UNIVERSIDAD POLITÉCNICA DE VALENCIA

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VISUAL IMPACT ASSESSMENT OF HUMAN INTERVENTIONS ON THE LANDSCAPE: THE CASE OF WIND FARMS AND SOLAR POWER PLANTS

PHD THESIS

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To my dad, my mum, and my sisters Leslie and Josie.
Because you are always there.

No te rindas que la vida es eso,
Continuar el viaje,
Perseguir tus sueños,
Destrabar el tiempo,
Correr los escombros,
Y destapar el cielo.

Don't give up, that's what life is,
Continue the journey,
Follow your dreams,
Unlock time,
Move the rubble,
And uncover the sky.

Mario Benedetti, *No Te Rindas, Don't Give Up*

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Summary

The United Nations Population Fund (UNFPA) has stated that in 2008, for the first time in history, more than half the population of the world was living in towns and cities. It is predicted that by 2030 this number will increase to 60% of the population [1]. The increasing size of urban areas, the growing population which requires us to convert more wilderness to agricultural or industrial use, and the more intensive use of that agricultural land, have combined to put the countryside under enormous pressure. As a result, the last few decades have revealed a growing social unease of the aesthetics of the landscape. Governments and citizens are becoming ever more concerned with the visual display of their everyday environment, both urban and rural. More and more, landscape, and particularly its Aesthetic Quality, is conceived as a resource - natural and societal -, highly fragile and capable of disappearing. Un-planned constructions, environmental hazards and bad usage of the territory, have influenced to its degradation, and so it becomes necessary to define conservation guidelines.

At the same time, increasing concentration of carbon dioxide in the atmosphere has caused a fear towards global warming. This fear, and the realisation that oil production is at, or near, its peak, have driven many countries to seek decarbonisation of their energy economies. Renewable energies, in particular wind energy and solar energy facilities, represent an attractive option in the move towards decarbonisation. However, these technologies frequently encounter public resistance, largely directed at their poor integration into the landscape. It is therefore important that the public resistance to renewable energy encounters be properly understood, so that, if needed, such facilities can be deployed on a large scale, without damaging the environment or people's perceptions of it.

To protect the visual quality of the landscape, it is necessary to understand it, and the first step to do so, is by carrying out a Visual Impact Assessment (VIA), which aims to identify and evaluate physical and perceptual landscape components that determine whether a particular landscape is aesthetically pleasing or not. Within the EU, countries and regions regulate the sustainability of their landscapes according to the Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, also known as the Environmental Impact Assessment Directive. The EIA Directive requires Environmental Impact Assessments to be carried out for certain construction projects (particularly large-scale) prior to their development, to ensure that the possible environmental consequences generated by the projects are identified and assessed before the constructions are authorised. The visual impact which is induced by human action on a landscape is one type of environmental impact which must be considered in EIA. Consequently, European countries and/or regions which have developed landscape laws according to the Commission's Directives, are legally committed to perform Visual Impact Assessments, as part of the project's EIA.

Although more and more tools are being developed for the execution of VIA, there is still not a universal tool which can be used by different types of users within the field of landscape research and landscape planning. Moreover, the tools developed are often too complicated, or too specific to be useful in practice, and in particular, in Environmental Impact Assessments.

Landscape analysis offers a wide spectrum of methodologies and tools which are based on different theoretical foundations, and which pursue varying objectives. The decision on which methodology to adopt is determined by the definition of the term *landscape* and on the objective pursued in the analysis. Studies in visual impact of landscapes have followed three main lines of investigation: The *Expert Approach*, the *Public Preference Approach* and the *Holistic Approach*.

The objective of this work is to develop reliable and easily-applicable tools to quantify the Visual Impact of human interventions on the landscape, by means of a potentially generalisable methodology. Three case studies are presented, whereby each study applies a separate approach to VIA. Each investigation aims to advance from the findings of the previous one, complementing the methodology with new tools.

In the first study, an indicator is developed to measure the magnitude of the aesthetic impact of wind farms, using the Expert Approach. The indicator combines tangible measures of visibility, colour, fractality and continuity which can be taken from photographs. Value functions are constructed for each variable and incorporated into the indicator. This indicator is used to calculate the objective aesthetic impact of five wind farms. Statistic comparison of the indicator results with a population survey shows that the indicator correctly represents the order of impact as perceived by the population sample, and is thus an appropriate objective measure of aesthetic impact of wind farms.

Continuing with the line of thought and results of this study, the second investigation first develops a similar indicator for solar power plants, and subsequently combines it with a Semantic Differential Analysis to evaluate variations in subjective human perception; thus introducing a Holistic Approach. The study proves that the combined use of an objective indicator and a subjective study faithfully explains user preferences.

The third study improves the reliability of the Semantic Differential Analysis, as a tool to evaluate the visual impact of different types of human interventions in a Public Preference Approach. This is done by incorporating the Intraclass Correlation Coefficient tool, which is applied to validate the semantic space of the perceptual responses as well as to determine the number of subjects required for a reliable evaluation of the data.

Finally, the methodology and the tools developed are analysed for reliability, validity, generalisability and applicability, with particular reference to VIA as part of the Environmental Impact Assessment.

This work has been carried out following the official procedure for the attainment of a European PhD. During the course of the PhD, the candidate has performed research studies at the *University of Oxford (Oxford, UK)* for a period of six months. In addition, this doctoral thesis is compiled in a "publications" format, in accordance with the requirements of the *Department of Engineering Projects, of the Polytechnic University of Valencia (Valencia, Spain)*. Two articles which correspond to the first two studies, have been published in the scientific journal *Renewable and Sustainable Energy Reviews*. To date, a third paper relating to the third study has also been submitted to *Environmental Impact Assessment Review*, for its evaluation. Additionally, the general content which is outlined in the literature review has also been published in the book entitled *Visual Perception: New Research* published by *Novapublishers*.

Resumen

El Fondo de Población de las Naciones Unidas ha declarado que en 2008, por primera vez en la historia, más de la mitad de la población del mundo vivía en pueblos y ciudades. Se ha estimado que para el año 2030 este número se incrementará al 60% de la población [1]. El creciente tamaño de las zonas urbanas, el incremento de población que requiere la conversión de terrenos naturales en suelo agrícola o industrial, y el uso más intensivo de los terrenos agrícolas existentes, suponen una enorme presión sobre el territorio. Como resultado, en las últimas décadas se ha puesto de manifiesto un creciente malestar social sobre la estética del paisaje. Los gobiernos y los ciudadanos están cada vez más preocupados por la presencia visual de su entorno cotidiano, tanto urbano como rural. Cada vez más, el paisaje, y especialmente su calidad estética, se concibe como un recurso -natural y social- de elevada fragilidad y susceptible de desaparecer. Las construcciones no planificadas, los riesgos ambientales y mal uso del territorio han influido en su degradación, por lo que se hace necesario definir unas directrices para su conservación.

Al mismo tiempo, la creciente concentración de dióxido de carbono en la atmósfera ha alertado sobre el peligro y las consecuencias del calentamiento global del planeta. El temor a este calentamiento y el hecho de que la producción de petróleo está en su pico, o cerca del mismo, han llevado a muchos países a seguir estrategias de ”descarbonización” de sus fuentes de energía. Las energías renovables, en particular la energía eólica y la energía solar, representan una opción interesante en el camino hacia la ”descarbonización”. Sin embargo, estas tecnologías se enfrentan frecuentemente con la resistencia del público, como consecuencia de su difícil integración en el paisaje. Por ello, es importante que esta contestación social hacia las energías renovables sea entendida adecuadamente, de modo que, si se necesitan, estas instalaciones puedan ser implantadas a gran escala, sin dañar el entorno o la percepción sobre las mismas.

Para proteger la calidad visual del paisaje, es necesario entenderlo y el primer paso para hacerlo es mediante la realización de una Evaluación de Impacto Visual, que tiene por objeto identificar y evaluar los componentes físicos y perceptuales del paisaje que determinan si un paisaje concreto es estéticamente agradable o no. En la Unión Europea, los países y las regiones regulan la sostenibilidad de sus paisajes según la Directiva 85/337/CEE de 27 de junio de 1985, relativa a la evaluación de las repercusiones de determinados proyectos públicos y privados sobre el medio ambiente, también conocido como la Directiva de Evaluación de Impacto Ambiental. Esta Directiva exige la evaluación del impacto ambiental de determinados proyectos de construcción (sobre todo a gran escala) antes de su desarrollo, para asegurar que sus consecuencias ambientales sean identificadas y evaluadas con carácter previo a su autorización. El impacto visual inducido por la acción humana en un paisaje es un tipo de impacto ambiental que debe ser considerado en la Evaluación de Impacto Ambiental. En consecuencia, los países y regiones europeas que han desarrollado leyes de protección del paisaje de acuerdo con las Directivas de la Comisión, se comprometen legalmente a llevar a cabo evaluaciones del impacto visual, en el marco de la Evaluación del Impacto Ambiental del proyecto.

A pesar del desarrollo de herramientas específicas para la Evaluación del Impacto Visual, todavía no existe una herramienta universal que pueda ser utilizada por diferentes tipos de usuarios dentro del ámbito de la investigación y la planificación paisajística. Por otra parte, las herramientas desarrolladas son a menudo demasiado complicadas o demasiado específicas para ser útiles en la práctica, y, en particular, en las Evaluaciones de Impacto Ambiental.

El análisis del paisaje ofrece una amplia gama de metodologías y herramientas basadas en diferentes fundamentos teóricos, y que persiguen objetivos diferentes. La decisión sobre qué metodología utilizar se toma en función de la propia definición paisaje y del objetivo concreto que se persigue en el análisis. Los estudios sobre el impacto visual de paisajes han seguido tres líneas principales de investigación: el Enfoque de Expertos, el Enfoque de Preferencia Pública y la Aproximación Holística.

El objetivo de este trabajo es desarrollar herramientas fiables y de fácil aplicación para cuantificar el impacto visual de las intervenciones humanas en el paisaje, por medio de una metodología potencialmente generalizable. Se presentan tres casos de estudio, y en cada uno de ellos se aplica un enfoque diferente. Cada investigación tiene como objetivo avanzar desde los resultados de la anterior, como complemento de la metodología, con nuevas herramientas.

En el primer estudio, se desarrolla un indicador para medir la magnitud del impacto visual de los parques eólicos, utilizando el enfoque Experto. El indicador combina medidas tangibles de visibilidad, color, fractalidad y continuidad que se puede tomar a partir de fotografías. Se construyen funciones de valor para cada variable y se incorporan al indicador. Este indicador se utilizó para calcular el impacto estético de cinco parques eólicos reales. La comparación estadística de los resultados del indicador con los obtenidos por consulta a una muestra de individuos, arroja como resultado que el indicador representa correctamente el orden de impacto según la percepción de la muestra de la población, por lo que es una medida objetiva y adecuada de los efectos visuales de los parques eólicos.

Continuando con la línea de pensamiento y los resultados de este estudio, en la segunda investigación se desarrolla, en primer lugar, un indicador similar para plantas de energía solar, y, posteriormente, se combina con un Análisis Semántico Diferencial para evaluar las variaciones en la percepción subjetiva, introduciendo así un enfoque holístico. El estudio demuestra que la combinación de uso de un indicador objetivo y un estudio subjetivo, explica fielmente las preferencias del usuario.

El tercer estudio mejora la fiabilidad de los análisis semánticos diferenciales, para evaluar el impacto visual de los diferentes tipos de intervenciones humanas, en un Enfoque de Preferencia Pública. Esta aportación se lleva a cabo mediante la incorporación del Coeficiente de Correlación Intraclase, que se aplica para validar el espacio semántico de las respuestas perceptuales y para determinar el número de sujetos necesarios para realizar una evaluación estadísticamente fiable de los paisajes.

Por último, la metodología y las herramientas desarrolladas se analizan desde la perspectiva de su confiabilidad, validez, generalización y aplicabilidad, con especial referencia a la Evaluación del Impacto Visual como parte de la Evaluación del Impacto Ambiental.

Este trabajo ha sido llevado a cabo siguiendo el procedimiento oficial para la realización de un doctorado con mención "europeo". Durante el transcurso de la tesis doctoral, la candidata ha realizado una parte de los trabajos de investigación en la Universidad de Oxford (Oxford, Reino Unido) por un período de seis meses. Por otra parte, esta tesis doctoral se ha elaborado de acuerdo con los requisitos del Departamento de Proyectos de Ingeniería de la Universidad Politécnica de Valencia (Valencia, España), para las tesis presentadas por compendio de publicaciones, incluyendo dos artículos, que corresponden a los dos primeros estudios, publicados en la revista científica *Renewable and Sustainable Energy Reviews*. Hasta la fecha, un tercer documento -relacionado con el tercer estudio- se ha presentado a la revista *Environmental Impact Assessment Review*, para su evaluación. Asimismo, el contenido del apartado de revisión de la literatura se ha publicado en el libro titulado *Visual Perception: New Research* publicado por *Novapublishers*.

Resum

El Fons de Població de les Nacions Unides ha declarat que en 2008, per primera vegada en la història, més de la mitat de la població del món vivia en pobles i ciutats. S'ha estimat que per al 2030 este número s'incrementarà al 60% de la població [1]. La creixent grandària de les zones urbanes, l'increment de població que requerix la conversió de terrenys naturals en sòl agrícola o industrial, i l'ús més intensiu dels terrenys agrcoles existents, suposen una enorme pressió sobre el territori. Com resultat, en les últimes dècades s'ha posat de manifest un creixent malestar social sobre l'estètica del paisatge. Els governs i els ciutadans estan cada vegada més preocupats per la presència visual del seu entorn quotidià, tant d'urbà com rural. Cada vegada més, el paisatge, i especialment la seua qualitat estètica, es concep com un recurs -natural i social- d'elevada fragilitat i susceptible de desaparéixer. Les construccions no planificades, els riscos ambientals i mal ús del territori han influït en la seua degradació, per la qual cosa es fa necessari definir unes directrius per a la seua conservació.

Al mateix temps, la creixent concentració de diòxid de carboni en l'atmosfera ha alertat sobre el perill i les conseqüències del calfament global del planeta. El temor d'este calfament i el fet que la producció de petroli està en el seu màxim, o prop del mateix, han portat a molts països a seguir estratègies de ”descarbonització” de les seues fonts d'energia. Les energies renovables, en particular l'energia eòlica i l'energia solar, representen una opció interessant en el camí cap a la ”descarbonització”. No obstant això, estes tecnologies s'enfronten sovint amb la resistència del públic, com a conseqüència de la seua difícil integració en el paisatge. Per això, és important que esta contestació social cap a les energies renovables siga entesa adequadament, de manera que, si es necessiten, estes instal.lacions puguen ser implantades a gran escala, sense danyar l'entorn o la percepció sobre les mateixes.

Per a protegir la qualitat visual del paisatge, és necessari entendre-ho i el primer pas per a fer-ho és per mitjà de la realització d'una Avaluació d'Impacte Visual, que té com a objecte identificar i avaluar els components físics i perceptuals del paisatge que determinen si un paisatge concret és estèticament agradable o no. En la Unió Europea, els països i les regions regulen la sostenibilitat dels seus paisatges segons la Directiva 85/337/CEE de 27 de juny de 1985, relativa a l'avaluació de les repercussions de determinats projectes públics i privats sobre el medi ambient, també conegut com la Directiva d'Avaluació d'Impacte Ambiental. Esta Directiva exigix l'avaluació de l'impacte ambiental de determinats projectes de construcció (sobretot a gran escala) abans del seu desenrotllament, per a assegurar que les seues conseqüències ambientals siguen identificades i avaluades amb caràcter previ a la seua autorització. L'impacte visual induït per l'acció humana en un paisatge és un tipus d'impacte ambiental que ha de ser considerat en l'Avaluació d'Impacte Ambiental. En conseqüència, els països i regions europees que han desenrotllat lleis de protecció del paisatge d'acord amb les Directives de la Comissió, es comprometen legalment a dur a terme avaluacions de l'impacte visual, en el marc de l'Avaluació de l'Impacte Ambiental del projecte.

A pesar del desenrotllament de ferramentes específiques per a dur a terme l'Avaluació de l'Impacte Visual, encara no hi ha una ferramenta universal que puga ser utilitzada per diferents tipus d'usuaris dins de l'àmbit de la investigació i la planificació paisatgística. D'altra banda, les ferramentes desenrotllades són sovint massa complicades o massa específiques per a ser útils en la pràctica, i, en particular, en les Avaluacions d'Impacte Ambiental.

L'anàlisi del paisatge oferix una àmplia gamma de metodologies i ferramentes basades en diferents fonaments teòrics, i que perseguixen objectius diferents. La decisió sobre quina metodologia utilitzar es pren en funció de la pròpia definició paisatge i de l'objectiu concret que es perseguix en l'anàlisi. Els estudis sobre l'impacte visual de paisatges han seguit tres línies principals d'investigació: l'Enfocament d'Experts, l'Enfocament de Preferència Pública i l'Aproximació Holística.

L'objectiu d'este treball és desenrotllar ferramentes fiables i de fàcil aplicació per a quantificar l'impacte visual de les intervencions humanes en el paisatge, per mitjà d'una metodologia potencialment generalitzable. Es presenten tres casos d'estudi, i en cada un d'ells s'aplica un enfocament diferent. Cada investigació té com a objectiu avanar des dels resultats de l'anterior, com a complement de la metodologia, amb noves ferramentes.

En el primer estudi, es desenrotlla un indicador per a mesurar la magnitud de l'impacte visual dels parcs eòlics, utilitzant l'enfocament Expert. L'indicador combina mesures tangibles de visibilitat, color, fractalitat i continuïtat que es poden prendre a partir de fotografies. Es construïxen funcions de valor per a cada variable i s'incorporen a l'indicador. Este indicador es va utilitzar per a calcular l'impacte estètic de cinc parcs eòlics reals. La comparació estadística dels resultats de l'indicador amb els obtinguts per consulta a una mostra d'individus, dona com resultat que l'indicador representa correctament l'orde d'impacte segons la percepció de la mostra de la població, per la qual cosa és una mesura objectiva i adequada dels efectes visuals dels parcs eòlics.

Continuant amb la línia de pensament i els resultats d'este estudi, en la segona investigació es desenrotlla, en primer lloc, un indicador semblant per a plantes d'energia solar, i, posteriorment, es combina amb una Anàlisi Semàntica Diferencial per a avaluar les variacions en la percepció subjectiva, introduint aix un enfocament holístic. L'estudi demostra que la combinació de l'ús d'un indicador objectiu i un estudi subjectiu, explica fidelment les preferències de l'usuari.

El tercer estudi millora la fiabilitat de les anàlisis semàntiques diferencials, per a avaluar l'impacte visual dels diferents tipus d'intervencions humanes, en un Enfocament de Preferència Pública. Esta aportació es du a terme per mitjà de la incorporació del Coeficient de Correlació Intraclasse, que s'aplica per a validar l'espai semàntic de les respostes perceptuals i per a determinar el nombre de subjectes necessaris per a realitzar una avaluació estadísticament fiable dels paisatges.

Finalment, la metodologia i les ferramentes desenrotllades s'analitzen des de la perspectiva de la seua confiabilitat, validesa, generalització i aplicabilitat, amb especial referència a l'Avaluació de l'Impacte Visual com a part de l'Avaluació de l'Impacte Ambiental.

Este treball ha sigut dut a terme seguint el procediment oficial per a la realització d'un doctorat amb menci "europeu". Durant el transcurs de la tesi doctoral, la candidata ha realitzat una part dels treballs d'investigació en la Universitat d'Oxford (Oxford, Regne Unit) per un període de sis mesos. D'altra banda, esta tesi doctoral s'ha elaborat d'acord amb els requisits del Departament de Projectes d'Enginyeria de la Universitat Politècnica de València (València, Espanya), per a les tesis presentades per compendi de publicacions, incloent dos articles, que corresponen als dos primers estudis, publicats en la revista científica *Renewable and Sustainable Energy Reviews*. Fins a la data, un tercer document -relacionat amb el tercer estudi- s'ha presentat a la revista *Environmental Impact Assessment Review*, per a la seua avaluació. Així mateix, el contingut de l'apartat de revisió de la literatura s'ha publicat en el llibre titulat *Visual Perception: New Research* publicat per *Novapublishers*.

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Chapter 1

Introduction

Society today presents two important traits: an increasing interest in construction projects, and concern for an ever more polluted environment. Any construction project, whether housing-, industrial-, renewable energies-, monumental- or for leisure, will inevitably bring about a visual effect upon the scenery in which it is carried out. In the last decades, increasing human intervention on the environment has propelled social concern of landscape degradation, and so the protection of the landscape is becoming a priority of today's governments.

The European Union's legal instrument for the protection of the environment from human interventions is the Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, also known as the Environmental Impact Assessment (EIA) Directive. The EIA Directive states that all large scale construction projects carried out within Europe, require an Environmental Impact Assessment to ensure that the possible environmental consequences generated by the projects are identified and assessed before the constructions are authorised by the competent administration. One such environmental impact, and the main topic of this work, is the visual impact generated by human intervention on the landscape.

The concept of *landscape* appears in various legal documents worldwide, in particular within the environmental sector. However, it was not until the ratification of the European Landscape Convention in October 2000, when it became a central object of these texts. Until then, legal documents had treated landscape as a secondary element in policy making. This new approach meant that explicit measures could be set out, specifically directed at its conservation. The main objectives of the Convention are to recognize the landscapes in law, and to establish and implement policies for landscape-protection, -management and -planning. To this date, 30 countries have ratified the European Landscape Convention.

Together, the EIA Directive and the European Landscape Convention have set the basis of modern landscape laws and guidelines in Europe. More and more, European countries, and particularly those which have ratified the Convention, are starting to develop exclusive landscape regulations, whether at regional or national level. Consequently, every large scale project constructed within these territories will, by law, require a Visual Impact Assessment (VIA) of the aesthetic impact generated by the project on the landscape, as part of the EIA. This legal requirement makes it essential for researchers to develop methodologies and tools to aid in the evaluation and protection of the Aesthetic Quality of the landscape.

Within the last decades, studies on landscape perception have seen exponential growth, propelled by the need to comply with legal mandates. However, there is not yet a general, unified tool which can be applied in all the countries at the same hierarchical level. Currently, each country and every region, uses its own methods to assess visual impact, basing these methods on different criteria. Different variables are being measured- all under the conglomerate name of Visual Impact- which consequently produce heterogeneous results. Given the inconsistency of the base assumptions, it becomes impossible to classify results in an orderly manner, limiting the possibility to compare them amongst each other.

The importance of devising a valid and reliable technique to measure the Aesthetic Quality of the landscape is also justified from the economics entailed of the construction projects in question. The projects which require a VIA under current regulations, are large-scale construction projects which demand substantial investments, but which can be rejected or even demolished solely due to public allegation on their visual impact.

Given the physical dimensions of the constructions and to justify the complexity entailed in the projects, the methods used in visual impact analysis to date, are costly and can be applied only by experts in the field. So is it then productive for governmental administrations to carry out extensive, difficult and costly VIAs, if different quantities are being measured and the results cannot be displayed in a general comparative scale which can be used by all?

This work will present a methodology and user-friendly tools for a valid and reliable analysis of the visual impact generated by human intervention on the landscape, which can be applied efficiently and universally. The aim being, that in the near future, an international ISO norm can be developed from the studies presented in this work, to calculate visual impact. Currently, the Spanish Association of Normalisation and Certification (AENOR) has expressed an interest in this work and discussions are underway to develop a Spanish national norm (UNE norm).

The methodology and the tools developed in the first two studies will be applied to two renewable energy construction projects, namely wind farms and solar power plants. Subsequently, another study is carried out, which seeks to evaluate the visual impact induced by different types of human interventions, such as housing, construction materials or roads. The aim of this last study is to demonstrate that the proposals made in this work can be applied with equally reliable results to further types of constructions, and not only those associated with renewable energies.

1.1 Visual Impact and Renewable Energies

Economic development has been based on access to readily available sources of energy, which are often damaging to the environment. The last few decades, however, have been characterised by growing concern about the environment. As a result, there is increasing demand for Renewable Energy which has a low, or negligible, environmental impact.

On the 12th of December 2008, the 27 EU Member States unanimously agreed on legislation to realise 20% renewable energy, 20% energy efficiency and at least a 20% drop in greenhouse gas emissions compared to 1990 levels, by 2020. To reach the 20% renewable energy target, the EU will need to increase the share of electricity from renewable energy sources from 6% in 1995, to 12% in 2010, to at least 34% by 2020 [2].

Wind power and solar power are to date, the most important contributors to the renewable energy mix in Europe. The European Commission expects wind energys share of the total EU electricity demand to increase from 5% in 2008 to 12% in 2020 [3]. Solar photovoltaic (PV) energy on the other hand, is expected to grow at an even faster rate than wind. In fact, it is the fastest-growing renewable energy technology, and costs are expected to drop faster than those of other electricity sources. If conditions are favourable and suitable measures are taken, an aggressive target has been set for the share of photovoltaics in the European electricity market to raise from 3% in 2009, to 6% or even 12% by 2020 [4, 5].

Renewable energies are encouraged primarily for their low carbon emissions. However, despite the fact that wind farms and solar PV plants are often represented as environmentally friendly projects which can also contribute to economic growth, they frequently encounter public resistance. On closer inspection, both types of construction projects are found to have significant impact on their local environment. One of the most important impacts produced by these developments is the visual impact they generate on a viewer. Both types of renewable projects have a highly artificial appearance set against a typically rural background, and require large areas of land.

Visual impact is a conflicting factor at the design and development stages of the project, as well as during and after the project lifetime. A wind farm proposal for example, can be rejected by the local communities solely due to visual purposes, and in an extreme case, an already constructed project can even be demolished and removed if it is found to affect the local population strongly. Such experiences suggest the need for a thorough analysis and evaluation of the aesthetic impact of such projects.

To mitigate and even cancel possible aesthetic impacts induced by a development, a Visual Impact Assessment, as part of the Environmental Impact Assessment, is a necessary and obligatory step in the design and execution of the project. Moreover, because landscape decisions directly impact environmental and socio-economic well-being, decision-makers find themselves under increased pressure to better justify management decisions. On these premises, this work aims to develop robust and reliable tools of Visual Impact Assessment.

1.2 Structure of this Work

How a landscape is affected by a construction project can be evaluated using different methods of analysis. Landscape analysis offers a wide spectrum of methodologies and tools which are based on different theoretical foundations, and which pursue varying objectives. The decision on which methodology to adopt is determined by the definition of landscape and the objective pursued in the analysis. This work begins with an analysis of the different definitions of landscape: Landscape as the "scenic appearance of land", landscape as a "scenic and natural resource" and landscape as a "relationship between people and place".

Studies in visual impact of landscapes have followed three main lines of investigation: The *Expert Approach*, the *Public Preference Approach* and the *Holistic Approach*. Different definitions imply different ways of understanding Aesthetic Quality of the landscape, and hence, diverging investigation objectives and results. Depending on which type of Aesthetic Quality the researcher decides to measure, the analysis will follow one approach or another.

This work describes the three analytical approaches, drawing back to examples from the literature. Evaluation tools and techniques corresponding to each approach are also listed. Subsequently, the approaches are assessed in terms of reliability, validity, generalisability and applicability.

Finally, three studies of visual impact assessment are presented, which will use Expert and Public Preference Methodologies, individually and in a combined manner, to evaluate the Objective and Subjective Aesthetic Impacts of human interventions on the landscape, with particular emphasis on renewable energies projects. The idea is to set the way forward towards a Holistic Assessment of Aesthetic Quality. Specifically, the studies will be the following:

- I The *Expert Approach* applied to evaluate the visual impact generated by *wind farms* on the landscape;
- II The *Holistic Approach* applied to evaluate the visual impact generated by *solar photovoltaic plants* on the landscape;
- III The *Public Preference Approach* applied to evaluate the visual impact generated by *general interventions* on the landscape.

The investigations carried out will present a) define a methodology and b) develop different tools for the respective analyses, evaluating them on reliability, validity and generalisability. In the first study, an indicator is developed to analyse the objective aesthetic impact of wind farms. Following the line of thought and results of this study, the second investigation first develops a similar indicator of objective aesthetic impact of solar power plants using the Expert Approach presented in the first paper, and subsequently combines this indicator with a Semantic Differential Analysis to evaluate the subjective aesthetic impact of solar power plants; thus introducing a Holistic Approach. The third study improves the subjective methods used in the second work, in a Public Preference Approach, to study visual impact of different types of human alteration of the landscape.

	Name of Publication	**Reference of Publication**	**Reference in Doctoral Thesis**
I	*Development and validation of a multicriteria indicator for the assessment of objective aesthetic impact of wind farms.*	Renewable and Sustainable Energy Reviews, Volume 13, Issue 1, Jan 2009, Pages 40-66. *Authors:* Torres-Sibille A.D.C., Cloquell-Ballester V.A., Cloquell-Ballester V.A., Darton R.	Case Study I
II	*Aesthetic impact assessment of solar power plants: An objective and a subjective approach.*	Renewable and Sustainable Energy Reviews, Volume 13, Issue 5, Jun 2009, Pages 986-99. *Authors:* Torres-Sibille A.D.C., Cloquell-Ballester V.A., Cloquell-Ballester V.A., Artacho-Ramírez M.A.	Case Study II
III	*Human alteration of the rural landscape: variations in visual perception.*	Paper submitted to Environmental Impact Assessment Review in April 10. *Authors:* Cloquell-Ballester V.A., Torres-Sibille A.D.C.	Case Study III
IV	*Analytical Approaches for the Study of Landscape Aesthetic Quality: An Underlying Structure.*	Chapter in Visual Perception: New Research, Novapublishers, ISBN: 978-1-60456-801-1. *Authors:* Torres-Sibille A.D.C.	State of Art

Table 1.1: References of the publications which comprise this doctoral thesis.

In accordance with the requirements of the Department of Engineering Projects of the Polytechnic University of Valencia, this doctoral thesis is compiled in a "publications" format, as opposed to the conventional "book" format. Two articles which correspond to the first two studies, and which have been published in the scientific journal *Renewable and Sustainable Energy Reviews*, are annexed to this document. To date, a third study has also been submitted to *Environmental Impact Assessment Review*, for its evaluation. This paper is also included in the annex. Additionally, the general content outlined in the literature review (Chapter 2) has also been published in the book entitled *Visual Perception* published by *Novapublishers*. Table 1.1 gives the specific details and references of the publications.

Chapter 2

Review of the Literature

This chapter is divided into four parts. Part I aims to give a general understanding of the European Legislation on landscape issues. It focuses on Visual Impact Assessment as a requirement of the Environmental Impact Assessment Directive. The European Landscape Convention is introduced and landscape regulatory standards of different European countries are revised, drawing particular emphasis to Spain. The remaining parts of this chapter will look at the scientific analysis of Visual Impact, presenting different ideas, opinions and studies that mould the landscape literature.

Landscape aesthetic quality analysis, as part of environmental studies, is a relatively new area of research. There is not yet a generally accepted definition of *landscape* amongst specialists. Consequently, landscape researchers are encountered with a wide spectrum of methodologies and tools which are based on different theoretical foundations, and which pursue varying objectives and produce divergent results. Part II of this chapter initiates with an analysis of the different definitions of the term *landscape*: Landscape as the "scenic appearance of land", landscape as a "scenic and natural resource" and landscape as a "relationship between people and place".

Visual Impact studies aim to measure the change in *Aesthetic Quality* of a scene, as the scene is altered. The approach taken for the measurement will differ depending on which aesthetics the researcher decides to measure. Part III will describe the analytical approaches to landscape assessment, drawing back to examples from the literature, namely the *Expert Approach*, the *Public Preference Approach* and the *Holistic Approach*.

Finally, different evaluation tools and techniques corresponding to each approach are shown in Part IV, and the approaches are subsequently compared and assessed in terms of reliability, validity, generalisability and applicability. In particular, the Indicator and the Semantic Differential Analysis are presented as Expert-based and Public-based tools, respectively, for use in landscape assessment studies.

2.1 Part I: European Landscape Legislation

2.1.1 Background to European Landscape Legislation

The European landscape is a reality that must be protected. *Landscape*, as EU legislation understands the concept, is an interactive constituent of the natural environment, and a fundamental contributor to environmental-, economic- and social-welfare [6]. This way, any harm caused to the landscape will set off a chain of negative reactions in all three domains.

The first characteristic of landscape which is perceived and evaluated by people is its Aesthetic Quality. The Aesthetic Quality of a landscape is the visual display of the quality of the territory, and triggers the first impression that is created in the mind of a viewer. The remaining features of landscape, such as its ecological diversity or its economic value are only perceived upon closer inspection, and often only by field experts. Aesthetic Quality, however, is an attribute that, inexorably, affects everyone, and for which all viewers have an opinion.

The importance of the Aesthetic Quality of the landscape, as a natural resource, for environmental and socio-economic welfare, has become indisputable amongst international institutions and experts in the field, and as human actions are increasingly modifying the landscape, social demand has grown for an evaluation of the visual impact derived from these alterations. From within the possible types of interventions brought about by humans on the landscape, this work will focus on construction projects, drawing particular attention to renewable energy projects. Nevertheless, other types of interventions such as road signalling or road works, will also be addressed, although to a lesser extent.

Human interventions, and construction projects in particular, can contribute to jeopardize the aesthetic quality of landscapes if they are carried out in an arbitrary manner. The lack of national and regional laws directed exclusively at landscape protection and landscape planning, has endorsed the independence with which local authorities have acted as regards this issue. With the exception of the Northern European countries, only within the last decade has Europe experienced joint efforts between administrations to create institutional organizations dedicated solely at landscape management and planning. Until recently, local administrations, which often lacked environmental expertise, had been deciding independently, and with a degree of randomness, on urbanisation plans, regardless of the consequences of these decisions on the neighbouring landscapes and on the environment in general.

Construction projects are regulated by the European Union, under EU Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment [7], which states that such ventures require an assessment of the effects the projects may induce on the environment, prior to their development. This assessment is referred to as Environmental Impact Assessment (EIA). Although landscape is addressed in the EIA Directive, and the EU Council expresses a general concern on its protection, the main intention of the EIA Directive is to treat the environment as a whole, addressing the landscape from a second-line perspective. However, as awareness of landscape fragility has grown stronger, institutions have become ever more conscious of the intrinsic relation between the landscape and environmental and socio-economic welfare. The landscape now has a representative body of its own (The European Landscape Convention), and progress is being made as regards legal measures.

It was not until the European Landscape Convention in 2000 when, for the first time, landscape acquired a primary status in policy making by the Council of Europe. One of the main objectives of the Convention is for its ratifying parties to recognize the landscapes in law. This new approach means that explicit measures can be set out, which are specifically directed at the protection of the Aesthetic Quality of the landscape. As a result, European countries are starting to develop exclusive landscape laws, whether at regional or national level, which require a Visual Impact Assessment (VIA) to evaluate the aesthetic impact of construction projects on the landscape, as part of the Environmental Impact Assessment.

2.1.2 The European Landscape Convention

Landscape, is not just a recreation to our visual sense, it is an environmental resource that must be preserved and protected. This is the message that the European Landscape Convention (ELC) seeks to transmit. The Convention represents the first tool at European level directed at the protection and restoration of landscape as a common asset, which until the birth of the Convention had been left in second line. It is an important step for many European countries, such as Spain, which to date, still lack legal tools to address this issue.

The ELC was adopted in October 2000 in Florence (Italy), and it came into force on the 1st of March 2004. The main objectives of the Convention are to recognize the landscapes in law, and to establish and implement policies for landscape protection, management and planning. Furthermore, the Convention also asks its signing parties to integrate landscape into regional and town planning policies, as well as to enable the general public, local and regional authorities, and other parties to take part in shaping and pursuing these policies.

To this date, 30 countries have ratified the ELC, however the Convention is not an EU's legal Act, and the Union is not a contracting Party to the Convention. The commitments that the countries accept upon ratification of the Convention are therefore not legally binding, rather the countries make a commitment to upholding the principles it contains within the context of their own domestic legal and policy frameworks. Because the Council of Europe has no legal powers over its members, the effectiveness of its conventions depends on the active use by signatories, and a state which ratifies a Convention cannot be taken to court if it fails to honour the commitments thereby made.

Landscape as Understood by the European Landscape Convention

The Convention understands landscape as comprising a physical dimension, an ecologic and natural dimension, and a subjective and cultural dimension. The inclusion of a human-related dimension means that landscape is also understood as an intangible and subjective quality, and not just a mere tangible, objective component.

Landscape is considered as a whole: it embraces the entire territory and not just those parts which exhibit prominent aesthetic qualities and are therefore worthy of preservation. Landscape is not only the protected areas of high ecological, social, cultural and economic value; landscape comprises vegetation grounds, inner and maritime waters, every-day landscapes and degraded lands. Precisely these areas which have suffered and continue to suffer the effects of human action, far from being ignored, should be the most important, because they make a living space for society. The consequences of focusing solely on the assessment and protection of high valued landscapes are dangerous, and as Lowenthal (1978) [8] observes for the American landscape, the neglect of the general in favour of a single focus of merit has badly served the American landscape, "the features most admired are set apart and deluged with attention; the rest of the country is consigned to the rubbish heap". It is therefore important to understand landscape as constituted not only by natural elements, but also by societal factors, including human perception, wellbeing and culture.

Action Items of the European Landscape Convention

Compliant with these premises, the European Landscape Convention sets action items for its ratifying parties to carry out at governmental, institutional and educational levels (Diagram 2.1). The first item calls for a compromise between the ratifying parties to recognise landscapes in law as an "essential component of people's surroundings", to ensure people's well-being and entity. The parties also agree to integrate the landscape into their regional and town planning policies and in its cultural, environmental, agricultural, social and economic policies, as well as in any other policies with possible direct or indirect impact on landscape.

The way to do this is by adopting three strategies for the prevention and/or mitigation of human alteration of the landscape: Landscape Protection, Landscape Management and Landscape Planning. Article 6 of the Convention enumerates a series of specific measures for the fulfillment of these steps. The first two are dedicated at awareness-raising, training and education of society and landscape professionals. Particular emphasis is placed on the need to train professionals and develop university courses on the subject. This way, the Convention promotes and supports proposals to introduce landscape to the university community.

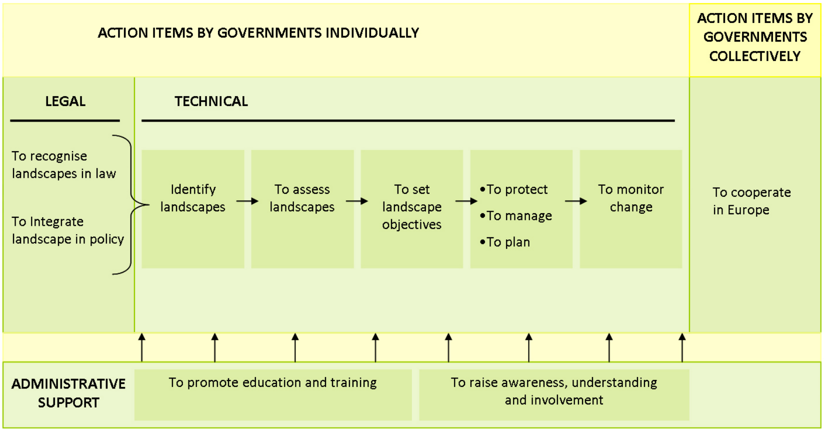


Figure 2.1: Diagram showing the schematics of the European Landscape Convention, adapted from Dower (2008) [9].

The same article identifies two further action items relevant to the investigations of visual impact assessment presented in this work: the identification of landscapes, that is to describe their character and the key elements in that character; and the assessment of landscapes, that is to analyse what contributes to, and what detracts from, their quality and distinctiveness. This is one of the major innovations of the Convention, the general idea being to determine "the type of landscape that society wants". The competent authorities have to formulate the aspirations of the public with regard to the landscape features of their surroundings as Landscape Quality Objectives. A simple, and at the same time, complex question, but also the starting point for the elaboration of landscape guidelines.

The Convention concludes by stressing the importance of European co-operation on landscape issues, that counts with sufficient flexibility to be a able to confront the totality of the pan-European landscapes.

2.1.3 Environmental Impact Assessment and Visual Impact Assessment

For the United Nations Economic Commission for Europe (1991), Environmental Impact Assessment is “an assessment of the impact of planned activity on the environment”, and Glasson et al. (1994) [10] define it as “a systematic process that examines the environmental consequences of development actions, in advance”. The purpose of the assessment is to ensure that decision makers consider the environmental impacts that arise from a construction project, in order to decide whether to proceed with the project.

The EIA of projects in Europe is regulated by the European Union Directive (85/337/EEC) on Environmental Impact Assessments [7], which was first introduced in 1985 and was amended in 2003. The revision of the EIA Directive in 2003 made it possible to incorporate certain provisions of the Aarhus Convention (1998) on public participation in decision-making and access to justice in environmental matters, in order to contribute to the protection of the right to live in an environment which is adequate for personal health and wellbeing. The public can express its opinion on the construction project, and this is taken into account in the permitting procedure. Afterwards, the public is informed of the final decision.

The annexes of the EIA Directive give guidance as to whether a project should be subject to formal environmental impact assessment under the Regulations. All types of developments are either classified as Annex 1 or Annex 2 projects. Those lying in Annex 1 are large scale developments such as motorways, chemical works, bridges, power stations, wind farms and solar plants etc. These constructions always require an EIA under the Environmental Impact Assessment Directive (85,337,EEC). Annex 2 projects are smaller in scale and include small installments and maintenance works; these are subject to a previous “screening” process which will determine whether an environmental impact assessment is required.

Under the EIA Directive, an environmental impact assessment must provide certain information to comply with the directive. Two of the key areas that are required are:

(a) the description of the significant effects on the environment, and;

(b) mitigation of the environmental impact.

One such environmental impact is the visual impact generated by the construction, which is evaluated through a Visual Impact Assessment. VIA has become a statutory requirement of Environment Impact Assessment. Large-scale construction projects, such as those dedicated to renewable energy production like wind farms and PV plants, require an EIA, and an assessment of the visual impact generated by the project on the landscape will form part of this.

2.1.4 Landscape Legislation in Europe and Visual Impact Assessment

In Europe, Switzerland, Germany and France, already have their own national laws for the protection of the landscape. The Swiss and German laws are the oldest, dating from the 1966 (Loi Fédérale du 1er juillet 1966 sur la Protection de la Nature et du Paysage (LPN) [11]) and 1976 (Bundesnaturschutzgesetz [12]) respectively. France also counts with a law [13] dedicated exclusively to landscape, which was approved in 1993, whereby the landscape has been integrated in all the norms of cultural and historical patrimony. As opposed to the German and Swiss laws, the French law makes special effort to protect "ordinary" landscapes in addition to areas of outstanding beauty.

Although national landscape laws in Europe are still scarce, in the last decade, the presence of landscape in regional regulation of most European countries has acquired more importance, including those countries that already have a specific law for the landscape. Nevertheless, regional laws are limited in their application, in the sense that they are confined to the respective territory, independently of whether the applicable areas are natural, rural, urban or peri-urban. Among the regional regulations that deal with landscape issues are those which refer to territorial planning; protection of nature; protection of cultural, architectural, and historic patrimony; protection of the water and coastal areas; the regulation of ground, town planning and architecture; and the forest and agrarian regulation. The question of Visual Impact is addressed in each one of these regulations.

Landscape competencies can be appointed to one single administration, but they can also be shared by several departments, in which case it is vital to develop efficient mechanisms of coordination and cooperation to be able to, jointly, establish objectives and the necessary tools. In general, it holds that in those countries where the landscape is related to the conservation of the nature, as is the case of Germany, it is the administration with competencies in that matter which regulates landscape issues. In other cases such as the French, landscape is dealt with directly by the department of the environment. On the other hand, in countries like the Netherlands, where the conservation of the landscape is connected to agriculture, the competent administration is the department of agriculture.

Landscape Legislation in Spain

In Spain, there does not yet exist a national law directed specifically at landscape protection and consequently visual impact protection, however, there are, although few, laws at regional level. Such laws seek to endow the landscapes with legal protection, as well as to establish the corresponding instruments for their management and improvement. Generally, these instruments include Landscape Catalogues and Landscape Guidelines, which rely heavily on the evaluation of Aesthetic Quality of the landscapes. From the autonomous communities, only the Valencian Community, Cataluña and Galicia have developed a specific law for the protection of the landscape. Nevertheless, most regions are generating landscape initiatives, such as the identification of landscapes and diagnosis of the changing factors which have affected their quality. In addition, the Spanish Ministry of the Environment has designed the Spanish Landscape Atlas, which defines the different types of landscapes in Spain according to their ecological and morphological characteristics.

(i) The Valencian Community

The Valencian Community was the first community in Spain to develop legal initiatives to incorporate the landscape into diverse sectors of public engagement. In September of 2004 the Valencian Government signed its adhesion to the European Landscape Convention, by virtue of which, the Community agreed to set up landscape policies destined to preserve the quality of the environment by means of the protection, management and planning of its regional landscape.

The Law of Territorial Planning and Protection of the Landscape (Law 4/2004, of 30 of June, of the Government, DOGV n 4788 of 02.07.04, LOTPP) was a pioneering experience in Spain as regards legislative development of the principles of the Convention within the framework of the European Union. This law incorporated the growing social concern on the landscape, raising it for the first time in Spain to a law rank.

In 2006 the law obtained its corresponding regulation (Decree 120/2006, of 11 of August, of the Government, DOGV n 5325 of 16.08.06, RPJECV), to normalise public intervention in landscape issues, and to develop instruments for its protection, management and planning. Basic concepts, criteria, guidelines and methodologies relating to the landscape have been set out and summarized.

One important outcome of the Regulation was the creation of a department dedicated, specifically, to the protection of the landscape. In 2007, the Valencian Community inaugurated the General Direction of Territory and Landscape.

(ii) Cataluña

The Catalan Parliament, by means of Resolution 364/VI, of December 14, 2000, agreed unanimously to adhere to the European Landscape Convention, and in the year 2005, it approved the Law of Protection, Management and Planning of the Landscape 8/2005. The corresponding regulation was approved in September of 2006.

In 2004, Cataluña created the Observatory of the Landscape, as an entity to support and contribute to the elaboration, application and management of landscape policies. Following the advice from the European Landscape Convention, this has developed Objectives of Landscape Quality, as a previous step to putting landscape policies into effect.

(iii) Galicia

On the 27th of March 2008, the Council of the Galician Government approved the Law of Landscape Protection of Galicia 7/2008. This way, Galicia became the third autonomous community in Spain to integrate the landscape in its legal code and in accordance with the European Landscape Convention.

Similarly to the case of the Valencian Community and Cataluña, Galicia has created a specific agency in compliance with the Convention: The Spanish Observatory of the Landscape as a unit of support and advice to the Galician Government in landscape issues.

2.1.5 Transboundary Efforts of Landscape Protection

Environmental threats do not respect national borders. European governments have realized that to avert this danger, they must notify and consult each other on all major projects under consideration that might have adverse environmental impact across borders.

The UNECE Convention on Environmental Impact Assessment in a transboundary context was signed in 1991 and entered into force in 1997. The Convention provides an international legal framework for transboundary EIA, between the Party (or Parties) of origin (States where an activity is planned) and the affected Party (or Parties) (States whose territory may be significantly adversely affected by the activity). The Convention dictates the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries.

The Convention has been amended twice, in 2001 and in 2004 though neither amendment is expected to enter into force for some time. The respective changes are to open the Convention to accession upon approval by United Nations Member States that are not members of the UNECE; and to allow, as appropriate, affected Parties to participate in scoping; require reviews of compliance; revise the Convention's Appendix I (list of activities); and make other minor changes.

Two examples of successful mandates for transboundary efforts of landscape protection, are the Benelux Convention on Nature Conservation and Landscape Protection (UNEP 1982), which was ratified in 1982 by Belgium, the Netherlands and Luxembourg, and the Mediterranean Landscape Charter, which was ratified a decade later in 1993, by the Andalusian Region (Spain), the Tuscan Region (Italy) and Languedoc-Roussillon Region (France). Both of these initiatives were aimed at regulating concerted action and co-operation among different Governments in the field of conservation, management and rehabilitation of the natural environment and landscapes. In particular they addressed issues related to the Conventions such as exchange of information, data and scientific investigation. These measures are included in Articles 8 and 9, the European Landscape Convention.

2.2 Part II: The Landscape Concept

The aim of this chapter is to provide an underlying structure of Visual Impact Assessment. An extensive literature review of over 100 investigations has revealed that there exist three types of analytical approaches to VIA, and the decision on which methodology to adopt is determined by the definition of the term *landscape*. Different definitions imply different investigation objectives and therefore different approaches to VIA. This section will review the evolution of the concept of landscape within a historical context.

Throughout history, and dating back to at least ancient Egypt, landscape aesthetics has inspired philosophers, painters, artists, landscape architects and novelists. More recently, psychologists, geographers and engineers have also offered insights into the evaluation of landscape beauty. It is evident that landscape affects every sector of society.

From the ancient Greeks to Renaissance Europe, beauty has been largely a question of aesthetics. Classical, medieval and Renaissance beliefs assumed that regularity, harmony, smoothness and symmetry were inherently pleasing. Plato argued that the beauty of an object resided in the proportion, harmony, and unity among its parts. Similarly, Aristotle defined the universal elements of beauty as order, symmetry and definiteness. The proportions of the human body or the mathematical perfection of geometric figures like the Golden Section were exemplars of beauty. The philosophical concern however, was with ”beauty” in general, and not in its particular application to landscape.

The first associations between aesthetic beauty and landscape date back to the 16th century, with the appearance of the concept *landscape*. Attitudes towards landscape aesthetics in post-Renaissance Europe, and particularly within Britain, are detailed in several works [8, 14–18]. In what follows, I have tried to give a brief summary of the flow of historic events that have determined the way we view landscape today.

2.2.1 Landscape as the Scenic Appearance of Land

The evolution of the term landscape has seen the adoption of different meanings, shaped by the social background and ideas of the time. The name landscape, in its earliest form, derives from the Dutch word *landschap* to describe a "region, tract of land". In the Netherlands of the 16th century, cradle of landscape artists, the term came to depict the area of a religious painting illustrating the setting of the drama. At that time, landscape was exclusively a painter's term. Intangible in nature, it was not something that could be attained, rather it depicted an ideal world worthy only of the superior.

Encouraged by Romanticism's worship of Nature in the 18th century, landscape became associated with the natural scenery. In this respect, a great step forward was made by Reverend William Gilpin. Gilpin traveled around different areas in England, making numerous sketches of the landscapes he saw, with the objective of discovering which parts of the countryside best represented a "picturesque" type of scenery [19]. He presented descriptive accounts of actual places, relating their physical attributes to the emotional response they aroused in him. Gilpin's work showed a strong connotation between nature and the idea of a beautiful landscape. In one of his accounts, Gilpin wrote:

"Nothing conveys an idea of beauty more strongly than the lake; nor of horrour than the mountains; and the former lying in the lap of the latter, expresses in a strong manner the mode of their combination."

At the same time, the beliefs and ideals distinctive of the Enlightenment era, began to have their effect on landscape aesthetics, and landscape came to serve as a walkway for the expression of ideas. The philosophical discussions of the time, the stimulus of the sublime and the fashion for collecting the works of seventeenth-century Dutch and Italian painters, all contributed to an urge among the aesthetic elite to try out new ideas. If one could identify the source of beauty in nature, it should be possible, by selecting only the most beautiful and eliminating the rest, to improve on nature and create even more beautiful landscapes [8]. This gave rise to the first landscape designers or landscape architects. These designers based their ideas on the works of William Kent (1684-1748). Kent modified the regular geometrical patterns which had until then dominated palace gardens, parks and avenues. He changed the shapes of paths, the disposition of trees and even the forms of ornamental water fountains, making them curvilinear to replicate the natural lines of the landscape. Appleton [17] describes these designs as:

"an accommodation between art and nature, in which each made the maximum concession to the other, and the result was a harmonious blend of the landscape components."

Throughout the 18th and early 19th century, gardening and architecture, influenced greatly by Romanticism, were the dominant ways of manipulating the physical environment for aesthetic purposes. Scenic touring and viewing became a popular pastime for the wealthy, encouraged by the advancements in transportation technology which facilitated travelling.

With the rise of an industrial society, migration from the countryside began, towards cities with their wealth and opportunity, but also with their grinding factory toil and social problems. As a result, people in an urban setting tended to look back to their rural roots with wistful longing for a quieter and simpler life, irrespective of the reality of what rural labouring had actually been like. In the twentieth century personal mobility and leisure greatly increased, so that people attained the ability to return to the countryside for rest and recreation. Landscape had ceased to be a Platonic ideal worthy only of the rich, it became something at everyone's reach, something that could be attained, touched and moulded to desire.

2.2.2 Landscape as a Scenic and Natural Resource

Aesthetics and nature have long been associated in the human mind. However, the artistic sense to beauty always predominated. The intellectual movement of the 19th century brought about new scientific ideas and with them, the distinction between aesthetics as understood by scientific knowledge and aesthetics as understood by the arts.

Darwin's (1809-1882) contribution to environmental sciences and aesthetics cannot go unmentioned. Darwin studied natural beauty in terms of striking phenotypic features of nature, such as flowers, a peacock's tail or animal courtship behaviour. He believed that aesthetics is a scientific phenomenon present in the natural environment, in particular in the flora and the fauna. That the features and behaviour of these organisms are an exemplar of the meaning of beauty. According to Darwinian theory,

"beauty is a promise of function in the environments in which human evolved, i.e. of high likelihood of survival and reproductive success in the environments of human evolutionary history. Ugliness is the promise of low survival and reproductive failure." [20]

This form of biological aesthetics has become a major research area in the last 30 years. Despite this however, beauty as an environmental concern to wider sectors of society is a more recent topic, although it maintains connections with these traditions [21]. In fact, Darwin already draws attention to the idea that environmental beauty is a consequence of human behaviour. In an environment affected by human action, beauty is the likelihood of survival and reproductive success.

The 20th century set a landmark in environmental awareness. Rachel Carson's *Silent Spring* [22] inaugurated the environmental movement in 1962. The book alerted the general public to the dangers of chemical pesticides to plants, animals and particularly to humans, making people think about the environment in a way they had never done before. In 1964, the Wilderness Act [23] was passed in the United States, establishing a process for permanently protecting fragile areas of wilderness from development.

Landscape acquired a more ecologic and geographical meaning: it was now regarded not only as a scenic, but rather a physical-natural resource, whose beauty derived from the dynamic relationship between the natural phenomena. Of particular importance here is how the environmental movement transformed the concept of landscape from landscape as a mere entity, to landscape as an entity of jeopardized existence, i.e. landscape as a 'resource'. Landscapes have so much scenic as ecological qualities, and these are ephemeral if treated deficiently.

Today, the Oxford Dictionary still understands landscape in its artistic sense. Landscape is defined as "inland natural scenery, or its representation in painting". Similarly, the Dictionary of the Royal Academy of Spanish Language, defines the term as "extension of territory viewed in its artistic sense". Yet, landscape seems to be much more than mere inert physical factors placed on canvas. Indeed, it appears to be other than just an artistic, unreachable entity; it is the product of natural systems interacting, while it itself is life-endowing [24].

2.2.3 Landscape as a Relationship between People and Place

Whichever point of view is adopted whether artistic, or environmental, there seems to have been a subconscious connection between landscape aesthetics and human sensitivity, ever since brush touched canvas in the Netherlands of the Renaissance. In 1940, a Spanish author wrote:

"Landscape is us; landscape is our spirit, its melancholies, its placidities, its yearnings" [25].

Throughout history, human sensitivity to landscape beauty has been present in the works of different disciplines. From Greek philosophers, to Renaissance artists, to Reverend Gilpin, landscape designer Kent and Darwinian science. Geographers too have not been oblivious to the influence of landscape aesthetics on human psychology, and even Humboldt in 1805 noted:

"A man sensitive to the beauties of nature will find in the study of plant geography the explanation of how the appearance of vegetation influences the taste and imagination of people... What is the psychological cause of the sensations?" [26]

Landscape's ability to evoke feelings is nowadays generally accepted. In addition, the effects of human action on landscape aesthetics are also acknowledged. However, it was not until the end of the last century, that landscape attributes were officially associated to human activity. With the adoption of the World Heritage Convention in 1972 [27], which recognised the existence of cultural landscapes, a new dimension was incorporated to the concept: landscape as a human habitat. With this, a relationship between the landscape and the people was established. The landscape became a system displaying physical-natural resources which interacted with social and economic issues, and which generated different reactions in the observer. This synthesis is well expressed by the definition given by the European Landscape Convention:

Landscape *"means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors."* [6]

2.3 Part III: Approaches to Visual Impact Analysis

The first classifications of landscape evaluation models identified two primary paradigms, the Expert line of investigation versus the Public Preference line of investigation [28–38]. The expert approach assumes that scenic beauty is inherent in the landscape itself- that a landscape may have certain characteristics which make it project a scene of better quality than others. These characteristics are found by objective categorisation and evaluation of the landscape's emitted attributes, and the analysis is carried out by a group of experts on landscape issues. Crudely speaking, the expert analysis represents a means of landscape *valuation*, where the objective of the analysis is to produce a ranking of the different landscapes. The Public Preference Approach on the other hand, believes that "beauty lies in the eyes of the beholder" [31], that a viewer does not judge every attribute individually and sums the results up to assess the total scenic beauty as would be the case in expert valuation, instead, scenic beauty is appreciated by the viewer as the composition of the scene as a whole. This analysis believes that landscape attributes interact with the viewer's feelings, experiences and life, such that for each scene the viewer searches for a meaning associated to the landscape. The observer processes the scene as a whole and makes judgements of the landscape according to his/her feelings. In other words, the viewer *evaluates* the landscape in its entirety, as opposed to *valuation* of individual landscape components.

Zube et al. [37] have carried out the most extensive analysis on evaluation approaches, analysing over 160 articles published during the period 1965 - 1980. They were probably the first to officially recognise on paper the existence of a line of investigation which appreciates the strengths of both expert and public preference approaches, and their possible synergic effects when combined. The fusion of the two theories seeks a perceptual characterisation of the landscapes by judging and ranking them. This is what this work will refer to as landscape *assessment*.

The literature provides different types of categorisation of landscape assessment models, depending on the theoretical basis assumed by the researcher. Zube et al. [37] distinguish between four paradigms: the expert paradigm, the psychological paradigm, the cognitive paradigm and the experiential paradigm. This division was the outcome of a human-landscape-interaction model. Daniel and Vining [38] also based their classification on this relation and came up with a list of five types of models: the ecological model, the formal aesthetic model, the psychophysical model, the psychological model and the phenomenological model.

Analytical approaches have also been classified in other ways. Differences can reside in an underlying objectivist-versus-subjectivist theory [28–31], or may depend on the measurement techniques used by the researcher [32–34], or may be due to a philosophical confrontation between activists, humanists, planners and experimentalists [35, 36], or may be the result of a combination of these factors [37, 38].

	Expert Approach	**Public Preference Approach**	**Holistic Approach**
Definition of Landscape	Scenic and natural resource	Relationship between people and place	Relationship between people and place
Definition of Aesthetic Quality (AQ)	An intrinsic physical attribute of individual landscape components	How the observer experiences the landscape in its entirety	A combination between the AQ of landscape components and public experiences of the landscape
Definition of Visual Impact (VI)	The degree by which the intervention changes the physical attributes of the landscape	The degree by which the intervention changes the viewer's experiences of the landscape	The degree by which the intervention changes the physical attributes of the landscape and the viewer's experiences of the landscape
Method of Analysis	Landscape Valuation	Landscape Evaluation	Landscape Assessment
Landscape Appraisers	The experts	The public	The experts and the public

Table 2.1: The Approaches to Landscape Analysis.

In this work, I will distinguish between three general approaches to landscape analysis. At one end of the spectrum lies the *Expert Approach*, at the other end of the spectrum, the *Public Preference Approach*, and finally, combining both methods, the *Holistic Approach*. The three lines of investigation all seek to determine the Aesthetic Quality of a given landscape, however, the difference lies in how Aesthetic Quality is understood by each approach. This in turn, will depend on the definition of landscape that the researcher seeks to adopt. Do landscapes have an objective beauty which may be measured or compared, or is scenic beauty a value that can only be attributed to a landscape in a subjective manner? What is more, can it be both? This way, the type of approach taken in the analysis will vary, depending on whether scenic beauty is considered objective, subjective, or a combination of both.

Table 2.1 summarises how each approach understands the concept *landscape*, the respective definitions of Aesthetic Quality of the landscape, and how each method is applied in landscape analysis.

2.3.1 The Expert Approach: Landscape Valuation

The Expert Approach evolves from the definitions of landscape as the scenic appearance of land, and as a scenic- and natural resource. To think of landscape as a scenic- and natural resource implies that any analysis derived from this assumption may be performed in a purely objective manner, contrary to that based on the definition of a landscape which assumes interaction with the observer's cognitive process.

This approach is based on two assumptions: first, that Aesthetic Quality is an intrinsic physical attribute of the landscape and second, that the Aesthetic Quality of a landscape results from the combination of the Aesthetic Quality values of its individual components. In other words, this type of analysis examines the physiology of a landscape, classifies its components and appoints them values according to some pre-established scale which, when combined, will give rise to the total Aesthetic Quality of the landscape. The Expert Approach thus adopts the following definition of Aesthetic Quality:

Aesthetic Quality *of a landscape is a characteristic inherent in the landscape, derived from the combination of the Aesthetic Qualities of the individual landscape components.*

(a)

(b)

Figure 2.2: Picture of a (a) lake, (b) an irrigation channel.

The major impetus for systematic analysis and study of scenic and natural values occurred during the decades of the 1960s and the 1970s. Legislation enacted during this period directed attention to the identification and management of scenic resources. Natural resource management agencies and the increasing scientific interest, stimulated considerable research on methods for Landscape Aesthetic Quality Analysis.

The primary aim of Expert based analysis is to devise ways of measuring physical attributes of the landscape to reflect visual quality [37]. This process is carried out by skilled and trained landscape specialists, in a procedure which generally involves verbal or numerical categorisation of the landscape parameters by means of descriptive inventories. Inherent in this approach is a strong connection to an ecological way of thinking [31]. Landscape preferences that are found to be contrary to good ecology are deemed unethical, immoral or the result of inadequate ecological sophistication [29, 39]. Thus, within this approach, there seems to exist a directly proportional relation between Ecological Quality and Aesthetic Quality: the higher the Ecological Quality of the landscape, the higher its Aesthetic Quality.

Figure 2.2 presents a simplified example of an analysis based on the Expert Approach, according to which the landscape with the lake depicted in Figure 2.2(a), has greater Aesthetic Quality than the landscape with the irrigation channel in Figure 2.2(b), because it has more water and contains abundant vegetation. The experts create an inventory of the components of the lake versus the components of the irrigation channel and assign a value of Aesthetic Quality of each component. Finally, the total Aesthetic Quality is calculated and compared.

Examples of Expert Analysis

Valuation studies usually depict the landscape in maps or photographs, although other means of representation are also possible, and divide it into a mesh of squares. For each square, landscape features are assessed and the square is assigned a score. The sum of the scores for the total grid represents the value of the landscape. Repeating the process for various landscapes enables their comparison such that the area with the highest score is considered the landscape of highest value, i.e. the better landscape.

Early studies assessed landscape quality of certain regions based on ecological value [40], land form and land use pattern [41, 42], landscape features [43], or mere professional judgements [44]. These studies were however not directly concerned with visual impacts, rather they sought to assess the quality of the landscape to derive Landscape Quality Objectives.

Lewis [43] was pioneer in creating inventories of natural and cultural landscape features. In 1964, he mapped over 200 landscapes resources, which included water resources (waterfalls, lighthouses), wetland resources (wildlife preserves), topographic resources (caves, ski trails), vegetation resources (virgin timber), historical, cultural and archaeological resources, wildlife and tourist service facilities. The more features that appeared on an area of land, the higher the quality of the landscape, and the more it needed to be protected. Lewis called these areas, "nodes of diversity". He suggested that instead of fighting for one particular scene, one should protect and enhance the areas that contain a variety of features and values that need to be protected.

Other inventories include Leopold's [40] work. Leopold differentiated landscapes by a "uniqueness ratio". He set out a primary assumption which stated that "a landscape which is unique either in a positive or negative way is of more significance to society than one which is common". Implicit in this assumption is the idea that aesthetic value is primarily a function of ecological criteria. The overall uniqueness index was constructed by adding individual uniqueness ratios of 46 landscape components like water depth, faunal content or environmental degradation and recovery rates. In fact, 40 out of the 46 components were ecological rather than aesthetic attributes. Experts evaluated each of the components according to their uniqueness on a five-point scale, and uniqueness ratios were calculated by comparing the individual value for a site with the frequency of values in that category for all the sites under consideration.

Because Leopold's method relies on expert judgement, reliability of the model is vulnerable to variations and inaccuracies in individual judgement. The validity of the results could be tested by having a number of experts independently assess the same landscape areas, but this has not been done. What is more, a major underlying assumption is that landscape quality is directly related to ecosystem integrity. However, this assumption has not been tested either.

Fines [44] proposed a method designed to give some kind of metric against which to judge landscape and hence minimise variability. He established a scoring scale by having 45 experts grade the scenic quality of 20 views from various parts of the world. The scores of 0 to 32 were divided into six descriptive categories: unsightly (0-1), undistinguished (1-2), pleasant (2-4), distinguished (4-8), superb (8-16) and spectacular (16-32). Fines finally produced a map showing the landscape quality of East Sussex (UK), for which a single expert was asked to evaluate different views of this county, on-site, against the test scale views.

Linton [41] recognised the importance of Fines's metric system, however he criticised that the method was not only "highly demanding of landscape labour", but it also lacked "a good deal of experimentation to establish a satisfactory test scale", arguing that the panel of observers was "rather small", and that there was no logical basis for the (partly) geometric scale of numerical values attached to the six categories.

Linton proposed a grid-square method to assess scenic quality based on the ranking of six landform types and nine land-use landscapes. Landform landscapes were evaluated according to the height of the topographic relief, to give a ranking from hills (5 points) through upland plateaux (2 points) to lowlands (0 points). Land-use landscapes on the other hand were ranked with regard to land use and diversity, e.g. "urban" ranked 0, whereas "water contribution" ranked 5. A simple algebraic summation of scores for landform and land-use landscapes, gave the final ranking of that area in the map, which in turn reflected the scenic quality of that particular territory.

Crofts and Cook [45] compared Linton's technique with Fines's method and concluded that the former "was more reliable, less complex and more practical". However, this technique is also subject to criticism. In a similar manner to Leopold's [40] work, Linton takes for granted that natural landscapes are preferred to more man-made landscapes. He also assumes that diversity is more attractive than uniformity. Such assumptions however, require empirical verification.

Few authors have offered empirical or theoretical justifications for their lists of basic concepts in landscape appraisal. Litton [42] recognised this apparent lack of justification and devised a model similar to Linton's ranking method.

He devoted a large amount of work to explaining the categorisation of the landscape, and trying to make it concrete enough to be instrumental. As a result, the author classified a landscape into six types (panoramic, feature, enclosed, focal, forest and detailed), based on factors such as form, space and observer position. He also suggested the application of three other criteria (unity, vividness and variety) to make aesthetic evaluations. Unfortunately, Litton devoted negligible effort to justifying and measuring these three criteria, as compared to his definition of the six landscape types.

The US Forest Service developed the first widely used visual assessment system in 1974 [46], the Visual Management System (VMS). The VMS is a methodology which assesses and maps landscape quality through categorical classification schemes that are based on Litton's six landscape types. The Bureau of Land Management later in 1980 generalised the aesthetic criteria used by the VMS into a procedure of making professional appraisals in scales of high, medium or low, of 4 qualities (form, line, colour and texture) inherent in 3 landscape components (land/water, vegetation and structures) [47]. Over the years, more qualities (e.g. line, variety, unity) have been added to the list, and these are widely referred to as formal design parameters. The VMS was typically used by landscape architects to evaluate and map specific areas, as an aid to landscape managers. Similarly to Linton's technique, the parameters contained in each square are assigned a score, and the sum of the scores for the total grid represents the value of the landscape. Repeating the process for various landscapes enables their comparison such that the area with the highest score is considered the landscape of highest value and of better quality.

Although the efficiency of the models listed above as regards time and applicability remains undisputed (with the exception of Fines's experiment), these models are not exempt of criticism. Arthur et al. [32] comment on the inappropriate use of data manipulation. For example, individual components are combined to provide a value for one landscape tract whereas interaction of components is sometimes more important than the separate effect of the individual components. In addition, Dunn [24] notes that typically, ordinal scales are applied to start with and it is then proceeded as if the scales were interval or ratio, by employing a standard arithmetic summation. In such a case, the use of statistical techniques would be more reliable [48].

In this sense, the Coventry-Sulihull-Warwickshire (CSW) team was the first to propose an expert-based measurement technique based on statistical methods [49]. Data on three landscape classes- landform, land use and land features -was collected. Two experts made an evaluation of these elements on-site, for each landscape tract. The weights of each element were calculated by step-wise multiple regression with the landscape features as the independent variables and landscape quality as the dependent variable. This technique was applied a year later in a different study, by a different administration and on a different British county, and the two evaluations correlated "fairly strongly" [50].

Even though statistical techniques can increase the validity of the results, it is often alleged that they are difficult to apply and time-consuming, which opposes to the general belief that expert-based systems should be time-efficient and wherever possible, easily applicable. Hence their use in expert valuation, particularly as regards their application by the administration staff, has been limited. Further and more recent examples of standard arithmetic summations applied in an expert approach include studies by The English and Scottish Countryside Commissions [51–53].

An alternative tool for VIA which combines the strengths of the arithmetic procedure and the strengths of statistical evaluation measures is the indicator [54–57]. A properly built indicator can offer a quick, easy and reliable means to quantify specific aspects of the landscape. Indicators typically take the form of a weighted sum, which is ideally the result of a statistical analysis, for example multiple regression, or an Analytical Hierarchy Process (AHP). Although the background mechanics of an indicator may be complicated, the end user is faced with a simple weighted sum, which is easy to understand but which at the same time is scientifically rigorous. Such an indicator can help to study the effects of individual landscape components, as well as their combined effects to facilitate evaluation and comparison of possible outcomes of a set management alternatives. The indicator as a tool for Visual Impact Assessment is discussed in more detail in section 2.4.2.

2.3.2 The Public Preference Approach: Landscape Evaluation

At the other end of the approaches spectrum lie the Public Preference models. Based on public subjective assessments of landscape quality, the essence of this approach resides in its definition of Aesthetic Quality. The Public Preference approach is founded on the idea that Aesthetic Quality is an attribute derived from the eyes of the beholder, rather than inherent in each landscape component [36]. The environment is seen as a total process, involving the participation of all aspects simultaneously, where man and his environment become inseparable [58].

The Public Preference Approach believes that a landscape does not just have a purely visual effect, rather a landscape interacts with the viewer's feelings and experiences. For each scene the viewer searches for a meaning associated to the landscape, and each individual will perceive a landscape differently depending on the emotions that the landscape evokes on him/her. The methodologies based on this approach therefore aim to investigate the feelings, expectations and interpretations that a scene, in its entirety, evokes in the observers.

Looking back at the previous example (Figure 2.2), the Public Preference Approach does not necessarily consider the landscape with the lake of greater Aesthetic Quality than the landscape with the irrigation channel. Rather Aesthetic Quality will depend on the observer viewing the scene. For example, an observer can prefer a scene with an irrigation channel because it reminds him/her of happy moments of his/her childhood. In other words, "Aesthetic Quality lies in the eyes of the beholder".

The question asked by Public Preference methods to determine the Aesthetic Quality of a landscape is therefore "What does the observer think of the landscape?" as opposed to "How much is the total Aesthetic Quality of the landscape, and how much does each individual component contribute to the total Aesthetic Quality?". This way, the definition of Aesthetic Quality of a landscape adopted by the Public Preference approach is purely psychological:

Aesthetic Quality *of a landscape is how the observer experiences the landscape.*

Examples of Public Preference Analysis

The Public Preference Approach argues that the best source of data for the evaluation of landscape aesthetics is the general public, as opposed to experts. The public is, after all, the one who finally experiences and lives the landscape [59]. Public-based research therefore requires the use of survey and psychological scaling methods. Non-quantitative as well as quantitative methods or techniques are available for sampling scenic preference. Questionnaires, verbal surveys and detailed personal interviews are made to the general public as part of the former, while tallying of verbal communications is prominent in quantitative assessment. Preference is used in these studies as an independent variable to assess the quality of the landscape.

A number of questionnaires for environmental assessment have been developed, such as the Environmental Personality Inventory [60], the Environmental Response Inventory [61], or the Environmental Preference Questionnaire [62]. In general, the aim of these questionnaires is to identify sources of satisfaction and patterns of preference pertaining to environmental settings, amongst different types of population. For example, the Environmental Preference Questionnaire consists of six questions or areas of concern such as "social issues relevant to the observer", which are subdivided into different items like "population", "inflation" or "environmental decline". The respondents are asked to indicate where they fall on a six-point scale for each one of these items. Responses are then analysed through factor analysis and hierarchical cluster analysis, and the results are compared with one another. Several studies have documented on the utility of these type of surveys in predicting environmental behaviour, especially as regards differentiation between population types. Interesting results can be derived from environmental questionnaires. For example, using McKehnie's [61] Environmental Response Inventory, Kegel-Flom [63] showed that optometrists migrated to urban locations.

Questionnaire results can provide an evaluation or assessment of landscape quality by indicating subject preferences. The responses can either take the form of written summaries or descriptions, or as graded scores. Verbal descriptions are often criticised because they do not provide clear thresholds of visual quality, or because they cannot represent landscapes as directly as numerical evaluation. Quantification of survey responses can be done in two forms. On the one hand, checklists may be created that include terms such as large, open, or colourful. In this case the number of observers checking each trait indicates how strongly a landscape evokes the feeling or reaction. On the other hand, a stimulus is presented to the observer, who evaluates it on an ordinal scale.

One of the most influential examples of the latter type of research within landscape literature, is the Scenic Beauty Estimation Method developed by Daniel and Boster in 1976 [64]. Colour photographs of various landscapes are shown to 20 different subjects who are asked to grade the landscapes according to their scenic value on a scale from 1 (extremely low scenic value) to 10 (extremely high scenic value). Scenic Beauty Estimates (SBE) are calculated for each observer of each scene, and the values are averaged to produce the SBE for the entire landscape. Subsequently, the authors undertake reliability and validity tests on this method which appear satisfactory. However, these tests are undertaken in relatively homogeneous areas. Would the results be valid for different landscape types? Furthermore, no attempt is made to identify the landscape components that influence the judgements, therefore it is unlikely that the technique can provide much information to predict the SBE unless a survey is carried out, and this is time-consuming. This is precisely one of the aims of the Holistic Assessment, namely to establish relationships between specific landscape components and public preferences.

Different procedures are used for showing the scenes to the subjects and obtaining their judgements. Daniel and Boster require the observers to assign a specific value to the scenes, whereas in other experiments, subjects are asked to choose the landscape they prefer from a set of scenes, or order the scenes from most preferred to least preferred. Generally, a relatively large sample of observers- usually over 15 subjects -is used and their individual scenic quality judgements are combined to produce an overall preference index. This index, whether a percentage, an average rank or a mean rating, translates directly to an estimate of the aesthetic quality of the landscape which is being evaluated.

Much of the research based on the Public Preference Approach aims to evaluate an observer's preference for a landscape, whereby emphasis is placed on the cognitive and affective reactions evoked by the landscape. A high-quality landscape will evoke positive feelings, such as security, relaxation, warmth or happiness. On the other hand, a low-quality landscape is associated with stress, fear or gloom [38].

Experiments have shown that it is possible to describe the total perception of an environment by a limited number of meaningful dimensions. Those dimensions will also be referred to as “concepts” in this work, and can be defined and measured separately. Osgood et al. [65] showed that dimensional analysis was possible through semantic evaluation. The Semantic Differential technique initially associated people’s preferences for a general environment to the E-P-A (evaluation, potency, activity) dimensions. The authors had however some difficulty in measuring the dimensions in a unitary way for different types of environments. Küller [66] later limited this area to an architectural environment and obtained eight dimensions by means of factor analysis. The use of Semantic Differential Analysis as a tool to evaluate subjective reactions on ordinal scales, is of particular importance to this work and will be discussed in further detail in section 2.4.3.

The influence of later studies has resulted in the incorporation of new dimensions to the original E-P-A semantic analysis. Acking and Sorte [67] used Küller’s [66] concepts in landscape analysis, although these authors focused primarily on the concept ”coherence”. Other studies, on the other hand, have included dimensions from Kaplan’s work [68–75].

Steven Kaplan has provided one of the most symbolic contributions to Public Preference Analysis with the development of the *Informational Model*. Kaplan demonstrated with his model that there are four psychological constructs which are important predictors of human preference, namely “coherence”, defined as the degree of order and organisation within the scene, “legibility”, defined as the simplicity of the view, “complexity”, defined as the diversity of the scene, and “mystery”, defined as the promise of new information. Herzog [76–80] and Gimblett [81] have demonstrated that Kaplan’s dimensions, especially “mystery” and “coherence” are particularly useful for urban landscape design.

Once the researcher selects the dimensions which he/she wishes to analyse for the landscape in question, the subjects are asked to rate a set of scenes with regard to preference for the scene, and evaluate that scene on each dimension. A factor analysis of these ratings can be used to reorganise the stimuli with regard to higher order composite factors. For example, it was found that the feeling of “mystery” was greater for natural scenes than for urban scenes, where “natural” and “urban” are the higher order composites.

Relationships between the different dimensions can also be investigated to define dependencies. For example, results show that naturalness is a relevant characteristic of the landscape [82, 83], and that it is positively correlated to its aesthetic quality [68, 84]. Ulrich [85] found that landscapes which are judged to be more beautiful are also more relaxing. Real et al. [83] on the other hand, suggested that there exists a dependency between “artificiality” and “happy” and “alive”.

There are various difficulties when carrying out evaluations based on public opinion. Little is known about the basis for differences in group preferences. The few studies that have included disparate groups of participants, have provided contradictory results. It has been found that the personality of the observers [86], age [87], culture [88, 89], socio-economic profile [90, 91], professional bias [92] can explain some of the differences in landscape preference.

However, Brush et al. [93] show that group differences will largely depend on the type of landscape being studied. For example, they analysed differences in the enjoyability of 800 people of different gender, age and profession, in driving through rural landscapes in Wisconsin, and deduced that for that specific situation, neither age, nor gender, nor professional experience accounted for variations between in the ratings. Instead, results showed that some of the variation could be attributed to knowledge regarding land management practices.

Similarly, Kwok [94] points out that there is possibly a similarity between the preferences of different cultures for visual environments. Kwok used Küller’s semantic scales and sample of architectural and landscape slides to obtain data from Chinese students in Singapore and British professionals in London. Semantic factors identified for both groups were nearly the same as Küller’s factors for Swedish subjects [66], which indicates striking similarities across different cultures as regards perceptual response.

2.3.3 The Holistic Approach: Landscape Assessment

The first holistic landscape studies appear in the US in the 1960s. Within Europe however, Holistic Assessment arises in England two decades later as a result of a change in the conceptualisation of landscape. Although landscape is still regarded primarily as the visual appearance of the land and an essential part of our natural resource base, a new dimension has been included: the meaning derived by human cognition from visual landscape features. In addition to scenery, landscape has now acquired meanings related to emotions and experiences.

Growing environmental concern on the destruction of various English, and European, landscapes within the wider countryside played an important role in the introduction of Landscape Assessment methods. If up to then, only landscapes of high quality had been protected, now all the countryside mattered, and so, because all landscape was equally important, the question was not so much to decide whether an area was better than another, but rather to determine the differences between those areas. The political developments of the time gave rise to the Bruntland Report (1987) on sustainable development [95] and the European Landscape Convention was established later in 2000 [6]. Landscape was to be regarded as an integrated part of our living system; as a relationship between people and place. Expert-led approaches to landscape analysis were no longer viable on their own; landscape was now also formed through perception. Indeed, nowadays there is an increased emphasis on landscape assessment through stakeholder involvement.

The Holistic Approach thus emerges from the combination of objective and subjective methods, and is represented by psychophysical models [37, 38]. This type of investigation argues that Aesthetic Quality of a landscape is the combination of visible features of the landscape interacting with psychological processes in the human observer; that Aesthetic Quality is both physiological and psychological, in other words, it is a psychophysical characteristic of the landscape. This is illustrated in Figure 2.3.

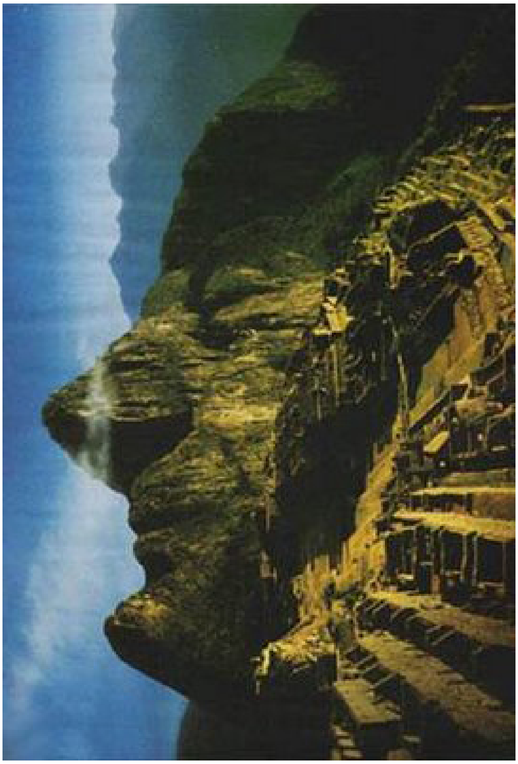
Figure 2.3 shows a landscape of a lagoon. The Public Preference Approach sees a couple looking over at the horizon; a beautiful landscape indeed, one which evokes feelings of love, serenity and happiness. However, experts will analyse landscape forms and features and value the water in the lagoon, and the tree and vegetation surrounding the lagoon. The Holistic Approach argues

Figure 2.3: Picture of a lagoon... or a baby?

that Aesthetic Quality is a psychophysical attribute, that so much physical as psychological attributes should be accounted for. Forms and features are examined first. Amongst others, these convey the figure of a baby depicted by the tree trunk and the tree branches. The Public Preference Approach then takes this figure and translates it into emotions. The result: Part of the beauty of a landscape which initially displayed a tree, a lagoon and a loving couple, is derived from the maternal and parental feelings it evokes.

Figure 2.4 gives another example. It shows the Macchupicchu in Cusco, Perú. The Expert Approach would value the Aesthetic Quality of this landscape highly for its elements of vegetation and wilderness. Public Preference viewers would admire the majestic remainders of an ancient civilisation. The Holistic Approach would take both these aspects into account: it would value the landscape so much for its nature as for its history and culture, and it would try to determine relationships between these features and public emotions. Additionally, careful examination of landscape forms will convey the profile of a face depicted by the mountain boundary, and the initial feeling of awe experienced by the viewer evolves into feelings of mystery.

(a)



(b)

Figure 2.4: (a) Picture of the Macchupicchu, Cuzco, Perú, (b) Picture of the Macchupicchu rotated 90 degrees anticlockwise, which conveys the profile of a face depicted by the mountain boundary.

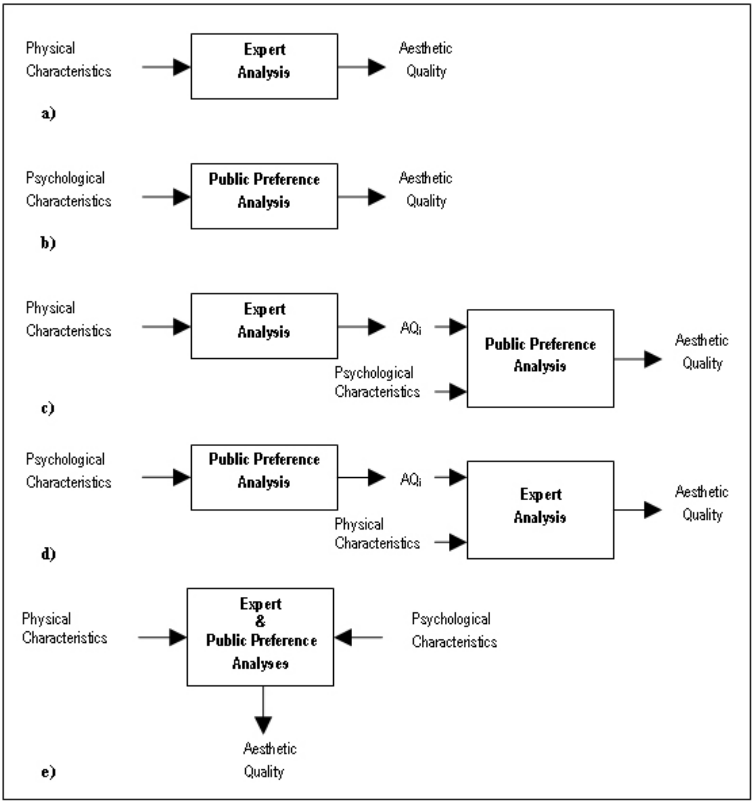


Figure 2.5: Approaches to VIA. Aesthetic Quality as understood by a) the Expert Approach, b) the Public Preference Approach, c) the Holistic Approach with physical initial inputs, d) the Holistic Approach with psychological initial inputs, e) the Holistic Approach with physical and psychological inputs.

Figure 2.5((c), (d) and (e)) explains the mechanics of the holistic process in a diagram. Physical characteristics of a landscape are identified and fed into an expert analysis which will give an initial value of Aesthetic Quality (AQ_i). This value is then imported into a public preference analysis. The result of this second analysis, given the AQ_i input, is the final Aesthetic Quality of the land under examination. A similar process occurs for the case where the initial input consists of psychological characteristics of the observer.

The questions asked in this approach to determine the Aesthetic Quality of the landscape are, "What does an observer think of a landscape of a given initial Aesthetic Quality (AQ_i)?" and "Given an observer's opinion of a landscape (AQ_i), what is the landscape's Aesthetic Quality?". Other analyses aim to find a relationship between landscape attributes and overall landscape preference. Research on how a certain landscape feature, or the combination of several features, affects perceptual judgement can point towards a measure of aesthetic quality. If that feature or a combination of various features affects the person positively, then the aesthetic quality of a landscape incorporating that feature is more positive than another landscape which exhibits negatively-affecting features. It follows that Aesthetic Quality for the Holistic Approach is:

Aesthetic Quality *of a landscape is a combination between the Aesthetic Quality of landscape components and public experiences of the landscape.*

Examples of Holistic Analysis

The Holistic Approach emerges from the combination of both Expert- and Public Preference- Approaches. It uses measurements of physical landscape features to predict people's preferences for the overall visual quality of landscapes [38,96,97]. Landscape features are classified and rated (validation) and are compared to overall landscape preference ratings (evaluation) to measure the contribution of particular components to the scenic beauty of the entire image. Statistical techniques, such as multiple regression analysis (whereby multiple linear regression is the most commonly used technique in holistic analysis [98]) are used to determine mathematical relationships between the physical features of the landscape (land cover, land use, forest stand structure, water, vegetation, etc.) and the psychological responses (judgements of preference) of human observers.

Holistic-oriented models include the Scenery Management System (SMS) [99] (developed from the expert-based Visual Management System (VMS) [46] by introducing perceptual assessment techniques) and the Explanation of Visual Assessments (EVA) model [98, 100]. Both models incorporate a computerised system which covers tasks ranging from inventory, valuation, evaluation and design of aesthetic components for landscape management.

Originally, holistic experiments focused on forest management practices. One of the first research studies to propose a holistic approach to VIA was that of Shafer et al. [101] in what they called, the *Landscape Preference Model*. With their work, the authors aimed to identify parameters of aesthetic quality, and quantify their effect on public preferences, to facilitate decision-making procedures. In introducing their method, they state, "by knowing what quantitative features in a landscape affect its aesthetic appeal, natural resource planners can make decisions on factual basis about purchasing, developing, or preserving these features." 100 photographs of diverse rural and wilderness landscapes were analysed in terms of 46 different variables. 250 respondents were chosen at random and each individual was given 4 packets of five photographs each, which they had to rank in order of preference from 1 to 5. Factor and multiple-regression analyses were undertaken and six independent variables were found to account for 66% of the variation in preference scores. These variables were: perimeter of immediate vegetation, perimeter of distant vegetation, perimeter of intermediate non-vegetation, area of intermediate vegetation, area of any kind of water and area of distant non-vegetation. Six field tests were carried out to test the predictive capabilities of the model in different parts of the US, and a statistically significant correlation was found between observed and predicted preferences in five of the tests. This results have been further substantiated by research conducted in Scotland by Shafer and Tooby [102] with preference ratings correlating very highly with ratings obtained from the American subjects ($r = 0.91$).

In general, efforts have been made to either assess a single type of landscape variation, like the area of insect damage to a forest [103], or a set of variations, such as differences in the areas occupied by trees, their sizes, their distribution, the skyline, light density or light direction [104]. In this case, Arthur [104] found that observers preferred areas with heavy grown canopies, because they were more vivid. Favourable responses to clouds and distinct contours were also noted, whereas rocks and slash seemed "dominating" and were therefore related to negative scenic evaluations.

Landscape variables can be defined by the amount of items of the same variable, such as trees per acre which are less than 20 inches in diameter [105], or by the size of the area they occupy in a photograph, like the area of a picture which is covered by the sky, vegetation, water or clouds or mountains [101, 106, 107]. Buyhoff et al. [107] also investigated the effect of sharp contours with respect to the area covered on the photograph. These authors showed that the quality of a scene improves with the area occupied by sharp mountains. However, a point is reached after which too much of the landscape covered by sharp mountains decreases pleasantness ratings and makes the scene less preferable.

Since the 1990s, and particularly in the last decade, holistic studies have moved from the assessment of forest management practices, to more general landscape management. Researchers have started to search for additional relationships between observer preferences and different types of land-use or land-topography [108, 109], as well as man-made structures [110, 111]. For example, Arriaza et al. [108] found that the perceived visual quality increases, in decreasing order of importance, with the degree of wilderness of the landscape, the presence of man-made elements, the percentage of plant cover, the amount of water, the presence of mountains and the colour contrast. Holistic models have also shown that naturalness in landscapes is highly dependent on the presence of artificiality in the area, which is itself of low aesthetic value. On the other hand, water [109,112], abundant vegetation [113] and colour contrasts [108] can increase the pleasantness of a scene and therefore its Aesthetic Quality of a landscape.

Similarly to the Public Preference Approach, observer perceptions may be expressed in several ways, such as pair-wise comparisons [107], rating scales [64], Q-sorts [114] or rank orders [115]. Tahvanainen and Tyravainen [116] performed pair-wise comparisons of 29 different scenes to examine the effect of specific amounts of afforestation. They showed that in highly preferred areas, it is important to preserve the balance between field and forest areas. This would instigate landscape managers to promote an aesthetic balance between agriculture and forestry.

Multiple linear regression predominates in Holistic analysis as a means to determine dependencies between the landscape variables and subjective preferences. In essence, this technique calculates the weightings to be applied to a set of predicting variables to give the best approximation to the effect of the predicted variable to Aesthetic Quality. Other models used to predict and explain scenic preference include paired comparisons combined with sorting and ranking scales, and multicriteria analysis [32].

Multiple regression is limited on theoretical grounds in the number of weightings that may be calibrated. Landscapes are composed of many different features which can themselves be defined in many different ways. In addition to this, various subjective emotions must also be taken into account. Therefore, the ten or so variables that are typically inputted in multiple regression analysis, remains quite a small number to represent the complexity of landscape perception. In this respect, recent developments in holistic analysis include neural network training to enhance the efficiency of the experiment [117]. The utility of neural networks lies in their ability to work with a large amount of data, to enable closer modelling of a complex landscape system. To this date however, research on neural network analysis applied to landscape management practices remains at a very early stage.

To end this section, I would like to emphasise the advantages of this approach. Holistic models relate scenic beauty to physical landscape characteristics, making it possible to estimate the cost of each landscape feature on subjective preference and aesthetic quality. This, in turn, can facilitate preservation, mitigation and enhancement of scenic beauty in terms of management inputs. It is therefore not surprising that Zube et al. [37] describe the Holistic Approach as "emerging as the dominant research dimension".

2.4 Part IV: Measuring Visual Impact

This work understands the Visual Impact (VI) of an intervention on the landscape, as the degree by which the intervention changes its Aesthetic Quality. This definition implies that to calculate the VI of an alteration, it is necessary to establish comparison methods to determine differences in AQ before and after the change. Whereby Aesthetic Quality, depending on the approach taken, can be characterised by purely physical attributes of landscape components, the viewer's experiences of the landscape, or a combination of the above. Therefore, Visual Impact can be described as:

$\boldsymbol{VI}_{ExpertApproach}$ *is the degree by which the intervention changes the physical attributes of the landscape.*

$\boldsymbol{VI}_{PublicPreferenceApproach}$ *is the degree by which the intervention changes the viewer's experiences of the landscape.*

$\boldsymbol{VI}_{HolisticApproach}$ *is the degree by which the intervention changes the physical attributes of the landscape and the viewer's experiences of the landscape.*

In general, landscape research has concentrated primarily on the evaluation of the Aesthetic Quality, rather than of Visual Impact. In such cases, studies which have attempted to calculate the VI, have ended up determining if the AQ of the landscape is high or low, whereas from the above, it is more appropriate to measure if the AQ is higher or lower than originally. In other words, the Visual Impact is proportional to the *change* in Aesthetic Quality (Figure 2.6), and this is the definition this work will adopt.

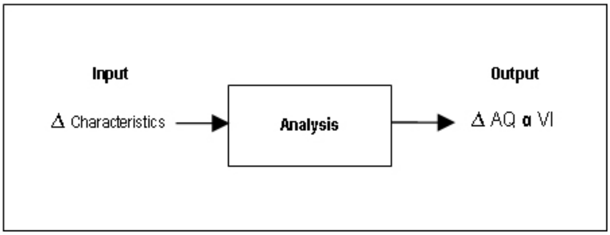


Figure 2.6: The process of analysis to determine VI. A change in the input characteristics results in a change in AQ, which is itself proportional to VI.

2.4.1 Visual Impact Magnitude and Visual Impact Perception

This section will give a brief review of the terms *Visual Impact Magnitude* and *Visual Impact Perception*, to set a basis for the development of the tools that will be used in this work.

Visual Impact Magnitude - Objective Component of Aesthetic Impact

The degree to which an object affects its surroundings is named impact significance. Two basic criteria of impact significance are the *magnitude* of the impact and its *spatial extension* [118]. It is important to distinguish between these two criteria. Magnitude refers to the difference in visual quality induced by placing the object in the landscape. Conversely, spatial extension means the physical extent of the impact, which will vary depending on the viewshed. In visual impact studies, the magnitude often includes the spatial extension, i.e. the degree of visibility.

The literature is proficient with studies on the extension of a visual impact [119–122], however impact magnitude as a separate characteristic of visual impact, and particularly its application to renewable energies is still limited. The purpose of this work is to quantify the magnitude of a visual impact, however, it is considered important, if at least informative, to give a previous summary of the methods that are used to determine the spatial extension of a development's visual impact.

Methods to calculate the extension of a visual impact

The extension of an impact is calculated by measuring the visible area of the object in question from different viewpoints (e.g. close-up, medium and far views) or from specific locations of visual importance to neighbours and tourists, such as scenic drives or picnic sites [123]. The visibility of the object will depend on the effective or visual distance between the observer and the object, as well as on the observer's viewshed. The larger the distance, the smaller the visible area and the smaller the impact. In addition, if the observer is located such that there are no obstacles (e.g. vegetation) lying between the him/her and the object, i.e. the viewshed is optimal, then the object's visibility is maximum and so is the impact.

Traditional techniques use photographic analysis of the area in question from different viewpoints. More recently, Geographic Information Systems (GIS) have been developed to offer the possibility to visualise relationships across time and space and to explore more comprehensive perspectives. Miller et al. [124] use GIS to determine visual impacts at different locations taking into account the distance depth cueing and the size perspective, the angle of intersection of the view with the terrain, and the land cover. With the application of this method, the authors show that the impact of afforestation in generally low because it tends to be below the horizon and blends in with the dark texture of the mountains.

Zones of Visual Influence (ZVI) and Viewpoint Analysis are two of the most common techniques for the analysis of the extension of a visual impact. The ZVI is a map-based method used to define the area of visibility (the view envelope) of a proposed development. It was originally developed by Tandy [125] and can be carried out manually, although this has been largely superseded by view area analysis software such as VIEW suite [126]. Viewpoint analysis commonly uses two- or three-dimensional representations of the landscape before and after the development has taken place. The key viewpoints are identified and agreed between the experts and the local planning authorities.

The extension of an impact is calculated in combination with magnitude-related variables, because visibility can be affected by features of the object or of the space between the object and the observer. For example, the colour and the texture of an object can help it blend in more or less with the surrounding landscape [127]. In a similar manner, the atmospheric conditions [119] can diffuse the visibility of the development.

This section will conclude with a brief summary of the procedure which is followed in Visual Impact Assessment as part of an EIA. The aim is to provide an overview of how and where the data which is obtained from the measurements, is used. Once the project is described, it is proceeded to describe the surrounding landscape. The viewshed is determined and a simulation of the project in the environment, whether photographic or computer-based, is carried out. This simulation will help identify and evaluate the possible impacts, and it will also facilitate the proposal of protection and correction measures. There is no generally accepted methodology, nor tool, used to determine the value of the impact, and it is up to the evaluator to decide which to adopt.

Visual Impact Perception - Subjective Component of Aesthetic Impact

The magnitude of the impact can be established through an objective evaluation of the physical characteristics of the impact. In contrast, whether a visual impact is positive or negative is determined through cognition; it is the observer viewing the intervention and processing the information who decides whether the impact is approved of, or not. Hence, determining the approval of a visual impact requires a subjective investigation of the viewer population by subjective opinions. The Sematic Differential method [65, 128] is applied in this work to study the viewer's feelings and emotional reactions towards the intervention.

Semantic Differential Analysis relies on public polls and surveying, which are qualitative reports. The evaluations are therefore, in truth, ordinal qualitative variables. However, because the scales have several point values and there is a large number of data, these variables can be approximated to quantitative variables. Hence, it is possible to use the same treatment for qualitative and quantitative variables [129–131].

2.4.2 The Indicator as a Tool for Expert Valuation

One way to evaluate the landscape and its components is by means of quantifiable indicators [55]. The word "indicator" derives from the Latin word "indicare", which means to show, to point out, to estimate or to assign a value. From the Latin definition, it can be deduced that the indicator can act as a tool for making numerical measurements.

For the Spanish Ministry of Environment, an environmental indicator is *"a variable which has been granted an additional meaning by society to the one derived from its on scientific configuration, with the aim to reflect, in a synthetic manner, a social concern of the environment, and insert this concern in the decision-making process in a coherent manner."* [132]

On the other hand, Mac Gillivray and Zadek stress the functions and advantages of an indicator as something that helps to understand where we are situated at a specific moment, and whose evaluation enables us to know the direction we are heading in [133]. Because indicators can give information of specific phenomena, they can help us prevent, anticipate and find solutions to particular problems.

Given these definitions, we can consider an environmental indicator to be any measurable parameter, or a value derived from parameters, of the natural medium that informs us of the condition of the medium, or of aspects related to it, with a significance extending beyond that directly associated with a parameter value [134].

Environmental indicators are widely used by the different administrations, governments, non-governmental organizations, community groups and research institutions to see if environmental objectives are being met, to communicate the state of the environment to the general public and decision makers and as a diagnostic tool to detect trends in the environment and to report on progress towards sustainable development.

As opposed to qualitative assessment of an impact, numerical evaluation is desirable because of the straightforwardness with which it can be used in Environmental Impact Assessment. If the indicator is developed such that it can be easily understood, its main advantage lies in its applicability and, as for the majority of expert-based models, the use of indicators is much less time-consuming.

In addition, indicators are based on inventory models which facilitate comparison of results and of individual component weights. These are especially useful in problem related research, particularly for landscape planning and management. Furthermore, by employing the same set of indicators over time, later indicator-based assessments can be compared with previous ones, providing more consistent coverage from one evaluation time-interval to another, and the indicator values can be compared at different intervals.

Optimally, indicators should be designed to translate complex information in a concise and easily understood manner in order to represent a particular phenomenon. Often however, indicators become too complicated, or too specific to be useful in practice. For example, they may require data that are not readily available, or incorporate subjective attribute judgements that are very difficult to quantify.

Mac Gillivray and Zadek are of the opinion that while the primary aim of an indicator is to measure something, its crucial role is in communication. These authors suggest that "good indicators will communicate information that is not only accurate, but also resonant for the intended audience. A 'good' indicator is one which achieves a judicious balance between accuracy and resonance." They also point out that the balance is difficult to achieve: indicators that are technically accurate (what they call 'cold' indicators) are often complex to interpret and therefore fail to reach a wider audience. On the other hand, 'hot' indicators that "strike a chord with their audience" are often rejected as lacking scientific rigour by technicians.

With regards to VIA of wind farms and solar plants, a limited amount of work (Bishop [135], Álvarez-Farizo and Hanley [136], Hurtado et al. [137], Möller [138, 139], Bishop and Miller [140], and Rodrigues et al. [141]) has been reported. Most of this work merely enumerates factors that influence the aesthetic impact of the projects. What is more, the majority of these studies have concentrated on analyses of individual attributes, thus assuming that the aesthetic impact depends solely on one single factor. On the other hand, this work understands that the aesthetic impact of a wind farm can be described by the collective effect of a set of components acting simultaneously.

Hurtado et al., Bishop, Möller and Rodrigues et al. analyse the visibility factor from the point of view of the *extension* of the impact, and not from an impact *magnitude* side. The authors work with visibility coefficients or indexes to represent the area of the wind farm that affects the nearby population. For example Hurtado et al. calculate different visibility coefficients of the wind farm for separate villages. These coefficients are then corrected by the effective distance or proximity, between the farm and the villages, and by the respective population coefficients. Similarly, Möller and Rodrigues et al. carry out an analysis of visual impact extension. Möller includes a calculation of the turbine density (i.e. the number of turbines in the farm), and Rodrigues et al. generate a visual perception estimation coefficient based on the distance to the nearest population, which aims to give an idea of the impact perceived by the viewer. However, the latter authors do not state how they derive the value function, nor do they clearly define what aspect of the impact is linked to perception- is it the magnitude, or the unpleasantness? In any case, it is evident that so much the variables as the coefficients and the value functions are derived by experts.

Bishop and Bishop and Miller highlight the importance of parameters which describe the intensity of the impact as well as its spatial extension, such as visibility, colour contrast and motion. The calculations include a combination of these variables, and photographs, computer simulations and interviews are used in their approach. However, although rigorous, the procedure is difficult to understand and is therefore of limited use.

In summary, a literature review of studies on landscape assessment reveals that there is currently no comprehensive system of visual impact indicators, particularly as regards the magnitude of the aesthetic impact generated by wind farms and solar plants. There is clearly a need for field professionals to be able to quantify the visual impact generated by changes in the landscape with an easy-to-use, readily available general formula.

2.4.3 Semantic Differential Analysis as a Tool for Public Preference Evaluation

Differential semantics is a Public Preference technique used to analyse the affective meaning of objects and proves particularly suitable to a type of problem in which the aim is to measure the overall impression of an environment [128]. It measures public preferences without influence of the researcher's personal preferences. And because it uses statistically significant measures, it is analytically highly reliable. Furthermore, it offers an easily interpretable means of conversion of qualitative arguments into quantitative evaluations which proves especially useful for Visual Impact Assessment as part of EIA, where impacts are evaluated quantitatively wherever possible.

Differential semantics is one of the most commonly used methods to assess product perception. Applications of this tool include kitchens [142], car interiors [131], mobile phones [143], footwear [144, 145], loudspeakers [146] and other products. Similar techniques such as the Differential Emotions Scale (DES) by Izard [147], or the Free Labeling Method by Jinwoo et al. [148], do not measure the direction of the subjects' answer. In contrast, differential semantics not only identifies divergences and their directions, but it also establishes in which concepts they appear.

Nevertheless, this methodology presents some restrictions that need to be addressed. Semantic evaluation of a product is a subjective technique which relies on perceptual responses and thus results are influenced by the subjects taking part in the evaluation. This way, unless the subjects are selected according to a very specific profile, inter-subject variability is expected and results should be interpreted with care. The most commonly used measures to search for consensus amongst subjects are statistical techniques based on the measurement of the standard deviation. However, as argued by Alcántara et al. [144, 145], although these techniques are statistically correct, they only measure an average value of the scores on each concept individually, without taking into account, that a certain quality of the subject, or a specific event, may additionally affect his/her evaluation of the other concepts. These authors introduce the Intraclass Correlation Coefficient (ICC) which embraces the disturbances arising in the global semantic evaluation and increase the reliability of the semantic differential study [144, 145].

Differential Semantics has been applied primarily in the context of product-perception, rather than environment- (and particularly *rural landscape*) perception. Studies have successfully applied this technique to evaluate different types of products as well as architectural interiors [131, 145, 149, 150]. However, its application to rural landscape analysis is still limited [67, 83]. Recent use of this technique for landscape assessment includes works by Lim et al. [151], Natori and Chenoweth [152] and Singh et al. [153]. The positive findings of these works provide a basis for landscape perception studies, and encourage the use of Differential Semantics in future landscape research.

2.4.4 Data Collection and Representation

Landscape appraisal can be carried out on-site and/or off-site. Analysis of the landscape on-field requires the presence of the evaluators, whether experts or the public, which can be costly and time-consuming. Because of this, the number of field observers is often kept to a minimum thereby constraining the validity and reliability of the results [45, 48, 154].

An alternative to field-analysis are the surrogate methods. These use different tools to represent landscape off-site, such as slides, photographs, videos or more recently, Geographical Information Systems (GIS). While the first tool has been shown to be the less valid one [155], the remaining options provide equally reliable information and valid results (Photographs: [64, 156–158], Videos: [93, 155, 159, 160], 3D Computerised assessment: [161–163] , GIS: [110, 164–168], or Coupling 3D visualisation systems with GIS technology [169]). However, photographic representation predominates in landscape analysis because it is less time-consuming, it requires lower levels of expertise, and information can be easily extracted from the pictures [155]. Moreover, they endow the researcher with better control and the possibility to perform quick comparisons between pictures [83]. Nevertheless, it is important that the photographs are taken with caution: they must adequately depict most of the variations of natural and man-made environments [170, 171].

Finally, to facilitate the evaluation based on photographic input, Wherrett [172, 173] and Roth [174] have proven that the internet provides an effective and reliable medium to undertake visual preference surveys, although particular parameters have to be respected such as the graphic format (GIF preferable to JPEG) and colour resolution (8 bit Visual Display Units are sufficient). On the other hand, the display size does not affect the results [172].

2.4.5 Advantages and Disadvantages of the Approaches

The necessity for landscape aesthetic quality analysis is evident. Part III of this chapter showed that current research methods can be categorised under three analytical approaches, namely the Expert Approach, the Public Preference Approach and the Holistic Approach. However, these approaches are not exempt from limitations. Feimer et al. [175] indicate that the quality and utility of any model used in landscape research will depend on its *reliability*, *validity* and *generalisability*. The following section (Part IV) looks at each research approach in turn, drawing on its advantages and disadvantages with respect to these three points, and the results are summarised in Tables 2.2. 2.3 and 2.4. The definitions for reliability, validity and generalisability are taken from Feimer et al. [175]:

Reliability *Consistency and precision of measurement; in visual resource and impact analysis: the degree to which a measure accurately reflects variations among landscapes and landuse conditions.*

Validity *The degree to which a measure represents the construct or variable of interest; in visual resource and impact analysis: validity provides an estimate of the degree to which a method is able to capture meaningful variations in the aesthetic quality of the landscape and to depict the impact of landuse activities upon them.*

Generalisability *Specification of the conditions for which the attained levels of reliability and validity are representative; in visual resource and impact analysis: factors which could constrain the generalisability of reliability and validity coefficients, e.g. physiographic landscape and landuse conditions, background characteristics of observers, media of presentation of landscape and landuse conditions, the extent of landscape and landuse information available for visual resource and impact analysis users.*

In addition to these three measures, the approaches will also be analysed with respect to their *applicability* in Visual Impact Analysis, where applicability is understood as:

Applicability *Ease with which the analysis can be undertaken by its user.*

Advantages of the Expert Approach

Expert evaluation models multiplied in the 1960s, and have been widely used in the field of landscape Aesthetic Quality Analysis. The main advantage of this methodology lies in its applicability. Expert-based tools such as inventory models, check lists or indicators, aim to give numerical results rather than verbal responses. Quantification in turn, facilitates comparison of results and of individual component weights, so that results are easily interpreted. What is more, clear impact thresholds can be established, which is especially useful for problem related research, such as landscape planning and management. Additionally, Expert-based models are much less time-consuming, and often more economical than methods involving public surveys.

Professional judgement, as opposed to public reactions, may also help prevent the use of unaesthetic and unhealthy treatments [104]. In a study on landscape vegetation, Cook [59] carried out a public enquiry whereby the subjects were asked to rate scenes showing different vegetation patterns. The subjects, who were oblivious of the diseased state of a group of trees, voted them as more picturesque and preferred them over more healthy trees. The study by Cook reveals that experts may be aware of features that are not apparent to the observing public, and can therefore come to a different, and perhaps better founded judgement, through their additional expert knowledge.

Disadvantages of the Expert Approach

It is widely argued throughout the literature that even though the expert approach claims to be highly objective, it does in fact possess a notable amount of subjectivity in its core, because the experts are, after all, people subjectively selecting and opining on the different criteria. Sometimes, as is the case of Cook's [59] experiment with disabled trees, empirical evidence contradicts professional judgement. Certainly professional judgements will be made as objectively as possible, but nevertheless, a certain amount of subjectivity will indeed be inherent in any of these decisions. As Crofts and Cooke [45] describe, the objectivity of their application and their precise, often quantitative results, disguise their underlying subjectivity.

The scales themselves, against which valuations are made, have been previously established by human judgement. And they are certainly not exempt from limitations, for not only do they cover a very limited range of landscape appraisals (e.g. three in VMS case, and five in SMS), but very few authors have actually offered empirical or theoretical justifications for their choice, for example Linton [41] and Litton [42].

The success of such an analysis depends largely on the reliability of the inputs on which they are based. It is not surprising thus, that the way in which landscape components are arbitrarily identified and the lack of empirical research to justify the inclusion of these abstract design parameters as determinants of scenic quality has also been criticised [41, 45]. What is more, several studies have questioned whether these components are at all relevant measures of landscape Aesthetic Quality [32, 176].

Other critics have pointed at an incorrect manipulation of data in expert models [177]; combinatorial functions are used when statistical techniques are more reliable, particularly for such cases where very few experts (often only one) are employed [24]. This leads to significant variations of aesthetic quality values between different groups of experts, and so, often, quality values can vary as much between different experts as between different landscapes.

Finally, analysts have also questioned the ecological intentions of expert analysis. Because this approach identifies the specific physiological components of a landscape which make it better than another landscape, and since these components are usually ecologically-based attributes of the landscape, it seems that expert assessments are good only as long as landscape quality assessments support ecological objectives [29, 31].

Advantages of the Public Preference Approach

Even though professional judgements can help prevent the use of unaesthetic treatments, it is ultimately the non-professional public who evaluates, and thus analyses based more on public input may be preferable. Such models seek to measure public preferences without influence of the researcher's personal preferences. Because they use statistically significant measures in the analysis (e.g. a statistically significant amount of people), the models are analytically highly reliable. This way, variation between landscapes can be several orders of magnitude greater than among observer's judgements [178, 179]. Indeed, even the reliability of Aesthetic Quality measures based on small to moderate sized groups of respondents (5 to 30 subjects) has consistently been very high [180–185].

Furthermore, due to the precise interval scale measures, it is possible to distinguish between landscapes that exhibit only small differences in visual characteristics [156, 182, 186]. An important consequence is manifested in the methodology's generalisability: this approach makes it possible to determine preferences for very divergent categories of landscapes and divergent demographic groups.

Disadvantages of the Public Preference Approach

Public preference models are not only costly and time consuming because of the large numbers of responses that are often required for statistically significant results, but the danger of manipulation of preferences as well as bias in questionnaire responses and analyses often obstructs their reliability [45]. For example, when asked to indicate their preferences for various landscapes, observers tend to apply criteria for use of those areas (recreation, residence, etc.) rather than for inherent beauty [44, 187, 188]. The experimenters themselves are also in danger of influencing the viewers responses, and so they must be very careful to choose the correct wording.

The Public Preference Approach has identified interpretable and reliable semantic domains that serve to predict and explain visual preferences for various types of landscapes, for example the works of Osgood et al. [65], Kaplan [68–74] or Küller [66]. However, the results of these research efforts have not been integrated into a more comprehensive assessment system [72, 189]. In order to be understandable and usable by resource managers, assessment procedures have had to be relatively simple and, therefore have been unable to include the assessment of complex psychological systems with more dimensions.

Advantages and Disadvantages of the Holistic Approach

The Holistic Approach combines the advantages of Expert and Public Preference Approaches. Expert based models have been criticised for untestable assumptions and subjectivity disguised by objectivity [38, 175]. In fact, as Ribe [190] argues, quantitative methods are not a substitute and only means for measuring aesthetic quality, but rather supplementary instruments for more effectively exploring and substantiating relations among aesthetic qualities. Psychophysical systems in contrast, incorporate stakeholder opinion in addition to expert knowledge. Substantial relationships have been demonstrated between landscape components and public preferences, which is particularly useful for construction projects and necessary in Environmental Impact Assessments.

Models based on this approach are "firmly are grounded in measurement theory and empirical testing of assumptions" [182]. Studies have shown that they are very sensitive to subtle landscape variations [92,97,103,156,191,192], and psychophysical functions have proven very robust to changes in landscapes and observers [38].

Holistic models provide a consistent descriptive system which can be applied to analyse a wide variety of landscape types and landscape components, as well as relationships between these and public perception. Relating scenic beauty to physical landscape characteristics, facilitates estimation of the cost of each landscape feature on aesthetic quality as perceived by the end user. This way, landscape management can derive appropriate measures of landscape preservation, impact mitigation and enhancement of scenic beauty.

All in all, holistic models have been highly reliable. However, there is still room for improvement as regards cost, time consumption, and the number of variables that can be analysed. For this, the author suggests the application of neural network technology. Advances are being made (e.g. Mougiakakou et al. [117]), although its use in VIA is still at a very early stage.

2.4.6 Conclusion

Landscape aesthetic quality analysis, as part of environmental studies, is a relatively new area of research. There is not yet a generally accepted structured theory to landscape analysis. Consequently, landscape researchers are encountered with a wide spectrum of definitions, methodologies and tools, which pursue varying objectives and produce diverting results.

No analytical approach on its own can deal with all types of problems of landscape aesthetics. Depending on what is to be studied, one methodology may be more appropriate than the others. The chapter has presented three general approaches to landscape analysis: the Expert Approach, the Public Preference Approach and the Holistic Approach. An assessment of these approaches with respect to reliability, validity, generalisability and applicability, has shown that where the Expert Approach is at a disadvantage, the Public Preference Approach presents an advantage and vice versa.

Expert-based models are particularly strong in applicability, however, often, they lack theoretical and/or scientific justification for the choice of visual impact parameters and scales, which makes them lose out on reliability and validity. Public preference systems on the other hand are particularly reliable due to the statistic foundations of their analyses. However, survey-based input makes them costly and time-consuming. As regards generalisability, both types of models can be adjusted to suit different objectives. For example expert models can apply ratio-based calculations, and public opinions can be analysed for demographic discrepancies. Because the Holistic Approach combines elements of both methodologies, it can make use of their advantages for an optimal analysis of Landscape Aesthetic Quality.

	Expert Approach	**Public Preference Approach**	**Holistic Approach**
	Advantages	**Disadvantages**	**Advantages and Disadvantages**
Applicability	Cost-efficient. Less time-consuming than other approaches.	Costly. Time-consuming.	Although time consuming, this approach can be less costly than public preference analysis.
	Results are easy to understand. The contribution of each component can be weighted. Ranking facilitates comparison. Results can be easily incorporated into managerial decisions.	Results are hard to understand. Weighting is not possible. Comparison is difficult.	Evaluation of results is difficult, but weighting and comparison are possible through the expert part of the analysis.
Reliability and Validity	Professional judgements prevent unaesthetic treatment.	Unaesthetic treatments possible.	Professional judgements prevent unaesthetic treatment.
		Discrepancies between individual averages and group averages.	Accounts for individual and group averages.

Table 2.2: Advantages and Disadvantages of the Analytical Aproaches with respect to Applicability, Reliability, Validity and Generalisability

	Expert Approach	**Public Preference Approach**	**Holistic Approach**
	Disadvantages	**Advantages**	**Advantages and Disadvantages**
Reliability and Validity	Subjectivity presented as objectivity; objectivity influenced by researcher's preferences.	Measures community preferences without influence of the researcher's personal preferences.	Genuine objective evaluation of the subjective.
	Analysis typically carried out by 1 person; AQ varies between different experts.	Analyses carried out for a statistically significant number of people.	Analysis carried out for a statistically significant number of people and precise interval scale measures make variation between landscapes of several orders of magnitude greater than among observers' judgements.
	Limited range of AQ values; no changes in AQ over a substantial range of land management options.	Precise interval scale measures; it is possible to distinguish between landscapes that exhibit only small differences in visual characteristics.	
	Variation between landscapes is often same order of magnitude as among observers' judgements.	Variation between landscapes is several orders of magnitude greater than among observers' judgements.	
	Often inappropriate data analysis.	Reliable statistical analysis.	Reliable statistical analysis.
Generalisability	Determination of preferences limited to specific landscape typologies.	Preferences can be determined for divergent landscape typologies.	Preferences can be determined for divergent landscape typologies.

Table 2.3: Table 2.2 continued

	Expert Approach	**Public Preference Approach**	**Holistic Approach**
	Disadvantages	**Disadvantages**	**Disadvantages**
Reliability and Validity	Data inconsistency; lack of theoretical and empirical justification for the choice of language, landscape components and scales.	Danger of manipulation during questionnaire creation and analysis. Danger of manipulation of the observer's responses. Danger of bias and inaccuracy in survey responses.	Possibility of dangers of inconsistency, manipulation and bias if theoretical and empirical justifications are not made.

Table 2.4: Table 2.3 continued

Chapter 3

Justification of the Research

3.1 Justification of the Topic

The European Landscape Convention (2000) defines landscape as:

> *"an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors."* [6]

This definition suggests that the landscape concept should be considered in terms of environmental, economic, and human/societal domains. Landscape is the result of the interrelation between these three domains (Fig. 3.1), and any harm induced on it will set off a chain of negative reactions in all three domains. Visual impact falls primarily within the human/societal domain, because it affects the perception of a human being, which in turn can affect the economics of a region through the stimulation of tourism for example. In a similar manner, a construction may be moved from an extremely visible location to another location, more fragile to the flora and the fauna, thereby endangering the surrounding natural environment.

Society values the landscape in three different ways: from a scientific and cultural point of view, a landscape is valued for its ecological diversity, its rarity, and for the landmarks inherited from history and culture; from a utility point of view, it is the functionality of the landscape that counts; finally there is the visual appeal, which is a question of aesthetics. Alone the integral value that landscape has for society, should be reason enough to encourage visual impact studies in order to protect and manage the landscape, and design successful construction plans.

The first characteristic of landscape which is perceived and evaluated by people is its Aesthetic Quality. The Aesthetic Quality of a landscape is the visual display of the quality of the territory, and triggers the first impression that is created in the mind of a viewer. The remaining features of landscape, such as its ecological diversity or its economic value are only perceived upon closer inspection, and usually only by field experts. Aesthetic Quality, however, is an attribute that inexorably affects everyone, and for which all viewers have an opinion.

The growing social unease of the aesthetics of the European landscape, is manifested in the substantial development of landscape mandates throughout the past decade. Governments and citizens are becoming ever more concerned with the visual display of their everyday environment, both urban and rural. More and more, landscape, and particularly its Aesthetic Quality, are conceived as a resource - natural and societal -, highly fragile and capable of disappearing. Un-planned constructions, environmental hazards and bad usage of the territory, have influenced to its degradation, and so it becomes necessary to define conservation guidelines for its protection and conservation.

To protect the visual quality of the landscape, it is necessary to understand it, and the first step to do so, is by carrying out Visual Impact Assessments, which aim to identify and evaluate physical and perceptual landscape components that determine whether a particular landscape is aesthetically pleasing or not. With this information, governments can set priority lists of sites and regions that should be preserved as part of the natural and cultural heritage.

A construction project will distort the existing aesthetic equilibrium of the landscape factors, bringing about a change in visual perception. Within the EU, countries and regions which regulate the visual sustainability of their landscapes, set their visual impact policy according to the European Commission's Directives, which requires Visual Impact Assessments for large-scale construction projects prior to their development. Smaller projects too may be subject to EIA, if the screening procedure considers it necessary.

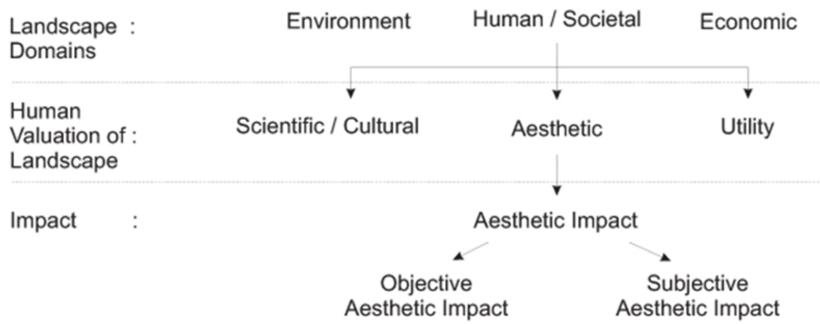


Figure 3.1: Landscape and Aesthetic Impact: The figure shows the three landscape domains. In bold are the issues of interest to this work. Aesthetic valuation of landscape falls within the human/societal domain. Aesthetic valuation is the response to an aesthetic impact, which is made up of objective and subjective parts.

The importance of VIA in public policy requires active and constant political involvement in landscape assessment. Regional and national governments need to create adequate tools to coordinate the directives, regulations, programs and practices between the different public administrations involved in landscape issues, correctly and efficiently. Similarly, it is important to promote and support educational campaigns directed at the recognition of the landscape as an environmental resource. Article 6 of the European Landscape Convention advocates for a solid incorporation of the landscape in the educational system, specially inside the university environment, whether in studies or in investigations, which can contribute to the technical and scientific knowledge of European landscapes and their management measures.

VIA can be beneficial to all the stakeholders involved in the construction project if it is carried out properly. A detailed identification and evaluation of the aesthetic impact generated by the development prior to its construction, will provide information for Ministers, local governments and the public, to help balance the benefits to be derived from the proposed development with any environmental, social and economic losses that may arise from the visual impact generated by the project. The decision on whether to build or not, or on how to build, will be based on substantiated information and it will justify the large investments entailed in the project's development.

Particularly when legal sanctions are involved, it is essential to define, as precisely as possible, what is permitted and what is not. The definition of workable and enforceable standards follows from the development of appropriate methodologies and tools to evaluate the aesthetics of the landscape and the human action which is carried out on it. Without these, the administration of broad and vague standards is likely to provide plenty of opportunity for making "capricious and irrational distinctions, for the exercise of various kinds of aesthetic and social prejudice, and for political favouritism and even corruption" [193].

3.2 Justification of the Methodology and Tools

For the general public, the most immediate and direct impact of land management is visual. It is not surprising then, that much of the reaction to public landscape planning practices concerns aesthetics. Partly in response to this public concern, numerous techniques for the evaluation of scenic quality are being developed. The proliferation of such techniques (and to a lesser extent, their use by managers and planners) is a strong indication that better justification for land use decisions is needed.

Although more and more tools are being developed for VIA (see Chapter 2, Parts II and III), the spectrum of techniques remains very wide, and there is still not a universal tool which can be used by different types of users within the field of landscape research and planning. This is largely due to the fact there does not yet exist a generally accepted definition of the term landscape by field specialists, and so techniques are being developed to cover a wide range of objectives. In addition, the tools developed are often too complicated, or too specific to be useful in practice. This section describes the qualities that the methodology and the tools should present for optimal VIA. The results are summarised in Figure 3.2.

3.2.1 Objective and Subjective Aesthetic Impact

The analysis of aesthetic impact should comprise both an objective part which includes physical characteristics of the landscape, and a subjective part which involves human perception of the landscape (Figure 3.1). For example a larger turbine will have a greater impact than a smaller one (objective component). This difference may be perceived differently by an external observer, compared to the local resident who may find the turbine unacceptable regardless of its size. Considering human perceptions thus introduces a subjective component. A purpose of this work is to evaluate the objective and the subjective visual impacts separately, and subsequently combine them in a holistic approach.

One way to evaluate the objective aesthetic impact is by means of quantifiable indicators [55]. The literature review showed that there is currently no comprehensive system of visual impact indicators. However, there is clearly a need for field professionals to be able to quantify the visual impact generated by changes in the landscape with an easy-to-use, readily available general formula.

On the other hand, whilst some argue that subjective judgements can never be accurately quantified [194], a large sector - this work included - believes there is considerable opportunity for a systematic incorporation of intangibles into the planning process. To achieve this objective, this work will apply the Semantic Differential Method.

3.2.2 Quantification

Because society is seeking more information and more involvement in public landscape planning, decision-makers are under increased pressure to better justify their choices. The importance of the parties involved and the considerable implications of their decisions, mean that the tools used in VIA must be highly reliable. In this sense, a tool which can empirically quantify the objective and subjective visual impacts of an alteration, can provide better justification to an increasingly concerned and skeptical society than do intuitive assumptions or unsupported expert opinions. In his book *The Complete Plain Words: A guide to the use of English* [195], Sir Ernest Gowers wrote that "words are an imperfect instrument for expressing complicated concepts with certainty; only mathematics can be sure of doing that." 30 years later, Peter Duinker goes so far as to state that, it is better to provide a quantitative evaluation, even if it is inexact, than a qualitative one which cannot be demonstrated [196].

Numerical evaluations are particularly useful to the general administration which has to evaluate and compare different types of impacts in EIA. In fact, the original approach to assess an overall impact in EIA is by applying a Leopold Matrix, where scores are assigned to the interaction between the environmental factors and the project activities. Although the Leopold matrix is continuously being amended to improve its reliability [118], the core idea remains the same, in that impacts are assigned numerical values.

It is much more straightforward and efficient to use numerical values in managerial decision-making, than qualitative results because numbers are easier to interpret and they can provide clear thresholds. This way, the countless ambiguities that may arise from verbal responses can be avoided. It is arguable that the thresholds have been, after all, set by a group of experts making use of a certain amount of subjective judgement, but the power provided by quantification to facilitate incorporation of the results into landscape-planning decisions, and the capability to compare results amongst one another, are far more advantageous. Indeed, quantification enables integration of Visual Impact Assessment into landscape-planning policies.

Quantification also facilitates comparison amongst results. If one can develop a means of aesthetically comparing sites, human impact can be used to an advantage. Landscape components and perceptual factors can be compared to help determine why a particular landscape is more aesthetically pleasing than another. What is more, the ability to compare results can help monitor deterioration of landscape Aesthetic Quality for specific places by means of periodic evaluations. Much more so, a comparative analysis can serve so much to predict the aesthetic impact of the intervention in the design phase of the product, as to evaluate the impact after product development; and this is vital for construction projects which entail large investments.

3.2.3 User-Friendliness

From the above, it follows that quantification enables making more enlightened, informed decisions, which can be based on as much substantive evidence as possible. Often however, the tools developed become too complicated, or too specific to be useful in practice. For example, they may require data that are not readily available, incorporate variables which are difficult to understand, or the mathematics of the tool itself are too demanding. General management advocates easy-to-use tools to facilitate their application by a public which is not necessarily specialised in the field.

3.2.4 Integration of Public Opinion

Landscape is an environment for all the people. This means that VIA should integrate the opinion of the general public as well as that of the inhabitants and users of the landscapes, and that of the different experts. It is, after all, the former groups who will be interacting with the altered landscape. This is also a requirement of the European Landscape Convention: in order to guarantee maximizing the welfare of all the stakeholders involved in the project, the Convention encourages the general public to take part in shaping the policies.

3.2.5 Extrapolation

Scientifically, the methodologies and tools presented in this work should be designed such that they can be used to assess the visual impact of a wide range of projects, at large- and small-scale; whether wind farms, solar plants, roads, bridges, housing, or reforestation measures. Minor amendments of the tools to adjust to the product specifications are expected.

3.2.6 Across-Border Scope

The European landscape embraces all the European territory as a whole, and not just each country separately [6]. One country's border cannot define the end of its landscape, because a visual impact can still affect the population viewing the landscape from the neighbouring country. In an effort to harmonise landscape regulations, programs and actions, landscape should also be present in across-border agreements like the Benelux Convention on Nature Conservation and Landscape Protection (see section 2.1.5). To facilitate these agreements, it is necessary to establish a unified methodology and widely applicable tools, that can be applied across the different landscape topographies.

It also becomes ever more important to set a universal base for landscape studies, so that evaluations occur at a homogeneous level within Europe, or within European Landscape Regions. This way, the Aesthetic Qualities of different landscapes can be compared against each other. For example, it would be interesting to compare the results of studies on the Mediterranean landscape with evaluations of the Nordic Fiords. Thus, the whole variety of pan-European landscapes could be measured in the same manner and under one same scale, and very importantly, they can be characterised and considered as a set of landscapes.

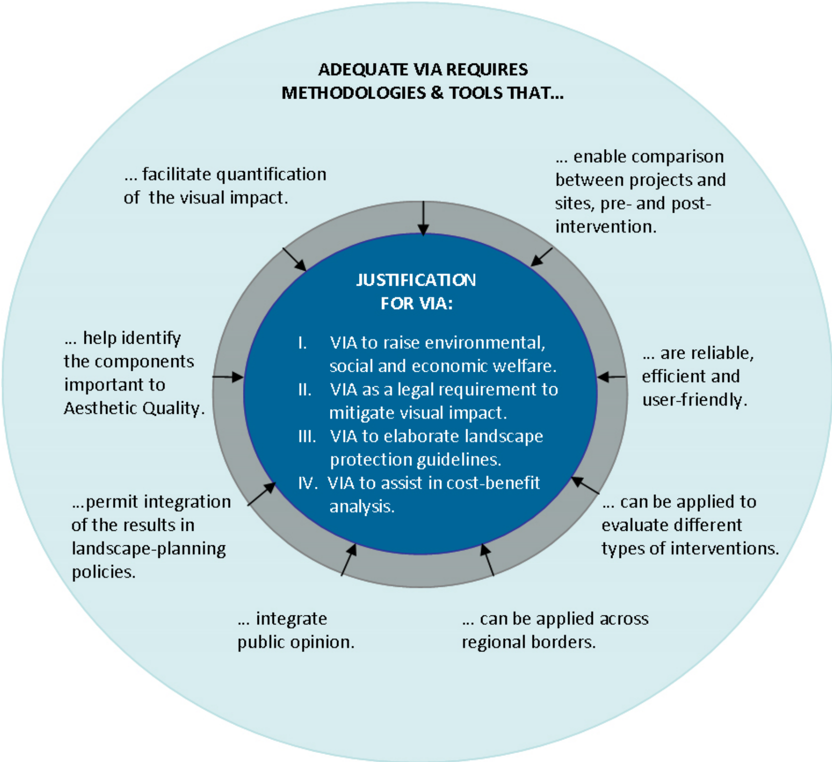


Figure 3.2: Justification for Visual Impact Assessment (VIA), and the optimal characteristics of methodologies and tools for adequate VIA.

3.3 Coherence between the Research Studies

The main objective of this work is to develop a systematic methodology and reliable tools to assess visual impact of human interventions on the landscape. There are different definitions of the concept of landscape, and depending on which definition is adopted, visual impact analysis will follow a different analytical approach. As Section 2.3 described, the three approaches to landscape analysis have their advantages and disadvantages, in reliability, validity, applicability and generalisability.

This work presents three case studies, whereby each study applies a separate approach to VIA. Each study aims to advance from the findings of the previous investigation, complementing the methodology with new tools, although the core objective remains the same. First, an indicator of visual impact of wind farms is developed using the Expert Approach. This methodology is repeated in the second study to develop an indicator for PV plants, and in addition, a subjective study using semantic scales is carried out to analyse the viewer's perception of the project in a holistic approach. The last investigation provides a supplementary tool to increase the reliability of the subjective analysis, namely the Intraclass Correlation Coefficient (ICC).

The methodology and the tools developed are used to analyse the visual impact of human interventions on the landscape, especially of large-scale construction projects. The examples used will be those of renewable energies, in particular wind farms and photovoltaic plants. These examples were chosen because of the strong reaction they arouse on society; paradoxically, despite the fact that renewable energies projects are considered to be environmentally friendly projects, they frequently encounter public resistance directed at their poor aesthetic integration into the landscape. Visual impact is so important that it can hinder and even cancel the execution of a so-called ”clean energy” project.

This work is not dedicated exclusively to the analysis of renewable energies. In fact, an aim of this doctoral thesis is to present a methodology and tools which can be extrapolated, i.e. that can be applied to other types of developments, which do not necessarily have to be large scale developments, nor industrial constructions. In order to demonstrate the scope and strength of the Semantic Differential, the third study evaluates and compares the perceptual responses to different types of human interventions, ranging from roads, to electric cabling, to rural constructions.

Chapter 4

Objectives

This research comes as a response to the evident necessity of establishing a general and easily applicable methodology/tool, to carry out visual impact assessments of construction projects, which has been validated socially and scientifically. It also has as an objective to raise awareness of the importance of the Aesthetic Quality of the landscape and of the need for such studies, and to instigate the creation of national and international norms.

The specific objectives of this work are:

Objective I: To develop tools to quantify the visual impact of a human alteration of the landscape, by means of a potentially generalisable methodology. Whereby the objectives of each separate case study are:

1. To quantify the magnitude of the visual impact induced by wind farms on the landscape, using the Expert Approach.
2. To assess the visual impact induced by solar photovoltaic plants on the landscape, by combining Expert and Public Preference Analysis, in a Holistic Approach.
3. To evaluate the behaviour of visual perception as the landscape is altered by human interventions, using the Public Preference Approach. In particular the aim is to understand:
   (a) How Visual Perception varies with the character and type of the intervention;
   (b) How Visual Perception varies with the number of interventions.

Objective II: The above mentioned tools should guarantee and improve the effectiveness of Visual Impact Assessment for all three approaches. These should be:

1. highly applicable: user-friendly;
2. reliable: scientifically and socially validated; and
3. generalisable: applicable across the rural pan-European landscape.

Objective III: To provide tools that will facilitate integration of Visual Impact Assessment in landscape (planning) policies.

4.1 Objective of Case Study I

Case Study I: Development and validation of a multicriteria indicator for the assessment of objective aesthetic impact of wind farms

The objective of the first investigation is to quantify the objective aesthetic impact generated by the installation of a wind farm on a given landscape. A working methodology is established based on the Expert Approach, to develop an indicator of objective aesthetic impact. This indicator is then used to quantify the magnitude of the impact of five different wind farms set on different types of landscapes. During this process, the indicator is assessed in terms of applicability, reliability, validity and generalisability. Reliability of the indicator is subsequently confirmed in a three-way system: ‘Sui validatio’, ‘Scientatis validatio’ and ‘Societatis validatio’.

4.2 Objective of Case Study II

Case Study II: Aesthetic Impact Assessment of Solar Power Plants: an Objective and a Subjective Approach

The previous study aims to determine the value of the impact of a wind farm, however it does not record how it affects human perception of the landscape. For example, one does not know if the intervention has raised or lowered the pleasantness of the view. This is what is referred to as the subjective impact generated by the project.

The second investigation presented in this work has the aim of assessing the objective and the subjective impacts generated by solar photovoltaic plants using a Holistic Approach. This is done by developing an objective indicator and combining the results with a Semantic Differential study.

4.3 Objective of Case Study III

Case Study III: Human alteration of the rural landscape: Variations in visual perception

The third investigation is a purely subjective analysis of the visual perception of different types of human interventions on the landscape. The objective of this investigation is to understand the behaviour of visual perception as the landscape is altered by human interventions. In particular the following questions will be addressed:

1. How Visual Perception varies according to the character and type of the intervention;
2. How Visual Perception varies according to the number of interventions.

As regards Semantic Differential Method, this study also has as an objective to improve the reliability of the technique with the Intraclass Correlation Coefficient, ICC.

Chapter 5

Hypotheses

In parallel with the objectives mentioned in the previous chapter, the general hypothesis to be tested in this work is that it is possible to evaluate the aesthetic impact generated by human interventions on the landscape. An aesthetic impact includes an objective part and a subjective part, and depending on which component one wishes to measure, a different analytical tool is applied. The aim is to develop tools that offer a reliable assessment of the objective and subjective aesthetic impact.

To quantify the objective aesthetic impact, the indicator is suggested as an efficient, reliable, valid and generalisable tool. For this analysis, an expert approach is adopted as this is thought to be the most appropriate means for quantification. For the evaluation of the subjective impact, Semantic Differential Analysis is suggested, which is based on the evaluations of public opinion.

The specific hypotheses are the following:

Hypothesis I: It is possible to predict the magnitude of the objective visual impacts of wind farms and of solar photovoltaic plants, by means of an indicator.

Hypothesis II: It is possible to meaningfully and consistently evaluate the subjective aesthetic impact of human interventions for comparative purposes, using the Semantic Differential Method.

Hypothesis III: There exists a degree of consensus in the perception of a landscape amongst viewers, which will vary depending on the concept.

Hypothesis IV: Perception of a landscape changes significantly when it is altered by a human intervention.

Hypothesis V: When a landscape is altered, perception changes negatively in some concepts, whereas it improves in other concepts.

Hypothesis VI: The concepts which undergo significant perceptual differences upon alteration of the landscape, are subject to the character and type of intervention which is carried out.

5.1 Definition of the Hypotheses

5.1.1 Conceptual Definition of Hypothesis I

The Expert Approach understands visual impact of an intervention on a landscape, as the degree by which the intervention changes the physical characteristics of the scene. This definition suggests that it is possible to quantify the magnitude of the visual impact by examining the physical features of the scene. Robust indicators are considered an efficient tool for valuation of environmental impacts. The aim is to develop an indicator of visual impact of wind farms, and verify that the results of the indicator adequately reflect public opinion of the impact.

5.1.2 Operational Definition of Hypothesis I

An indicator will be developed using expert knowledge, and it will be used to calculate the magnitude of the objective visual impact of five wind farms of different characteristics. A similar analysis is carried out for solar photovoltaic plants. The wind farms are ranked according to their impact magnitude. The results will be contrasted with the results of a survey to the general public, in which the subjects are asked to order the wind farms according to their level of impact, and to record the factors that influence their decision. To validate the subjects' choices, a probability analysis will be carried out to ensure that these were made according to preferences and not in a random manner.

5.1.3 Conceptual Definition of Hypothesis II

The Public Preference Approach understands visual impact of an intervention on a landscape, as the degree by which the intervention affects the emotional experiences which are perceived by the viewer of the scene. The Semantic Differential method will be applied to evaluate perception of the landscape. The aim is to evaluate the statistic significance of the results. Finally, the third study will seek to improve the reliability of this type of analysis for landscape research.

5.1.4 Operational Definition of Hypothesis II

The semantic concepts will be selected based on studies by Küller (1979) [197] and Karlsson et al. (2003) [131], which have had positive results in architectural and product design. The authors themselves encourage the use of these concepts for landscape analysis. Other concepts, descriptive of landscape settings will be added, as well as a concept to measure the emotional state, and another to record the value of the landscape.

A survey will be carried out, in which the subjects are asked to evaluate photographs with respect to each concept. Unipolar scales will be used to avoid possible ambiguities arising from bi-polar antonyms, and these will vary between -3 and +3 to ensure greater precision and internal validity of the method.

5.1.5 Conceptual Definition of Hypothesis III

Different people react differently to a stimulus, due to varying personal, social or cultural conditions. However, it is probable that despite these differences, the subjects share certain standards, social practices and cultural routines, which can create perceptual response patterns. This indicates that it may be possible to establish a degree of consensus amongst the different viewers. The aim is to compare the degree of consensus for the different concepts that make up the perception of a landscape.

5.1.6 Operational Definition of Hypothesis III

In Case Study II, the consensus amongst subjects, is studied by measuring the mean and standard deviation, at 95% significance levels.

In the third study on the other hand, the ICC is calculated to determine the robustness with which each concept is transmitted by the landscape. Following instructions by Alcántara et al. [144], a computer program is used which firstly calculates the ICC for every axis, for each landscape. Each axis is then eliminated once and the ICC is recalculated each time. The axis whose removal results in the highest ICC, is eliminated because it is the axis which is generating more noise and including it would mean reducing the ICC. This process is repeated until the last two axes remain. This way, the concepts that are eliminated in the first stages of the process, are the concepts which provide less consensus to the general evaluation of the product, whereas those which are eliminated at later iterations reflect a higher degree of agreement amongst observers' evaluations.

5.1.7 Conceptual Definition of Hypothesis IV

The definition of Visual Impact adopted by the Operational Definition of Hypothesis II, suggests that it is possible to evaluate changes in the viewer's perception, between pre- and post-installation of the project. The aim is to identify statistically significant differences in perception and to record these values.

5.1.8 Operational Definition of Hypothesis IV

In the solar plants study, the semantic profiles of the landscapes, both pre- and post- installation of the solar plants will be compared and evaluated for statistically significant differences. In a similar procedure, landscapes showing different sets of interventions and surroundings, are also compared and evaluated for statistical differences.

In the third study, the semantic space will be delimited by the concepts which obtain a higher index of consensus from the survey. Given the subjective nature of the perceptual evaluations, the literature suggests that an ICC of 0.5 and higher is acceptable [144]. Therefore, those concepts which appear at an ICC equal or greater than 0.5, will form the Consensuated Semantic Space, and the analysis will pay particular attention to these concepts.

5.1.9 Conceptual Definition of Hypothesis V

This hypothesis follows from Hypothesis III, which aims to show that there exists a degree of consensus amongst viewers, in the perception of a landscape, and that consensus will vary depending on the concept. Consequently, perception in each semantic concept can be predicted to certain degrees. Given this, and because each concept represents a different cognitive and affective response, it is expected that an intervention will improve the perception of the landscape for some cases, whereas it will deteriorate for others.

5.1.10 Operational Definition of Hypothesis V

The perceptual patterns of the concepts are studied for pre- and post intervention cases. Similarly to Hypothesis IV, the evaluation of Hypothesis V will also search for statistically significant differences between the responses, drawing particular attention to the direction of the response. The same parameters are applied in both evaluations.

5.1.11 Conceptual Definition of Hypothesis VI

Acking and Sorte [67] found that the character of an intervention could influence the complexity and unity of an urban scene. The aim of this hypothesis is to test how the degree and the sign of the perception of all the concepts, relate to the character and type of the intervention, in a rural environment.

5.1.12 Operational Definition of Hypothesis VI

Initial landscapes are altered with an intervention. The interventions, typical of rural scenes, are separated into three categories, depending on their character: industrial interventions (industrial roads, posts, constructions and quarries), rural interventions (cultivation and rural constructions) and other objects of temporary character. Each landscape is evaluated in all concepts by a group of subjects. Significant differences between the average values of un-intervened and intervened landscapes are recorded, for those concepts which, for and ICC equal to or greater than 0.5, form the Consensuated Semantic Space pre- and post-intervention.

Chapter 6

Methods and Materials

This chapter describes the methodology applied for the analysis of the objective and subjective components of aesthetic impact. The tools developed in the case studies are described in detail, together with the materials used in the process.

Each study aims to advance from the findings of the previous investigation, complementing the methodology with new tools. First, an indicator of visual impact of wind farms is developed using the Expert Approach. This methodology is repeated in the second study to develop an indicator for photovoltaic plants, and in addition, a subjective study using semantic scales is carried out to analyse the viewer's perception of the project. The last investigation provides a supplementary tool to increase the reliability of the subjective analysis, namely the Intraclass Correlation Coefficient (ICC).

6.1 Methodology

6.1.1 Development of the Indicators

Case Studies I and II develop an indicator to calculate the magnitude of the visual impact of wind farms and PV plants respectively. Expert opinion is used to quantify the objective aesthetic impact of an intervention. First, the variables that affect this impact are determined. Next, value functions are generated to describe the impact of each variable. The indicator should enable comparison between impacts generated by different types of human interventions on different types of landscape. Consequently, for every combination of development type and landscape type, each impact represented by its respective value function, will be a function of the contrast between the intervention and the surrounding landscape. The indicator is finally developed from the combination of the value functions in a weighted sum.

6.1.2 The Variables of the Indicator

The variables result from a study of the literature and discussion sessions between experts in the field. For the wind farm study, the variables of the indicator are visibility, colour, climatology, fractality and continuity. For solar power plants these are visibility, colour, climatology, fractality and concurrence.

The concept of *visibility* refers to the degree to which it is possible to see within a certain territory, through a certain medium. Introduction of a wind farm into a landscape will decrease the amount of visible area, thereby obstructing the view of the background.

Differences in hue, saturation and brightness between the object and the background sky can also generate contrasts in *colour* and affect aesthetic impact.

Visibility and colour will depend on the atmospheric conditions of the area, and so the impact due to visibility and colour must be corrected by an *atmospheric coefficient*.

Fractality is quantified by the fractal dimension. As nature builds many of its patterns from fractals, the fractal dimension can be used to identify the naturalness of a pattern. Thus man-made structures, such as wind turbines or solar panels, against natural backgrounds will generate an impact which can be represented by contrasts in fractal values.

Continuity refers to the silhouette enveloping a group of objects and is measured in terms of the number of “turns” in the silhouette. An envelope can turn depending on the layout of the turbines and on the line defining the topography of the area, making the farm appear more or less continuous with respect to the background. A difference between the number of turns of the wind farm envelope and the number of turns of the background envelope will affect impact perception.

Finally, *concurrence* refers to the similarity in concentration of two types of solar modules (fixed or tracking technology) within one solar plant. Each panel type can have a different concentration and the contrast between both concentrations will cause an impact.

6.1.3 Analysis for Visibility

Photoshop is used to measure the amount of visible area of the turbines and of the background photograph. Whereas the area of the initial background landscape is simply equal to the area of the photograph, the area of a wind farm or of a solar plant is equal to the sum of the areas occupied by the individual turbines or solar panels respectively. In particular, the area of a turbine is calculated by combining the area of the mast with the area of the ellipse formed by the rotation of the blades. The total area of the wind farm is then equal to the sum of the areas occupied by the individual turbines.

6.1.4 Analysis for Colour

Colour contrasts are measured using the CIELAB colour formulae [198]. For each object, whether wind turbines or solar panels, mean values of the three characterising parameters known as the L, a, b parameters were obtained using Photoshop. Similarly, mean values of the L, a, b parameters are calculated for the area surrounding the farm. As suggested by Bishop [199], in such cases where the object does not display major colour variations, as is that of turbines or PV panels, the background area to be considered in the analysis should be that of a surrounding ellipse, a little bigger than the object itself.

With respect to the Solar Plant Study, given the proximity of the solar panels to the ground, and depending on the position of the viewer, impacts in colour may arise due to contrasts between the panels and the ground, or between the panels and the sky. Hence, value functions are developed for both sets of contrasts.

6.1.5 Fractal Analysis

There are various methods to calculate the fractal dimension, D. The wind farms study applies the box counting method [200]. For this analysis, the contour of the wind farm is extracted from the photograph (Figure 6 of Publication I) which can be done using Photoshop. The information is fed into the program 'fdc Linux' which calculates the fractal dimension from $N(d) = 1/d^D$, where

$N(d)$ is the number of boxes of linear size d necessary to cover a data set of points distributed in a two-dimensional plane. The ratio 'fractal dimension of the farm versus fractal dimension of the main topographic line of the background (usually the skyline)' is then calculated. In the solar plants study, the contour of the plant is extracted from the photograph using Photoshop and the fractal dimension is generated using the 'matlab' fractal calculation toolbox.

6.1.6 Development of the Value Functions

For the development of the value functions, three wind farms and five solar plants are used. For each site, three photographs (at optimal climatology levels) are analysed for contrasts in visibility, colour, fractality, continuity and concurrence. This is done by calculating ratios between the farm values and the background values, so that in average, a total of nine (three photographs x three sites) ratios are obtained for each wind farm variable, and 15 (three photographs x five sites) ratios for each solar plant variable.

The photographs and their respective ratios are presented to a panel of ten experts in environmental sustainability, who are asked to evaluate the visual impact induced by each variable on a scale from 0 to 1. Minimum and maximum ratios are assigned impact values of 0 (no impact) and 1 (total impact) respectively. Value functions are derived from these results using the probability software SPSS. The specific calculation procedures for each variable are detailed in the papers annexed to this work.

6.1.7 Operational Definition of the Indicator

The formula of the indicator takes the form of a weighted sum, which combines the value functions of the individual variables. The weights are given by a panel of seven experts in a Delphi procedure [201, 202], and analysed by means of the multicriteria Analytic Hierarchy Process (AHP) [203]. The experts are shown a series of photographs of the projects, with varying degrees of visibility, colour, fractality, continuity and concurrence. They are then asked to compare the importance of each variable on visual impact, i.e. they have to state whether visibility makes the project more impacting than does colour, and by how much on a scale from 1 to 7. The process is repeated until consistency is achieved. The geometric mean of the results gives the weights of each variable.

6.1.8 Data Collection for the Valuation

For each study site, a map of the area is used to identify all the points from which the wind farm can be viewed and which are easily accessible to people, such as motorways, points of scenic value and roadside restaurants. Their position is later confirmed in situ. Locations with the highest number of visitors are chosen for the analysis. Once at the observation points, the views are subdivided into close-up views, middle plane and far planes, depending on the size of the area enveloping the wind farm. A close-up view of a wind farm is one for which the area required to enclose the farm takes up more than 33% of the actual view. Middle planes are characterised by wind farms taking up between 15% and 33% of the actual view and far planes are distinguished by wind farms covering less than 15% of the view. This categorisation is taken from the Valencian (Spain) Law of Land Planning and Landscape Protection (for specific references, refer to section 2.1.4), as it is thought to be a reasonable approach.

From each location, panoramic photographs are taken of the entire expanse of the wind farm and grouped into the corresponding planes. In cases such as roads, where the pictures can be taken from different positions, the photographs are made from those points which offer maximum visibility of the farm at each plane.

6.1.9 Application of the Indicators

The indicators are applied to quantify the objective aesthetic impact at close-up view of five different wind farms and five different solar plants located in areas showing differences in weather conditions and vegetation patterns.

For every photograph, the fractal value of the intervention and the fractal value of the background is calculated, and similarly for visibility, colour, continuity and concurrence. Ratios for each variable are computed and translated into impact values using the value functions. Subsequently, the average impact value of each variable is calculated. The climatology coefficient is calculated for each plant using atmospheric data obtained from the Meteorological Office websites of the specific country.

The final step is to combine these data in a general indicator which takes the form of a weighted sum. The value resulting thereof will be the objective aesthetic impact of the intervention.

6.1.10 Validation of the Indicators

The indicators are designed using a significant amount of expert input, however it is the general public which is ultimately going to judge the aesthetic impact of the intervention and so public opinion cannot be omitted from any analysis [68]. An indicator should be validated by three different groups of people, by the designers during the design process (Sui validatio), by scientific representatives who validate the output (Scientatis validatio), and by society itself, who are the impacted and the end-users of the indicator (Societatis validatio) [204, 205]. The former two types of evaluation are implicit in the development and application phases.

The aim of the social validation is to ensure that the indicator results reflect public preferences. In section 6.1.9, the values of the impact of different wind farms and solar plants are calculated. If these values are to reflect public preferences, the way in which the farms/plants are ordered according to their impact should correspond to the order chosen by the public. Five photographs, each a representative close-up view of the intervention, are chosen and passed in a survey. The subjects, who are students and teachers of the engineering and social-sciences disciplines, are presented different pairs of photographs and are asked to order them according to how impacting they consider the farm/plant to be. For example, for the combination composed of photographs A and B, X subjects choose sequence "$A > B$", i.e. photograph A is more impacting than photograph B. Five photographs give a total of ten pair-wise combinations, and within each combination, two sequences are possible, such that 20 sequences are evaluated. The subjects are also asked to record what has driven them to make that choice. They are not provided further information or material, other than the photographs themselves, so as not to bias their judgement.

To verify the validity of the subjects' decisions, it is necessary to ensure that they indeed choose each sequence according to some preference and not in a random manner. Thus we need to confirm that the probability the subjects decided on a sequence according to some preference is statistically significant. This probability is given by Equation 6.1. A sample size of five photographs is used to reduce the probability that the subjects choose a sequence at random. A sample size of five gives ten possible pair-wise combinations. Under the null hypothesis and assuming that the probability of choosing any one sequence is equal to 0.5, the probability that the subjects choose a sequence of photographs at random is reduced to 0.001 ($= 0.5^{10}$).

$$P(H_1|N,s) = \frac{P(s|N,H_1)\cdot(1-p_0)}{P(s|N,H_1)\cdot(1-p_0)+P(s|N,H_0)\cdot p_0} \tag{6.1}$$

where:

$$P(s|N,H_1) = \frac{N_1!N_2!}{(N_1+N_2+1)} \tag{6.2}$$

$$P(s|N,H_0) = (p_0^{N_1})\cdot(1-p_0)^{N_2} \tag{6.3}$$

where $P(H_1|N,s)$ is the probability that the subjects decided according to some preference, $P(s|N,H_1)$ is the probability that sequence s is chosen according to preferences, $P(s|N,H_0)$ is the probability that sequence s is chosen at random, H_1 is the hypothesis that sequence s is chosen due to preferences, H_0 is the null hypothesis that sequence s is chosen at random, p_0 is the probability of the null hypothesis, s is the preferred sequence within a pair, e.g. sequence A over B, N is the number of subjects evaluating a combination, and N_i is the number of people choosing sequence i.

6.1.11 Semantic Differential Analysis

Integrating expert knowledge with public evaluative reaction constitutes an important step towards holistic landscape assessment, which is gaining more strength in landscape evaluation practice [37]. Case Study II incorporates the Semantic Differential tool to analyse the behaviour of human perception towards the aesthetic impact of different human interventions. The semantic profiles of five landscapes, both pre- and post-installation of the intervention are compared and evaluated.

The subjects are chosen to be university students from the engineering disciplines, between the ages 20-25. They are also selected on the premises that they are not familiar with the landscape or the type of landscape under analysis. Every photograph is evaluated on ten Likert scales, each representing a different semantic concept. The subjects answer as they agree or not with the statement. Unipolar scales are used to avoid possible ambiguities arising from bi-polar antonyms, and these are made to vary between -3 and +3 to ensure greater precision and internal validity of the method while at the same time allowing for simplicity. Figure 6.1 shows an example of a scale.

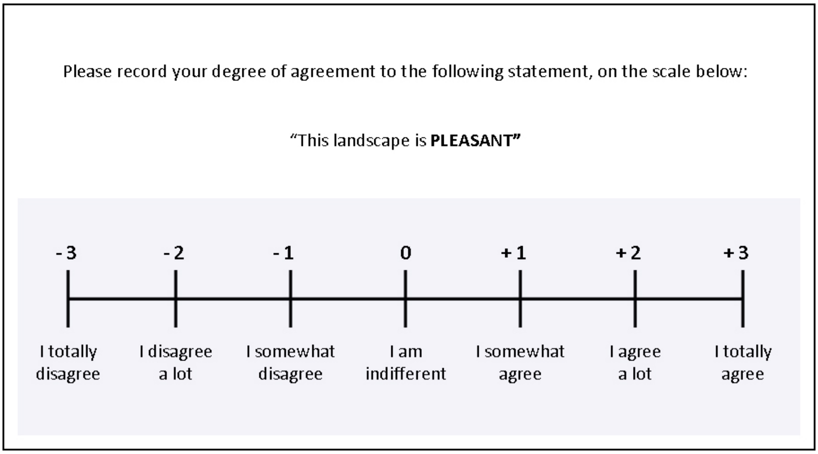


Figure 6.1: The semantic scale for the evaluation of ”Pleasantness” of a scene.

The Semantic Concepts

The concepts used in this investigation were selected based on studies by Küller [66, 197] on the SMB (“Semantisk Miljö Beskrivning” in Swedish, or Semantic Environment Description in English)-method, which used these scales to analyse architectural landscapes [150, 197]. Karlsson et al. [131] later applied the same semantic environment to product design, and given their positive results, they encourage the use of these scales in landscape analysis.

The SMB-method originally collected more than 1000 words that could describe the environment and, by means of factor analysis, reduced this word collection into a questionnaire with 36 adjectives, which were later clustered together into eight factors, or components of different dimensions: “Pleasantness”, “Complexity”, “Unity”, “Enclosedness”, “Social Status”, “Potency”, “Affection” and “Originality” (Table 6.1). Factor analyses in various empirical tests have shown that this grouping is independent and reliable [197]. “Social status” and “Potency” were considered for the analysis, but were finally removed, as they proved to be invariant to the type of landscape being studied, namely, a rural (fixed social status) and a quiet, and not busy (fixed potency) landscape. Instead, it was found necessary to include scales of “Naturalness” and “Liveliness” as landscape descriptives used by Real et al. [83], “Stimulation” as a descriptive measure of the emotional state [206, 207] and finally “Degree of Protection” as a direct measure of the value of the landscape.

Throughout the evolution of environmental evaluation, two paradigms have been used to describe the environment: cognition and the emotional-affective state. Both of these aspects are intimately related and it is difficult to do without one [208]. With respect to the emotional impact of environments, Mehrabian and Russell [209] obtained three basic dimensions, which they called pleasure, arousal, and dominance. Later however, Ward and Russell [208], on the basis of multivariate analyses of data from several independent studies concluded that "Pleasure" and "Arousal" (equivalent to "Stimulation") were "sufficient to characterise the affective meaning of place". Both of these concepts are used in this work to measure the emotional reaction to a visual impact.

Concept	**Description**	**Adjectives positively correlated to the concept**	**Adjectives negatively correlated to the concept**
Pleasantness	The degree of pleasantness, beauty and security which the individual experiences in the environment.	good, idyllic, secure	ugly, boring, brutal
Complexity	The environment's diversity.	motley, composite	subdued
Coherence	How well the various components in the environment seem to fit and function together.	functional, consistent, whole	
Openness	The openness and degree of demarcation of the space.	open, airy	closed
Affection	An age as well as a feeling of the old and genuine.	timeless, aged	modern, new
Originality	The unusual and surprising in the environment.	curious, surprising, special	ordinary
Naturalness	The environment's authenticity, often connoted to elements of flora and fauna.		
Liveliness	The degree of life-emanation of the environment.		
Stimulation	The degree of stimulation, suggestion and interest which the individual experiences in the environment.		
Degree of Protection	The degree of protection attributed to the environment.		

Table 6.1: The semantic concepts and their description. Table adapted from Küller (1991) [150] and Karlsson et al. (2003) [131]

Table 6.1 gives the definition of the ten semantic concepts. The first six scales are taken from studies on semantics, which were performed on Swedish subjects. However, the semantic survey in this work is carried out in Spanish language, with Spanish-speaking subjects. There is no assurance that respondents associate the semantic content of words in a consistent way across different languages. Although verbal responses may be similar, they may differ in specific meanings intended by the respondents. To confront this constraint, the concepts are translated using the general idea expressed by the words of the same factor.

Following Küller's [128] general administration recommendations, if participants ask about the meaning of a concept they are encouraged to "think of the meaning he/she put into the word in this context". If they are not satisfied, the test-leader can provide one or more of the other words in the same factor as an association [131].

6.1.12 Improvements to the Semantic Differential Analysis - The Intraclass Correlation Coefficient

The third investigation presented in this work makes improvements to Case Study II. The Intraclass Correlation Coefficient (ICC) is applied, following instructions by Alcántara et al. [144, 145], to:

- validate the Cosensuated Semantic Space;
- determine the minimum number of subjects required for a reliable and more efficient analysis.

In a similar approach as for Case Study II, 115 photographs of different landscapes are evaluated on the same ten semantic scales, by 30 subjects each. This way, a total of 34,500 evaluations are made. The subjects are also asked to state, on the same scale, how environmentally friendly they consider themselves to be. All of these evaluations are made using a software package which is specifically designed to facilitate evaluation over the internet.

The photographs show un-altered and altered rural landscapes. The interventions range from rural harvesting to small constructions, to historical monuments, to large buildings. The landscapes are chosen to provide a wide range of perceptive stimuli to the subjects, such that valuations of initial and intervened landscapes are widely distributed throughout the semantic axes.

Validation of the Consensuated Semantic Space

The next step is to validate the Consensuated Semantic Space (CSS, [144, 145]). The CSS is formed by those concepts which are transmitted robustly by the scene, and the degree of robustness is determined with the ICC. Different people react differently to a stimulus, due to dissimilar conditions of personal, social or cultural type. However, it is probable that despite these differences, the subjects share certain standards, social practices and cultural routines, which can create perceptual response patterns.

The consensus amongst subjects on their evaluations of the semantic concepts, is studied using the ICC. Standard statistical parameters like the standard deviation give a measure of the variability due to subject differences. The ICC on the other hand, also measures the variations between the concepts. Therefore, a lack of consensus will show that either population differences are too large, and/or that the landscape does not stimulate the subjects enough on that concept, whether it is 1) because the concept is not understood, or 2) the photograph is not able to portray the concept adequately. This way, the ICC is able to determine the robustness with which each concept is transmitted by the landscape. Robust concepts will form the Consensuated Semantic Space.

Each photograph or landscape has its own Consensuated Semantic Space. An ICC between 0.5 an 0.7 is universally considered to indicate a pattern with a moderate consensus, between 0.7 and 0.9 good, and over 0.9 very good [210]. Given the subjective nature of this work, an ICC of 0.5 is accepted for this investigation. This value has also been suggested for similar works in the literature [144, 145]. The analyses hereof look, in greater detail, at those concepts which form the Consensuated Semantic Space at ICC levels equal to 0.5.

Determination of the number of subjects

The ICC is also used to calculate the minimum number of subjects necessary to provide valid and reliable results. Five photographs are chosen for this analysis. For each landscape, 10 subjects are selected at random and the set of axes which provide an ICC equal or greater than 0.5 are recorded. Another five subjects are added, and the ICC is computed again. These subjects are then removed and another five are incorporated, and new ICC values are obtained. The process is repeated six times. Axes displaying ICC values equal to or greater than 0.5 in at least four of the six cases are considered part of the semantic space of the first round. Another five subjects are incorporated and the round is repeated until the semantic space shows no further changes. This process is carried out for all five landscapes.

6.2 Materials

6.2.1 Photographic Analysis

The case studies presented in this work use photographic representations of landscapes. The validity of photographs in landscape assessment is well documented throughout the literature and is now widely accepted [157, 158, 170].

For the development of the indicators in the wind farms- and in the solar plants-studies, three and five sites are used respectively. The projects are located in areas of different topographic and climatic conditions. For each site, five photographs are analysed for visibility, colour, fractality, continuity and concurrence. The value functions are derived from the resulting values.

The same sites are used for the application of the indicator. This is so because using a different set of farms required travelling even further out than had already been the case. The bias that could result from this inconvenience is cancelled out with two important steps. Firstly, a different photograph of each site is used, whereby each picture is a representative close-up view of the intervention. Secondly, these pictures are also evaluated by the general public. And a statistical analysis is carried out on the results to ensure that they reflect public preferences.

The third study on different types of interventions, makes use of 115 pictures displaying virgin- and intervened-rural landscapes. The photographs are made so that the interventions are depicted from a similar distance.

Wherever possible, real-life scenes are used in all the studies. However, because the photographs are taken when the landscapes are already altered, at times it is necessary to apply Photoshop to erase the interventions and create pre-installation samples. Nevertheless, to avoid possible noise in the experiment, the use of this software is kept to a minimum, and wherever possible, photographs of similar neighbouring landscapes are used, to act as realistic representatives of the scene.

The use of Photoshop is also required to calculate visible areas and to determine colour parameters (see Sections 6.1.3 and 6.1.4).

6.2.2 Surveys and Subjects

Surveys are used for the validation of the indicators, and for the semantic analysis. An internet-based platform is created to generate photographs in a random manner. Because it is on the university intranet, the platform is easily accessible to the public it is directed at. The evaluations of each photograph are recorded, as well as the personal data of the person performing the evaluation.

This work uses two types of surveys; the social validation survey and the semantic survey. Social validation is applied in the wind farms- and solar plants-studies to ensure that public preferences correspond with the indicator results. In the first case, pair-wise comparisons of five photographs are performed by 123 subjects. The subjects are students and teachers of the engineering and the social-sciences disciplines. The first three combinations are evaluated by 103 students, and the remaining seven combinations are assessed by 20 students. Similarly, in the second study, five photographs of the solar plants are evaluated in pairs by 120 people; 70 compare three pictures with one another, and 40 perform the remaining comparisons.

Semantic surveys are carried out in the solar plants scenario, as well as in the third study. In the former, five photographs of the plants, together with their corresponding un-altered landscapes, are evaluated by 35 engineering students between the ages 20 and 25. In the study on general human interventions, 115 pictures are evaluated on 10 different semantic scales by 595 students of similar characteristics. The pictures are randomly sorted into 15 groups of seven pictures each, and two groups of five. Every picture is evaluated by 35 subjects on ten semantic scales, such that a total of 40,250 responses are obtained. Later, the analysis on the number of subjects via the ICC will show that for further experiments using these photographs, the evaluations of only 25 subjects will provide reliable results.

Chapter 7

Summary of the Publications

7.1 Publication I

Development and validation of a multicriteria indicator for the assessment of objective aesthetic impact of wind farms

Ana del Carmen Torres Sibille [a], Vicente-Agustín Cloquell-Ballester [a], Víctor-Andrés Cloquell-Ballester [a], Richard Darton [b]

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This work presents a methodology to develop a composite, user-friendly indicator, to assess the magnitude of the objective aesthetic impact generated by the construction of a wind farm on a given landscape, OAI_{WF}.

Aesthetic impact of a wind farm is described by the collective effect of a set of components acting simultaneously. From a study of the literature, this work suggests that the variables affecting visual impact of a wind farm are the visibility of the wind farm, the colour, the fractality and continuity of the layout of the turbines. The variables will affect the indicator results differently, and each will generate a separate impact which can be described by independent value functions.

The concept of visibility refers to the degree by which the wind farm obstructs the view of the background landscape. Visibility is also affected by the atmospheric conditions in the area, and hence it is corrected by an atmospheric coefficient. In a similar manner, colour differences between the turbines and the background sky will generate an impact, which is also dependent on the climate. The fractal dimension describes the impact arising from the contrast between the artificiality of the wind turbines with respect to the natural background. Finally, continuity refers to the organisation of the layout of the turbines with respect to the topography of the land.

The global indicator OAI_{WF} combines value functions of the separate impacts in a weighted sum. The weights are given by expert judgement in a Delphi procedure and are analysed by means of the Analytical Hierarchy Process (AHP). Greatest importance is attributed to visibility, which is considered more than three times as important as the second most important attribute, colour. Fractality and continuity are assigned smaller weights, but are still significant.

OAI_{WF} is applied to calculate the magnitude of the aesthetic impact of five different wind farms, located in different landscapes. Panoramic photographs are taken of each farm, with varying contrasts in visibility, colour, fractality and continuity, and the ratios are calculated and translated into impact values using the value functions. The analysis is carried out for close-up views of the wind farm, as a worst case scenario. The impact values of the wind farms are compared, and the influence of each variable on the final result is evaluated.

In an attempt to develop OAI_{WF} as objectively as possible, the approach taken in this study is analogous to the expert-based approach, which uses a significant amount of expert input. However, it is the general public which is ultimately going to judge the impact of the wind farm. Therefore a social validation is carried out in addition, to ensure that the indicator results reflect public preferences. The indicator has ordered the wind farms according to their aesthetic impact, and this order should correspond to the order chosen by the public. A survey is passed to 123 subjects who are asked to order five photographs of the wind farms, according to how impacting they consider each farm to be. The subjects also record why they make their choice.

A probabilistic analysis based on Bayes' Theorem is carried out on the population survey data. A comparison of these results with the indicator magnitude values shows that the indicator correctly represents the order of preference as perceived by the public. Nevertheless, although consistency is achieved with statistically significant probability values, further study on subjective judgement is recommended to better understand how human perception changes when a wind farm is incorporated in the landscape.

7.2 Publication II

Aesthetic Impact Assessment of Solar Power Plants: an Objective and a Subjective Approach

Ana del Carmen Torres Sibille [a], Víctor-Andrés Cloquell-Ballester [a], Vicente-Agustín Cloquell-Ballester [a], Miguel Ángel Artacho Ramírez [a]

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This work develops a composite indicator, OAI_{SPP}, to determine the objective aesthetic impact of a solar plant located in a defined landscape. The methodology which was developed in Publication I (see Annex I) is applied for the generation and validation of the indicator. The variables entailed are visibility, colour, fractality and concurrence between fixed and tracking panels. The values of the variables can be taken from photographs. The relative importance of each variable and the corresponding value functions are derived using expert contribution. The results are subsequently combined in a weighted sum, in a multicriteria procedure. Greatest importance is attributed to visibility, which is considered three times as important as the second most important attribute, colour. Fractality and concurrence are assigned smaller weights, but are still significant.

The visibility of a PV plant refers to the area of the plant which is visible from specific locations. Depending on the position of the viewer, impacts in colour may arise as much due to contrasts between the panels and the ground, as between the panels and the sky. Both visibility and colour will depend on the atmospheric conditions of the area. The fractal dimension makes reference to the artificial appearance of the solar modules with respect to the natural background. Finally, concurrence refers to the sizes of the areas occupied by different types of solar modules. Whereas fixed systems are laid out in a more compact manner, trackers require more space in their distribution. Each panel type therefore has a different layout concentration, and the contrast between both concentrations will generate an impact.

OAI_{SPP} is applied to calculate the objective impact of five solar plants of different characteristics, and a population survey is undertaken to analyse consensus between indicator results and public opinion. Comparison of the indicator results with a probabilistic analysis of the population survey shows that the indicator correctly represents the order of preference as perceived by the public. The survey also suggests that both objective and subjective preferences influence aesthetic impact.

A study of cognition is therefore carried out using the Semantic Differential method. The perception of a sample of individuals of five landscapes, pre- and post-installation of the solar plant, is analysed and preferences between the PV plants are determined. Photographs of the landscapes are shown to 35 individuals who evaluate the scenes on ten Likert scales. Each scale represents a different semantic concept: “Pleasantness”, “Complexity”, “Coherence”, “Openness”, “Affection” and “Originality”, “Naturalness”, “Liveliness”, “Stimulation” and “Degree of Protection”.

The perceptual responses are studied for significant differences. The results show that the combined use of an objective indicator with a Semantic Differential analysis, faithfully explains user preferences and can help control aesthetic impact in the design phase of the project. The optimal design of a solar plant can be developed to reach not only appropriate levels of impact magnitude, but also desired reactions from the viewers.

Further research is recommended to establish relationships between physical and psychological attributes of aesthetic impact of solar power plants, in order to determine which components and how much of these components generate which reactions. Investigations should also concentrate on how cognition values arising from differential semantics can be combined with objective magnitudes to produce one final value of aesthetic impact.

7.3 Publication III

Human alteration of the rural landscape: Variations in visual perception

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The objective of this investigation is to evaluate how visual perception varies as the rural landscape is altered by human interventions of varying character. Two experiments are carried out. The first experiment reviews the effect of the character and the type of the intervention on perception. Subsequently, the second experiment will study how landscape evaluation is affected with the continuous incorporation of elements into a scene.

In the former case, developments are divided into elements of "*permanent industrial character*", "*elements of permanent rural character*" and "*elements of temporary character*". These categories are sub-divided into smaller groups according to the type of development. Permanent character is defined as "difficult to move or affect", and examples of such types of developments include roads, industrial constructions, quarries, power lines and paved roads. On the other hand, elements of permanent rural character cover cultivations, traditional stone houses, or unpaved sandy roads. Finally, elements of more temporary character include sheds, cars, sign posts, small random objects, etc.

A survey is conducted to 595 subjects who are asked to evaluate photographs of different types of interventions on ten semantic scales, also referred to as the semantic concepts: "Pleasantness", "Complexity", "Coherence", "Openness", "Affection" and "Originality", "Naturalness", "Liveliness", "Stimulation" and "Degree of Protection". A total of 40,250 perceptual responses are analysed.

To increase the reliability of the results, both of the experiments presented in this work apply of the Intraclass Correlation Coefficient tool, ICC, which is used to validate the semantic space of the perceptual responses, as well as to determine the minimum number of subjects required for a reliable evaluation of the photographs.

The results of the first study show that the perceptual profile will differ depending on the type of intervention. The second experiment works with landscape sequences and looks for variations in the semantic concepts as elements are continuously incorporated into a scene. In particular, it looks for differences due to the predominating character of a sequence. The semantic profile of eight sequences consisting of five photographs each, are compared and evaluated. The results suggest that a saturation point is reached as more industrial elements are incorporated into a scene. To improve landscape design, further investigations should be dedicated to determining where this point is positioned for each concept.

To conclude, with respect to the tools applied for this study, the results support the validity of using Differential Semantics as a technique to integrate the general public in landscape decision-making. In addition, the analysis has shown that the robustness of the technique is increased by means of the ICC.

Chapter 8

Discussion

Chapter 4 listed the specific objectives of this doctoral thesis, and Chapter 5 specified the hypotheses to be tested. The discussion in this section will follow three steps: first, the general results of the studies will be discussed with reference to the hypotheses. Secondly, the methodology and tools developed will be assessed with respect to reliability, validity, generalisability and applicability. Within this scope, particular attention will be drawn to facilitate the integration of visual impact assessment in landscape planning policies. Finally, future works deriving from this doctoral thesis will be proposed.

8.1 Discussion on Objective I

Objective I: To develop tools to quantify the visual impact of a human alteration of the landscape, by means of a potentially generalisable methodology.

This work has presented three studies to evaluate the visual impact generated by human interventions on the rural landscape. A methodology and tools have been developed to assess the aesthetic impact of wind farms and of solar power plants, and to set the way forward towards the holistic assessment of landscape Aesthetic Quality.

The methodologies and tools presented in this work have been developed to assist in Landscape Visual Impact Assessment, which is a prior step to establishing the Landscape Quality Objectives. These objectives will then set the base for the elaboration of guidelines of Landscape Protection, Landscape Management and Landscape Planning, as outlined by the European Landscape Convention.

The analyses in this work have been developed on the premise that visual impact comprises objective and subjective aesthetic components. Indeed, in the surveys undertaken, both the experts and the general public recorded a wide range of variables which could be separated into objective and subjective attributes. For example in the case of the solar power plant survey, the subjects explained that the size of the plant contributed greatly to its visual impact, however the "liveliness" perceived from a particular scene was also influential. The objective variables they listed were physical attributes or design features of the intervention, such as size and colour, which were used in the studies to determine the magnitude of the impact. The subjective attributes on the other hand, represented feelings and emotions perceived from the impact. These were included in a Semantic Differential Analysis, to interpret how the impact is perceived along different conceptual scales.

A comparison between experts and public opinion showed that both groups agreed that visibility and colour were the most influential characteristics of wind farms and solar plants, together with the atmospheric conditions present in the area of study. Fractality, continuity and concurrence on the other hand, were less important, however they were still significant to the results.

A particular advantage of both Indicator and Semantic Differential Analysis lies in their capability to be applied to study different types of landscapes. Quantification and the use of fractions to compare the impact of an intervention against the background characteristics, make the Indicator appropriate for generalisation. Similarly, the Semantic Differential can be applied to evaluate different landscapes, although a demographic analysis of the subject pool is always encouraged.

Additionally, the methodology and the tools have also been developed in such a way that they can be applied to study different types of human interventions on different rural landscapes. As regards this issue, the third study presented in this work draws a distinction between interventions of permanent industrial character, interventions of permanent rural character and interventions of temporary character. The results show that if the landscape is altered, the perceptual response of the visual impact will vary between an unaltered and its corresponding altered landscape, whereby the degree and the sign of this variation will depend on the character and type of the intervention.

In summary, every human intervention will modify the perceptual semantic profile of a viewer. For scenes of predominating rural character evaluations remain within the positive sector, whereas scenes with predominating industrial character are evaluated negatively. Human interventions of permanent industrial character induce a loss in "Naturalness", "Pleasantness", "Affection", "Liveliness" of the scene and in the "Degree of Protection" of the landscape, whereas they raise the levels of "Stimulation" and "Complexity". This is a consequence of the incorporation into the scene of elements which are substantially different to elements characteristic of a rural landscape. Interventions of permanent rural character, on the other hand, have the opposite effect, and increase levels of "Naturalness", "Pleasantness", "Affection", "Coherence", "Stimulation", "Liveliness" and "Degree of Protection". Finally, interventions of temporary character raise the stimulation, but are perceived as less original, less coherent and less likely to be protected. In general, any human intervention will increase the levels of the perceived "Stimulation". The importance of this result is emphasized in the design phases of the development project. Interventions should be previously and rigourously analysed to ensure that the degree of "Stimulation" (existing per se) is accompanied by as "Pleasant" as possible a perception.

A final objective of this doctoral thesis was to understand how visual perception varies as more interventions are inserted into a landscape. Although the results are only preliminary, and more research is required in this topic, the third study suggests that as more interventions are incorporated into the scene, perception reaches a saturation point. Further investigations should be dedicated to finding where this point is positioned for each concept, as this can be advantageous for landscape design.

8.2 Discussion on Objective II

Objective II: The tools should guarantee and improve the effectiveness of Visual Impact Assessment for all three approaches. These should be highly applicable, reliable and generalisable.

Probably the most important questions which are placed in any empirical study refer to the reliability of the results, and whether they adequately represent real life situations. The quality and utility of the measurement method will largely depend on its reliability, validity, generalisability and applicability. Chapter 2 on the Literature Review analysed each of the methodological approaches used in Visual Impact Analysis, searching for advantages and disadvantages in these four concepts; this section will draw on these results.

8.2.1 Reliability and Validity of the Indicator as a Tool for Objective Valuation

When one speaks of visual impact of an intervention, the first issue that comes to mind are subjective feelings towards the impact: whether it is liked or disliked? Whether it is preferred in one colour or another? However, there is also an unquestionable objective aspect to visual impact. Recognising this objective side and being able to represent it in a coherent manner, is of great advantage. Objectivity means that the impacts can be represented in a quantitative manner so that all the ambiguities which are often involved in qualitative assessment can be avoided.

The objective component of the aesthetic impact is analysed using the Expert Approach. From the possible choices, this approach is the most objective in its methodologies, and hence the most neutral method to assess the influence of objective variables in the most impartial and empirical manner possible.

The indicator can calculate the visual impact of an intervention as a total impact or as a combination of the impacts of each individual variable. In other words, it does not only give a measure of the total impact, but it can also provide separate impact magnitudes from each individual variable. Furthermore, because the impacts are calculated with respect to the characteristics of the background landscape (as fractions), the indicator proves optimal for comparative purposes, both for comparison of the total impact between one intervention and another, and for comparison between the individual impacts.

Quantification of the impact and the possibility to compare impacts between each other is particularly advantageous for landscape planning management procedures such as Environmental Impact Assessments, where interventions are ordered according to their impact, whether very impacting, fairly impacting or not impacting at all, and are often compared with one another [211]. Quantification is also particulary useful to governmental administrations which set Quality Objectives for specific landscapes and compare aesthetics between them.

Advantageous too are the reduced time requirements to carry out an objective evaluation of an intervention. Both in the example of the wind farms and in the example of the solar power plants, once the indicator is constructed, all there is left to do is take the photographs of the farm and analyse each variable using the value functions to arrive at the total impact. Perhaps the most time-consuming part of this process is taking the photographs, as this requires traveling to the point of interest as well as taking pictures from various other points in the vicinity. However, once this process is finalised, the analysis of the pictures is merely a question of hours.

It is widely argued throughout the literature that even though the expert approach claims to be highly objective, it does in fact possess an amount of subjectivity in its core, for the experts are, after all, people who subjectively select and opine on the different criteria. Validation of the indicators with the survey to the general public, has demonstrated that the indicators, and hence expert opinion, correctly represent public preferences. What is more, validity of the indicator is confirmed in the studies in a three-way system, : 'Sui validatio', 'Scientatis validatio' and 'Societatis validatio', as required in the literature [204, 205], for a complete and correct evaluation of indicators.

An indicator, as opposed to scales based on inventories, is not based on a system of professional appraisals which covers a very limited range of values (high, medium or low), instead it is based on a scale with one hundred scale points ranging all the way from 0.00 as not impacting at all, to 1.00 as totally impacting. This way, bias and ambiguities are avoided, and precision of the results is augmented.

The success of expert-based analysis also depends on the reliability of the inputs on which it is based [32]. Expert-based models are often criticised for the way in which landscape components are arbitrarily identified and the lack of empirical research to justify the inclusion of these abstract design parameters [212]. Furthermore it has also been criticised that few experts (often only one) are employed for the analysis [31, 34]. To overcome these problems, the variables which make up the indicators presented in these investigations have been carefully chosen by a group of five experts. The decisions were based on their knowledge of visual impact, together with an extensive literature review on the subject which was previously prepared by the researchers. The results of this review were divided into groups of independent variables. One of the objectives of the indicator is that it should be user-friendly, and so the fewer the variables, the easier the indicator can be understood and the faster it can be applied. Hence, the fewer the groups of variables that resulted from the clustering process, the better. Nevertheless, the variables had to be sufficient and fully representative of the impact. In a second step, the respective value functions were derived from the opinion of a separate group of ten experts. Another seven experts were then asked to value the importance of the impact of each variable and a multicriteria analysis was carried out in a Delphi procedure to guarantee the reliability of the resultant weights. This way, the methods used were fully substantiated scientifically, and completely independent from one another, to avoid repetitions and noise in the output results.

The use of the AHP is fully justified as there is no danger of rank reversal of the results. Rank reversal is problematic only if the aim of the analysis is to determine the distribution of the alternatives (the farms/plants). However, this is not the case in this work, where the AHP is applied to calculate the distribution of the criteria (the weights of the variables), and the values of the alternatives are given by individual value functions which ensure univocity.

The photographs were taken to adequately depict most of the variations of the natural and intervened landscapes. The validity of photographs as surrogates of field analysis is fully justified in the literature [157, 158, 170]. Photographic representation predominates in landscape analysis over on-site evaluation and the use of video and/or Geographical Information Systems, because it is less time-consuming, because it requires lower levels of expertise, and because information can be easily extracted from the pictures [155]. Moreover, they endow the researcher with better control and the possibility to perform quick comparisons between pictures [83].

Even though the validity of photographic representation has been demonstrated, the studies could be improved by using computerised 3D-models, which are currently used in product development, and/or by incorporating stimulants to the senses, such as smells and noises typical of the landscape shown. However, this would not only increase the level of difficulty, but it would also extend the time required to pass the surveys, making the tool less efficient for today's markets, where time and cost go hand by hand.

In general the statistical validation of the indicators has proven that a properly built indicator fully represents public opinion, and is therefore a reliable tool for measuring objective aesthetic impact. Finally, it should be noted that all the investigations presented in this paper are exempt of data manipulation.

8.2.2 Reliability and Validity of the Semantic Differential Analysis as a Tool for Subjective Evaluation

The subjective aesthetic impact is studied using a public preference approach. A survey is carried out to a statistically significant number of people who express their opinion on semantic scales. The scales are made to vary between -3 and +3 to ensure greater precision than the usual five-point scales, while at the same time allowing for simplicity.

The results of a subjective analysis are often hard to integrate into a comprehensive assessment system [72, 189]. In order to be understandable and usable by resource managers, the use of semantic scales seeks to overcome this problem, by quantifying as far as it is possible, qualitative preferences. This not only supports interpretation of the results, but it also facilitates the combination of objective and subjective results in a holistic assessment.

There are methodological problems in the use of the Semantic Differential method. One inevitably faces the limitations of language in attempting to verbalise perceptual dimensions which are nonverbal in nature. Words cannot represent the totality of any environmental or behavioural situation [213], and so verbal responses can explain only a fraction of all that one perceives in an environment. Furthermore, there is no assurance that respondents associate the semantic content of words in a consistent way across different languages.

In spite of these constraints however, for practical reasons we have to use language to discuss and make written assessments, so we are forced to use words and language in the best way we can. Language is a fundamental means of communication and it is the most frequently employed mode of environmental assessment. What is more, the semantic scales provide a means to quantify qualitative variables. If a future aim is to combine objective and subjective analysis in a Holistic Approach for landscape planning activities, then quantification of variables is most desirable.

The surveys in the studies have been set up so as to avoid bias in questionnaire responses or manipulation of preferences. One measure which is taken is the use of unipolar scales to prevent possible ambiguities arising from bi-polar antonyms. Authors [83] argue that individuals have different connotations to the meaning of the adjectives, and so bi-polar descriptors are often not regarded as entirely incongruent; an individual's understanding of one adjective, as radical as it may be, can still enclose attributes of its antonym. This is because not everyone understands the same under every adjective. A good example is the bi-polar scale 'boring-stimulating'. What is understood under 'stimulating' by an old farmer is not the same as what is understood by a young city dweller. What is more, is 'stimulating' the correct opposite of 'boring'? Maybe 'exciting' or 'stressful' are more appropriate. This problem arises from the subjectivity of the interpretation of the context being analysed. The confusion induced by bi-polar scales is such that various professional fields prefer to use unipolar scales (e.g. Ishihara [214] for industrial products).

There is a long list of studies which have been carried out to search for significant semantic dimensions underlying people's responses in the field of product design [142–144, 146], architectural design [149, 150], urban environments [151, 215], and even car interiors [131]. Yet, there are only few studies which have, in one way or another dealt with some aspects of semantic dimensions of rural landscapes [67]. The scales used in this work have been chosen primarily from the results of the semantic studies by Küller [128], which originally collected more than 1000 words that could describe the environment and, by means of factor analysis, reduced this word collection into eight factors. The use of these scales on the rural environment was suggested by Acking and Sorte [67] and Karlsson [131]. However, perhaps, for the rural environment which is largely homogeneous, the scales attempt to englobe too many aspects, and are therefore limited in their application. Küller [197] himself agrees that one does not find his factors in every analysis and that, from time to time, it is interesting to add a greater number of categories to better discriminate on the stimuli to be judged, and achieve even more detailed results [197]. For example, in the third study of this work, the concept "Stimulation" does not provide discriminatory information as regards the subjective visual impact of a human intervention. Perhaps an improvement would be to incorporate the concept "Stressful", which has been shown to be affected by the type of intervention. Studies by Ulrich [85, 216–220] demonstrate that individuals are stressed by scenes which incorporate urban elements, and feel much better after exposure to nature scenes. This is also referred to as the Attention Restoration Theory (ART), developed by Rachel and Stephen Kaplan in 1989 [75], which asserts that people can concentrate better after spending time in nature, or even looking at scenes of nature.

Does the addition of further scales mean that the concepts are not completely independent from one another anymore? Is this an undesirable situation? Küller arrived at his concepts by performing orthogonal factor analysis, so that all the resulting factors are uncorrelated. However, such factors may, depending on the homogeneity of the sample of photographs, be better described by an oblique model which results in correlating factors. Correlation between the factors would not be wrong given the strong psychological premise of the study. When factor analysis is done to a correlation matrix, one is continuously using linear transformations, such that the independence of factors is linear, which means that they are not directly or inversely related, but they might (probably) be related in a non-linear way. Maybe both extremely high and extremely low "Originality" can give rise to low "Pleasantness" (see the results of the third study, semantic graphs of: Initial - Temporary Elements, Initial - Industrial Construction). The answer to the problem lies in the size of the sample used. For a model with large samples (a heterogeneous model) of environments, there will be more independence between the concepts, however, for a model with a homogeneous rural environment, with a reduced amount of possible interventions, there will inevitably exist a degree of relationship between the concepts. Given the homogeneity of our samples, and the strong psychological setting of the investigation, a situation in which there is some correlation between the concepts is not necessarily undesirable. In fact, it should be interpreted as new findings which have to be investigated in more detail.

Generally, any study in which a semantic dimension is related to some other type of measurement, should be considered an attempt at validation. To find that some types of interventions of permanent industrial character (industrial quarries) do not affect the pleasantness of a scene, whereas other types of permanent industrial interventions (industrial posts) reduce it significantly, is already of relevance in real life situations, and can help landscape planners to design environments that cover industrial elements with specific features, which can increase the pleasantness of the landscape for the neighbouring population and for the visitors.

Typically, another problem that arises when surveys are made to a group of subjects, is the inter-variability between the subjects, which can induce disturbances in the responses. These factors constitute primarily personal characteristics of the subject such as the age, the area of expertise, and previous knowledge of the study area. To avoid noise in the results, the studies presented in this work have tried to keep the characteristics of the pool of subjects as homogeneous as possible, controlling those aspects which are connected to the landscape and highly influential to the results. This way, the subjects consisted of a group of university students between the ages 20 and 25, of the engineering disciplines. They all lived in the same region in Spain, however they were not closely related to the type of landscape in question.

There are also other factors which can act as noise in landscape studies, such as if the individual is sensitive and considerate with the environment, cultural differences or personal experiences. The first variable should certainly be analysed in future studies. As regards cultural differences, the subjects were chosen so that they all came from and lived in the same region, however it has been demonstrated in previous works that regional differences can affect the results [88, 89, 93, 221, 222] in landscape analysis. In fact, it would be interesting to analyse how a person from Northern Europe would evaluate the arid rural landscapes of the Valencian Region in question, and compare these results with the ones recorded in these studies. Similarly, would protection values be equally high? Consequently, although the methodology and tools presented in this work can be applied across countries and to different types of landscapes, the results will probably vary between countries. This can be due both to language differences, and/or to sociocultural differences. Hence, a demographic of the population sample analysis is always encouraged.

Differences in language and sociocultural changes can also affect the selection of the semantic concepts. This study in based largely on the work of Küller, who worked in Swedish, a language of germanic origin. The question remains as to whether this approach can be carried over to a romance language like Spanish, or to a language with mixed germanic and romance etymology, such as English. An exhaustive study would have required developing the concepts by performing surveys, in the respective language, on the target population to collect adjectives that describe different types of scenes. In a similar manner to Osgood [65], Küller [128], or Alcántara et al. [144], factor analysis could then be used to reduce the number of words to a minimum. Although more rigorous, this process is very time-consuming and requires above-standard statistical abilities. It does therefore not comply with the objectives of this work as regards applicability. The tool hence gains in applicability, but does it lose out on reliability and validity? To overcome this problem, translations were made of Küller's concepts, using the general idea expressed by the description of the concept and by the adjectives relating to them (see Table 6.1). Remaining variances are then detected using the ICC, which will tell whether a concept has not been understood properly, thus guaranteeing that decisions are made using particularly those concepts that have demonstrated consensus amongst the subjects.

Another means to overcome variances arising from language differences is by comparing the semantic profiles with the final purely emotive responses of the viewer [223, 224]. With this purpose, Desmet [224] developed the *Product Emotion Measurement Instrument*, which consisted of fourteen different pictures of facial expressions, each representing a different reaction towards a product. The subject is asked to rate by how much each face reflects his/her feelings. Nevertheless, this work is still at a beginning phase, because fourteen categories makes the survey last too long.

Personal experiences of the viewer may also affect the emotional response. Places that produce anxiety and stress in childhood for example, may be regarded with dismay later in life [150]. The aim of the present work is to open up a new approach, it does, by no means, intend to provide a final solution to the problem of Visual Impact Assessment. Such a solution would require extensive analysis of an infinite number of variables. Given this, it has not been possible to analyse the effect of personal experiences, however, it is encouraged in future studies.

The Intraclass Correlation Coefficient, ICC, is applied in the third investigation to consolidate the reliability of the findings of the Semantic Differential Analysis, which can be affected by variations in the subject pool and in the photographs. The third survey aims to improve the reliability of the previous semantic study. It will determine in which axes the photographs have been understood, and it will also help to determine the number of subjects required to give reliable results in the analysis.

The ICC establishes the level of consensus among the subjects on the concepts, so that the researcher can clearly distinguish between those results which are more reliable, and therefore interpret them in the correct manner. The advantage of the ICC over other types of variance analysis like the standard deviation, is that the ICC takes into account the *global* variability of the scores, and not just the mean of the scores of a single axis or concept, thus enabling a holistic evaluation of the results. This way, differentiation between a consensuated and non-consensuated semantic space of a scene, can help improve landscape planning decisions.

The Semantic Differential, as used in this work, provides a robust instrument with which to measure the cognitive, and to a certain extent the emotional, response to a visual stimulant. However, once the scales have been properly developed, the researcher is faced with the issue that a fair amount of time is required to conduct the survey. Nevertheless, careful planning of logistic affairs can avoid excessive time-consumption, for example this work makes use of web-based surveys which are an efficient and reliable [172–174] alternative to manual or telephone survey methods.

8.2.3 Applicability and Generalisability of the Indicator and of the Semantic Differential Analysis

The discussion in the first two parts of this chapter has concentrated on the reliability of the tools and the validity of their respective results. This section will examine their applicability and generalisability.

Two indicators have been developed for the examples of wind farms and solar power plants. In each case, the methodology followed for the analysis has been the same. For the development of the indicators, a methodology is used in which value functions are created to represent the impact of each variable and are then put together in a weighted sum. Validation of the indicator consists of a statistical analysis of survey results in which public opinion is compared to indicator results. A great advantage of this methodology is that the same procedure can be applied to study the impact of different types of interventions, such as buildings, roads or bridges. Differences would be limited to the definition of the variables, which depend on the type of intervention being studied. It is hence recommended that a group of experts develop the indicator and that a literature review is carried out.

Similarly, the Semantic Differential method can also be extended to evaluate the subjective impact of other types of landscapes, regardless of whether they have been altered or not. In this case too, modifications of the concepts may be necessary to appropriately represent the type of landscape being studied.

Both types of evaluation procedures, whether indicator or Semantic Differential Analysis, have managed to translate a subjective trait, visual impact, into a numerical quantity. Even though there is still a lot of research required to facilitate combination of these measures into one final value in a holistic approach, the fact that an initial measure is provided is already a great advance.

The practical use of these investigations cannot go unmentioned. The ease and speed with which they can be applied is an important advantage of these tools, especially if the evaluation concerns a project which already exists. Once the methodology has been developed and validated, the only task which would take up a considerable amount of time would be taking the photographs, but even this is faster and easier than working with virtual reality models. Often, a large part of the administration staff working on landscape issues is not experienced in the field, nor does it consist of mathematical professionals who can easily interpret and apply the formulae. However, both of the tools, as well as their results can easily be applied and quickly interpreted.

In those cases where the project is at the planning phase, the most appropriate way to approach the problem is to simulate the real scene with computer graphics. A replica of the 3D environment is created by matching the topographic points of the area onto a three-way coordinate system. Today, simulations can closely match real life conditions as regards colour, texture and depth of the image. Therefore, they provide a good representation of the natural setting. The project is then inserted into the computerised scene and its impact is calculated from the different viewpoints. The parameters of the project are varied and different values of visual impact are determined. With these values, the costs and the benefits of impact mitigation can be weighed out. Unlike for the case where an impact is determined after the project has been built, simulation during the planning stages is a more tedious task as it requires higher levels of expertise in information technology. However, it is a process which is carried out by companies responsible for the development of the project, which have the resources, knowledge-wise and technology-wise, to work with computer simulations.

The works presented here are not only useful for Environmental Impact Assessment, but they can also help to evaluate and compare landscapes and interventions with one another, and they can help predict the impact of future interventions. Landscape Catalogues can be created and adequate management practices derived thereof. Statistically significant inventories of landscapes and interventions can be generated quickly and cheaply. Numerical assessment of visual impact facilitates integration of Visual Impact Assessment in landscape planning policies, so that governments can set (numerically-based) visual impact thresholds for landscape planners to design their sceneries within these boundaries. It also becomes possible to control contrast levels within the impacting variables between the object and the background at different time intervals, to match vegetation and topographic changes which commonly occur within landscapes and between countries and regions. This is particularly useful for governments which seek to protect and potentiate their landscapes. In monetary terms, these measures can draw tourism and if carried out with care, bring about great economic profit to the region.

8.3 Validation of the Hypotheses

This section reviews the specific hypotheses listed in Chapter 5, and records how each one has been validated.

Hypothesis I: It is possible to predict the magnitude of the objective visual impact of wind farms and of solar photovoltaic plants, by means of an indicator.

Hypothesis I is verified if one compares the results of the indicators with the social validations in the first two studies. Both of these studies develop an indicator to assess the magnitude of the objective impact of the wind farms. Five wind farms and five solar plants are assessed using the respective indicator and ordered according to the results. In an attempt to develop the indicators as objectively as possible, the approach taken in this study is analogous to the expert-based approach, widely used in landscape evaluation. Nevertheless, even though professional judgements can help assess the landscape, it is ultimately the non-professional public who evaluates it. Hence the need for the social validation of the indicator.

The aim of the social validation was to ensure that the order of the visual impacts of the wind farms as given by the indicator corresponds to the order as perceived by the people. A probability analysis based on Bayes Theorem was carried out to determine the order of preferences. In the case of the wind farms study, consistency was achieved in 80% of the cases, whereby 60% surpassed 95% significance levels (Table 5 of Publication I). In the case of the solar plants study, the order of preferences also coincided for the majority of the cases, with 50% at 95% significance levels (Table 3 of Publication II).

Hypothesis II: It is possible to meaningfully and consistently evaluate the subjective aesthetic impact of human interventions for comparative purposes, using the Semantic Differential Method.

With the subjective study it is possible to record changes in perception between pre- and post-intervened landscapes. A comparison between the results of the second study conveys significant differences in perceptual concepts (semantic profile graphs of Publication II). The reliability of the Semantic Differential tool is increased in the third study by incorporating the Intraclass Correlation Coefficient, ICC, to the analysis.

Hypothesis III: There exists a degree of consensus in the perception of a landscape amongst viewers, which will vary depending on the concept.

Case Studies II gives the means and standard deviations of the viewers' evaluations on each concept, at 95% significance levels, showing therefore that there exists a consensus amongst the viewers, on the different concepts, which gives statistically significant results.

Case Study III incorporates the ICC, which increases the reliability of the analysis. The ICC also confirms that consensus is reached amongst the viewers, and shows that the degree of consensus will vary with the concept being evaluated. As Figure 2 of the third publication (page 9 of Publication III in the Annex) shows, for an ICC value equal to 0.5 (moderate consensus) which represents a moderate consensus level, some concepts ("Pleasantness", "Naturalness" and "Degree of Protection") were transmitted with greater consensus than others ("Complexity" and "Coherence"). In fact, even for an ICC value equal to 0.7 (good consensus), all the concepts scored over 30%, which lies over the 10% boundary accepted in the literature [144].

Hypothesis IV: Perception of a landscape changes significantly when it is altered by a human intervention.

As can be observed from the results of the second and third study, there exist significant differences between the semantic profiles of the un-intervened and intervened landscapes. This shows that every alteration of the landscape modifies its perception. What is more, these differences are not equal in magnitude, nor equally significant for each one of the concepts in the Consensuated Semantic Space.

Hypothesis V: When a landscape is altered, there are concepts for which perception changes negatively, whereas there are other concepts for which perception improves.

Given the fact that the Consensuated Semantic Space includes concepts of different meanings, it was expected that the intervention would improve the perception of the landscape for some cases, whereas it would deteriorate it for others. This behaviour is displayed in the semantic profiles of the second study, and particularly of the third study. In fact, this tendency is also observed in those concepts which present significant differences.

Hypothesis VI: The concepts which undergo significant perceptual differences upon alteration of the landscape, are subject to the character and type of intervention which is carried out.

This hypothesis is corroborated with the results from the third study, which show that the degree and the sign of the perceptual difference in a concept, will depend on the character and type of the intervention. In particular, the character and the type of intervention will affect: (i) the perceptual profile, and (ii) the direction of the variations in each concept of the Consensuated Semantic Space - whether positively or negatively.

Chapter 9

Conclusions

9.1 Conclusions in English

Landscape Visual Impact analysis, as part of environmental studies, is a relatively new area of research. Until recently, only few European countries counted with specific measures directed exclusively at the protection of the landscape. However, increasing social concern on the deterioration of its Aesthetic Quality, has pushed governments to address its conservation in their directives. Consequently, the past decade has revealed important advances in landscape VIA. Nevertheless, general consensus amongst the scientific community is that to date, research in this area remains relatively modest, specially if compared to other scientific fields. This doctoral thesis has been developed in response to the emerging social demand, with the aim of contributing significantly to the development of a research area which is still at its initial phase.

This work concerns the evaluation of the aesthetic impact of human interventions on the landscape. Given the novelty of the topic however, there is not yet a generally accepted means, nor manner, to study landscape aesthetics. Consequently, the studies presented in this work develop and assess a methodology and two different tools for an effective and efficient assessment of landscape Aesthetic Quality, which can be applied both by the scientific community, and by the governmental and/or general administration, with high reliability levels.

Quantification of a subjective trait like visual impact enables making more enlightened, informed decisions, which can be based on as much substantive evidence as possible. Often however, the tools developed become too complicated, or too specific to be useful in practice. For example, they may require data that are not readily available, incorporate variables which are difficult to understand, or the mathematics of the tool itself are too demanding. General management advocates easy-to-use tools to facilitate their application by a public which is not necessarily specialised in the field.

The tools which have been developed and implemented are: an indicator as a means to calculate the magnitude of a visual impact, and the Semantic Differential Analysis to evaluate the viewer's perceptual response of a landscape. In a third study, and with the aim of testing the applicability and generalisability of the Semantic Differential, this technique is applied to study the impact of different types of human interventions.

The indicator developed in this work represents the first attempt in landscape literature to assess the magnitude of a visual impact by combining different variables in one single measurement. The semantic differential on the other hand, has been used in previous analysis, however, this work applies a different set of scales which have demonstrated successful results in architectural and product design. Additionally, the Intraclass Correlation Coefficient (ICC) is applied as a means to increase the reliability of the analysis, and enhance the interpretation of the results.

Particularly interesting is the paradoxical setting of the first two studies, namely the assessment of an environmental impact (in this case the aesthetic impact) which is generated by so-called clean, renewable energies (wind and solar energy).

The main conclusions of this doctoral thesis refer to the achievement of the principal objectives and the specific objectives outlined in Chapter 4, as well as to the validation of the hypotheses formulated in Chapter 5. The Discussion in Chapter 8 analysed looked at these results in detail, outlining each objective and hypothesis, to show how each one of them has been validated by the results of the studies. To avoid reiteration, this section will only refer to the general conclusions, and the reader is invited to review the Discussion in the previous chapter.

The objectives and the hypotheses set out at the beginning of this work have been fully achieved and validated. In the first two case studies, a composite indicator was developed which combines variables of visibility, colour, fractality and continuity or concurrence. These measures can be taken from photographs, and are included in the indicator in a weighting function. In both studies, comparison of the indicator results with a population survey showed that the indicators correctly represent the order of preference of the general public on the perception of the impact. The surveys also proved that aesthetic impact concerns objective issues as well as subjective preferences. A semantic analysis was thus carried out in the second and third study, to evaluate the cognitive variables of aesthetic impact.

The indicators were developed using an Expert Approach, whereas the perceptual response was studied in a Public Preference Approach. Examples from the literature show that both of these approaches present advantages and disadvantages. However, the results of this work demonstrate that with a proper application of the tools, the advantages of the indicator and the advantages of the Semantic Differential Method, overcome the disadvantages inherent in each approach. What is more, the results encourage the combined use of the tools, to study landscape aesthetic quality in a holistic analysis.

The methodology and the tools have been evaluated with respect to reliability and validity. The expert-based methodology has proven valid and reliable for the analysis of objective aesthetic impact, if it is used in combination with an indicator tool, and its use for the valuation of the magnitude of other construction projects is encouraged. In a similar manner, the Public Preference Approach has also proven valid and reliable for the analysis of subjective aesthetic impact when used in combination with a Semantic Differential Analysis, which gains robustness with the application of the ICC.

Emphasis should be given to the advantage brought about by the possibility to predict the aesthetic impact (both its objective component and its subjective component) of a large-scale construction project, for which the large investments entailed require sound justification. Particularly as regards the subjective aspects, it is evident that perception patterns cannot be analysed from a pilot model which has smaller dimensions and which presents different characteristics with respect to the background. However, this work has shown that this it is possible to assess the visual impact of large projects by performing a Semantic Differential Analysis using photographs or computer simulations of the projects. All in all, this work has presented useful, robust and rigorous tools for the project developer to carry out tests prior to, and especially after, the project's construction phase, at acceptable costs, particularly if compared to the benefits that can be obtained.

Given that the methodology has provided successful results in the analyses of both types of renewable energies, its use for the evaluation of other types of construction projects is encouraged. The utility of the methodology and the tools that have been developed in this work reaches out further to include the ease and speed with which they can be applied to assess the visual impact of different types of human alteration of the landscape, such as roads, bridges and buildings.

Another advantage is that the tools help to define the perceptual factors and physical components that are important to perception, and can therefore determine why a particular landscape is or not aesthetically pleasing. The tools in addition, serve to predict the aesthetic impact of the intervention in the design phase of the product, as well as to evaluate the impact after product development. For this same reason, this methodology can be used to identify and characterise landscapes of special quality such as natural parks or degraded territories, with the aim of executing the correct conservation and recovery procedures. If applied properly, these tools can contribute to the protection of the landscape, and at the same time stimulate important economic development for the region.

Finally, no analytical approach or tool, on its own, can deal with all types of problems of landscape aesthetics. Depending on what landscape characteristic is to be studied, one methodology may be more appropriate than the others. In fact, expert-based research and Public Preference Approach are not excluding, rather they should complement one another. Because the Holistic Approach combines elements and tools of both methodologies, it can make use of their advantages for an optimal analysis of Landscape Aesthetic Quality. The final aim of this work was to set the way towards the assessment of the total aesthetic impact of human interventions using a Holistic Approach. This is reflected in the objective and subjective evaluations carried out on the solar power plants. Future studies should seek a method to combine both results for their application in Landscape Planning Policies.

9.2 Conclusiones en Español

El Análisis de Impacto Visual, en el ámbito de la evaluación ambiental, es un área de investigación relativamente nueva. Hasta hace poco tiempo, eran escasos los países europeos que contaban con medidas legislativas dirigidas exclusivamente a la protección del paisaje. Sin embargo, las últimas décadas han puesto de manifiesto un creciente malestar social respecto al deterioro de su calidad estética, por lo que se comienzan a contemplar, desde las administraciones públicas, medidas para su conservación. Como resultado, durante este periodo se han registrado avances importantes en el desarrollo de diferentes tipos de análisis de impacto visual. A pesar de esto, la opinión general entre la comunidad científica es que, hasta la fecha, la investigación en este área sigue siendo relativamente modesta, lo cual resulta evidente al contrastarse con los progresos registrados en otros campos científicos. Esta tesis doctoral responde a la demanda social emergente, con el objetivo de contribuir de manera significativa al desarrollo de un campo de investigación que se encuentra en su fase inicial.

En el trabajo se trata, como tema principal de estudio, la evaluación del impacto estético de intervenciones humanas en el paisaje. Dada la novedad de la materia, no existe todavía un método universalmente aceptado para el análisis de la estética paisajística. Es por ello que los trabajos presentados en esta tesis doctoral han buscado desarrollar una metodología y dos herramientas que puedan ser aplicadas tanto por la comunidad científica, como por la administración, con altos niveles de fiabilidad.

La cuantificación de una cualidad subjetiva como el impacto visual permite tomar decisiones que se basan en pruebas sustanciales. A menudo sin embargo, las herramientas aplicadas en este ámbito son demasiado complicadas, o demasiado específicas para ser útiles en la práctica. Por ejemplo, pueden requerir datos que están difícilmente disponibles, o pueden incorporar variables que son difíciles de entender, o las matemáticas de la herramienta en si son de un nivel demasiado elevado. La administración general aboga por herramientas de fácil uso, para que puedan ser aplicadas por un público que no está necesariamente especializado en el campo.

Las herramientas que se han desarrollado e implementado son las siguientes: un indicador para calcular la magnitud de un impacto visual y el Análisis Semántico (Semantic Differential Analysis) para evaluar la respuesta perceptiva del espectador hacia un paisaje. Con el objetivo de probar la aplicabilidad y la generalización del Análisis Semántico, esta técnica también se ha utilizado para estudiar el impacto de diferentes tipos de intervenciones humanas.

El indicador representa un primer intento en la literatura de paisaje, para determinar la magnitud de un impacto visual, combinando diversas variables en una sola medida. El Análisis Semántico, por otra parte, ha sido utilizado anteriormente. Este trabajo aplica un sistema de escalas que ha demostrado resultados exitosos en el ámbito de diseño arquitectónico y de producto. Además, el Coeficiente de Correlación Intraclase (ICC) se aplica como medida para aumentar la fiabilidad del análisis.

Resulta especialmente interesante el marco paradójico de los primeros dos estudios, es decir, la evaluación de un impacto ambiental (en este caso el impacto estético) generado por un tipo de energía renovable (viento o energía solar), que es supuestamente limpia.

Las conclusiones principales de esta tesis doctoral hacen refencia al cumplimiento de los objetivos principales y los objetivos específicos enunciados en el Capítulo 4, además de la validación the las hipótesis formuladas en el Capítulo 5. La discusión en el Capítulo 8 analiza estos resultados detalladamente, y muestra cómo han sido validados por las soluciones propuestas en los estudios. Para evitar redundancias, esta sección expondrá solamente las conclusiones generales, y se invita al lector a revisar el apartado de Discusión.

Los objetivos y las hipótesis que se propusieron, han sido alcanzados y validados. En el caso de los dos primeros estudios, se ha desarrollado un indicador que combina variables de visibilidad, color, fractalidad y continuidad o concurrencia. Éstas se pueden medir a partir de fotografías, y se incorporan en el indicador en una suma ponderada. En ambos estudios la comparación de los resultados del indicador con los resultados de una encuesta al público, ha mostrado que el indicador representa correctamente las preferencias públicas respecto a la percepción del impacto. Las encuestas también han demostrado que el impacto estético concierne, tanto aspectos objetivos, como preferencias subjetivas. Como resultado se realiza un análisis semántico en el segundo y terer estudio, para evaluar las variables cognitivas del impacto estético.

Los indicadores se han desarrollado aplicando el método por Expertos, mientras que las respuestas perceptuales se analizan mediante las Preferencias Públicas. Los ejemplos de la literatura revelan que ambos tipos de análisis presentan ventajas y desventajas. En respuesta, los resultados de este trabajo muestran que si estas herramientas se aplican correctamente, las ventajas del indicador y del Análisis Semántico, superan las desventajas inherentes a cada método. Es más, los resultados sugieren el uso combinado de ambas herramientas para estudiar la calidad estética del paisaje de manera holística.

La metodología y las herramientas propuestas han sido validadas respecto a la fiabilidad y la validez de sus resultados. La metodología por expertos ha demostrado ser válida y fiable en el análisis del impacto estético objetivo si se emplea en combinación con la herramienta del indicador, por lo que se recomienda su aplicación para la evaluación de otros tipos de costrucciones. De manera similar, el método por Preferencias Públicas también ha demostrado ser válido y fiable en el análisis del impacto estético subjetivo al utilizarse con un Análisis Semántico. Este último ganará en robustez con el ICC.

Se debe de poner énfasis en la ventaja que supone la posibilidad de predecir el impacto estético (tanto su componente objetivo como su componente subjetivo) de proyectos de construcción a gran escala, que requieren inversiones económicas sustanciales, por lo que se exige una justificación basada en fundamentos sólidos. En cuanto a los aspectos subjetivos, es evidente que los patrones de opinión no pueden analizarse a partir de un modelo experimental de dimensiones reducidas, que además se situaría en un entorno diferente de la realidad. Sin embargo, este trabajo ha demostrado que es posible determinar el impacto visual de un proyecto de gran magnitud, realizando un análisis semántico mediante el uso de fotografías o simulaciones por computador. Para ello se presentan herramientas útiles, robustas y rigurosas que permitirán al proyectista realizar pruebas de bajo coste, antes y, en especial, después de la fase de construcción.

Puesto que la metodología ha proporcionado resultados contundentes en los análisis de ambos tipos de energías renovables, se recomienda su uso para la evaluación de otros tipos de construcciones. La utilidad de esta metodología y de las herramientas se deriva también de la facilidad y la velocidad con que éstas pueden ser aplicadas para determinar el impacto visual de otros tipos de alteración del paisaje, bien sean carreteras, puentes o edificios.

Otra ventaja de estas herramientas es que permiten definir los factores perceptivos y los componentes físicos que son importantes para la evaluación de un impacto, pudiendo determinar de esta manera por qué un paisaje es o no estético. Como además, las herramientas facilitan la predicción del impacto de un producto durante la fase de desarrollo, al igual que su evaluación una vez finalizado, esta metodología puede utilizarse para identificar y caracterizar paisajes de especial calidad, como parques naturales o territorios degradados, con el objetivo de ejecutar procedimientos adecuados de protección y recuperación. Aplicándose correctamente, estas herramientas contribuirían a la protección del paisaje, a la vez que fomentarían un importante desarrollo económico en la región.

Finalmente, ningún método analítico o herramienta puede resolver todos los tipos de problemas asociados con la estética del paisaje. Una metodología resultará ser más apropiada que otra, dependiendo de la característica del paisaje que se pretenda estudiar. Es más, el método por Expertos y el método por Preferencias Públicas no son excluyentes, sino que se complementan. Puesto que el procedimiento Holístico combina elementos y herramientas de ambos métodos, puede aprovechar sus ventajas para un análisis óptimo de la calidad estética del paisaje. El objetivo final de este trabajo es dar un primer paso hacia la evaluación Holística, lo que se refleja en las evaluaciones objetivas y subjetivas de las huertas solares. Futuras investigaciones deberían dedicarse a la búsqueda de un método que permita combinar ambos resultados y que pueda aplicarse en políticas de planificación paisajística.

Chapter 10

Future Research

The last two chapters have demonstrated that the objectives of this doctoral thesis have been achieved and the hypotheses validated. In this chapter, further research is recommended to improve both the methodological aspects, and the tools themselves. Furthermore, suggestions are also made to advance in Landscape Visual Impact Analysis.

10.1 On the Methodology

The results show that a combination of thorough objective and subjective studies can help to evaluate and thereby control the aesthetic impact during the design phase of a project. The same methodology can be used to evaluate the impact after the product has been developed, as has been shown for example in the case of a wind farm. Thus, a technique of holistic analysis, which combines objective and subjective elements is recommended.

The semantic study presented in this work is primarily a cognitive analysis which should be extended to include an analysis to determine relationships between the physical and psychological attributes of aesthetic impact. A recent example of such an analysis includes the work by Real et al. in 2000 [83]. By means of a hierarchical cluster analysis on several landscape features displayed on photographs, the authors found that the Galician landscapes in Northern Spain could be classified by four criteria: “artificiality” or “landscapes polluted by human action”, “presence of water”, “roughness of the landscape”, and “human presence” or “landscapes inhabited by human action”. Subsequently, these authors performed a multidimensional analysis of 23 bi-polar scales which represent cognitive variables, and showed that these scales could be grouped into the three dimensions suggested by Osgood et al. [65] to address semantic preferences, namely “emotion”, “potency” and “activity”. 14 physical landscape attributes, such as the “area of water” are also listed. A first attempt is made to determine relationships between the attributes and the subject’s judgement. However, relationships are established indirectly via the three dimensions and a direct correlation is not measured. The analysis is as follows: If the criterion “artificiality” is closely related to the dimension “activity” by a correlation of $r = X$, and if the concepts “happy” and “alive” are also related to the “activity” dimension by $r = Y$, then there exists a dependency between “artificiality” and “happy” and “alive”. Because the value and sign of this correlation is not determined, Real et al. themselves encourage the extension of their analysis to study direct relationships between physical landscape features and the cognitive measurements. This would also be an interesting development of our semantic method.

The efficiency of the regression analysis can be enhanced by neural network training. Up to now, only one study exists in the literature that addresses the use of a neural network system for Visual Impact Analysis of the landscape. This work was performed by Mougiakakou et al. [117] in 2005, who sought to establish relationships between *landscape features* and *landscape types*. These authors found that for example, typical of an urban landscape are features such as existence of man-made elements, of low vegetation and of visual variety of objects. However, as this is the first study using neural networks, the number of features used is limited to ten, and four of them are largely correlated to each other, reducing the number of independent variables.

Simple models suffice for simple systems, but to model complex systems with accuracy, it is necessary that the complexity of the model should approach the complexity of the system. One of the advantages of the neural network technique is that it can work with a large amount of data, and so it is highly appropriate for landscape analysis, where a large number of landscape components are possible. For example, within the forest environment, Arthur [104] was able to list 45 different main features which could be subdivided into sub-features. An attribute “size of trees” could be broken down to distinguish between five sizes, along a five point scale ranging from very small to very large. This gives an idea of the large amount of data that is possible in a landscape environment, and which needs to be evaluated. This type of analysis would give a detailed understanding of exactly which landscape features make up which landscape types. Similarly, and as encouraged by Real et al. [83], the work should be extended to determine correlations between the specific attributes of the landscapes and the subject's judgement.

A model which is able to explain the relationship between the cognitive and physical attributes of landscape will provide a theoretical and quantitative explanation of preferences. The following suggestions are made to extend the work presented in this thesis. The first proposal is to study the relationship between the value of a visual impact and the subjective response. This is done by using an indicator in an Expert Approach which will provide a value of the physical aesthetic quality of the landscape. If in addition, one also evaluates the psychological Aesthetic Quality by means of a Semantic Differential Analysis, a neural network system will give the relationship between the value of the impact and the cognitive response. This holistic process is exemplified in Figure 10.1.

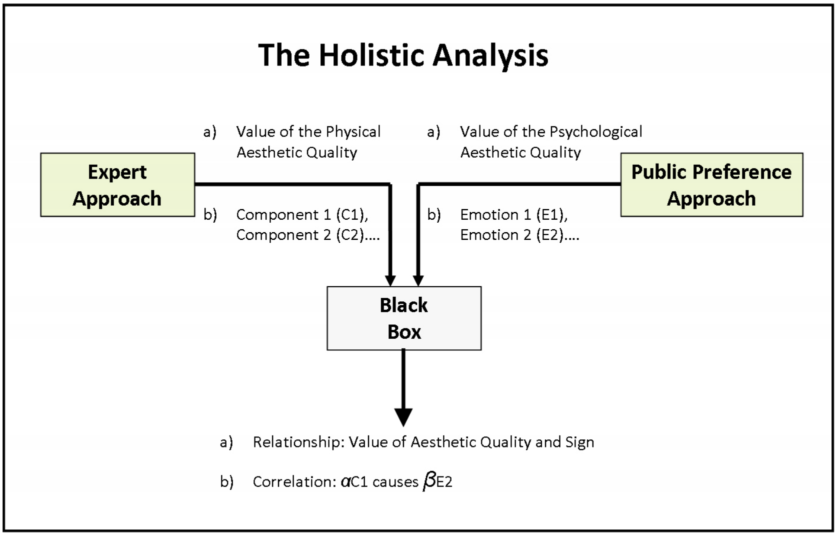

Figure 10.1: The analytical procedure of a Holistic Approach.

Second, it is also suggested to study the relationship between the components which make up the landscape and the perceptual response. An inventory of landscape components is created by means of an Expert-based analysis which classifies the components. Simultaneously, a Semantic Analysis is carried out on the same landscapes. If the values of both analyses are correlated, relationships between component types and emotions can be established, as well as between the number of components and the value of the emotion. At this point, it would be interesting to study possible synergetic effects between the number of interventions and the emotions evoked. Further study should also be devoted to analysing personal characteristics of the subjects (e.g. intercultural differences) in more detail, and how these affect their responses.

Once a proper Holistic Analysis has been performed, it is important to establish a means of incorporating both objective and subjective results in a comprehensive manner for Environmental Impact Assessment.

Finally, and perhaps one of the most important implications of this work is that the successful application of visual impact studies for renewable energies technologies, encourages the application of the methodology to other types of construction projects. In addition, the methodology and the tools could be used to identify and characterise landscapes of special quality such as natural parks or degraded landscapes such as disused industrial zones, with the aim of applying the correct conservation or recovery procedures.

10.2 On the Tools

Analysis of the data suggests that the indicator variables are representative objective measures of aesthetic impact of wind farms and solar power plants, but the indicator might be improved by incorporating new variables, such as the dynamic properties of the wind turbine blades. The wind will not hit each turbine at the same speed, and so rotation velocities will differ amongst turbines. What is more, there are cases when some turbines in an array are disconnected because of light winds. Gipe [225] points out that differences in rotation velocities between the turbines can affect the viewer's perception.

Time is also an issue. Landscapes are continuously transformed by natural and socioeconomic factors, as is the way in which they are perceived and valued as society changes and advances. Advancing in landscape assessment requires taking into account two new dimensions: the transformation of landscape with time, and changes in societal landscape perception with time.

The use of Semantic Differential Analysis could be improved by incorporating new concepts, which describe the object which is being analysed in more detail. Six of the concepts used in this work are the result of a factor analysis of over 1000 words used to describe an environment. Reducing the semantic environment from 1000 to 6 means that the six concepts are very general and may, at times, not be specific enough for some types of design. For this reason, 4 more scales were incorporated in this work. For example, if the aim is to study the design of a new agricultural farm in the rural landscape, then adjectives specific to that farm should be included to the concepts proposed in this work. In this case, an evaluation of different designs of the farm as regards its "functionality" would provide more information to a designer.

Once a pool of concepts is created, factor analysis will determine the correlations amongst them [144, 150]. Ideally, no correlation should exist between adjectives, however, given the homogeneity of the samples (due to the rural landscape setting), and the strong psychological setting of the investigation, it is very possible that there will exist some correlation between the concepts. In fact, there may be cases when, for design reasons for example, it is necessary to study the reaction towards two different adjectives which are slightly correlated. As discussed in Chapter 8, this situation is not necessarily undesirable, rather more research is encouraged in this area.

Furthermore, should new concepts be introduced to the Semantic Analysis, the ICC can help to determine which concepts are most fruitful for the analysis, because it can help establish reliability thresholds of the concepts: concepts which are only portrayed by a reduced number of landscapes ($< 10\%$ of the total landscapes) are susceptible to revision [144]. Additionally, and as the third case study shows, concepts displaying ICC values equal to or greater than 0.5 will form the Consensuated Semantic Space [144].

10.3 On Visual Impact Analysis of the Landscape

The definition of *landscape* given by the European Landscape Convention (2000) suggests that the landscape concept can be understood in terms of environmental, economic, and human/societal domains. Visual impact falls within the human/societal domain and it can be valued in three different ways: from a scientific/cultural point of view, from a utility point of view and finally for its visual appeal. This work has assessed the objective and the subjective sides of aesthetic impact. In this case, objectivity has been measured in terms of impact magnitude, however impact magnitude is only one of the various factors which make up the significance of an environmental impact.

The significance of an environmental impact incorporates a set of basic criteria and a set of supplementary criteria [118,226]. Basic criteria include the impact magnitude and its spatial extension (often measured as one), and the duration of the impact. Supplementary criteria involve synergy between the variables, cumulative effects and controversy surrounding the interaction. Evaluation of a visual impact for Environmental Impact Assessment should therefore address each one of these aspects. In this sense, the indicators developed in this work have addressed the magnitude of a visual impact, and the Differential Semantic Analysis provides an insight to the issue of controversy. However, the duration of the impact, its synergy and the cumulative effects are also issues that need to be addressed an EIA. The combined assessment of these criteria for an overall impact is currently performed using a Leopold Matrix, where numerical scores are assigned to the interaction between the environmental factors and the project activities. Therefore methodologies and tools developed to study these criteria should preferably generate quantifiable results.

As regards synergetic effects, this work has pointed to the necessity of studying human perception as the number of interventions on the landscape is incremented. Further research is also recommended on perceptual saturation; more specifically, at determining where the saturation point is positioned for each concept. It is important to understand how human perception behaves as alteration of the landscape increases, to be able to identify and apply the correct measures that mitigate a negative impact, or which can perhaps even change its sign. The saturation point reflects where the visual impact has reached a maximum. Once this point is reached, the incorporation of more interventions will not generate further significant changes in the impact.

Impact maximums, if negative, should be avoided at all costs. If on the other hand, the incorporation of interventions increases perception positively, the landscape designer should be warned that there exists a point- if this is indeed the case- where further incorporation of elements will cease to improve perception. In fact, in a worse case scenario, the saturation point may become a turning point and so perception will start to decrease. Understanding the behaviour of perception as regards synergy, saturation and inflection is therefore of great advantage for correct landscape design.

To conclude, whilst it is evident that there remains a lot of work yet to be done on Visual Impact Assessment, this doctoral thesis opens up a new, preliminary approach to studies in this field, demonstrating the benefits of rigorous and, where possible quantitative, analysis of Visual Impact of the landscape.

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Glossary

A

Aesthetic Quality (AQ)	A measure of the visual appearance or of the beauty of the landscape.
AQ$_{ExpertApproach}$	An intrinsic physical attribute of individual landscape components.
AQ$_{HolisticApproach}$	A combination between the AQ of landscape components and public experiences of the landscape.
AQ$_{PublicPreferenceApproach}$	A measure of how the observer experiences the landscape in its entirety.
Analytic Hierarchy Process (AHP)	A systematic procedure for representing the elements of any problem. It organizes the basic rationality by breaking down a problem into its smaller constituents and then calls for only simple pair-wise comparison judgments, to develop priorities in each level.
Applicability	Ease with which the analysis can be undertaken by its user.
Atmospheric Coefficient	A coefficient used to describe the atmospheric conditions of a geographic area.

C

Character of an Intervention	Refers to the nature of a Human Intervention. Interventions are divided into elements of "*permanent character*" and "*elements of temporary character*". The former are difficult to move or affect, whereas the latter are easily moved.
Colour	The appearance of objects, described in terms of their hue, saturation and brightness.
Concurrence	In this work, Concurrence describes the similarity in the concentration of two types of solar modules (fixed or tracking technology) within one solar plant. Each module can have a different concentration level in areas of equal size.
Consensuated Semantic Space (CSS)	A set of concepts which are transmitted robustly by a scene, at an Intraclass Correlation Coefficient (ICC) larger or equal to 0.5.
Continuity	In this work, Continuity describes the silhouette enveloping a group of objects (e.g. wind turbines) and is measured in terms of the number of turns in the silhouette along a horizontal plane.

D

Delphi Method Collaborative estimating or forecasting technique that combines independent analysis with maximum use of feedback, for building consensus among experts who interact anonymously. The topic under discussion is circulated, in a series of rounds, among participating experts who comment on it and modify the opinions reached up to that point. The process is repeated until some degree of mutual agreement is reached.

E

Environmental Impact Assessment (EIA) A systematic process to assess the actual or potential effects of policies, objectives, programs, plans or activities on the local or global environment. An assessment of risks to the environment either directly or indirectly as a result of human activities. The aim is to find ways of reducing adverse impacts, shape projects to suit the local environment and present predictions and options to decision-makers. EIA is regulated in Europe by the EIA Directive.

Environmental Impact Assessment Directive (EIA Directive) Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment.

Environmental Indicator Measurable parameter, or a value derived from parameters, of the natural medium that informs us of the condition of the medium, or of aspects related to it.

European Landscape Convention (ELC) European Convention directed at the protection and restoration of the landscape as a common asset. The main objectives of the Convention are to recognise landscapes in law, and to establish and implement policies for landscape protection, management and planning. The Convention was adopted in October 2000 in Florence, and came into force on the 1st of March 2004.

Expert Approach Type of analysis used in landscape visual impact appraisal, which makes use of expert knowledge. The landscape's Aesthetic Quality is measured by objective categorisation and evaluation of the individual landscape's attributes.

F

Fractality The geometry of a pattern that is repeated at every scale and so it cannot be represented by classical geometry. Fractality describes the naturalness of a pattern and it is quantified by the Fractal Dimension D.

G

Generalisability Specification of the conditions for which the attained levels of reliability and validity are representative.

H

Holistic Approach Type of analysis used in landscape visual impact appraisal, whereby assessments are made by combining categorisation of landscape components with the viewer's perception of the scene.

Human Intervention Any type of alteration to the landscape caused by human action, e.g. a wind farm or a building.

I

Impact Significance The degree by which an object affects its surroundings.

Indicator A measurable variable used as a representation of an associated (but non-measured or non-measurable) factor or quantity.

Indicator variables A characteristic of the landscape that takes different values in different visual situations. A set of variables make up the indicator. The variables are determined through expert procedure.

Intervention Any type of alteration to the landscape.

Intraclass Correlation Coefficient (ICC) In statistics, the ICC is a measure of correlation, consistency or conformity for a data set when it has multiple groups. In this work, the ICC measures the consensus amongst subjects on their evaluations of the semantic concepts, for a scene. The ICC therefore determines the robustness with which each concept is transmitted by a scene.

L

Landscape An area, as perceived by people, whose character is the result of the action and interaction of human and/or natural factors (Definition by European Landscape Convention).

Landscape Assessment The study of the landscape by using methods typical of the Holistic Approach. The degree by which the intervention changes the physical attributes of the landscape and the viewer's experiences of the landscape, is measured.

Landscape Evaluation The study of the landscape by using methods typical of the Public Preference Approach. The degree by which the intervention changes the viewer's experiences of the landscape is measured.

Landscape Valuation The study of the landscape by using methods typical of the Expert Approach. The degree by which the intervention changes the physical attributes of the landscape is measured.

Likert Scale A subjective scoring system that allows a person being surveyed to quantify preferences on a scale. This work uses 7-point Likert Scales, ranging from -3 to +3, with -3 being total disagreement, 0 indifference, and +3 total agreement.

O

Objective Aesthetic Impact The objective component of visual impact. Also referred to as Visual Impact Magnitude.

P

Public Preference Approach Type of analysis used in landscape visual appraisal, which evaluates the viewer's judgement of the composition of the landscape scene as a whole, according to his/her feelings.

R

Rank Reversal A change in the ranking of old alternatives, when new alternatives are added to a decision-making problem.

Reliability Consistency and precision of measurement; in visual resource and impact analysis: the degree to which a measure accurately reflects variations among landscapes and landuse conditions.

S

Semantic Concept (Concept) In this work, a Semantic Concept is a word used to describe the semantic meaning of a particular scene.

Semantic Differential Analysis Method to analyse the affective and/or emotional meaning of things. This type of analysis uses rating scales to study the connotative meaning of words, objects, scenes, events and concepts.

Semantic Profile A graphical representation of the behaviour of a viewer's (or several viewers') perception on different semantic concepts.

Subjective Aesthetic Impact The subjective component of visual impact. Also referred to as Visual Impact Perception.

V

Validity The degree to which a measure represents the construct or variable of interest; in visual resource and impact analysis: validity provides an estimate of the degree to which a method is able to capture meaningful variations in the aesthetic quality of the landscape and to depict the impact of landuse activities upon them.

Value Function A mathematical expression that describes the behaviour of the impact of an indicator variable

V

Visibility	The degree to which it is possible to see within a certain territory, through a certain medium.
Visual Impact (VI)	A change in the aesthetic quality of the landscape. In this work, Visual Impact has two components, an objective component, also referred to as Visual Impact Magnitude, and a subjective component, also referred to as Visual Impact Perception.
$\mathrm{VI}_{ExpertApproach}$	The degree by which the intervention changes the physical attributes of the landscape.
$\mathrm{VI}_{HolisticApproach}$	The degree by which the intervention changes the physical attributes of the landscape and the viewer's experiences of the landscape.
$\mathrm{VI}_{PublicPreferenceApproach}$	The degree by which the intervention changes the viewer's experiences of the landscape.
Visual Impact Assessment (VIA)	The study of the visual impact generated by alterations of the landscape (also referred to as Landscape Assessment in this work).
Visual Impact Extension	The physical extent of the visual impact, which will vary depending on the viewshed. A criterion of Impact Significance.
Visual Impact Magnitude	The difference in visual quality induced by placing an object in the landscape. A criterion of Impact Significance. In this work, Visual Impact Magnitude is considered the objective component of visual impact.
Visual Impact Perception	Affective and/or emotional meaning of a visual impact. In this work, Visual Impact Perception is considered the subjective component of visual impact.

Appendix

PUBLICATION I:

Development and validation of a multicriteria indicator for the assessment of objective aesthetic impact of wind farms

Torres-Sibille A.D.C., Cloquell-Ballester V.A., Cloquell-Ballester V.A., Darton R.

Renewable and Sustainable Energy Reviews, Volume 13, Issue 1, January 09, Pg 40-66

PUBLICATION II:

Aesthetic Impact Assessment of Solar Power Plants: an Objective and a Subjective Approach

Torres-Sibille A.D.C., Cloquell-Ballester V.A., Cloquell-Ballester V.A., Artacho-Ramírez M.A.

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PUBLICATION III:

Human alteration of the rural landscape: Variations in visual perception

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Human alteration of the rural landscape: Variations in visual perception

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Abstract

The objective of this investigation is to evaluate how visual perception varies as the rural landscape is altered by human interventions of varying character. Two experiments are carried out using Semantic Differential Analysis. The first experiment reviews the effect of the character and the type of the intervention on perception. Interventions are divided into elements of "*permanent industrial character*", "*elements of permanent rural character*" and "*elements of temporary character*", and these categories are sub-divided into smaller groups according to the type of development. Subsequently, the second experiment will study how landscape evaluation is affected with the continuous incorporation of elements into a scene.

To increase the reliability of the results, the Intraclass Correlation Coefficient tool, is applied to validate the semantic space of the perceptual responses and to determine the number of subjects required for a reliable evaluation of the scenes.

Key words: Visual Perception, Human Intervention, Semantic Differential Analysis, Landscape Sequence, Intraclass Correlation Coefficient

Contents

1 Introduction

The objective of this investigation is to evaluate how visual perception varies as the rural landscape is altered by human interventions of different character. Within the literature, two studies on landscape evaluation are particularly significant to this work: Jacobs and Way (1969) [1] and Acking and Sorte (1973) [2].

Jacobs and Way (1969) concentrate on the capability of an environment to visually ”absorb” development activities by screening or masking them. Their experiment consisted of photographic superimposition of different types of artificial elements and constructions, such as roads and houses, on a landscape. Viewers were asked to record the extent to which the developed and undeveloped landscape differed from one another. The responses showed that the greater the visual complexity in a landscape, the greater its capability to absorb change. It was also shown that complexity increased as more elements of different types were incorporated into the scene.

Acking and Sorte (1973) separated development types into two groups, according to their character: elements of permanent character, and elements of temporary character. Permanent character is defined as ”difficult to move or affect”. Examples would be roads, buildings and power lines. On the other hand, elements of more temporary character include sheds, cars, sign posts, small random objects, etc. Individuals were asked to rate slides with varying character on each of Küller's (1975) [3] semantic concepts on a scale from 1 to 7. A correlation of results showed that elements of permanent character reduced the experience of coherence.

This work presents two experiments which build up from the above mentioned studies, in an attempt to progress in landscape research. The first experiment will review Acking and Sorte's (1973) results. The concept of permanent character will be recategorised into ”permanent industrial character” and ”permanent rural character”. These categories will then be sub-divided further into smaller groups according to the type of development. For example, groups belonging to the former category would include: industrial constructions, quarries and paved roads. Whereas the second category covers interventions such as cultivations, traditional stone houses, or unpaved sandy roads. The objective is to analyse in greater detail the behaviour of visual perception according to the character and to the type of the development. Subsequently, the second experiment will study the behaviour of the perceptual responses with the continuous incorporation of elements into a scene.

2 Methods and materials

The analysis is carried out using Differential Semantics [4], which is a technique used to analyse the affective meaning of things. Semantic Differential Analysis has been widely used in architecture and product design [5–10], however, its application to landscape analysis is limited [2, 11]. Recent use of this technique for landscape assessment includes works by Lim et al. (2006) [12], Natori and Chenoweth (2008) [13] and Singh et al. (2008) [14].

Individuals are shown a variety of photographs displaying different types of artificial elements on homogeneous un-intervened landscapes, which are to be evaluated on different semantic scales. The semantic differential method is chosen over other possible analytical methods as it is particularly suited to a type of problem in which the aim is to measure the overall impression of an environment such as a landscape [2, 3] and guarantees high reliability and validity [7, 8].

Ten semantic scales are defined for the analysis. The scales are unipolar to avoid ambiguity between antonyms and they take the form of seven-point Likert scales varying from -3 to +3. Eight scales have been taken from the literature [3, 11]. These are: ”Pleasantness”, ”Complexity”, ”Coherence”, ”Openness”, ”Affection”, ”Originality”, ”Naturalness” and ”Liveliness”. Two additional scales are proposed, as measures of emotional state as well as of landscape value. These are: ”Stimulation” and ”Degree of Protection”. The former enables us to understand how a landscape affects the viewer emotionally. The latter scale is added to understand what levels of protection the viewer assigns a landscape, because the end objective is to know what type of landscape people believe should be protected. This information can help authorities to establish adequate landscape protection guidelines and measures.

115 photographs are evaluated on each one of the ten semantic scales by 595 subjects. The photographs are randomly put into 15 groups of seven pictures each and two other groups of five. Each group of photographs is evaluated by 35 subjects on the 10 scales and a total of 40,250 responses are obtained. The subjects are also asked to state, on the same scale, how environmentally friendly they consider themselves to be. All of these evaluations are made using a software package which has been specifically designed to facilitate evaluation over the internet.

The data obtained is analysed, with the purpose of studying:

(1) How Visual Perception varies according to the character and type of intervention;
(2) How Visual Perception varies according to the number of interventions.

To ensure validity of the experiment, the following investigation makes use of the Intraclass Correlation Coefficient, ICC, as per Alcantara et al. (2005) [8]. The aim is to increase the reliability of the results by applying the ICC to validate the semantic space, and to determine the number of subjects required for a reliable evaluation of the photographs.

2.1 Validation of the semantic space

2.1.1 Distribution of the scores

The landscapes evaluated, whether un-intervened or intervened, are chosen to provide a wide range of perceptive stimuli to the subjects, such that valuations of the initial and altered landscapes would show a wide distribution throughout the semantic axes. For this, a study was carried out to monitor the behaviour of the mean and standard deviation of every landscape in each axis.

A uniform and wide distribution of the scores assigned to the landscapes by the subjects was achieved for every semantic axis. Figure 1 shows an example of the distribution of the scores for the concept ”Pleasantness”. As expected, landscapes with water presence (number 80) and a high degree of vegetation obtained higher scores (36, 52 and 92), whereas landscapes in which construction features predominate were considered to be less pleasant. This would corroborate literature findings from Real et al. (2000) [11] and Nasar and Li (2004) [15], amongst others, who determine the positive influence of vegetation and water on the viewer’s perception of a landscape.

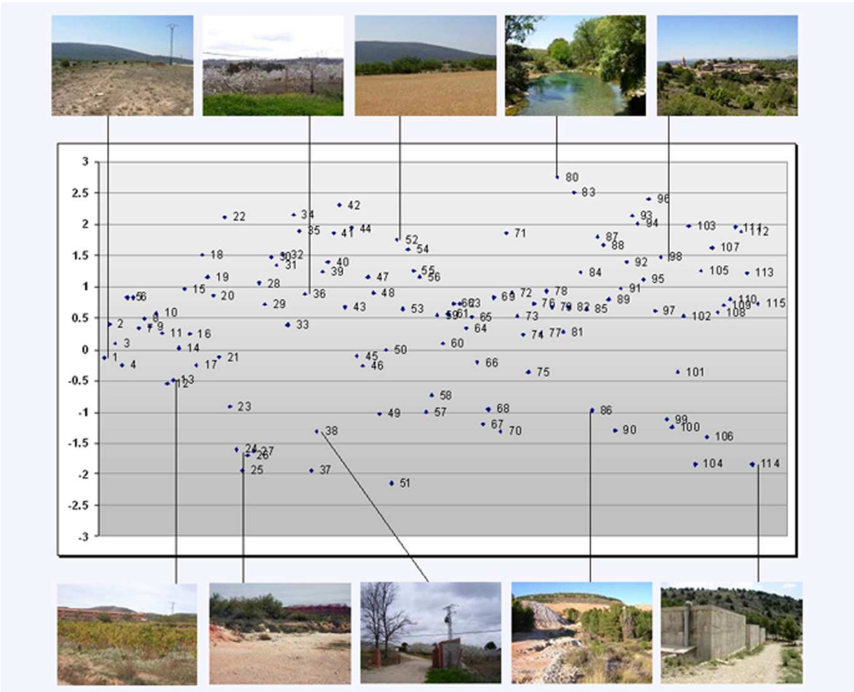


Fig. 1. The distribution of the scores for the concept ”Pleasantness”.

2.1.2 The Consensuated Semantic Space

Different people react differently to a stimulus, due to dissimilar conditions of personal, social or cultural type. However, it is probable that despite these differences, the subjects share certain standards, social practices and cultural routines, which can create perceptual response patterns. The consensus amongst subjects, is studied using the ICC, which will determine the robustness with which each concept is transmitted by the landscape. Robust concepts will form the Consensuated Semantic Space, CSS [8, 9]). A lack of consensus on a given concept shows that the landscape does not stimulate the subjects enough on that concept, whether it is 1) because the concept is not understood, or 2) the photograph is not able to portray the concept adequately.

An event may provoke a change in the viewer's reactions along various axes, and not on just one axis. The reaction of a group of viewers towards a stimulus is usually represented using the mean of the recorded values, however an average value of the scores on each axis individually, does not take into account that this event may also have affected evaluations of the other axes. This is the advantage of the ICC: unlike other statistical parameters such as the standard deviation, the aim of the ICC is to embrace the disturbances arising in the global semantic evaluation, to reduce the noise [9, 16, 17].

For a given stimulus, the ICC is equal to the ratio between the variability in perception of one axis, and the total variability of all axes. This way, the ICC takes into account the variability of the entire set of concepts, as opposed to the differences reflected in the evaluations of only one of the concepts. In general, a good consensus will reflect a lower subject variability on all axes, with respect to the subject variability of one axis. An ICC between 0.5 an 0.7 is generally considered to indicate a pattern with a moderate consensus, between 0.7 and 0.9 good, and over 0.9 very good [18]. Given the subjective nature of this work, an ICC of 0.5 was accepted for this investigation. This value has also been suggested for similar works in the literature [8].

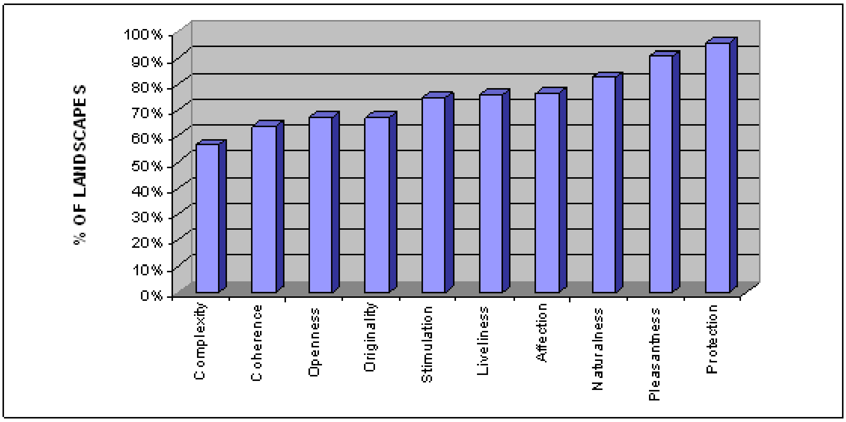
In a first round, the ICC is calculated for every axis, for each landscape. Each axis is eliminated once and the ICC is recalculated each time. The axis whose removal results in the highest ICC, is eliminated because it is the axis which is generating more noise and including it would mean reducing the ICC. This process was repeated until the last two axes remain. This way, the concepts that are eliminated in the first stages of the process, are the concepts which provide less consensus to the general evaluation of the product, whereas those which are eliminated at later iterations reflect a higher degree of agreement amongst observers' evaluations. Consequently, the axes with ICC values equal or greater than 0.5 will form the Consensuated Semantic Space of the landscape.

Subsequently, the ICC is used to determine to what degree each concept influences a viewer's perception of the landscape. This is to say, that if the consensus of the evaluations reached for a landscape is lower than 10%, then the concept does not successfully reflect preferences and its utility in landscape analysis should be reconsidered [8].

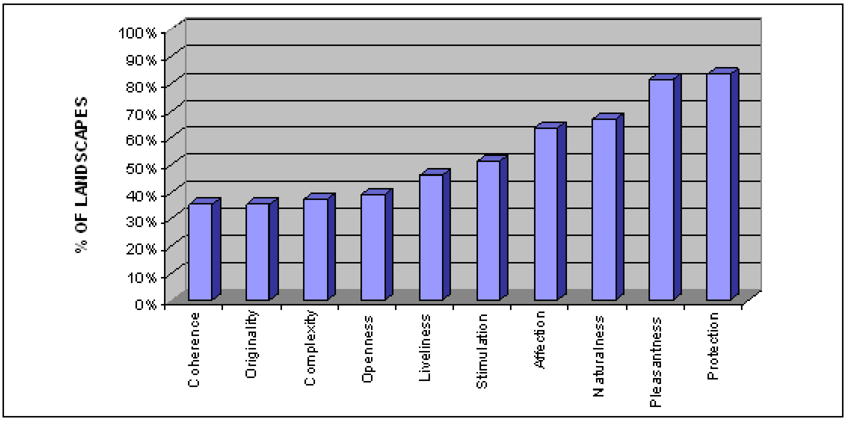
Figure 2 shows the percentage of landscapes that contain each concept in its consensuated space. It shows that for an ICC value of 0.5, all concepts were thoroughly represented in the majority of the landscapes, scoring over 50%. It should be noted that previous studies assume successful results at minimum 10% [8, 9]. Best understood concepts are "Degree of Protection", "Pleasantness" and "Natural", for which more than 80% of the landscapes can be found in the CSS. "Complexity" and "Coherence" on the other hand, were less clear to the subjects, and consensus was reached for less than 62% of the landscapes. The analysis was repeated using an ICC value of 0.7. Figure 2(b) shows that concepts scored over 30% this time round.

2.2 The number of subjects

The ICC is also used to calculate the minimum number of subjects necessary to provide valid and reliable results. Five photographs are chosen for this analysis; two of the landscapes have over 70% of the axes in its Cosensuated Semantic Space, and three have less than 30%. For each landscape, 10 subjects are chosen at random and the ICC is calculated for every axis. The axes whose ICC values are greater than 0.5 were recorded. The ICC is computed again with an additional five subjects chosen at random. These subjects are then removed and another five are added to obtain new ICC values. ICC values are recorded another six times. Axes displaying an ICC greater than 0.5 in at least four of the six cases are considered part of the semantic space of the first round. Another five subjects are incorporated and the round is repeated until the semantic space shows no further changes. This process is carried out for all five landscapes. The results show that the landscapes reached a stable Consensuated Semantic Space with 25 subjects. Therefore, a minimum of 25 subjects were required to achieve reliable results.



(a)



(b)

Fig. 2. Percentage of landscapes that contain each concept in its consensuated space, for a) $ICC = 0.5$, b) $ICC = 0.7$.

3 Experiment I: Significant differences between initial and intervened landscapes, depending on the character and type of the intervention

The objective of this experiment is to analyse the effect of incorporating an alteration to an initial landscape. 45 initial landscapes were altered with an intervention. Wherever possible, a real picture of the intervention was used, however there were cases, although few, where it had to be simulated using Photoshop. The interventions were divided into three categories: industrial interventions (industrial roads, posts, constructions and quarries), rural interventions (cultivation and rural constructions) and other objects of temporary character. The photographs were made so that the interventions were depicted from a similar distance. Each landscape was evaluated in all ten concepts by 25 subjects. To guarantee reliability of the study, only those concepts which displayed ICCs greater than 0.5 so much before as after the intervention, were taken into consideration. For each one of these concepts, significant differences between the average values of un-intervened and intervened landscapes were recorded. The results are shown in table 1.

3.1 Results

In general, incorporating industrial elements to a landscape reduces its ”Naturalness” and ”Pleasantness” significantly, whilst stimulation appears to increase (e.g. Figures 3, 4 and 5). In fact, no type of alteration can increase the ”Naturalness” and ”Pleasantness” of an initial scene except with the plantation of trees.

It can be distinguished between two types of human alterations of different heights: tall interventions which surpass the skyline, such as trees or wind farms, and low interventions which remain within the skyline like crops. The study shows that only tall, rural plantations can increase the feeling of ”Pleasantness” in a landscape. On the other hand, tall artificial interventions generate negative significant differences in this axis, whereas low cultivations do not have any effect.

The concept ”Openness” also seems to be determined by the height of the intervention. No significant differences have been appreciated by the subjects with respect to the concept ”Openness” except when tall trees are incorporated into the landscape, and thereby enclose it.

The ”Liveliness” of a scene is only increase with rural cultivation (e.g. Figure 7). Two hypotheses to be studied in future works (for example using a neural network system) is that ”Liveliness” is positively correlated to colour and that it is associated with living-systems. Plantations introduce seasonally changing colours into a scene, as well as biologically active elements which supply organisms with living necessities (food) and which can generate further life.

”Affection” is semantically related to tradition, and positively correlated to rural life-style. Landscapes are considered less traditional when items of permanent industrial character are incorporated in the scene, whereas components of permanent rural character make the scene more traditional.

”Protection” of a landscape is an interesting topic. Only rural cultivations help increase the ”Degree of Protection” attributed to a landscape, although the scene is not necessarily found to be more pleasant. On the other hand, permanent industrial constructions and temporary elements have a negative effect on preservation.

”Complexity”, ”Originality” and ”Coherence” are concepts which, as expected from section 2.1.2, have not been understood by the subjects in as many cases as the rest of the concepts. However, in such cases where they have been identified correctly ($ICC > 0.5, see Table 1$), the results agree with Acking and Sorte (1973) in that complexity is increased by elements of temporary character. Such element types may brake the ”Coherence” of a scene, but they add to the ”Originality” of the view. The results also show that ”Coherence” of a rural landscape can also be reduced by permanent industrial constructions (Figure 5), and increased with the incorporation of rural constructions and rural roads (Figure 8).

3.2 Discussion

As can be observed from Figures 3-8, there exist differences between the semantic profiles of the un-intervened and intervened landscapes. This shows that every alteration of the landscape modifies its perception. What is more, these differences are not equally significant for each one of the concepts in the Consensuated Semantic Space. In fact, it can be stated that the semantic profiles of un-intervened and intervened landscapes differ, and that there exist significant differences for at least two or more concepts.

Because the Consensuated Semantic Space includes concepts of varying meanings, it was expected that the intervention would improve the perception of the landscape for some cases, whereas it would deteriorate for others. Except for the case of the rural construction (Figure 8) and the paved roads 3, where the perceptual response

Character	Type	Landscape pairs	Concepts with $ICC > 0.5$	Positive significant differences	Negative significant differences	No significant differences
Permanent Industrial	Paved road	5	Openness, Naturalness, Affection, Pleasantness, Stimulation, Protection		Naturalness, Affection, Pleasantness	Openness, Stimulation, Protection
	(a) Industrial posts (e.g. transmission towers), (b) Construction apparatus	(a) 3 (b) 3	Openness, Naturalness, Affection, Pleasantness, Stimulation, Liveliness, Protection, Complexity	Complexity, Stimulation	Naturalness, Affection, Pleasantness	Openness, Liveliness, Protection
	Industrial constructions	7	Openness, Naturalness, Affection, Pleasantness, Stimulation, Coherence, Liveliness, Protection, Complexity	Complexity, Stimulation	Naturalness, Affection, Pleasantness, Coherence, Liveliness, Protection	Openness
	Industrial quarry / pit	5	Naturalness, Affection, Pleasantness, Stimulation, Liveliness, Protection			Naturalness, Affection, Pleasantness, Stimulation, Liveliness, Protection
Permanent Rural	Rural cultivation	7	Openness, Naturalness, Affection, Pleasantness, Stimulation, Liveliness, Protection	Naturalness (HP), Affection (HP & LP), Pleasantness (HP), Stimulation (HP & LP), Liveliness (HP & LP), Protection (HP & LP)	Openness (HP)	Naturalness (LP), Pleasantness (LP), Openness (LP)
	(a) Unpaved roads, (b) Rural constructions	(a) 4 (b) 4	Openness, Naturalness, Affection, Pleasantness, Coherence, Protection	Affection (constructions), Coherence (constructions)	Openness, Naturalness, Affection (road), Pleasantness, Coherence (road), Protection	
Temporary industrial and rural	Temporary elements	7	Originality, Openness, Naturalness, Affection, Pleasantness, Stimulation, Coherence, Protection	Originality, Stimulation	Coherence, Protection	Openness, Naturalness, Affection, Pleasantness

Table 1
Significant differences according to the character and type of intervention, for concepts with $ICC > 0.5$, where *HP* means High Plantation, and *LP* Low Plantation.

for each concept is incremented positively or negatively respectively, one can observe how for every intervention, some concepts are affected in a negative manner, and others experience a positive perceptual increase. In fact, this behaviour is also observed in those concepts which present significant differences.

The most important finding of this experiment relates to significant differences in the perception of the landscape, brought about by human interventions. In general, it can be stated that the degree and the sign of the perceptual difference in a concept, will depend on the character and type of the intervention. More specifically, the results described in section 3.1 demonstrate that:

(1) the perceptual profile will differ depending on the type of intervention;
(2) the concepts in the Consensuated Semantic Space will present significant variations - whether positive or negative - depending on the type of the intervention;
(3) human interventions of permanent industrial character induce primarily significant differences, revealing a loss in ”Naturalness”, ”Affection”, ”Pleasantness”, ”Liveliness” and in the ”Degree of Protection” of the landscapes;
(4) with the human interventions of permanent industrial character, the landscape is perceived as more stimulating and complex. This is justified by the incorporation into the scene, of elements which are substantially different to elements characteristic of a rural landscape;
(5) with the interventions of permanent rural character, the main significant differences are positive and reveal an increase in ”Naturalness”, ”Affection”, Pleasantness”, ”Coherence”, ”Stimulation”, ”Liveliness” and ”Degree of Protection” of the intervened landscapes, as compared to the initial landscapes. On the other hand, perception is only significantly worsened for the concept ”Openness”;
(6) within the interventions of temporary character, the resulting landscape is perceived as more stimulating and less original, as well as less coherent and less likely to be protected.

Other results show that the interventions on the landscape induced by human action, portray a scene which is perceived as significantly more stimulating, independently of the type of alteration. Therefore, the analysis of this concept does not provide any discriminatory information as regards the subjective visual impact of a human intervention.

In general, any intervention will increase the levels of the perceived ”Stimulation” and ”Complexity”, although it should also be stated that not every case shows sufficient consensus or portrays significant differences. Consequently, any sort of human modification of the landscape will generate a signal in the perception of the viewer, which is interpreted at first as a loss in the simplicity of the scene. This implies that, in general, there exist no human interventions which are innocuous or relaxing for a viewer. For this reason, any human intervention should be previously and rigourously analysed to ensure that the degree of ”Stimulation” (exiting per se) is accompanied by as ”Pleasant” as possible a perception.

In reference to the results by Acking and Sorte (1973) which concluded that elements of permanent character reduce the experience of coherence, the results of this study show that for a rural landscape, this statement is only valid for industrial constructions, because ”Coherence” is increased with rural constructions.

Rural interventions, whether cultivations or constructions, help to improve landscape perception in general in all the concepts. More specifically, however, positive significant differences can be observed in the axes ”Affection” and ”Coherence”. These results make these interventions antithetic of the industrial interventions, which demonstrates objectively that the negative impact of human interventions on the landscape does not reside in its presence in the landscape, rather in the unexpected type of ”architecture” of the intervention (i.e. forms, colours, textures). This is made clear if the perceptual profiles of Figures 5 and 8 are contrasted, whereby the former shows an industrial intervention and the latter a rural construction.

Interventions of temporary character are clearly perceived as more odd in the environment, which can be deduced from their significantly lesser ”Coherence” and greater ”Originality”. Figure 9 gives an example of a case where the difference in ”Coherence” can be appreciated even more because the element portrayed in the scene seems abandoned. In fact, it seems so neglected that it could even be perceived as a permanent intervention, which would corroborate the lower level of ”Protection” and ”Pleasantness” assigned to the scene.

From all the cases studied, the type of alteration that has revealed the most anomalous results, corresponds to the open air industrial quarries (6). In this case, the semantic profiles that were obtained, showed that not only were there no significant differences, but also that there were no evident differences between the perception of the initial landscape and the altered one. This fact does not correspond to what would be expected from the controversy that this type of intervention generates amongst the public. The reason for this could lie in that it is not clearly visible from the photographs that the intervention is of mining type, and this information was not given to the subjects to avoid influencing the results of the survey. Given this and the differences described above, it is possible that the subjects were not able to determine the character of the intervention, and hence the emotional component of perception was canceled.

(a) (b)

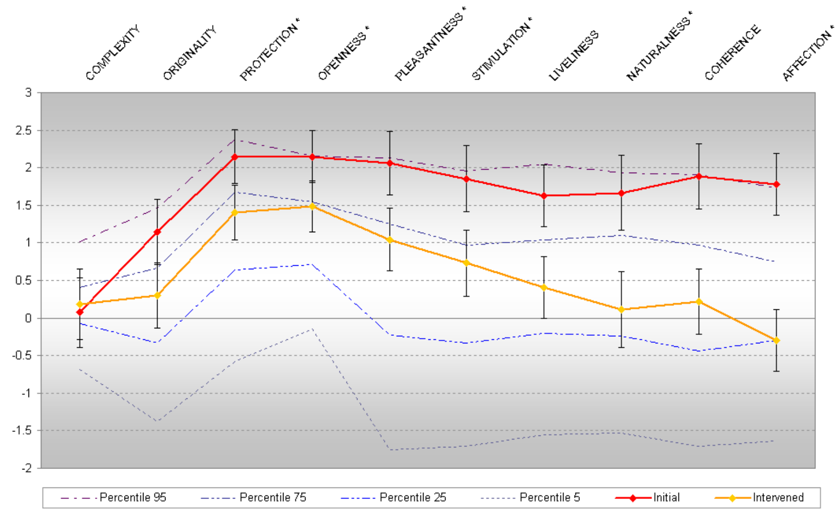


Fig. 3. Example I: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with a paved road. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

(a) (b)

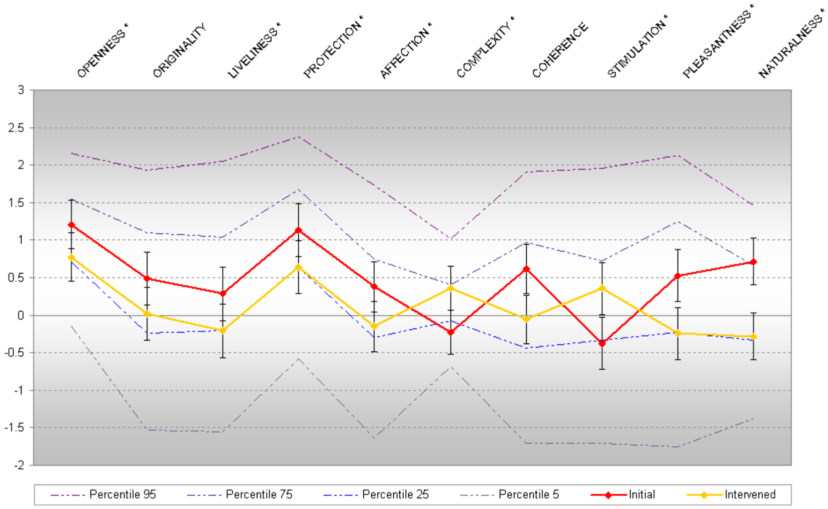


Fig. 4. Example II: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with an industrial post. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

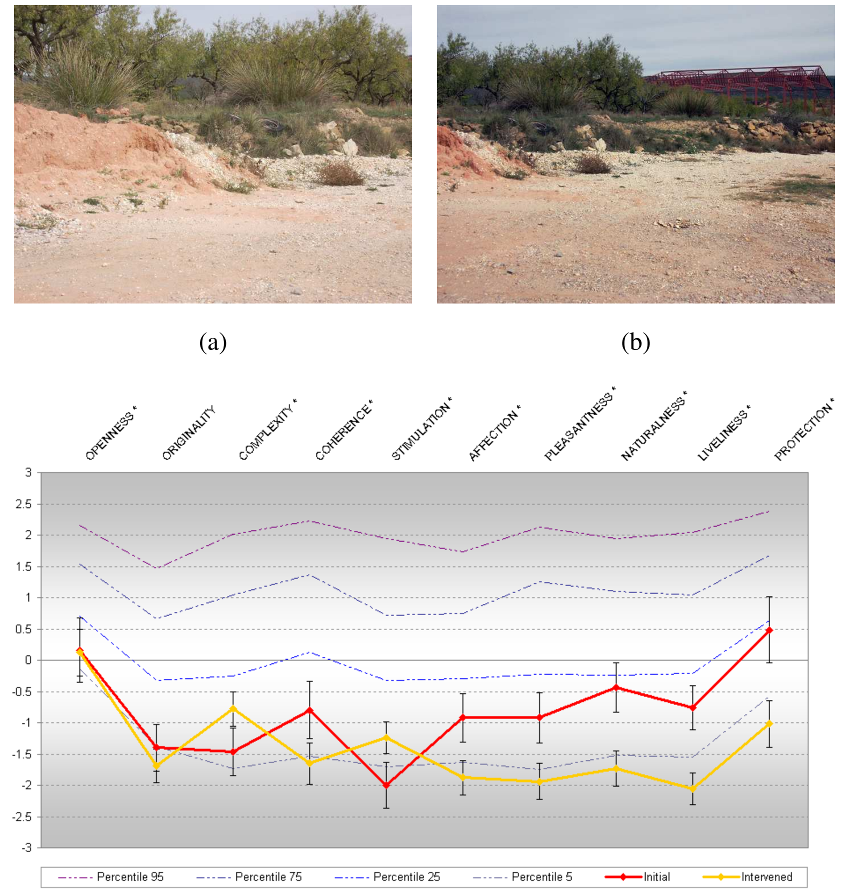


Fig. 5. Example III: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with an industrial construction. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

(a) (b)

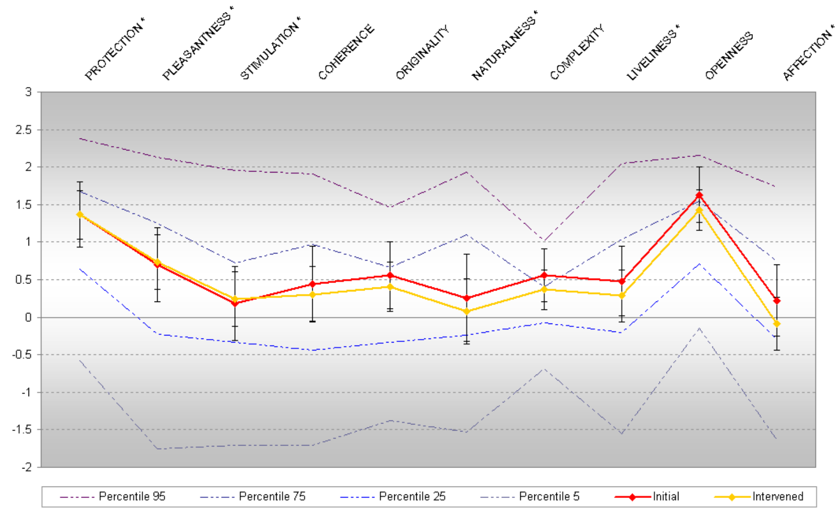


Fig. 6. Example IV: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with an industrial quarry. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

(a)

(b)

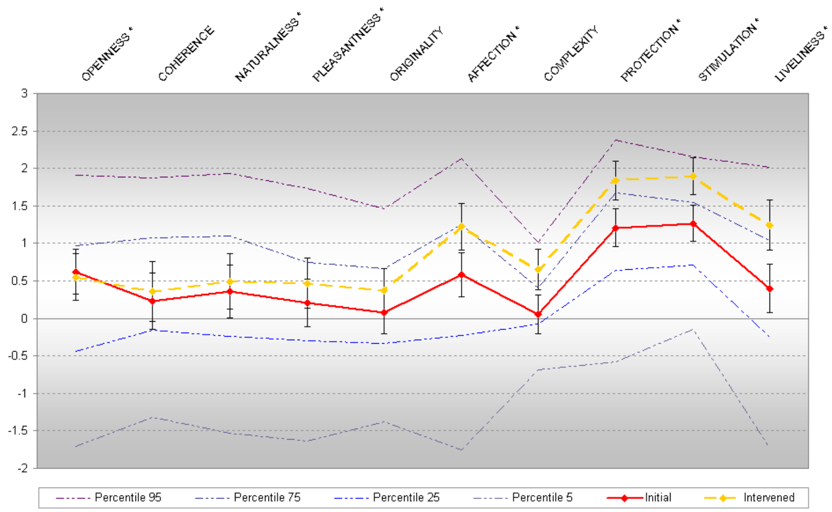


Fig. 7. Example V: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with a rural cultivation. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

(a) (b)

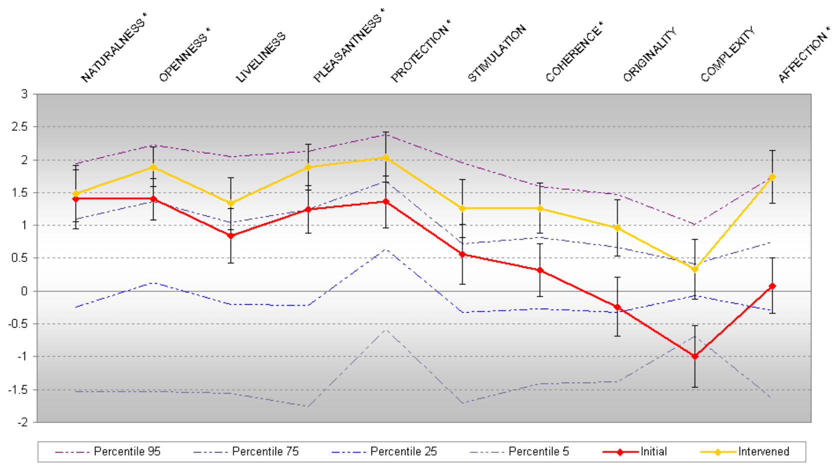


Fig. 8. Example VI: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with a rural construction. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

(a) (b)

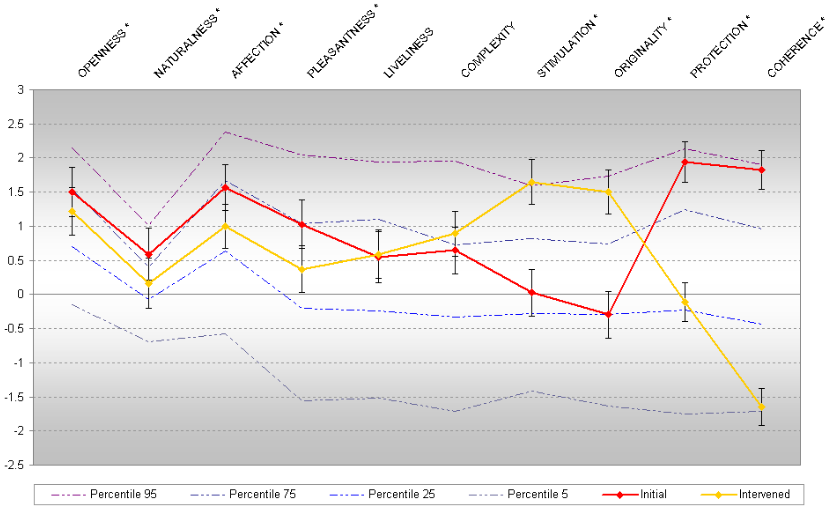


Fig. 9. Example VII: Semantic profile of (a) an initial landscape, and (b) the initial landscape altered with a temporary element. The starred concepts portray $ICC > 0.5$ for pre- and post-intervened scenes.

4 Experiment II: Alteration of the landscape through successive incorporation of elements of different character

The following section works with landscape sequences. The previous study analysed the behaviour of visual perception according to the character and type of the development. Progressing from these results, this experiment will study variations in the concepts as elements are incorporated successively into a scene. In particular, it will look for perceptual differences due to the predominating character of a sequence.

One landscape sequence consists of five photographs. The first photograph shows the initial, unaltered scene. In the second picture, an element of a specific character is introduced into the scene. Gradually different elements are introduced into the previous scene until a sequence of up to four different types of elements is reached. A total of eight sequences are constructed, four of which have a predominantly permanent industrial character, and another four contain elements of different characters. A sequence of predominantly rural character could not be put together, because according to the classification of characters and types of character in Table 1, such a sequence would consist of only two different types of elements instead of four, i.e. rural cultivations and constructions or roads.

The ICC of the scenes was calculated first to ensure that there was consensus among the subjects with respect to the valuation of the concept in each scene. An ICC value lower than 0.5 would suggest lack of consensus, which can be interpreted as if the scene did not stimulate the subjects clearly enough in this concept, regardless of whether it is the concept that has been misunderstood, or the stimulus itself. Generally, and as expected, concepts which were not understood so clearly were ”Coherence”, ”Originality” and ”Complexity”, which account for only 30% of the concepts. In some scenes, ”Openness” also showed ICC values below 0.5. Photographed scenes are perhaps not the most appropriate type of representation for the concept ”Openness”, which is probably portrayed more accurately in a video simulation or an on-site evaluation.

We define dominant character of a scene as the character exhibited by the majority of the elements in the scene. Consequently, the dominant character of a sequence is defined by the character exhibited by the majority of the scenes.

The examples below show the analysis of a sequence of dominating industrial character (Sequence A), and a sequence of mixed character (Sequence B). The results of the experiment showed similar semantic behaviour between sequences of the same group. In the examples below, Sequence A faithfully reflects the trends of the other three sequences of permanent industrial character, and Sequence B is also characteristic of the behaviour of the results of the remaining mixed sequences.

4.1 Results and Discussion of Landscape Sequence A: Dominating permanent industrial character

This section summarises the perceptual responses to Landscape Sequence A, which are shown in Figure 10 and 11.

As was expected from the results shown in Table 1, the incorporation of an unpaved road into a rural landscape does not bring about any significant changes in the behaviour of the concepts. Changes first occur when elements of permanent industrial character appear in the scene. The general trend is an immediate change in the concept when one type of industrial element is incorporated. Depending on the concept, the change may move in a positive or a negative direction. As more industrial elements are incorporated, further differences are reported in each concept, and always in the same direction as the initial change. Finally there comes a point when the addition of an extra element does not induce further change. At this point, the landscape has reached saturation. Further investigations should be dedicated to finding where this point is positioned for each concept, as this is of great advantage for correct landscape design.

In general, it can be said that when rural elements predominate in the scene, the landscape is valued along the positive side of the axis for most concepts. With the exception of ”Stimulation”, predominance of a permanent industrial character affects the evaluation of the landscape in each concept negatively, bringing results down to negative numbers.

This particular initial landscape presents a dry meadow surrounded by arid mountains, typical of the Mediterranean region, and it is valued along the positive side of all axes (except in the case of ”Complexity”, where it is negative). Values for ”Originality”, ”Affection”, ”Liveliness”, ”Pleasantness” and ”Stimulation” range around 0.5, which manifests a slight (positive) indifference from the subjects towards this type of landscape. As soon as an industrial building is constructed, values for the first four concepts drop heavily and large significant differences are observed. As construction apparatus are incorporated into the scene, values drop further significantly, so much so that they surpass the 5 percentile range, meaning that this landscape is perceived as less original, traditional, lively and pleasant than 95% of the landscapes in the experimental sample. The incorporation of an electricity line does not bring about further changes. In a similar manner, the landscape becomes significantly less coherent and less natural as it undergoes alteration, although values are initially higher and remain above the 5 percentile. In the case of the concept ”Stimulation”, changes occur in the opposite direction with values nearly reaching the 95 percentile, and similarly with ”Complexity”.

The last scene of the sequence (scene (e)) exhibits a large amount of industrial elements. However, it is interesting to observe that subjects do not consider the landscape worthy of no protection at all, in the worst case, they are indifferent to its protection. This could be because even though the type of alteration is predominantly industrial, the area occupied by unaltered land is larger. In this case too, a study is suggested to investigate on the relationship between the magnitude of the intervention and its semantic evaluation.

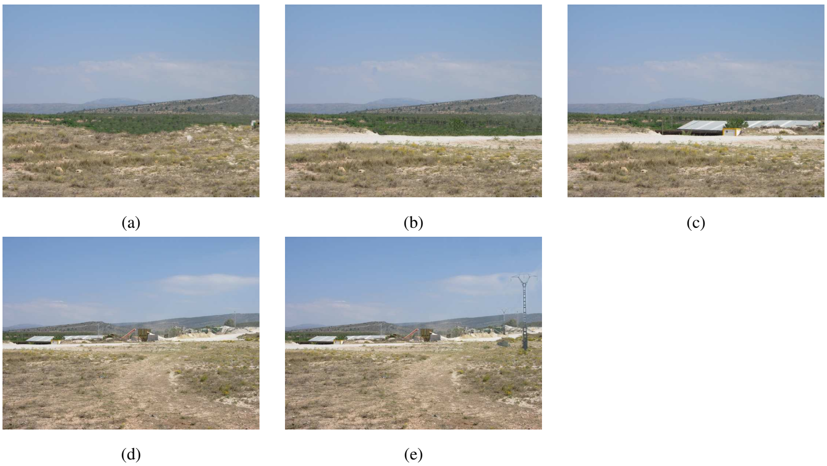
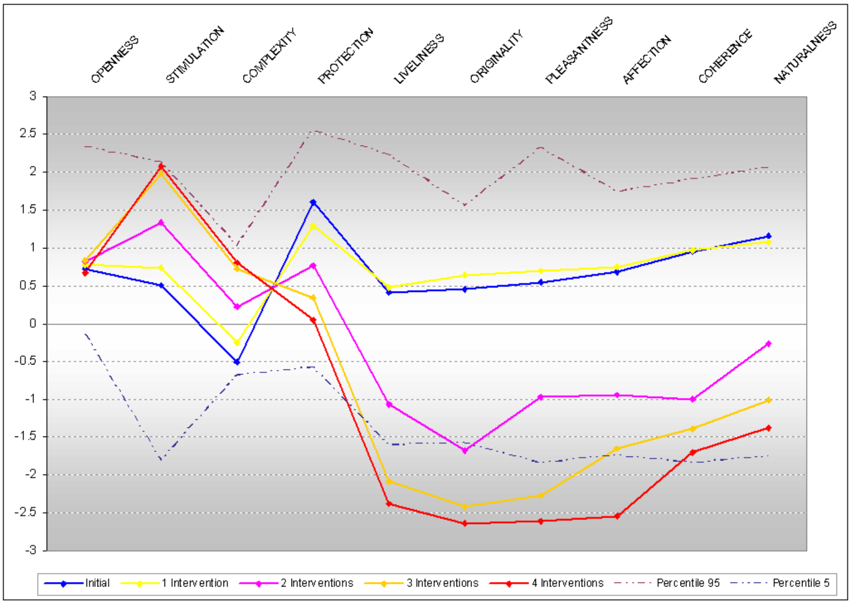


Fig. 10. Sequence A: Semantic profile of (a) an initial landscape, altered with (b) an unpaved road, and (c) an industrial construction, and (d) industrial apparatus, and (e) an industrial post.



Concept	Step 0-1	Step 1-2	Step 2-3	Step 3-4
Complexity	+	++	++	0
Originality	0	- -	- -	-
Openness	0	0	0	0
Naturalness	0	- -	- -	-
Affection	0	- -	- -	- -
Pleasantness	0	- -	- -	-
Stimulation	+	++	++	0
Liveliness	0	- -	- -	-
Coherence	0	- -	- -	-
Protection	-	- -	- -	-

Fig. 11. Figure 10 continued. The table shows the direction of the perceptual response between the scenes (no change, positive or negative). Significant differences are marked with double signs (”++” or ”- - ”).

4.2 Results and Discussion of Landscape Sequence B: Mixed character

This section makes reference to the perceptual responses to Landscape Sequence B, which are shown in Figures 12 and 13.

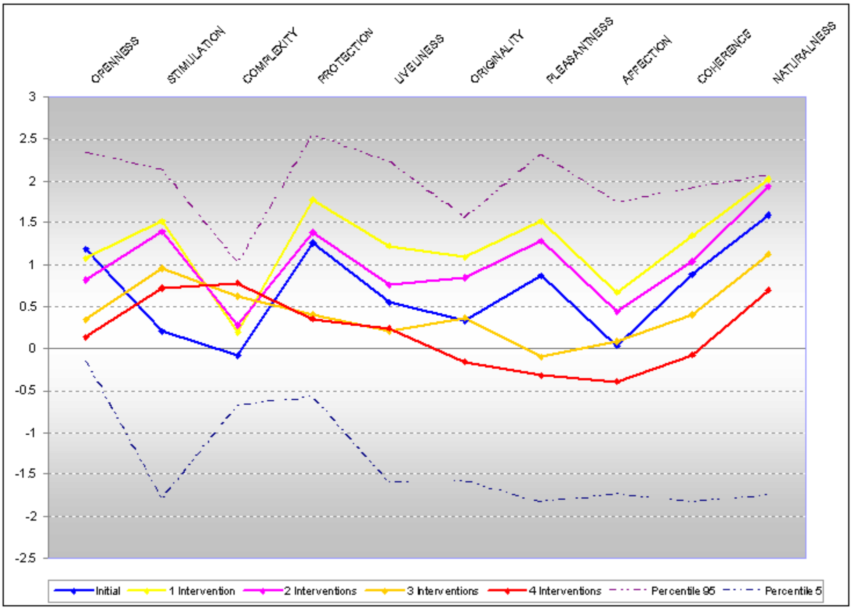
Figure 12 shows consistent results with Experiment I. When rural elements (trees and rural house) enter a landscape, a positive influence can be observed on the majority of the axes, with the exception of ”Complexity” and ”Openness” which remain unaltered. On the other hand, industrial elements have a negative effect on the evaluations.

Evaluations remain largely within the positive sector. This positive attitude of the subjects is due to the nature of the setting of the scene: a rural landscape. In a similar case to Sequence A, here it is also important to separate between the type of character of the elements in the scene, and the type of character of the scene which is defined by the background. This could be done in future analyses, for example, by examining the percentage of a scene which must be taken up by industrial elements for the scene to become industrial. It would also be interesting to find a means to locate the point when elements become part of the background.

This landscape sequence initiates with a similar scene as in the case before: an arid meadow surrounded by mountains. Therefore, in both cases, the initial values in the concepts are similar. Incorporating a rural construction into a landscape of predominating rural character has little influence. Permanent industrial constructions such as industrial roads however, have a significantly negative effect in all axes except for ”Stimulation” and ”Complexity” which increases with the number of elements in the scene. In fact, the landscape sequence experiences significant positive changes in ”Complexity” with the incorporation of elements of different character, thus confirming Jacob and Way’s (1973) results.

(a) (b) (c) (d) (e)

Fig. 12. Sequence B: Semantic profile of (a) an initial landscape, altered with (b) a rural cultivation, and (c) a rural construction, and (d) a paved road, and (e) an sign post.



Concept	SD 0-1	SD 1-2	SD 2-3	SD 3-4
Complexity	+	0	++	+
Originality	+	- -	- -	- -
Openness	0	- -	- -	-
Naturalness	++	0	- -	- -
Affection	++	-	- -	- -
Pleasantness	++	-	- -	-
Stimulation	++	0	- -	-
Liveliness	++	- -	- -	0
Coherence	++	-	- -	- -
Protection	++	-	- -	0

Fig. 13. Figure 12 continued. The table shows the direction of the perceptual response between the scenes (no change, positive or negative). Significant differences are marked with double signs (”++” or ”- - ”).

5 Conclusions and Future Research

Every human intervention will modify the perceptual semantic profile of a viewer. In general, for scenes of predominating rural character evaluations remain within the positive sector, whereas scenes with predominating industrial character are evaluated negatively.

There exists a pattern in the perceptual response towards an intervened landscape, and these standards are maintained overall, when different elements are introduced successively into the scene, although it is possible to distinguish between types of interventions which are more determinant than others.

When industrial elements are incorporated into the rural landscape, significant negative changes occur in the concepts ”Affection”, ”Protection”, ”Pleasantness”, ”Coherence” and ”Naturalness”. On the other hand, with the exception of unpaved roads, rural elements induce positive changes in these axes. These is perceptual changes are explained by the *unexpected* type of ”architecture” of the intervention (i.e. forms, colours, textures) with respect to the background scenery.

In general, any human intervention will increase the levels of the perceived ”Stimulation”. The importance of this result is emphasized in the design phases of the development project. Interventions should be previously and rigourously analysed to ensure that the degree of ”Stimulation” (exiting per se) is accompanied by as ”Pleasant” as possible a perception.

As regards the concept ”Openness”, so much the results from the perceptual evaluation as the results from the ICC study seem to suggest that representation of rural landscapes through photographs is perhaps not the most appropriate means to assess this concept. Future studies should consider the application of virtual reality techniques, or on-site evaluations of the landscape wherever possible.

From Experiment II it cannot be concluded that the perceptual variation of each concept can be adjusted to a specific function (linear, square, exponential, logarithmic, etc.). For example, for the concept ”Naturalness”, Landscape Sequence B could be adapted to follow a linear variation, whereas this behaviour would not apply to Landscape Sequence A. Future research should be directed at finding and determining possible perceptual variation patterns for each semantic concept individually. Particular attention should be paid to the evaluation of perceptual saturation as more interventions are incorporated into a scene.

Given the sensitivity of the results with the incorporation of new elements into a landscape, it can be concluded that the Semantic Differential as a tool for the evaluation of the effect of human interventions on the landscape, can be applied in the design phase to study potential solutions to the architectural design of an intervention. The utility of this tool does not only reach construction projects, but also other types of artificial elements, regardless of whether their design allows only for a narrow design margin (e.g. roads, electric posts). In fact even in these extreme cases, the designer can pre-evaluate different solutions for materials, colours, surfaces or spatial distribution. This way, that solution which produces the most satisfactory perception, can be adopted.

For this same reason, this methodology can be used to identify and characterise landscapes of special quality such as natural parks or degraded territories, with the aim of applying the correct conservation and recovery procedures.

To conclude, further to the validity and reliability of the methodology, the results support the use of Differential Semantics as a technique to integrate the general public in landscape decision-making. In addition, the analysis has shown that the robustness of the technique is increased by means of the ICC, which helps to determine the Consensuated Semantic Space as well as the number of subjects required for a reliable evaluation of the landscapes.

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