the perception of landscape quality as seen from Mediterranean motorways using a photo-based method [25]. The analysis was done by applying simple linear and multiple regression to compare visual landscape quality in 128 photographs using the photo-based method, and the public's landscape preferences determined using a survey of the same set of photographs. The results provide evidence that the overall score assigned to each photograph by the photo-based model is a good estimator of the public's preference (at least for the photographs used). The predictive power of the method—in terms of the adjusted coefficients of determination—was stronger when the model used groups of attributes and attribute scores. Despite having the highest coefficient of determination, the regression with attributes reveals three non-significant attributes that could be eliminated from the model: views, form, and unity.

These results are compatible with the importance of physical attributes when making a quantitative evaluation of visual landscape quality, as reported by [24]. In fact, physical attributes have the highest coefficient when modelling with the three attribute groups, and eight out of nine physical attributes are significant in the model. However, this analysis also reports evidence of the significance of aesthetic and psychological attributes.

This is in contrast with some the results of [31], who performed a similar analysis using 48 photographs of landscapes and a survey of 183 people. They found that the predictive power of the regression model was stronger when using attributes, but not when using groups of attributes. They also found that landforms, fauna and views could be eliminated from the model. The reason for these differences may be due to the set of photographs used in this study, which show landscapes seen from Spanish motorways, not scenic views. However, vegetation, land use and texture are significant in both studies. These attributes were used in a simplified model for the particular case of landscapes seen from rural roads proposed by [21]. Further investigation could focus on simplifying the photo-based method.

The second objective of this paper was to investigate whether the motorway elements and the aesthetic characteristics of minor infrastructures and planting affect landscape quality as perceived from motorways. The analysis involved adding two dummy variables to the multiple regression with attributes that represent the presence of the road in the photographs, distinguishing between good and bad landscape integration practices, as identified in the work of [27]. The results show that the adjusted coefficient of determination was stronger than in the previous model, indicating that the last regression model proposed explains public perception better than the model adapted from the scores obtained for the attributes in the photo-based method alone. These two variables are negatively associated with the landscape preference expressed by the public. The coefficients of the dummy variables resulted in the highest association with public perception of all the variables. This result indicates that the presence of the highway with poorly integrated elements causes a greater decline in the quality perceived by the observers than the presence of the road with good integration practices. The high negative association of the variable representing poor landscape integration highlights the importance of motorway elements and the aesthetic characteristics of minor infrastructures and planting in landscape perception, as also concluded by [27]. It is important to highlight that the landscape integration measures summarized in Table 1 are general design recommendations that should provide aesthetically appealing outcomes, while maintaining and even enhancing the safety and functionality of the infrastructures [34]. For example, road legibility can be reinforced by adequate planting in the verge and central reservation, which also contributes to reduce glare [34,35]. The use of colours that blend with the landscape should never interfere with the drivers' visibility of the roadway and infrastructure elements and every intervention should respect the traffic signing.

The results of this work may help to address aesthetical aspects in road planning praxis, which has become a valued issue in the last decades [14] and can be applied in the decision-making process for potential investments to integrate new and existing motorways in the landscape. However, this study has limitations that open up new opportunities for further research. The results of this study are limited to the particular characteristics of the landscapes in the photographs shown. Differences between population groups and types of landscape integration measures were not studied. More detailed studies on these topics may be useful for landscape management. Furthermore, this study is restricted to the cross-sectional data collected in the survey. A new longitudinal study that takes this one as base could add valuable results to the literature on landscape change and its relationship with roads.

Another limitation that points to further research is the set of variables included in the model. New approaches may consider not only the presence of the road and its integration measures—in addition to the attributes proposed by [25]—but also other important aspects of the territory, such as different landscape types, unique landscape features, endangered or vulnerable environmental characteristics, among others.

Additionally, other authors have discussed that photographs may sometimes poorly represent the scenic quality of the landscape due to the difficulty of providing a representative photo sample and their limitations when capturing potential views [15,17]. Further work may complete the assessment of visual landscape using driving simulators as substitutes for photograph surveys to study experiences of landscape [36,37], or new data sources, such as crowd-sourced (social media) photo data [38]. The use of the proposed photo-based approach has the advantage of incorporating the user's perception from the motorway. It is a contribution that can be used in the study of everyday landscapes as cultural ecosystem services. However, landscape structure and character cannot be assessed using this type of data, which is limited to a local scale. GIS map-based indicators may be applied to complement this analysis, incorporating landscape character in the evaluation [10,17,39], and assessing whether the motorway conveys the character of the landscape of which it forms part [15].

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References

1. Vukomanovic, J.; Singh, K.K.; Petrasova, A.; Vogler, J.B. Not seeing the forest for the trees: Modeling exurban viewscapes with LiDAR. *Landsc. Urban Plan.* **2018**, *170*, 169–176. [CrossRef]
2. Van Eetvelde, V.; Antrop, M. Indicators for assessing changing landscape character of cultural landscapes in Flanders (Belgium). *Land Use Policy* **2009**, *26*, 901–910. [CrossRef]
3. Kienast, F.; Frick, J.; van Strien, M.J.; Hunziker, M. The Swiss Landscape Monitoring Program–A comprehensive indicator set to measure landscape change. *Ecol. Model.* **2015**, *295*, 136–150. [CrossRef]
4. Millennium Ecosystem Assessment Board. *Millennium Ecosystem Assessment*; World Resources Institute: Washington, DC, USA, 2005.
5. Wartmann, F.M.; Purves, R.S. Investigating sense of place as a cultural ecosystem service in different landscapes through the lens of language. *Landsc. Urban Plan.* **2018**, *175*, 169–183. [CrossRef]
6. Dronova, I. Environmental heterogeneity as a bridge between ecosystem service and visual quality objectives in management, planning and design. *Landsc. Urban Plan.* **2017**, *163*, 90–106. [CrossRef]
7. Jessel, B. Elements, characteristics and character–Information functions of landscapes in terms of indicators. *Ecol. Indic.* **2006**, *6*, 153–167. [CrossRef]
8. Council of Europe. *European Landscape Convention*; Council of Europe: Firenze, Italy, 2000.
9. Mata Olmo, R. El paisaje, patrimonio y recurso para el desarrollo territorial sostenible. Conocimiento y acción pública (The landscape, heritage and resource for sustainable territorial development. Knowledge and Public Action). *ARBOR Cienc. Pensam. Cult.* **2008**, *184*, 155–172. [CrossRef]
10. Jellema, A.; Stobbelaar, D.J.; Groot, J.C.; Rossing, W.A. Landscape character assessment using region growing techniques in geographical information systems. *J. Environ. Manag.* **2009**, *90*, 161–174. [CrossRef] [PubMed]
11. Antrop, M. Background concepts for integrated landscape analysis. *Agric. Ecosyst. Environ.* **2000**, *77*, 17–28. [CrossRef]
12. Antrop, M. Landscape change and the urbanization process in Europe. *Landsc. Urban Plan.* **2004**, *67*, 9–26. [CrossRef]
13. Garré, S.; Meeus, S.; Gulinck, H. The dual role of roads in the visual landscape: A case-study in the area around Mechelen (Belgium). *Landsc. Urban Plan.* **2009**, *92*, 125–135. [CrossRef]
14. Blumentrath, C.; Tveit, M.S. Visual characteristics of roads: A literature review of people's perception and Norwegian design practice. *Transp. Res. Part A Policy Pract.* **2014**, *59*, 58–71. [CrossRef]
15. Martín, B.; Ortega, E.; Otero, I.; Arce, R.M. Landscape character assessment with GIS using map-based indicators and photographs in the relationship between landscape and roads. *J. Environ. Manag.* **2016**, *180*, 324–334. [CrossRef] [PubMed]
16. Arriaza, M.; Cañas-Ortega, J.F.; Cañas-Madueño, J.A.; Ruiz-Avile, P. Assessing the visual quality of rural landscapes. *Landsc. Urban Plan.* **2004**, *69*, 115–125. [CrossRef]
17. Ode Sang, Å.; Tveit, M.S.; Fry, G. Advantages of using different data sources in assessment of landscape change and its effect on visual scale. *Ecol. Indic.* **2010**, *10*, 24–31.
18. Lee, K.C.; Son, Y.H. Exploring Landscape Perceptions of Bukhansan National Park According to the Degree of Visitors' Experience. *Sustainability* **2017**, *9*, 1306. [CrossRef]
19. Loures, L.; Loures, A.; Nunes, J.; Panagopoulos, T. Landscape valuation of environmental amenities throughout the application of direct and indirect methods. *Sustainability* **2015**, *7*, 794–810. [CrossRef]
20. Rogge, E.; Nevens, F.; Gulinck, H. Perception of rural landscapes in Flanders: Looking beyond aesthetics. *Landsc. Urban Plan.* **2007**, *82*, 159–174. [CrossRef]

21. Ramírez, Á.; Ayuga-Téllez, E.; Gallego, E.; Fuentes, J.M.; García, A.I. A simplified model to assess landscape quality from rural roads in Spain. *Agric. Ecosyst. Environ.* **2011**, *142*, 205–212. [CrossRef]
22. Kalivoda, O.; Vojar, J.; Skřivanová, Z.; Zahradník, D. Consensus in landscape preference judgments: The effects of landscape visual aesthetic quality and respondents' characteristics. *J. Environ. Manag.* **2014**, *137*, 36–44. [CrossRef] [PubMed]
23. Clay, G.R.; Smidt, R.K. Assessing the validity and reliability of descriptor variables used in scenic highway analysis. *Landsc. Urban Plan.* **2004**, *66*, 239–255. [CrossRef]
24. Churchward, C.; Palmer, J.F.; Nassauer, J.I.; Swanwick, C.A. *NCHRP Report 741: Evaluation of Methodologies for Visual Impact Assessments*; Transportation Research Board of the National Academies: Washington, DC, USA, 2013.
25. Cañas, I. *Introducción al Paisaje (Introduction to Landscape)*; Unicopia: Madrid, Spain, 1995; ISSN 84-89189-13-7.
26. Otero, I.; Cañas, I.; Esparcia, P.; Navarra, M.; Martín, M.C.; Ortega, E. La carretera como elemento de valor paisajístico y medioambiental. Captación del valor del paisaje a través de la carretera. *Inf. Constr.* **2006**, *58*, 39–54. [CrossRef]
27. Martín, B.; Loro, M.; Arce, R.M.; Otero, I. Different landscaping integration techniques in roads. Analysis of efficacy through public perception. *Inf. Constr.* **2012**, *64*, 207–220. [CrossRef]
28. Burley, J. Visual and ecological environmental quality model for transportation planning and design. *Transp. Res. Rec.* **1996**, *1549*, 54–60. [CrossRef]
29. Froment, J.; Domon, G. Viewer appreciation of highway landscapes: The contribution of ecologically managed embankments in Quebec, Canada. *Landsc. Urban Plan.* **2006**, *78*, 14–32. [CrossRef]
30. Wolf, K. Assessing public response to freeway roadsides: Urban forestry and context-sensitive solutions. *Transp. Res. Rec.* **2006**, *1984*, 102–111. [CrossRef]
31. Cañas, I.; Ayuga, E.; Ayuga, F. A contribution to the assessment of scenic quality of landscapes based on preferences expressed by the public. *Land Use Policy* **2009**, *26*, 1173–1181. [CrossRef]
32. Smardon, R.C.; Palmer, J.F.; Knopf, A.; Grinde, K.; Henderson, J.E.; Peyman-Dove, L.D. *Visual Resources Assessment Procedure for US Army Corps of Engineers*; Instruction Report EL-88-1; US Army Engineer Waterways Experiment Station: Vicksburg, MS, USA, 1988.
33. Otero Pastor, I.; Casermeiro Martinez, M.A.; Ezquerra Canalejo, A.; Esparcia Mariño, P. Landscape evaluation: Comparison of evaluation methods in a region of Spain. *J. Environ. Manag.* **2007**, *85*, 204–214. [CrossRef] [PubMed]
34. Español, I. *La Carretera en el Paisaje: Criterios Para su Planificación, Trazado y Proyecto*; Junta de Andalucía Consejería de Obras Públicas y Transportes: Sevilla, Spain, 2008; ISBN 978-8480955546.
35. Transit NZ. *Guidelines for Highway Landscaping*; Transit New Zealand: Wellington, New Zealand, 2006.
36. Antonson, H.; Ahlström, C.; Wiklund, M.; Blomqvist, G. Effect of surrounding landscape on driving behaviour: A driving simulator study. *J. Environ. Psychol.* **2009**, *29*, 493–502. [CrossRef]
37. Antonson, H.; Ahlström, C.; Wiklund, M.; Blomqvist, G.; Mårdh, S. Landscape heritage objects' effect on driving: A combined driving simulator and questionnaire study. *Accid. Anal. Prev.* **2014**, *62*, 168–177. [CrossRef] [PubMed]
38. Langemeyer, J.; Calcagni, F.; Baró, F. Mapping the intangible: Using geolocated social media data to examine landscape aesthetics. *Land Use Policy* **2018**, *77*, 542–552. [CrossRef]
39. Martín, B.; Ortega, E.; Martino, P.; Otero, I. Inferring landscape change from differences in landscape character between the current and a reference situation. *Ecol. Indic.* **2018**, *90*, 584–593. [CrossRef]