USING GIS IN LANDSCAPE VISUAL QUALITY ASSESSMENT

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Landscape Visual Quality (LVQ) 'assessment has become a core component of landscape architecture, landscape planning and spatial planning. Different approaches for assessing the scenic qualities of landscapes have been developed in the last few decades. Two contrasting paradigms, expert/design approach and community perception-based approach, have dominated methodology development. In the expert-design approach the landscape visual quality is defined by biological and physical (or biophysical) values, while the perception-based approach emphasises the human view (subjective) of the landscape. This paper outlines a methodology combining expert and perception approaches to assess the LVQ.

The application of information technology to landscape analysis dates back to the early work in computer-based mapping. Much of the early work on what became Geographic Information Systems (GIS) and three-dimensional landscape modelling was carried out by landscape architects and landscape planners. In the past years, significant advances in computers and GIS have enabled analysis of vast amounts of spatial information, which is the foundation of the methodology described in this paper. The methodology is explained in detail through its application to assess the LVQ of the Mornington Peninsula Shire, Melbourne, in the State of Victoria, AUSTRALIA.

There are six stages in the procedure: viewpoints selection; calculation of factor indices based on Visual Exposure Modelling; landscape preference rating; use of statistical methods (such as multiple regression model) to determine the key predictors of LVQ; application of the formula thus generated to assess the LVQ of viewpoints; and use of spatial interpolation to map LVQ across the study area.

The results are discussed in the last section of this paper with reference to key methodological issues. Results show that the perceived LVQ increases with the area of water visible, the degree of wilderness and percentage of natural vegetation, and the presence of hills. On the other hand, it decreases with the presence of perceived negative human-made elements such as roads and buildings.

BACKGROUND – CONSTRASTING PERSPECTIVES

In the 1960s and 1970s, landscape quality assessment was mostly the domain of landscape planners and architects, especially Lewis (1966), McHarg (1969), Fabos (1979, 1985) and Zube (1980) and their associates[1]. McHarg wrote a seminal book, *Design with Nature*, which was translated into many languages and more widely read than any other book written by a landscape architect/planner. McHarg popularised the landscape or topological approach which describes and analyses the vertical relationships between many factors that occur at a given location be it a forest, a patch of wetland, or a residential neighbourhood. The approach builds layers of factors which collectively describe a place or places. The factors considered often start at the bottom of the landscape system with bedrock geology and groundwater, and are followed by soils, subsurface and surficial hydrology, vegetation, wildlife, and climate. In many landscape planning methods, based on McHarg's approach, such factors are overlaid to generate aggregate values derived from the combinations of concurrent spatial factors.

Another important contribution of that period is Lynch's *The Image of the City* (1960) where he contended that vividness and coherence of the environmental image is a crucial condition for the enjoyment and use of the city. According to Lynch (1960), this image – "the sense of place" – is the result of a two-way process between observer and object, in which the external physical shape upon which a designer can operate plays a major role. In a later book, *Managing the Sense of a Region* (1976), Lynch extended his approach to the regional scale arguing that the (human) experiential quality of the environment must be planned at that scale.

During those two decades, the modern conception of 'sustainability' came to the forefront of scientific and political debate responding to major concerns about the socio-cultural and environmental impacts of rapid technological change and economic growth. The initial international response culminated with the release of *Our Common Future* by the World Commission on the Environment and Development (WCED 1987), which put forward the most quoted definition of sustainable development. "Humankind has the ability to make development sustainable – to ensure it meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987:8).

There are multiple dimensions to sustainability including economic, socio-cultural, ethical, and spatial (Pearce et al. 1989; Daly 1992; Yencken and Wilkinson 2000). Landscape planning is most fundamentally linked to the latter, the spatial dimension, and predominantly at the landscape scale (Forman 1995; Forman and Godron 1986). Increased international interest in sustainable landscape planning have encouraged a dialogue between ecologists and landscape planners within the new discipline of landscape ecology, and several landscape planning methods have been developed that explicitly include a landscape ecological perspective (Vos and Opdam 1993; Steiner 1991; Ahern 1999).

A parallel development can be seen in spatial planning (urban and regional planning), which, since the 1980s, has been increasingly guided by the principles of sustainability (Beder 1996; Healey et al. 1997; Layard et al. 2001). There is a multiplicity of characteristics that describe sustainable cities and regions (see, for instance, Hugh 1994; Burton et al. 1995; State of the Environment Advisory Council 1996, 2001). They include aspects related to the quality of life and 'livability' such as the quality of landscapes. The assessment of landscape quality is thus becoming a major component of spatial planning, particularly over wide areas (Bishop and Hulse 1994; Schmidt 2001; Bishop and Lange 2005). In visually sensitive areas, this includes assessment of the significance of regional scenic resources. The development of large structures in natural rural regions has highlighted the need for accepted ways to assess landscape quality and the effects of development as one of a number of aspects which must be considered in the planning process.

To assess the 'quality' of a landscape, the contributions of many different viewpoints must be considered. For instance, McHarg (1969) argued that any place is the sum of historical, social, physical and biological values. The UK Living Landscape Project, by the Countryside Commission (1993), and its successor, the Countryside Agency (2004a), developed an 'integrated characterisation' that gives equal weight to landscape character, ecological character (biodiversity), historic character, the resources of air and water, recreational character and accessibility. Gomez-Sal et al. (2003) developed a model that takes into account five evaluative dimensions which are considered to be independent – the ecological, productive, economic, social and cultural – each of which is analysed by specific indicators.

To clarify, therefore, the term 'landscape quality' as used in this paper is restricted to its visual properties, including human-made components and biological and physical (or biophysical) resources (Daniel and Vining 1983; Amir and Gidalizon 1990). The scenic beauty of a landscape comes from two sources which cannot be separated: from the object itself and from the observer (Laurie 1975). Consequently, the focus is on *Landscape Visual Quality* (LVQ) assessment. As stated, visual quality has to be considered alongside other values such as nature conservation value, agricultural and forestry values, water resources, culture heritage, and residential value.

LVQ assessment is a well recognised field of scientific research with a substantial literature base. Its recent development has been dominated by two contrasting paradigms leading, in turn, to several methods and various classifications of them: expert/design approaches and community perception-based approaches (Arthur et al. 1977; Daniel and Vining 1983)[2].

The expert-design approach to landscape analysis has dominated environmental management practices and underlying it is the belief that LVQ is defined by intrinsic biological and physical (or biophysical) values, independent of human perception and experience (Callicott 1985; Rolston 1988). The role of the human viewer is acknowledged by the importance of viewpoints (from which viewers observe the landscape) and sensitivity (number of viewers and the context landscape which is viewed).

Perception-based approaches emphasise the human viewer. Aesthetics is a well travelled path of study for philosophers, artists, designers and more recently environmental managers and policy makers (Lothian 1999). It is considered that the aesthetic (beauty) of an object is in the eye of the beholder. A LVQ is a joint product of particular (visible) features of the landscape interacting with psychological (perceptual, cognitive and emotional) processes in the human observer. Perception-based approaches treat biophysical features of the landscape as stimuli that evoke relevant psychological responses (Shafer et al. 1969; Kaplan and Kaplan 1989).

Both approaches share a basic conception of LVQ in which biophysical features of the environment and human perception/experience are essentially interacting components. LVQ arises from the relationship between properties of the landscape and the effects of those properties on human viewers (Daniel 2001). In the past few years, these two contrasting perspectives are merging into a more balanced and comprehensive view, which is supported by the use of statistical techniques to determine the mathematical relationships between landscape elements and the scenic preferences of observers (Palmer 1983, 2004; Wherrett 2000; Real et al. 2000). This approach has parallels to earlier psychophysical methods (Daniel and Vining, 1983) and underpins the methodology presented in this paper.

Photographic media have generally been found to be a valid representation of the landscape in visual quality studies (Palmer and Hoffman 2001), and have been used extensively (Law and Zube 1983; Palmer 2004; Perez 2002; Arriaza et al 2004). The LVQ assessment methodology outlined in this paper uses photographs to asses the scenic preference of observers.

In the past fifteen years, significant advances in computers and Geographic Information Systems (GIS) have led to an increasing deployment of GIS to assess visual landscape variables using reproducible methods over wide areas. One of the first examples of mapping visual qualities using a GIS is found in Steinitz (1990). He used GIS with the land cover and digital terrain model of Acadia National Park, in USA, for mapping visual quality based on the occurrence of key features within the viewshed of each selected point, and regression analysis to identify eight key variables of landscape public preference. The approach to GIS-based VQL modelling taken by one of the authors of this paper (Bishop and Hulse 1994) was quite similar to Steinitz's, except that (a) the public evaluation was based on a 360 degrees view at each sample location, and (b) the predictor variables used in regression analysis were derived from GIS rather than being estimated from photographs. GIS was applied by Germino et al (2000) to estimate the visual properties of Rocky Mountain landscapes in USA. In this study, GIS was deployed to generate the panoramic simulations as well as analyse the viewshed lines. The UK Living Landscape Project developed a structured, GIS-based landscape character framework for describing and analysing the countryside (Warnock 2002; Countryside Agency (2004b). The framework operates at different levels of spatial resolution, ranging from regional (level 1–1:250,000) through the country/district (level 2–1:50,000), down to the individual site (1: 10,000).

The following sections of this paper consist of three main parts. The first briefly explains the methodology followed in this research. The second presents the results of the application of the methodology in a region of Melbourne, State of Victoria, Australia (**Figure 1**); further details of the methodology are explained in this section. Finally, the authors provide a summary of the research with some conclusions.

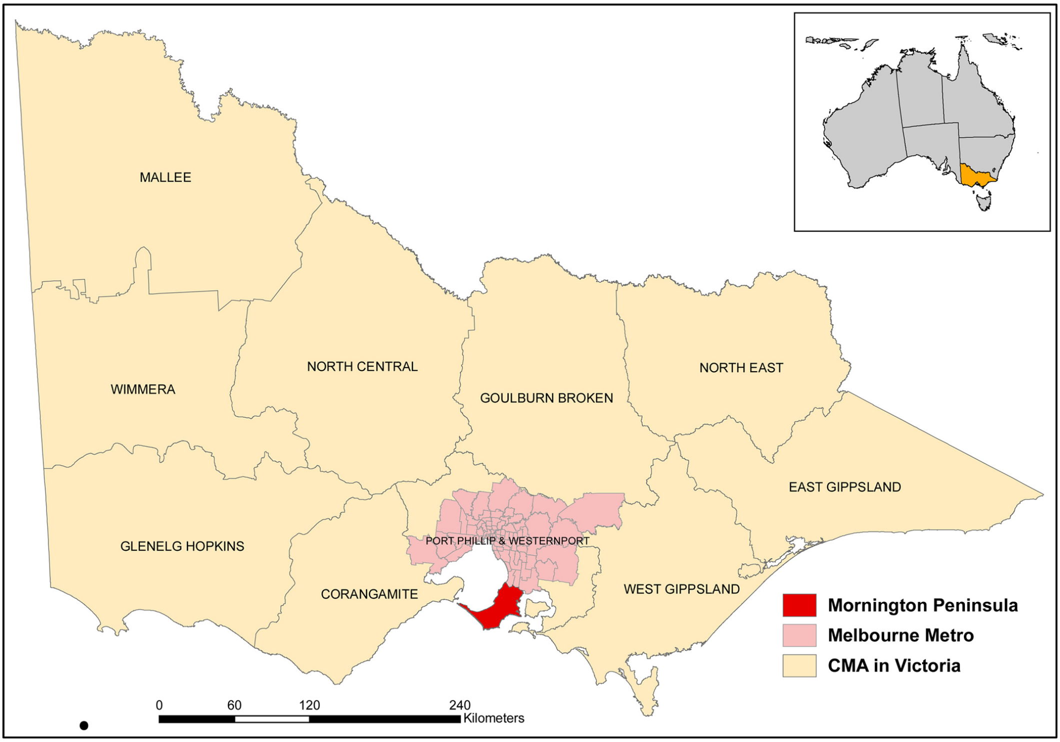

Figure 1 Location of the State of Victoria, Melbourne and Mornington Peninsula in Australia

METHODOLOGY

The methodology presented in this paper can be divided into six major stages, as shown in **Figure 2**. Stage 1, Data Preparation, comprises two parts (i) identification of key visual features to be used as potential LVQ factors in the following procedures; and (ii) selection of locations for visual analysis, known as 'viewpoint selection'. In Stage 2, Factor Indexes are calculated based on Visual Exposure Analysis, which is also known as 'viewshed analysis'. The output of this stage is presented in a table containing a full set of factor indexes for each selected viewpoint. In Stage 3, Landscape Scenic Preferences, an initial investigation of community scenic preferences is undertaken based on the photographs taken from the selected viewpoints. Several means can be used to elicit community views, including workshops and dedicated websites. In Stage 4, Statistical Analysis & Formula Generation, the scenic preference investigation results and the Factor Indexes are used to develop and run the regression model to simulate the relationship between indicator values and LVQ. In Stage 5, Landscape Visual Quality Assessment, the model created in the previous stage is applied to all the viewpoints, including those that had been ranked by the community. The LVQ values are then used in Stage 6, Interpolation Analysis, which broadly assesses LVQ for the whole study area. The main output of the overall procedure is a classification map (grid) throughout the study area of LVQ on an ordinal scale.

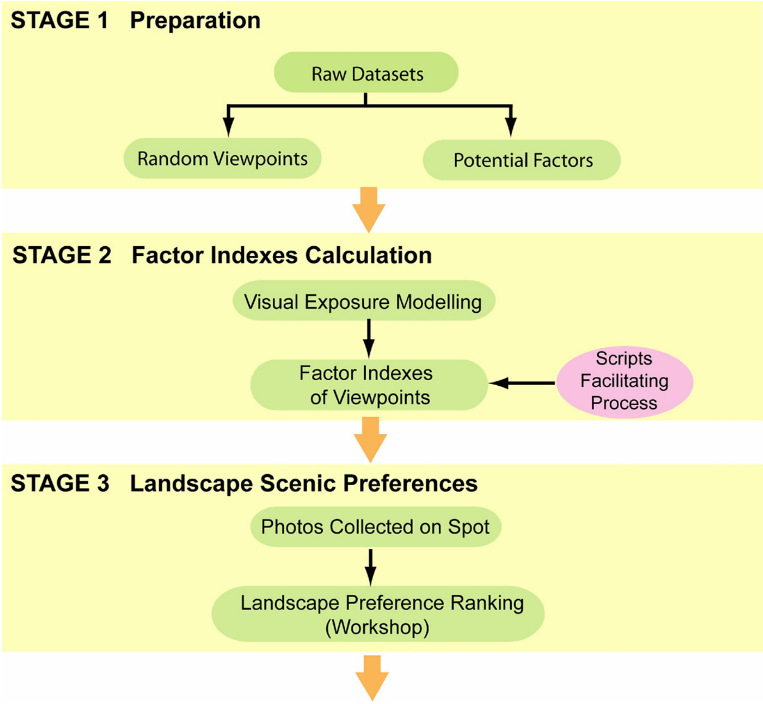

Figure 2 Main Stages Involved in Landscape Visual Quality Assessment

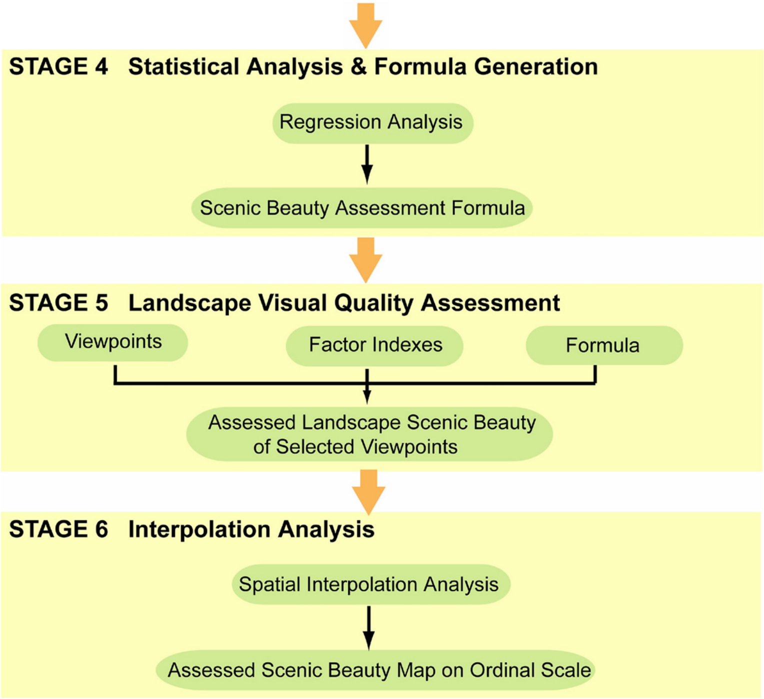

Figure 2 (cont'd) Main Stages Involved in Landscape Visual Quality Assessment

APPLICATION – METHODOLOGICAL SPECIFIC DETAILS AND RESULTS

The methodology was first fully applied in the Mornington Peninsula Shire located in the peri-urban region of Metropolitan Melbourne, State of Victoria, Australia[3]. The south-central portion of the Mornington Peninsula was chosen as the study area (**Figure 3**). It contains a diversity of scenic landscapes and is surrounded by the sea, with coastal boundaries of over 190km and a mixture of urban areas, resort towns, tourist development and rural land.

STAGE 1 – DATA PREPARATION

There are two parts in the stage of data preparation; the first one is the identification of the key visual features to be used as potential LVQ factors in the following procedures. The second is the selection of locations for visual analysis, known as 'viewpoint selection'.

KEY VISUAL FEATURES

Over half the study area is covered by pasture (grazing) with other significant features including a variety of forests and woodlands, golf courses and horticultural fields. In principle, every feature in the landscape can be considered as a LVQ factor. Some of them were assumed to have similar effects on LVQ and therefore were categorised as one key visual feature. After classification, eight representative features from the study area were identified: Pasture, Other Vegetation,

Figure 3 Study Area in Mornington Peninsula Shire

Shore, Creek, Road, Building, Slope, and Sea. Each landscape feature is represented in a corresponding spatial layer for later processing. Most of the layers are derived data sets from originals at 1:25,000 geographic scales.

PASTURE

The information was derived from land use data based on the Australian land use code and description (Bureau of Rural Sciences, 2002). Polygons with land use Code 3.2.0 and description 'Grazing modified pastures' were selected.

OTHER VEGETATION

This layer was extracted from both land use and Ecological Vegetation Classification (EVC) data.[4] It presents the vegetation cover of the area except pasture. It includes all the woodland, forest and shrubland as a whole.

SHORE

Since the study area has a long coastline, shore (or coastline) comes as a potential factor of LVQ. The layer was derived from digital topographic data set.

CREEK

As shown in **Figure 3**, creeks are scattered throughout the whole Mornington Peninsula. This layer was extracted from the waterway layer of Victoria.

ROAD

This layer contains all roadways in the study area, including private access. The data was derived from land use and digital topographic data sets.

BUILDING

The building layer was derived from the digital topographic data set. Most buildings recorded in this data set are farms and residential houses and are presented as point objects.

SLOPE

The Slope layer was directly derived from an original Digital Elevation Model (DEM) by SLOPE command in the Surface Analysis. The result layer is a continuous surface with floating point values.

SEA

The Sea layer was derived from the DEM. An area without elevation value (that is outside the mainland) is given the value of 0. The area with elevation 0 was extracted as Sea layer.

The layers mentioned above were converted into raster (grid) format to facilitate the spatial analysis. The grid cell size used in the operations is 20 by 20 meters.

VIEWPOINT SELECTION

The visible landscapes are determined by the location of the viewpoints. A set of viewpoints should be used which cover the range of type and LVQ existing in the study area. In Mornington Peninsula, the viewpoints were chosen along the tourist roads because most people experience the visual qualities of the area from the roads. This decision also facilitated easy access to the viewpoints when taking the photographs for the public preference evaluation. The location can be any point along the road, thus allowing random viewpoint selection. In our study, the random points were generated by a short computer program using Visual Basic for Applications (VBA) embedded in ArcMap.

This operation had two parts:

A. The computer program was used to generate a raster layer in which each cell has a random value. The points outside of the tourist road were then removed by intersecting the random point layer with the road. About one percent of road points (i.e., those with the lowest random numbers) were kept for further selection (**Figure 4**, a1 – a3).
B. The quantity of points was reduced to half (112 in this case) manually. The purpose was to avoid the urban areas and zones in which there would be distorting effects from being at the edge of the study area. Those points located very close together were removed as well (**Figure 4**b). **Figure 5** shows the final selection of viewpoint locations along the tourist roads of Mornington Peninsula.

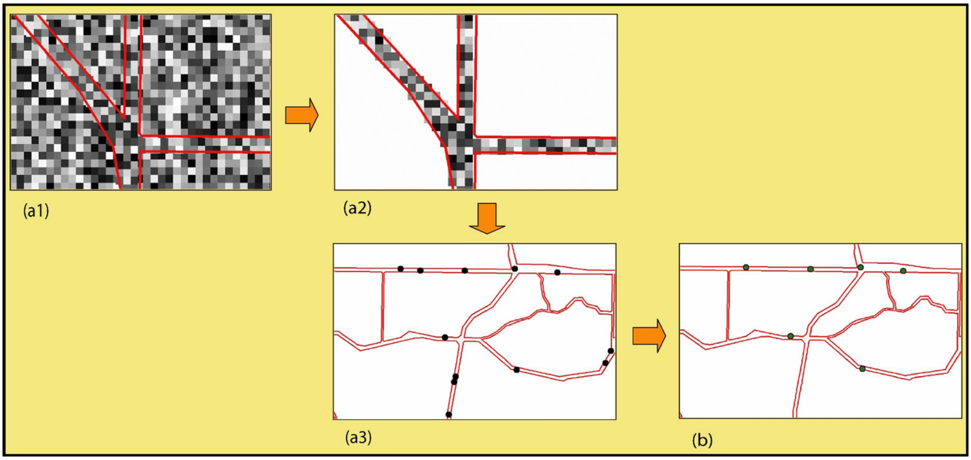

Figure 4 Viewpoint Selection Procedure

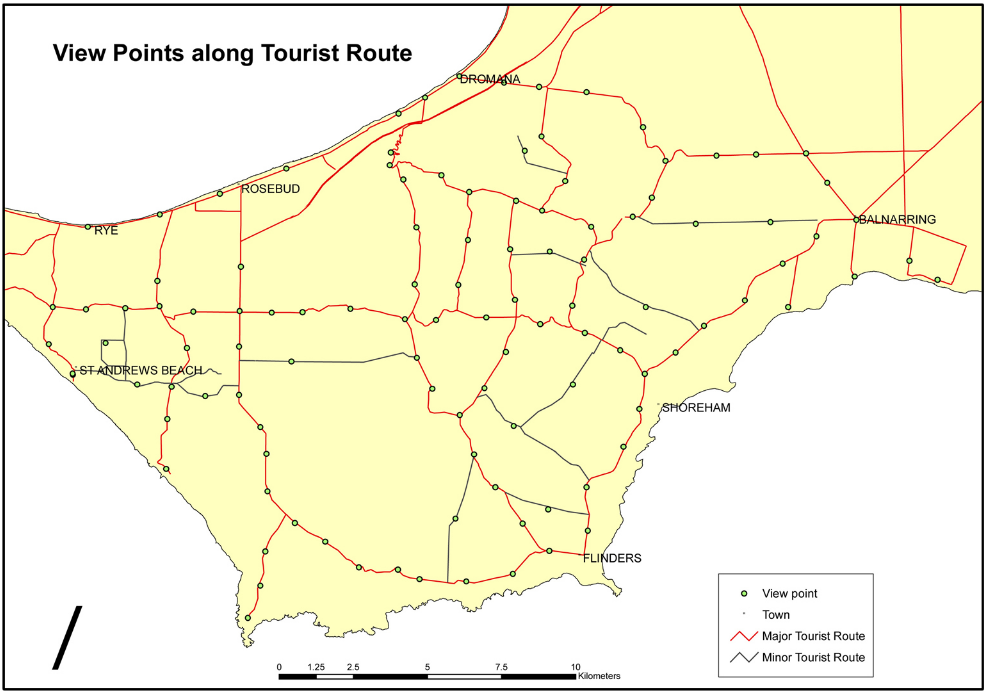

Figure 5 Viewpoints along Tourist Routes

STAGE 2 – FACTOR INDEX CALCULATION

In this stage, a Factor Index was calculated based on Visual Exposure Analysis, which is also known as viewshed analysis. The output of this stage is presented in an Excel table which contains a full set of factor indexes for every viewpoint.

VISUAL EXPOSURE MODELLING

A viewshed computation identifies the cells that can be seen from one or more observation points or lines. If only one viewpoint is involved, viewshed is then the area visible from a given point. Each cell seen from the observer point is given the value of 1 and cells that can not be seen are given the value of 0. Although this study involved multiple viewpoints, we were concerned with modelling the influence of visual features on specific views and so viewsheds were computed for each sample point individually.

A DEM derived from mapped contours does not take into account features such as woods or buildings which can also block the view. To overcome this, the heights of mapped surface features were superimposed onto the DEM. Although non-pasture vegetation was treated as a single visual feature in the LVQ modelling, at this stage of the overall procedure, different vegetation classification were treated separately. Thus, the average tree height was assumed to be 20 meters, while shrubs were assigned 5 meters. Buildings were judged to average 4 meters. The value of each cell in the resulting DSM (Digital Surface Model) was the sum of the ground elevation (DEM) and vegetation height or building height.

CREATING A FACTOR INDEX

LVQ assessment is based on an analysis of human landscape preferences as viewed from fixed points at ground level. In modelling terms, scenic beauty depends on the particular features present in the view, the pattern, and whether these features and patterns are close or distant. A close object clearly has more impact than a distant one and should be weighted accordingly. The geometry of vision suggests that as distance ‘d’ increases, size diminishes as $1/d^2$. However, perception studies suggest that the true rate of decline of influence is considerably slower. Indeed some works (e.g. Benson et al. 1998, as reviewed by Bishop et al. 2004) suggest a linear relationship.

In our study, the relationship between the feature and its impact to local LVQ was considered as something between the $1/d^2$ relationship, suggested by geometry, and a linear relationship; hence, a 1/d relationship was assumed. The visibility of a factor (object) from a viewpoint is first determined by multiplying the viewshed (0/1) and the factor layer. Each visible cell containing the factor is weighted by 1/d and then these values all added together. This gives a measurement of degree of the factor’s visibility from each viewpoint. This relationship was applied to all the LVQ factors (identified in Stage 1) except *Slope* and *Sea*. Due to the relatively large visible area, the index calculation of Slope and Sea is different to the other factors. The distance from the viewpoint was divided into 4 zones: 0 – 400m (zone 1), 400 – 1000m (zone 2), 1000 – 5000m (zone 3) and greater than 5000m (zone 4). The Zonal Statistics function was applied to Slope and Sea viewshed layers. The output table indicates the count (number of grids), mean, standard deviation and other statistical information about each distance zone of the layer. The values of count, mean, standard deviation of each zone were used as sub-factors under Slope. Count is simply the total number of visible cells, mean is a measure of the average slope of the visible land and the standard deviation suggests the diversity of visible terrain types. Only the values of count were considered as the index of Sea since we were only concerned with the area of visible sea (water body). Names of these sub-factors are formed by the abbreviation of the statistical type (C for count, M for mean slope, ST for standard deviation and S for sea) with a zone number suffix. For example, M1 means mean slope in zone 1, ST4 means standard deviation of slope in zone 4.

A table of Factor Indexes was then constructed after the operation described above was performed in all viewpoints. This table was the core element in our methodology for LVQ assessment. It not only shows the main features composing the landscape, but it is also the base of the statistical analysis undertaken in Stage 4.

STAGE 3 – LANDSCAPE SCENIC PREFERENCES

In this stage, an initial investigation of community scenic preferences was elicited based on the photographs from 60 selected viewpoints. The objective was to have people assess the visual quality of the location, not just in a specific view direction. Consequently, four photographs from each viewpoint were used to record the significant landscape features. These photos were taken with a standard lens camera (Olympus C-8080 Wide Zoom) with approximately 60 degree field of view. For that reason, four images did not record the full panorama. Decisions were therefore necessary on which parts of the view to capture for community evaluation at each point. Meitner (2004) has shown that the combination of selected views generates very similar public responses as a full panorama. His work was based on 4 images taken in the cardinal compass directions. In our study, the choice of images was based on ensuring that key features (positive or negative) were included and that the 4 images were, collectively, representative of the landscape character of the viewpoint.

Figure 6 Photo Slide for Landscape Preference Rating

Photos from a viewpoint were grouped in a PowerPoint slide (as illustrated in **Figure 6**) and shown in the community investigation workshop. The landscape scenes were shown randomly to the participants. Participants included representatives from the local residents; Shire Council officials; and landscape, planners and environmental experts. A survey form was handed out to every attendee to rank the landscape preference of each viewpoint from least to most preferred (scaled 1 to 7). The average value for the 4 images at each viewpoint was recorded as the community visual preference of the viewpoint. Givon and Shaphira (1984), Crask and Fox (1987) and Jaccard and Wan (1996) support this approach providing that the scale items have at least five and preferably seven categories, such as in our study.

STAGE 4 – STATISTICAL ANALYSIS & FORMULA GENERATION

Multiple linear regression-based modelling of factors weights is widely accepted in the field and specialised literature (Palmer 1983 and 2004; Daniel and Vining 1983; Wherrett 2000; Real et al. 2000; Daniel 2001; Arriaza et al. 2004). An alternative is a neural network based mapping which might also be used for research purposes; see Bishop (1996).

The scenic preference investigation results and the Factor Indexes were used to formulate and run the regression model to simulate the relationship between indicator values and LVQ. The regression analysis was based on the Factor Indexes (those with photos only) as the independent variables, and the landscape community preference results as the dependent variable. Using a backward regression approach, the analysis is able to filter out the less significant factors and give coefficients of the stronger ones. **Table 1** shows the standardized coefficient between factor and ranked LVQ.

Factor	Pasture	Creek	Shore	Road	EVC	Building
Standardised Coefficients	-0.352	0.053	0.332	-0.103	-0.083	-0.168

Factor	C1	C2	C3	C4	M1	M2
Standardised Coefficients	-0.261	0.357	-0.237	0.115	0.152	-0.174

Factor	M3	M4	ST1	ST2	ST3	ST4
Standardised Coefficients	-0.217	0.467	-0.042	0.128	0.223	-0.446

Factor	S1	S2	S3	S4
Standardised Coefficients	-0.048	-0.009	0.147	0.055

Table 1 Factor's Standardised Coefficient to LVQ
Note: C1 – C4 are the factors indicating visible area in 4 zones, as mentioned in "Creating a Factor Index" section; M1 – M4 are the mean slope in each zone; ST1 – ST4 show the slope standard deviation and S1 – S4 indicate the visible sea area.

This table shows that pasture, roads, buildings and mean slope at foreground and background and Ocean view at the background have high predictive significance of the LVQ in the study area. Although visible area and standard deviation of slope have significant impact on LVQ, they are strongly correlated to mean slope. Therefore, these two factors have not been considered in the model. The mean slope at foreground and background and the ocean view have positive effects on the LVQ, whilst pasture, road and building have negative effects.

In the equation below the coefficients are different from those in **Table 1** because they are not standardised, but are based on the units used in the regression. More than 70% (R-square is 0.493) of variation in preference ratings is explained by the following model:

LVQ = 4.893 – 0.012Pasture – 0.008Road – 0.01Building + 0.018MeanSlope(F) + 0.008MeanSlope(B) + 0.001Ocean(B)

The absence of a tree/vegetation index in this model is interesting, and contrary to the results of similar studies. However, it appears clear that the negative coefficient on pasture arises from the influence of trees on the view. Large areas of pasture are visible when there are few foreground or middleground trees in the view. In other respects, the equation accords with both intuitive expectation and the visual quality literature.

STAGE 5 – LVQ ASSESSMENT ON VIEWPOINTS

The model created in the previous stage was applied to all the viewpoints, including those that had been ranked by the community. The LVQ values are then used in the interpolation analysis in the next stage, which broadly assesses LVQ for the whole study area.

STAGE 6 – SPATIAL INTERPOLATION ANALYSIS AND LVQ MAPPING

Spatial interpolation calculates an unknown value from a set of sample points with known values that are distributed across an area. This is usually undertaken in a raster format with the viewpoint providing known grid values and the remainder of the grids initially unknown. The distance from a grid with unknown value to the known sample grids contributes to its final value estimation. The primary assumption of spatial interpolation is that points near each other are more alike than those further away; therefore, any location's values should be estimated based on weighted values of points nearby.

There are 3 main methods for spatial interpolation: "Inverse Distance Weighted" (IDW), "Spline" and "Kriging". The IDW method is based on the assumption that the interpolating surface should be influenced most by the nearby points and less by the more distant points. An IDW surface never exceeds the highest or lowest values in the sample point set. Spline estimates grid cell values by fitting a minimum curvature surface to the sample data. A Spline surface can exceed the highest and lowest values in the sample point set, but the surface must pass through each sample point. Kriging is regarded as the "optimal prediction" interpolation model. This method uses a variogram to express the spatial variation, and it minimizes the error of predicted values which are estimated by spatial distribution of the predicted values. A Kriging surface can exceed the highest and lowest values in the sample point set, but does not have to pass through any sample points.

Kriging is the interpolation technique used in this study because, unlike Splining, it does not introduce extreme (and highly unlikely) values, and responds more appropriately to the scale of variations in the landscape than does IDW. The LVQ values of the viewpoints were used as samples in the interpolation analysis. Due to the relatively small amount of samples, the LVQ value of a particular grid was determined by the 3 nearest samples. The output, as shown in **Figure 7**, is a map indicating the LVQ of the study area with ordinal scale.

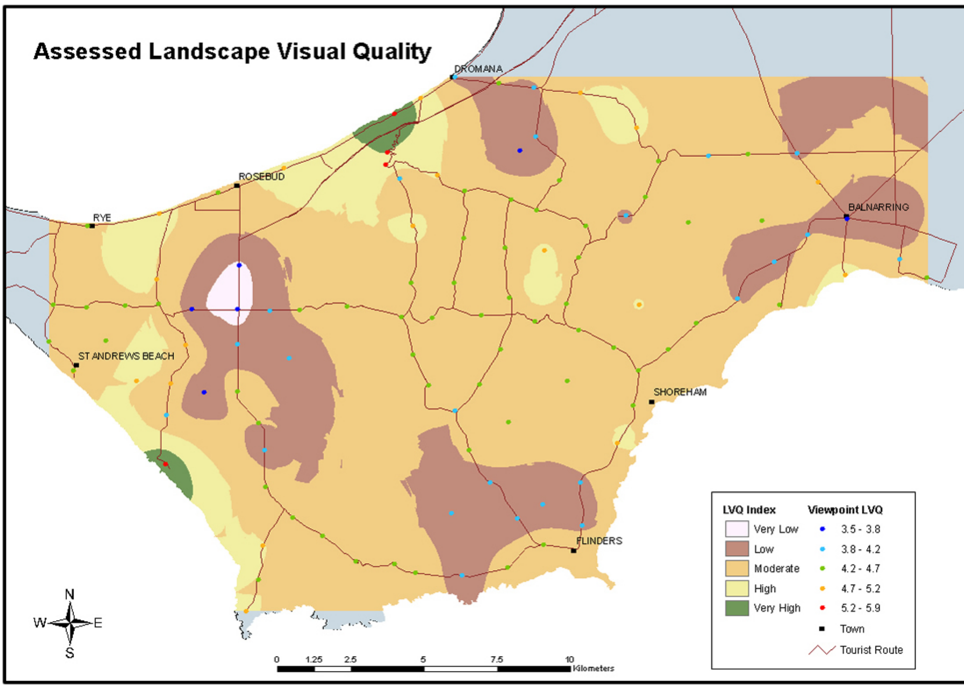

Figure 7 Assessed Landscape Visual Quality

MAP DESCRIPTION

In **Figure 7**, the assessed LVQ for the study area is classified into five classes. Most of the south-central portion of Mornington Peninsula was rated as moderate. There are two patches rated as high: one on the north coast, the other on the west. The viewpoint located in the patch on the west has a very high LVQ value and contributes significantly to the surrounding area. It has a superb view to the ocean and was the most preferred location in the community workshop. The patch along the western coast also has a very high LVQ value because of the high LVQ value viewpoints in the surrounding areas with great ocean views, or is at the middle of a high hill with excellent panoramic views of the peninsula. The area which was assessed as having a very low LVQ is in the western centre of the Mornington Peninsula; it is a flat terrain, far from the coast and where horticultural and agricultural land uses predominate. Accordingly, in our study landscape visual quality increases with the area of water (ocean) visible, the degree of wilderness and quality of the vegetation, and the presence of hills (horizon). On the other hand, it decreases with the growing presence of negative human-made elements, including roads, electric power lines, etc.

DISCUSSION AND CONCLUSION

In this paper, a new method for assessing the visual quality of landscapes has been described and applied in a region of Melbourne, State of Victoria, Australia. The same methodology can be applied in other regions to explain and rank the scenic beauty of landscapes. A discussion of its salient features is hence in order.

The computation of factors to calculate LVQ is based on the estimation of the visible area from each viewpoint in the landscape. In our study, terrain, in conjunction with data derived from the vegetation and building layers, was used in the analysis. The analysis was based on a 360 degree view potential. Together, the four photographs, used for public evaluation of the visual quality of each location, covered around 240 degrees, and so some potential for a poor fit between computed visual indicators and observed visual features existed. For example, if the coastal view is significant for a location, then the photographs may emphasise this but not the pasture located next to it. This may lead to a biased result when formulating the assessing model using regression analysis. Although this may seem to be contrary to the contention of Meitner (2004), his results were based on 360 degree coverage in the 4 images. One solution to this issue is to limit the viewshed analysis angle approximately to the one recorded by the photograph. This would give a more reliable fit between the components used in the model but would give distorted results when the model is applied to the sample points which were not the subject of public evaluation. Other options include:

- Using full panoramas, or six images to cover the whole view. This has some logistical problems for presentation to large audiences.
- Using a camera set to a 90 degree field of view. Unless this was a special panoramic camera, or the images were stitched together, the typical distortion of a wide angle lens would be created with foreground objects being diminished in perceptual significance.
- Developing an algorithm which incorporates our tendency to concentrate attention on the more eye catching parts of the view and reduce the significance in the modelling of the more 'neutral' view components. This is an option worth of further research.

There were more than 10 factors considered in the Factor Index calculation, including those sub-factors under Slope. However, only 6 of them were used in the final LVQ regression model. It was also found that some factors have high correlation to others. Therefore, some preliminary assessment of likely relevance and correlations would potentially save time in calculating the Factor Indexes and make it easier to construct the LVQ model.

It can be argued that linear regression is not appropriate in LVQ analysis since visual response to landscape factors is unlikely to be either linear or independent. Other regression modelling techniques (e.g. Neural Network regression model, Bishop 1996) are available but have methodological issues of their own. As mentioned, most research in this field simulates LVQ using linear regression. The Analytic Hierarchy Process (AHP) is also widely used in multi-criteria decision making (Saaty 1994; Schmoldt et al. 2001). However, AHP or similar methods are not suitable for visual modelling because of the difficulty people have in identifying the role of individual factors in their subjective landscape judgements. Consequently, despite its deficiencies, the regression approach still dominates research and application to visual quality landscape assessments.

The community's visual quality perception of the landscape is an important feature of the methodology presented in this paper and provides the basis for the equation-derived assessment of LVQ. Community choice can hence strongly influence the assessment modelling. Consequently, the selected community group must be a good representation of all community values.

According to landscape studies undertaken by Crawford (1994), Williamson and Calder (1979); Mitchel (1991); and Arriaza et al. (2004), the scenic quality of regional and rural areas increases as:

1. topographic ruggedness and relative relief increase,
2. the presence of water bodies increases,
3. natural landscapes increase, and
4. other cultural landscape elements decrease.

These points match parts of this study's LVQ assessment model. Landscape visual quality increased with the presence of water bodies (ocean view), the percentage of natural vegetation, and rugged terrain (mean slope), whilst it decreased with the presence of perceived negative human-made structures such as road and buildings. As mentioned, the only exception is the pasture, which is both a very common/familiar feature to the community and tends to be present when natural vegetation is absent.

Therefore, planning the modernisation of rural regions should include the impact of such features on the landscape and the possibility of using them as development tools. Human-made structures, the amount of (natural) vegetation and the colour contrasts are elements of the landscape that can be influenced by landscape architects, landscape planners and spatial planners.

The case study presented in this paper explains the methodology at a large-scale. The GIS-based method makes the assessment output easily used in conjunction with other spatial data as a component of a Spatial Decision Support System (SDSS) leading to a full landscape significance assessment. This systematic, repeatable method can be applied (i) in regional scale assessments, such as for catchments and rural and coastal areas; (ii) to gain a better understanding of the local landscape before a proposed landscape change (e.g. construction of structure); and/or (iii) prior to, or as component in, the development of a spatial planning strategy.

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ENDNOTES

1 An interesting review of the historical development of landscape planning and landscape architecture in the United States linked to the 'greenway planning' can be seen in Fabos (2004). An international review can be seen in Fabos and Ahern (1996).

2 It is worth noting that there exist more complex categorisations of landscape assessment methods. For instance, Garcia and Canas (2001) divide the methods into five categories: direct models, models to predict public preferences, indirect models, and economic evaluation models. See also Arriaza et al. (2004).

3 Mornington Peninsula is located in the south-east of Metropolitan Melbourne, about 60 km from the CBD, with an extensive coastline to Port Phillip Bay, Western Port Bay and Bass Strait. The peninsula features a more or less continuous strip of urban settlement along the Port Phillip Bay coast. On its southern part, a significant proportion of the dwellings provide holiday homes for Melbourne's residents. Inland, the peninsula is characterised by relatively densely settled farmland, with a number of rural townships. It contains also substantial areas of public land. About 140,000 permanent residents live in the Mornington Peninsula.

4 Ecological Vegetation Classes (EVCs) are the basic units used for mapping biodiversity and conservation assessment at landscape, regional and larger scales in the State of Victoria. They are derived from large-scale forest-type and plant community mapping. Each EVC represents one or more plant (floristic) communities that occur in similar types of environment and respond to environmental events, such as bushfires, in similar ways.

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