Analysis of Sequential Landscape Experiences

Ian BISHOP

1 Introduction

Much landscape change – for example the construction of wind farms, or logging of native forests – has negative impacts on visual quality of surrounding areas, and this impact has become the focus of public protest. Many land management agencies therefore consider visual assessment of landscape change a vital tool for exploring public responses to alternative landscape futures. Most landscape assessment work to date has relied on public reactions to edited photographs showing static views of landscape change. More recently, researchers have used a combination of geographic information system (GIS) based visual analysis and public responses gathered from original or manipulated photographs to estimate visual impacts of change in a larger landscape (BISHOP & HULSE, 1994; GERMINO et al., 2001; MOLLER, 2006). Both of these approaches have been criticized for ignoring critical aspects of landscape experience (HULL & STEWART, 1992). Of particular concern is the dependence of both approaches on public evaluation of individual views. While people often pause to admire a single view, large landscapes cannot be experienced at a single point, at a single time. More usually, large landscapes are revealed gradually or sequentially over time as a person moves through the landscape.

Indeed, much of our landscape experience comes while moving: cross-country skiing, cycling, hiking, driving, travelling by train or flying. More distance is covered driving than through any other mode of movement. In Victoria, Australia each vehicle averaged 14,500 km in 2010. Someone insulated from the landscape within a speeding capsule may not be as aware of his or her environment as the skier or the hiker (OKU & FUKAMACHI, 2006). Nevertheless this paper focuses on extended movement, such as travelled by car, in order to test some parametric approaches to landscape evaluation in this dynamic context.

Few studies have sought to understand how people evaluate landscapes experience sequentially. HULL & STEWART (1992) considered evaluations of views within a ‘trip’, but provides little insight to the relationship between individual views and evaluation of the trip as a whole. STEINITZ (1990) analyzed the driving experience around the Loop Road in Acadia National Park based on view analysis and a visual quality model. While the processing was based on point evaluations, Steinitz commented that “the rhythm of positive views along the clockwise direction is more frequent ...” (p. 238) indicating a sense that the sequence was as important as the set-by-step conditions.

To gather data on sequential experiences, QIN et al. (2008) created 2 minute animated drives using Visual Nature Studio (3dnature.com). They then recorded the perceived scenic beauty progressively using an electronic slider devices controlled by the viewer. The drive sequences included elements of interest such as billboards, a barn, lakes and different levels of enclosure. In that research they also asked for an overall assessment of the drives. However, they did not report the relationships between the sequential ratings and the overall rating.

Buhmann, E., Ervin, S. M. & Pietsch, M. (Eds.) (2013): Peer Review Proceedings of Digital Landscape Architecture 2013 at Anhalt University of Applied Sciences. © Herbert Wichmann Verlag, VDE VERLAG GMBH, Berlin/Offenbach. ISBN 978-3-87907-527-0.

Determining this relationship is one of the key questions relating to sequential experiences. It seems unlikely, although possible, that the overall scenic assessment of a journey, for most people, will be a simple average (time-weighted) of the value of the views along the way. There are other possibilities which also do not draw on the ordering within the sequence of views: the overall perceived quality might be approximated by the best view scene on the journey, or the lowest rated view, but this also seems unlikely. No matter how pleasing the view of a wide beach leading to an azure sea, it may start to loose its lustre if unchanging over a long distance. As Schoenberg wrote, in a musical context: “Two impulses struggle with each other within man: the demand for repetition of pleasant stimuli, and the opposing desire for variety, for change, for a new stimulus”. (SCHOENBERG, 1911, quote on p48 of 1978 translation)

In the particular context of landscape change, such as created by forest harvesting or energy infrastructure, we need to know whether a short exposure to very high/low quality landscape raises/lowers the overall assessment disproportionately. There may exist the sequential equivalents of meta-variable such as complexity and coherence. What kinds of transitions are expected, unexpected, confusing, overwhelming, soothing, exciting?

The many parameters that may be used to quantify the sequential experience should include those that are normally evaluated in studies of static views and, in addition, those that are specific to moving views. ZIPF (1972) argued that many things in nature and society have a 1/k relationship meaning that the kth ranked item in a set (such as a list of city populations) occurs with 1/k of the frequency of the first ranked item (the second biggest city is half the size of the biggest etc). VOSS & CLARKE (1978) measured physical variable, including fluctuations in loudness and pitch, for several types of music including classical, jazz, blues, and rock. They found that the pitch and loudness fluctuations did approximate Zipf’s distribution. MANARIS et al. (2003) sought to develop 'fitness functions for pleasant music' based on Zipf-distributions. They concluded: “If nothing else, since Zipf distributions appear to be a necessary, but not sufficient condition for aesthetically pleasing music, such fitness functions could minimally serve as an automatic filtering mechanism to prune unpromising musical samples.” (p. 530) They suggested that Zipf analysis was not sufficient because two pieces of music could both fit the Zipf distribution perfectly but one could be quite monotonous because all the highest ranked notes occurred in one block (as if, for example, all occurrences of 'the' in a book came at the beginning). To go beyond the global balance identified by the Zipf coefficient, they suggested order could be incorporated in the analysis by also estimating the fractal dimension (a statistical measure of complexity) of a musical piece. They suggested that the box-counting method, as applied to the paintings of Jackson Pollock by TAYLOR et al. (1999), could also be applied to music. Here I suggest it might also be applied to sequential landscapes experiences.

2 Method

2.1 Landscape Elements

The following were identified as potential parameters of interest along road segments in Victoria, Australia: road orientation, relative elevation, openness, distance to horizon, and presence of specific elements (individual trees, forest, water, beach, shore rocks, snow, steep slopes, rock outcrops, green grass, brown grass, crop, bare earth, wind turbines, buildings, farm animals, wildlife). Some of these are well recognized in the literature of landscape aesthetics, others are less well accepted as features of interest but included because of their potential contribution to the unfolding landscape. Additional variables of interest during a journey include changes in road orientation and elevation. These were also recorded along with a very subjective impression of 'openness', an estimate of the distance to the furthest horizon (no including views directly along the road itself) and the extent to which high slopes were present in the view.

2.2 Sample Road Segments

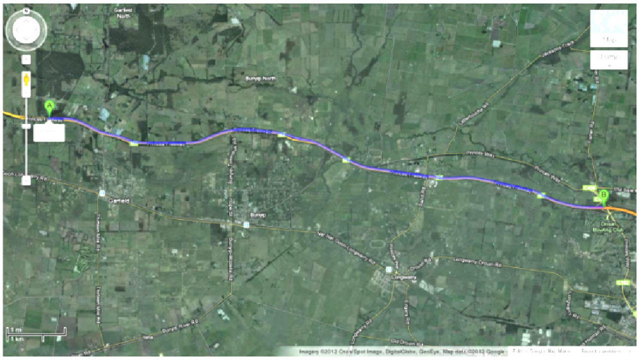
One of the most popular tourist drives in Australia is the Great Ocean Road (GOR) running along the Victorian coast for 243 km from Torquay to Port Campbell. This is too long for this exploratory analysis and so a 16 km long section between Lorne and Apollo Bay was chosen (Figure 1).

To contrast with the GOR, I chose a section of road that I travel often and find pleasant but uninspiring. This is part of the Princess Highway (PHW) running east from Melbourne for around 400 km before turning north towards Sydney. Again a 16 km section was chosen between Nar Nar Goon and Drouin (Figure 2).

Fig. 1:
(a) The chosen section of the Great Ocean Road, Victoria, Australia
(b) A panorama illustrating the kind of landscape typical on this road segment

(a)

(b)



(a)

Fig. 2:
(a) The chosen section of the Princess Highway, Victoria, Australia
(b) A panorama illustrating the kind of landscape typical on this road segment

(b)

2.3 Data Extraction

The sample road segments were selected as travel routes in Google Maps using the names of towns beyond the two ends. After dragging the start marker to my chosen start point I activated Street View at that point. By rotating the view I could indentify the presence or absence of each of the landscape elements. When an element was present I assigned it a prominence, within the full 360-degree arc, on a scale of 1-10. I then dragged the end mark to a point 0.5 km along the route from the start point and repeated the process. By repeatedly dragging the end marker I could assess the landscape every 0.5 km over the 16 km segments. One possibly pertinent variable I could not extract in this way was the elevation. For this I switched to Google Earth and chose the corresponding point using the satellite images in the two products.

Street views have been captured more frequently than every 0.5 km and so a more fine-grained analysis would have been possible. However this seemed to be a useful initial distance at which to test the process. It did however created some ambiguity in selecting the Street View since Google Maps only gave the route length to the nearest 0.5 km. An alternative approach would have been to select locations where the view included elements of special interest, such as water bodies.

It would also have been an option to only use the part of the view in one direction of movement and so use, for example, an arc of 100 degrees on either side of the direction of motion. However I used 360 degrees because landscape elements behind the car would have typically been seen in front a few hundred meters earlier. This also made the assessment direction independent.

2.4 Creation of Indices

While each entity was recorded individually, they also form compatible groups with similar expected influences. These were combined into interest indices as follows:

- road_interest (variation in direction and elevation) = ABS(change_of_orientation (degrees)/10 + change_of_elevation (meters)/5)/3. (Changes are since last view point).
- view_extent = openness + furthest_horizon (meters)/10000.
- terrain_interest = slope + beach + shore_rocks + rock_outcrops
- vegetation_interest = individual trees + native forest - plantations_and_exotics
- agricultural_interest = crops_and_horticulture + green_pasture + brown_pasture/2 - bare_earth + farm_dam*2 + domestic_animals*2
- water_interest = sign_of_creek/2 + visible creek + river + lake + sea/ocean + snow
- infrastructure_impact = enhancing_buildings - ugly_buildings - transmission_pylons*2 - transmission_poles

Each index was transformed to an integer to allow frequency ranking and fractal analysis. Each was also normalized, so as to give an approximate range of 0 to 10, over the two road segments. However the indices would need adjustment if different roads with higher scores on particular indices were included in the analysis.

2.5 Analysis

For the Zipf distribution analysis, the frequency of occurrence of each index score, from 0 to 10, was recorded and then ordered by frequency rank. The $\log_{10}$ of each rank and each frequency were calculated and a simple linear regression run for each index. The coefficient (slope) of the regression and the R-squared value, showing goodness of fit to the regression line, were recorded for comparison.

The fractal dimension of each index distribution was estimated using the R statistical software (v2.15.2 for MacOS X) in conjunction with the Fractaldim package (v0.8-1). Both can be found at cran.r-project.org. Fractaldim gives a number of different techniques for estimating the fractal dimension of 1-dimensional time series. In this case, in the absence of a particular rationale for a more sophisticated method, the simple box-counting method was used. Dimensions were first calculated for each segment independently. This could be misleading because then a different interval would be used, on each segment, for the side of the boxes representing the index scores. This gave a high fractal dimension for some sequences with low variation in their index. To create a valid comparison it was necessary to give the sequences of index scores for each segment the same score range. This required introduction of a dummy maximum value into the sequences since the box dimensions could not be controlled independently.

2.6 Sensitivity to Landscape Change

To explore the effect of repeated instances of negative changes in landscape quality such as by forest harvesting or wind energy installations a different approach was necessary. We know quite a bit about the effect of these elements on individual views but next to nothing about their sequential effects. In order to begin exploration of the effect and the influence of different spacings, I made changes to the scores within the two road segments. To check this properly an experimental distance greater than 16 km may be necessary to allow a gradual increase in prominence, but in this case I look the liberty of assuming that the installations could appear suddenly and disappear just as suddenly. Three conditions were tested, (a) 10 consecutive points (5 km) were deemed to have a prominent wind farm, (b) 10 points in 5 equally spaced groups of 2, and (c) 10 individual equally spaced points. At these points the sum of the index values was reduced to zero. That is, the high infrastructure impact (II) negated any other positive index values. This is almost certainly too extreme but serves to test the effect on fractal dimension.

3 Results

Table 1 shows the index scores for each 0.5 km along each road segment, and summary statistics for the segments. A very clear difference between the two roads is the high level of water interest along the GOR and the complete absence of water features at the sample points along the PHW. In general the scenic value of the GOR is higher and so the segment as a whole has higher total and averages then the PHW segment. This tells us nothing about the effect of sequence however.

Table 1: Illustrative index values for the two 16 km road segments. The index values for the first 6 km (at 0.5 km intervals) of each segment and the summary values for the whole segment are shown.

Dist. (km)	**Road Interest (RI)**		**View Extent (VE)**		**Terrain Interest (TI)**		**Veg. Interest (VI)**		**Agriculture Interest (AI)**		**Water Interest (WI)**		**Infrastructure Impact (II)**	
	PHW	GOR	PHW	GOR	PHW	GOR	PHW	GOR	PHW	GOR	PHW	GOR	PHW	GOR
0	1	1	0	9	1	3	6	3	1	2	0	7	1	-2
	1	0	0	4	0	5	4	1	2	0	0	6	0	0
1	1	2	6	6	2	6	1	3	2	0	0	7	1	-1
	1	7	2	4	1	9	6	2	1	0	0	6	0	0
2	0	9	1	5	0	10	0	3	7	0	0	10	0	-1
	0	10	0	7	0	7	4	1	0	1	0	7	0	0
3	2	6	5	4	1	7	3	3	2	1	0	6	0	-1
	1	1	4	7	4	6	4	4	6	0	0	6	2	-1
4	0	1	1	9	0	7	4	3	2	2	0	7	-1	-2
	0	1	2	8	0	5	4	1	4	3	0	8	2	-3
5	0	1	2	8	1	3	4	1	3	1	0	6	1	-3
	0	1	7	1	1	0	0	0	4	0	0	0	-7	0
6	0	3	8	7	2	4	3	3	3	3	0	5	-3	-3
Sum	15	98	123	179	35	181	113	106	68	23	0	182	-56	-29
Mean	0.45	2.97	3.73	5.42	1.06	5.48	3.42	3.21	2.06	0.70	0.00	5.52	-1.7	-0.88
SDev	0.67	2.82	3.16	2.24	1.22	2.60	1.80	2.07	1.56	1.24	0.00	2.32	2.82	1.17

Table 2 shows the Zipf statistics for each index on the two segments. On the GOR the coefficients range from -0.69 (view extent) to -1.82 (agriculture interest) indicating that the variation in view extent and terrain interest are less than 'ideal' while the variation in agriculture and infrastructure interest is more than 'ideal' (where ideal is a coefficient of -1). Water interest and road interest have coefficients very close to -1 and reflect the sense that these are the dominant reasons why people choose the GOR as a driving experience. On the PHW, there is no water interest recorded and so no Zipf statistic. Among the other indices, view extent drops away only slowly with a wide range of values whereas road interest has only few values and so drops more quickly than 'ideal'. The latter reflects the general straightness and relative flatness of the PHW whereas the former reflects a fairly even mixture of view bounded by vegetation and open views to distant mountain ranges.

Table 2: Log(Rank) versus log(Frequency of Indices) give Zipf slope coefficients and R-squared estimates of fit

A. Princess Highway

	log(RI)	**log(VE)**	**log(TI)**	**log(VI)**	**log(AI)**	**log(WI)**	**log(II)**
Coefficient	-1.712	-0.616	-0.994	-0.871	-1.432	n/a	-1.134
R-squared	0.797	0.679	0.851	0.972	0.966	n/a	0.896

B. Great Ocean Road

	log(RI)	**log(VE)**	**log(TI)**	**log(VI)**	**log(AI)**	**log(WI)**	**log(II)**
Coefficient	-1.084	-0.691	-0.759	-1.157	-1.815	-1.067	-1.574
R-squared	0.959	0.935	0.785	0.78	0.986	0.898	0.902

Table 3: Local and global fractal dimensions (FD) of road segments based on index variability

	PHW		**GOR**	
	local FD	**global FD**	**local FD**	**global FD**
Road Interest	1.67	1.36	1.65	1.65
View Extent	1.71	1.58	1.78	1.62
Terrain Interest	1.62	1.53	1.76	1.76
Vegetation Interest	1.62	1.55	1.58	1.58
Agriculture Interest	1.63	1.63	1.66	1.58
Water Interest	1.00	1.00	1.83	1.83
Infrastructure Interest	1.36	1.36	1.82	1.64
TOTAL Interest	1.54	1.42	1.63	1.63

Table 3 shows the fractal dimensions of each of the indices on the two road segments, both 'local' and 'global' dimensions are shown the former using box counting based on the range of local index values and the latter using the full range of values found across the two road segments, giving a better direct comparison. Except for agricultural interest, the dimensions on the GOR are higher than on the PHW with water interest and terrain interest having the highest dimensions.

Each of the three sets (group of 10, 5 groups of 2, and 10 individual views) of wind turbines added to the segments by reduction of the index sum to zero at 10 points naturally had the effect of reducing the total and mean scores of the whole road segments. The degree of change depends on whether the insertions are at high scoring or low scoring points, but the effect is independent of the sequential pattern. Similarly, changes in the Zipf distributions are not order dependent. It is the fractal dimension that is prone to different effects. New fractal dimensions were calculated for the sum of the indices (representing overall visual quality). As with the total and mean, it was quickly apparent that the new fractal dimensions were dependent on which actual points were used as the start point for insertions. Therefore I used six replicates of the three test conditions each with a different starting point for the turbine-affected views. When these were averaged a clear trend emerged. On both road segments the 10 consecutive points with turbines gave the result with the lowest fractal dimension (PH $\mu = 1.38$, $\sigma = 0.087$, GOR $\mu = 1.50$, $\sigma = 0.087$), the case of 5 groups of 2 was next (PH $\mu = 1.66$, $\sigma = 0.046$, GOR $\mu = 1.70$, $\sigma = 0.064$) and the case of 10 individually affected points had the highest fractal dimension at each segment (PH $\mu = 1.69$, $\sigma = 0.082$, GOR $\mu = 1.84$, $\sigma = 0.052$). This can be compared with the global dimensions in the absence of the turbine insertions (PH 1.42 and GOR 1.63). Thus, 10 consecutive affected points somewhat reduced the fractal dimension of each road segment but the other configurations increased the fractal dimension in each case.

4 Discussion

At this stage we have no empirical data on liking for the road segments from which to judge these results. A small survey has been conducted on four different 16 km segments on the PHW. However neither the process nor results are reported here because the survey was very exploratory. Indeed, undertaking the analysis reported here on the feature sequences along road segments will help in designing a better survey.

So, what can we determine from the analysis so far? The major outcome is a set of more precise questions about sequential experience and the statistics that may be used to characterize that experience. These include:

- What is the relative importance of individual views and the sequential aspects of the experience?
- Is a Zipf distribution with a slope of -1 really 'ideal'?
- A higher fractal dimension suggests a more interesting range of experiences, and this is backed up by the higher dimension on the tourist favored GOR, but is this really so?
- If it is so, is it preferable to break intrusive elements, such as wind farms, into smaller groups, which create a higher fractal dimension, than to localize them in a single larger group?
- The fact that the more distributed turbines increased fractal dimension over the situation with no wind infrastructure suggests that using the index sum as the basis for calculation of fractal dimension is too blunt an instrument. Can an index such as fractal dimension, which has promise, be made more sensitive?
- Even though the analysis included infrastructure (houses, farm buildings, electrical pylons and poles etc) there was no clear way to score these as part of an index. It would be become still more problematic if the roads included (or might include in the future) elements like wind turbines, which provoke very mixed responses.

- What is the effect of landscape familiarity on these relationships? In high quality landscapes in or adjacent to key tourism areas (e.g. GOR) many of those making the journey will be first time visitors. On a major intercity highway (e.g. PH) many people will have made the journey before and the making the journey for reasons other than enjoyment.

References

Bishop, I. D. & Hulse, D. W. (1994), *Predicting scenic beauty using mapping data and geographic information systems.* In: Landscape and Urban Planning, 30, 59-70.

Germino, M. J., Reiners, W. A., Blasko, B. J., McLeod, D. & Bastian, C. T. (2001), *Estimating visual properties of Rocky Mountain landscapes using GIS.* In: Landscape and Urban Planning, 53, 71-84.

Hull, R. B. IV & Stewart, W. P. (1992), *Experience patterns: the dynamic nature of a recreational experience.* In: Journal of Leisure Research, 24, 240-252.

Moller, B. (2006), *Changing windpower landscapes: regional assessment of visual impact on land use and population in northern Jutland Denmark.* In: Applied Energy, 83, 477-494.

Oku, H. & Fukamachi, K. (2006), *The differences in scenic perception of forest visitors through their attributes and recreational activity.* In: Landscape and Urban Planning, 75, 34-42.

Manaris, B., Vaughan, D., Wagner, C., Romero, J. & Davis, R. B. (2003), *Evolutionary music and the Zipf-Mandelbrot law: Developing fitness functions for pleasant music.* In: Lecture Notes in Computer Science, 2611, 522-534.

Qin, X-c, Meitner, M. J., Chamberlain, B. C. & Zhang, X-n (2008), *Estimating visual quality of scenic highways using GIS and landscape visualizations.* ESRI Users Conference, San Diego CA, August 2008.

Rodrigues, M., Montañés, C. & Fueyo, N. (2010), *A method for the assessment of the visual impact caused by the large-scale deployment of renewable-energy facilities.* In: Environmental Impact Assessment Review, 30, 240-246.

Schoenberg, A. (1978), *Theory of Harmony.* Berkeley, University of California Press (translated by R. E. Carter from 1911 original).

Steinitz, C. F. (1990), *Towards a sustainable landscape with high visual preference and high ecological integrity: the Loop Road in Acadia National Park, U.S.A.* In: Landscape and Urban Planning, 19, 213-250.

Taylor, R. P., Micolich, A. P. & Jonas, D. (1999), *Fractal Analysis Of Pollock's Drip Paintings*. In: Nature, 399, 422.

Voss, R. F. & Clarke, J. (1978), *1/f Noise in Music: Music from 1/f Noise.* In: Journal of Acoustical Society of America, 63, 258-263.

Zipf, G. K. (1972), *Human Behavior and the Principle of Least Effort.* New York, Addison-Wesley (original publication Hafner Publishing Company, 1949).