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A new methodology for evaluating coastal scenery: fuzzy logic systems

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Coastal scenery evaluated by utilization of selected landscape components was subjected to a fuzzy logic systems approach. Twenty-six top-rated parameters were identified from a literature search/questionnaire surveys carried out in Malta, Turkey and the UK and coastal scenery investigated at 57 sites. A coastal scenic evaluation checklist system was finalized and consisted of assessment parameters based on a five-point scale ranging from low to high attribute values. Coastal user parameter preferences and priorities for these parameters were obtained by a questionnaire perception study (n=270) given to both locals and visitors. Assessment parameter weights were calculated from this public perception survey via matrices relating to the selected landscape components. For each of the 26 parameters, a membership-graded matrix was established to counteract potential errors in assigning grades to the parameters when one has to give a unique number to the attribute value. To overcome subjectivity and quantify uncertainty, fuzzy logic mathematical methodology was adopted to this checklist approach. This enabled an Evaluation Index (D) value to be calculated, establishing a 5-class evaluation system. Class 1 scenery (extremely attractive natural site) had D values > 0.85; Class 2, between 0.85 and 0.65; Class 3, between 0.65 and 0.4; Class 4, between 0.4 and zero; Class 5 (very unattractive, intensively developed urban) below zero.

Key words: *coastal scenery assessments, fuzzy logic, Turkey, UK, Malta*

Introduction

Tourism is the world's largest growth industry, with an average increase of 9 per cent per annum since 1985 and it is the world's largest export earner (WTO 2001). Thirty per cent of this industry occurs in the Mediterranean (Povh 2000). There, tourist destination centres are mainly coastal and repeated surveys have shown that both tourists and locals appreciate the magnificent beaches (Chivas Poll 2001), but the anthropogenic squeeze affects an important asset – scenery. Beaches are important to the economy of many coastal countries around the world and surveys have shown that excellent scenery is one of the major components that tourists would like to have in their immediate beach surroundings. For example, Morgan and Williams (1995) showed that more than 200 beach visitors at Gower beaches, Wales, rated scenic beauty as their number one choice with respect to prioritized beach aspects. Micallef *et al.* (1999), in a study of 266 Maltese beach users, found that scenery ranked a close fourth (after clean water, clean sand and facilities). Unal and Williams (1999), in a study

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utilizing 120 beach users at Cesme peninsula, Turkey, found that scenery ranked second after clean bathing water.

Sauer (1969), brought landscape studies to the fore of geographic thought. The Merriam-Webster dictionary defines landscape 'as a picture representing a view of *natural inland* scenery . . . the art of depicting that scenery' (1995, our emphasis)! This is a commentary regarding the lack of precise terminology in this field. Irrespective of the definition, landscape 'provides scenic, economic, ecological, social, recreational and educational opportunities' (GCDLVI 2003, 7), and scenic evaluation – a subset of the voluminous landscape evaluation genre, has had a long and chequered history, of which coastal scenic evaluation has occupied only a small segment. Scenic evaluation is an important consideration for aerial comparison purposes, as 'coastal landscape is a very important resource' (GCDLVI 2003, 9). In most countries, specially designated scenic areas exist, all having a myriad of names. For example, in the UK: National Parks, Areas of Outstanding Beauty, Heritage Coasts, etc., all designations invariably reflecting scenery.

Scenery is part of a coastal landscape inventory available for managers or planners for coastal preservation, protection, development etc. Such an inventory would provide baseline information to managers so that a sound scientific basis could be available for any subsequently envisaged management plans. Landscape management deals with heterogeneity in space, e.g. type, shape etc. of the elements, and time, i.e. the disturbance regime – either natural or anthropogenic (Turner 1987). Researchers have employed many different techniques: those pertaining to field-based objective replication studies (Linton 1968), statistical techniques obtained from site observations (Clamp 1976), and assessing public attitudes and landscape preferences (Penning-Rowsell 1989). Amongst the many models/rating schemes that have accrued in this field, most have been in existence for *c.*30 years. Many authors/authorities have written about this topic, e.g. Lowenthal (1961), Sauer (1969), Appleton (1975), Carlson (1977), Briggs and France (1980), Buyoff and Arndt (1981), Williams (1986), Kaplan and Kaplan (1989), Eletheriadis *et al.* (1990). Amongst the more important evaluations, in chronological order, have been the works of Fines (1968), Linton (1968 1982), Leopold (1969), Robinson *et al.* (1976), Penning-Rowsell (1982 1989), the Countryside Commission (1987 1993), University of Ulster (1996), SCU (1997), the Countryside Council for Wales (CCW 1996 2001), DEFRA (2001), CA/SNR (2002), Ergin *et al.* (2003) and GCDLVI (2003).

Fines (1968) stressed the usage of photographs in his identification of landscape units. Linton (1968 1982) obtained a landscape scenic assessment number from assessing landform parameters (six in number) together with usage (seven in number). Leopold (1969), in a seminal paper, stressed scenic uniqueness based upon physical, human and biological parameters. Robinson *et al.* (1976) used the 'best/worst' case scores obtained from 1 km square grids analysed by professionals in order to derive landscape values. The Countryside Commission (1987 1993) obtained a range of landscape types from assessing the natural landscape, cultural and aesthetic associations. The CCW (1996 2001) LANDMAP series was similar in its approach, emphasizing GIS. However, few have addressed the detailed specificities of coastal scenery.

In evaluating coastal scenery, this paper utilized a checklist approach, a methodology that is popular in many facets of both the natural and socio-economic disciplines. Critics of such checklists have argued that subjectivity can creep into the lists, as a viewer's personal preferences (a function of age, sex etc.) play a part in any scenic evaluation. Transient items also affect the equation, e.g. the smell of new-mown hay, the chirping of birds. These cannot be quantified and the resulting checklist plus a fuzzy logic systems approach is put forward as a means of attaining an optimum semi-quantifiable analysis for coastal landscapes. A fuzzy logic approach enables an expert group to quantify the uncertainties and subjective pronouncements inherent in most scientific studies (Ambala 2001).

Methodology

Parameter selection

As part of a three-year study, a literature search, together with questionnaires given to coastal users in Malta, Turkey and the UK, and consultation with coastal landscape experts, an assessment was made as to what were the main parameters essential in coastal scenery perception (BCR 2003). Landscape values 'can be assessed and described or illustrated in objective and subjective terms by landscape professionals, consulting with a wide range of interest groups and people and analysing all relevant information' (LIIEA 1995, 19). Results obtained through this work enabled key elements to be condensed down to 26 'coastal scenic assessment parameters' and these are given in Table 1, together with the 'attributes' represented by numbers ranging from a low to high rating (1, 2, 3, 4 and 5).

Perception studies

Lowenthal (1961) argued that perception depended upon imagination and experience. This is highly individualistic as 'no two individuals see scenery in the same light. Each brain is nontrivially unique' (Tuan 2003, 879). Therefore it has both internal and external elements, or as Lippmann put it, 'the world outside and the pictures within our head' (1961, 56). In most coastal scenic assessment studies, assessment parameter gradings have tended to be obtained from subjective observations. These depend on a number of factors such as the national and cultural background, age, gender, education and training. Eletheriadis *et al.* (1990) found that European nationality groups agreed as to the least/preferred landscape types, but that cultural traits could give differences. Zube and Pitt (1981) also argued that not all cultures shared similar perceptions of landscapes. However, shape and form are still the prime considerations for any epistemological approach.

To re-evaluate the validity of this assumption and bring out viewers' preferences and priority to the different assessment parameters, a questionnaire perception survey was inaugurated in Turkey and the UK. Coastal questionnaire surveys have generally tended to be of two types: postal, e.g. Myatt *et al.* (2002), who studied attitudes, opinion, perceptions, or via interviewing actual users, e.g. Pereira da Silva (in press). The latter methodology was chosen for fieldwork carried out in this paper. Based on results from these surveys, a 'Coastal Scenic Assessment Inquiry Form' was finalized (Table 2). This consisted of some 29 parameters and respondents were asked to grade parameters on a five-point scale (1 being not important, 5 being extremely important). In Table 2, the y-axis bold-faced parameter numbers correspond to the physical and human parameters listed in Table 1, and were used in evaluation of the weighting parameters. The column reserved for the 'top six' preferences in Table 2 are for a quick preview of the priority given by the public to the parameters.

Fuzzy logic approach

In coastal assessment studies, as in many other fields, judgements made by an expert or a group of experts have a great influence on the results and sometimes can be stated in vague language format. Although some characteristics or parameters used to assess a certain region can be measurable (cliff height, shore width, etc.), many others are experts' view of the coastal scenery and are given using terms 'good' or 'bad'; 'clean' or 'not clean', etc. Experts are also sometimes guilty of using vague concepts based upon experience, intuition, human nature, environmental conditions, national cultural and social policies and economic conditions. Further, when several factors are to be considered in an analysis and/or assessment, it is difficult to describe a mathematical expression based on deterministic methods. Fuzzy Logic Approach (FLA) is a tool to assess the possibility (magnitude) and the degree of each factor considered to affect the evaluation results. Zadeh (1965) proposed making the membership function (or the values True and False) operate over the range of real numbers in the interval [0.0, 1.0] instead of on 0 and 1 of classic Boolean logic. This implies that fuzzy logic may allow more than one conclusion per rule. Since Zadeh (1965), the theory has developed and found uses in several wide-ranging areas where subjective pronouncements are inherent in most scientific fields, from communication to financial systems (Ambala 2001).

This study aims to comprehensively assess the dominance of physical and human factors, with their attendant subsections, in coastal scenery evaluation. Therefore it is an appropriate study in which to use fuzzy logic mathematics. For the sake of simplicity in mathematical and numerical processing, a condensed version of fuzzy analysis was adapted for the decision-making phase of the coastal scenery investigated.

The scenic assessment factor set F is defined as composed of physical (P) and human (H) factors and symbolically, F is expressed as:

$$F = (\text{Physical, Human}) = (P, H)$$

where subsets of P and H are formed from the following listed file characteristics as:

P = (cliff, beach, rocky shore, dunes, valley, land form, tides, coastal landscape features, vistas, water colour and clarity, natural vegetation cover, vegetation debris)
H = (noise, litter, sewage, non built environment, built environment, access type, skyline, utilities)

In P, cliff, beach and rock shore characteristics are further formed from sub-characteristics or

Table 1 Coastal scenic evaluation system

Site name:			Rating				
No:	*Physical parameters*		1	2	3	4	5
1	CLIFF	Height (m)	Absent	>5 ≤ 30	3 ≤ 60	61– 90	>90
2		Slope (°)	Absent	>45°	circa 60°	circa 75°	circa vertical
3		Special features*	Absent	1	2	3	Many >3
4	BEACH FACE	Type	Absent	Mud	Cobble/boulder	Pebble/gravel (±sand)	Sand
5		Width	Absent	<5≥100 m	5 ≤ 25 m	25 ≤ 50 m	50–100 m
6		Colour	Absent	Dark	Dark tan	Light tan/bleached	White/gold
7	ROCKY SHORE	Slope	Absent	<5°	5°–10°	10°–20°	20°–45°
8		Extent	Absent	<5 m	5–10 m	10–20 m	>20 m
9	DUNES	Roughness	Absent	Distinctly jagged	Deeply pitted and/or irregular (uneven)	Shallow pitted	Smooth
10			Absent	Remnants	Fore-dune	Secondary ridge	Several
11	VALLEY		Absent	Dry valley	(<1 m) Stream	(1–4 m) Stream	River/limestone gorge
12	SKYLINE LANDFORM		Not visible	Flat	Undulating	Highly undulating	Mountainous
13	TIDES		Macro (>4m)		Meso (2–4 m)		Micro (<2 m)
14	COASTAL LANDSCAPE FEATURES**		None	1	2	3	>3
15	VISTAS		Open on one side	Open on two sides		Open on three sides	Open on four sides
16	WATER COLOUR & CLARITY		Muddy brown/grey	Milky blue/green; opaque	Green/grey blue	Clear blue/dark blue	Very clear turquoise
17	NATURAL VEGETATION COVER		Bare (<10% vegetation only)	Scrub/garigue (marram/gorse, bramble, etc)	Wetlands/meadow	Coppices, maquis (±mature trees)	Variety of mature trees/mature natural cover
18	VEGETATION DEBRIS		Continuous >50 cm high	Full strand line	Single accumulation	Few scattered items	None
	Human parameters		1	2	3	4	5
19	NOISE DISTURBANCE		Intolerable	Tolerable		Little	None

Table 1 ***Continued*****.**

Site name:		Rating				
20	LITTER	Continuous accumulations	Full strand line	Single accumulation	Few scattered items	Virtually absent
21	SEWAGE DISCHARGE EVIDENCE	Sewage evidence		Some evidence (1–3 items)		No evidence of sewage
22	NON-BUILT ENVIRONMENT	None		Hedgerow/terracing /monoculture		Field mixed cultivation ± trees/natural
23	BUILT ENVIRONMENT***	Heavy industry	Heavy tourism and/or urban	Light tourism and/or urban and/or sensitive industry	Sensitive tourism and/or urban	Historic and/or none
24	ACCESS TYPE	No buffer zone/heavy traffic	No buffer zone/light traffic	No buffer zone/light traffic	Parking lot visible from coastal area	Parking lot not visible from coastal area
25	SKYLINE	Very unattractive	Unattractive	Sensitively designed high/low	Very sensitively designed	Natural/historic features
26	UTILITIES****	>3	3	2	1	None

*Cliff Special Features: Indentation, banding, folding, screes, irregular profile
**Coastal Landscape Features: Peninsulas, rock ridges, irregular headlands, arches, windows, caves, waterfalls, deltas, lagoons, islands, stacks, estuaries, reefs, fauna, embayment, tombola, etc.
***Built Environment: Caravans will come under Tourism, Grading 2: Large intensive caravan site, Grading 3: Light, but still intensive caravan sites, Grading 4: Sensitively designed caravan sites
****Utilities: Power lines, pipelines, street lamps, groynes, seawalls, revetments

Table 2 Overall questionnaire result for Turkish beaches (n = 270)

Parameters					Grading Not Important → Very Important 1	2	3	4	5	'Top 6'
1	1		Height		47	29	76	64	54	6
2	2		Slope		50	34	81	53	52	6
3	3	Cliff	Special features (indentation, bending, folding)		34	19	49	58	110	13
4	4			Sand	32	17	24	51	146	81
	5		Type	Pebble	75	46	68	45	36	18
	6	Beach face		Rocky	124	40	44	31	31	5
5	7		Width		30	22	48	58	112	22
6	8		Colour		42	30	54	57	87	8
7	9	Rocky shore platform	Slope		58	47	77	52	36	2
8	10		Extent		45	54	79	53	39	3
9	11		Roughness		38	35	62	54	81	16
10	12	Sand dunes			74	64	53	40	39	4
11	13	Valley and river mouth			42	25	42	75	86	14
12	14		Flat		70	51	68	43	38	12
	15	Landform	Undulating		51	40	86	66	27	3
	16		Mountainous		37	23	43	53	114	28
13	17	Tides			85	52	61	33	39	5
14	18	Coastal landscape features (caves, waterfalls, islands, rocks, . . .)			7	5	21	53	184	**90**
15	19	Vistas of far places			18	15	49	65	123	23
	20	Historical features (castles, towers, historical remains, . . .)			8	16	23	63	160	**85**
16	21	Water colour and clarity			4	0	5	21	240	**183**
18	22	Seaweed banquettes			35	24	44	41	126	35
	23	Biotype diversity (fauna)			17	6	44	58	145	64
17	24	Natural vegetation cover			10	7	23	71	159	76
19	25	Absence of noise			7	6	13	39	205	**138**
20	26	Absence of litter and sewage			6	0	5	13	246	**210**
21										
22	27	Land use (monoculture, many crops, . . .)			40	24	84	62	60	15
23	28	Absence of buildings and utilities (power-lines, . . .), natural view of skyline			3	5	16	40	206	**137**
25										
26										
24	29	Ease of access			26	33	44	53	114	48

Numbers in bold in the first column correspond to the evaluation numbers of the parameters used. 'Top six' = number of people choosing this parameter. The actual 'top 6' numbers are given in bold

elements, and for simplicity of notation, P is expressed as:

$P = (P_1, P_2, P_3, P_{other})$

where

P_1 = (height, slope, special features) refers to the cliff

P_2 = (type, width, colour) refers to the beach

P_3 = (slope, extent, roughness) refers to the rocky shore

P_{other} = refers to the remaining nine physical parameters in P that are not listed in P_1, P_2 and P_3, i.e. from dunes to vegetation debris and will be denoted as P_4 to P_{12}.

P and H were established with 18 and 8 assessment parameters, respectively.

Weights of assessment parameters

Membership grades of the factors P and H to the assessment class were expressed by assigning weight numbers w_P and w_H, respectively. These numbers reflect the importance of the factors in the overall evaluation, and will be represented as a row matrix (or vector) for the purpose of computational simplicity:

$$\mathbf{W}_F = (w_P \; w_H)$$

The weight numbers or the elements of $\mathbf{W}_F$ are to be non-negative (positive numbers together with zero) and generally so chosen that their sum was equal to zero (the normality condition). These numbers are subjective; they rely on the experience and preference of experts. Therefore, $\mathbf{W}_F$ is a fuzzy matrix and the assessment result will be different, for different choices of entries or weights. Initial choice for the weights in this study were that both P and H have the same significance, that is:

$$\mathbf{W}_F = (0.5 \; 0.5)$$

Re-evaluation of $\mathbf{W}_F$ is possible with further surveys and more expert opinions.

The weights for the parameters (or subsets) of P and H were estimated from public perception survey data (Table 2). The first column of the table with bold-faced numbers corresponds to the parameters used in the weight evaluation of the assessment parameters. The grading parameters are categorized from 1 to 5, i.e. from not important to very important. Weight numbers of the corresponding parameters were based on the weighted averages of ticked boxes 4 and 5, in order to promote the higher preference values. For 270 observations these weighted averages are shown in Tables 3 and 4 for the physical and human parameters, respectively.

As listed above, cliff, beach and rocky shore parameters all appear with three sub-features, whereas remaining parameters have only one basic feature. In order to give equal weight gradings to every factor of P from P_1 to P_{12}, the sub-features were considered to have a weight of 1/36 and the others 1/12 for the physical parameters. Similarly, for the human parameters, the equal weights were as 1/8. Normalized weights for all parameters are listed in the last columns of Tables 3 and 4 and also summarized in Table 5 (column 3) for further evaluation.

Table 3 Weight evaluation for physical parameters

Physical parameters		Number of ticks (from Table 2)		Overall weighted average	Significance grades for parameters	$w_i \times g_i$	Normalized final weights of parameters, $\mathbf{w}_P$
No	Name	Box 4 N_4	Box 5 N_5	$\frac{4N_4 + 5N_5}{270}$ w_i	g_i		
1	Cliff height	64	54	1.948	1/36	0.0541	0.019
2	Cliff slope	53	52	1.748	1/36	0.0486	0.017
3	Special features	58	110	2.896	1/36	0.0805	0.028
4	Beach type	51	146	3.459	1/36	0.0961	0.034
5	Beach width	58	112	2.933	1/36	0.0815	0.029
6	Beach colour	57	87	2.456	1/36	0.0682	0.024
7	Rocky shore slope	52	36	1.437	1/36	0.0399	0.014
8	Rocky shore extent	53	39	1.507	1/36	0.0419	0.015
9	Rocky shore roughness	54	81	2.300	1/36	0.0639	0.022
10	Dunes	40	39	1.315	1/12	0.1096	0.039
11	Valley	75	86	2.703	1/12	0.2253	0.079
12	Landform	53	114	2.896	1/12	0.1969	0.085
13	Tides	33	39	1.211	1/12	0.1093	0.036
14	Landscape features	53	184	4.193	1/12	0.3494	0.122
15	Vistas	65	123	3.241	1/12	0.2701	0.095
16	Water colour	21	240	4.756	1/12	0.3963	0.139
17	Vegetation cover	71	159	3.996	1/12	0.3330	0.117
18	Seaweed	41	126	2.941	1/12	0.2451	0.086
				Total	1	2.846	1.000

Table 4 Weight evaluation for human parameters

Human parameters No	Name	Number of ticks (From Table 2) Box 4 N_4	Box 5 N_5	Overall weighted average $\frac{4N_4 + 5N_5}{270}$ w_i	Significance grades for parameters g_i	$w_i \times g_i$	Normalized final weights of parameters w_H
19	Disturbance factor	39	205	4.374	1/8	0.547	0.137
20	Litter	13	246	4.748	1/8	0.594	0.149
21	Sewage	13	246	4.748	1/8	0.594	0.149
22	Non-built environment	62	60	2.030	1/8	0.254	0.064
23	Built environment	58	23	4.407	1/8	0.551	0.137
24	Access type	53	114	2.896	1/8	0.362	0.091
25	Skyline	40	246	4.407	1/8	0.551	0.137
26	Utilities	40	246	4.407	1/8	0.551	0.137
				Total	1	4.004	1.001

Matrices

The dominance of physical and human factors with various sub-factors becomes very important in obtaining weight matrices, as given above. In return, weight matrices affect the final assessment results via weighted averages of the parameters. A Fuzzy Logic Assessment Matrix is given as an example in Table 5 for Little Haven, UK. The weight matrices WP and WH for factors P and H are 1 × 18 and 1 × 8 row matrices, respectively, with their entries as listed in column 3 of Table 5.

For every graded assessment parameter j, a possible square membership-grading matrix $\mathbf{M}_j$ was established with estimated membership grades. This matrix was based on the idea that an error may be introduced in the chosen grades, as one is obliged to make a unique decision among several other possible grades, over an attribute based on vague characteristics. For the present study, attributes were formed from a set of five ordered grades (from 1 to 5). As an example for parameter seven, i.e. the rocky shore slope (the angle between the rocky shore and the horizontal), the membership grading matrix M_7 and related attributes were as follows:

$$M_7 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 3 & 4 & 5 \end{array} \\ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.5 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.5 & 1 & 0.5 \\ 0 & 0 & 0 & 0 & 0.2 \end{bmatrix} \end{array}$$

1 Absent
2 Smaller than 5°
3 Smaller than 10° greater than 5°
4 Smaller than 20° greater than 10°
5 Smaller than 45° greater than 20°

In matrix M_7, every row corresponds to each of the attributes listed above, with the order 1 to 5. The first row's elements is reserved for the grading of 'no rocky shore' (absent state), the second row for the angle of the rocky shore being less than 5°, etc. The estimated membership grades for each attribute, i.e. every element of the matrix, was formed from possibilities ranging from 0 to 1, where 0 implies no possibility and 1 implies the highest possibility on the given grades. Values for the possibilities in the present study were based on expert opinions and usually based on the possible error that a person could make in deciding the grades. If the parameter was absent or not relevant, then the first element of the first row is 1, while all other entries of this row are zero, denoting the absoluteness of the grade 'absent'. If the rocky shore slope was present but had an angle of less than 5°, then 1 is inserted into the second entry of the second row. Due to the possibility of an error in assessing the angle as less than 5° when it might be larger than 5°, the third entry of the second row (implying the third attribute) is given as 0.5. As it is extremely unlikely that the error 'jumps' an assessment grade, the remainder of the row is given a zero probability. Similarly, if a score of 4 was recorded, the error could now be on

Table 5 Fuzzy assessment matrices for Little Haven, UK

No	Assessment parameters *Physical*	Weights of parameters, W_P	Graded attributes	Input matrices D_J					A matrices	Fuzzy assessment matrix Attributes C10 to C14				
*C1**	C2	C3	C4	C5 to C9						1	2	3	4	5
1	Cliff height (1–1)	0.019	3	0	0	1	0	0	A_P	0.00	0.30	1.00	0.30	0.00
2	Cliff slope (1–2)	0.017	5	0	0	0	0	1		0.00	0.00	0.00	0.50	1.00
3	Special features (1–3)	0.028	4	0	0	0	1	0		0.00	0.00	0.00	1.00	0.30
4	Beach type (2–1)	0.034	5	0	0	0	0	1		0.00	0.00	0.00	0.00	1.00
5	Beach width (2–2)	0.029	5	0	0	0	0	1		0.00	0.00	0.00	0.60	1.00
6	Beach colour (2–3)	0.024	4	0	0	0	1	0		0.00	0.00	0.60	1.00	0.00
7	Rocky shore slope (3–1)	0.014	4	0	0	0	1	0		0.00	0.00	0.50	1.00	0.50
8	Rocky shore extent (3–2)	0.015	5	0	0	0	0	1		0.00	0.00	0.00	0.40	1.00
9	Rocky shore roughness (3–3)	0.022	5	0	0	0	0	1		0.00	0.00	0.00	0.50	1.00
10	Dunes (4)	0.039	1	1	0	0	0	0		1.00	0.00	0.00	0.00	0.00
11	Valley (5)	0.079	3	0	0	1	0	0		0.00	0.00	1.00	0.00	0.00
12	Landform (6)	0.085	3	0	0	1	0	0		0.00	0.60	1.00	0.60	0.00
13	Tides (7)	0.036	1	1	0	0	0	0		1.00	0.00	0.00	0.00	0.00
14	Landscape features (8)	0.122	5	0	0	0	0	1		0.00	0.00	0.00	0.00	1.00
15	Vistas (9)	0.095	5	0	0	0	0	1		0.00	0.00	0.00	0.30	1.00
16	Water colour (10)	0.139	3	0	0	1	0	0		0.00	0.50	1.00	0.50	0.00
17	Vegetation cover (11)	0.117	4	0	0	0	1	0		0.00	0.00	0.20	1.00	0.20
18	Seaweed (12)	0.086	4	0	0	0	1	0		0.00	0.00	0.20	1.00	0.00
FUZZY WEIGHTED AVERAGE MATRIX ELEMENTS FOR SUBSET PHYSICAL ($K_P = W_P A_P$)										0.074	0.126	0.38	0.468	0.372
	Human			W_H					A_H					
19	Disturbance factor (1)	0.137	5	0	0	0	0	1		0.00	0.00	0.00	0.20	1.00
20	Litter (2)	0.149	4	0	0	0	1	0		0.00	0.00	0.20	1.00	0.20
21	Sewage (3)	0.149	5	0	0	0	0	1		0.00	0.00	0.20	0.00	1.00
22	Non-built environment (4)	0.064	5	0	0	0	0	1		0.00	0.00	0.20	0.00	1.00
23	Built environment (5)	0.137	4	0	0	0	1	0		0.00	0.00	0.30	1.00	0.00
24	Access type (6)	0.091	5	0	0	0	0	1		0.00	0.00	0.00	0.20	1.00
25	Skyline (7)	0.137	5	0	0	0	0	1		0.00	0.00	0.00	0.00	1.00
26	Utilities (8)	0.137	4	0	0	0	1	0		0.00	0.00	0.20	1.00	0.00
FUZZY WEIGHTED AVERAGE MATRIX ELEMENTS FOR SUBSET HUMAN ($K_H = W_H A_H$)										0.000	0.000	0.141	0.468	0.608

Final Assessment Matrix (Membership Degree), R

$$R = W_r K = (0.5\ 0.5)\begin{bmatrix} 0.074 & 0.126 & 0.385 & 0.468 & 0.372 \\ 0.000 & 0.000 & 0.141 & 0.468 & 0.608 \end{bmatrix} = (0.037\ 0.063\ 0.263\ 0.468\ 0.490)$$

Evaluation Index (D) = 1.00

*C1 to C15 represent the number of columns in the Table either side of the true grade, so 0.5 was given on either side. The remaining rows of the matrix were built up via similar logic. Membership grading matrices M_i were established in a similar way for all other 25 coastal scenic assessment parameters (BCR 2003).

Since experts may give different grades to the same parameter for the same beach, fuzzy assessment matrices $\mathbf{A}_P$ and $\mathbf{A}_H$ were developed based on the degree of possibility among the grades obtained from $\mathbf{M_j}$. $\mathbf{A}_P$ and $\mathbf{A}_H$ are 18 × 5 and 8 × 5 rectangular matrices where any j'th row of both matrices refers to the membership grades decided by the experts, evaluated from its input matrix and membership grade matrix as:

$$\mathbf{A}_{P,j} = \mathbf{D}_j \mathbf{M_j} \text{ (j = 1 to 18) and } \mathbf{A}_{H,j} = \mathbf{D}_j \mathbf{M_j} \text{ (j = 19 to 26)}$$

where $\mathbf{A}_{P,j}$ and $\mathbf{A}_{H,j}$ are the j'th rows of the fuzzy assessment matrices for the physical and human factors, respectively. Their elements are listed in columns 10 to 14, reflecting the corresponding attributes from 1 to 5, respectively. In Table 5, $\mathbf{D}_j$ is the 1 × 5 input matrix with the entry as 1 on the ticked attribute, all other entries being zero (as shown row-wise in Table 5, under the heading of 'input matrices' from columns 5 to 9, for every parameter).

If the ticked grade box (graded attribute given in column 4 of Table 5) for the rocky shore slope (parameter 7) is 4, the input matrix is:

$$\mathbf{D}_7 = (0\ 0\ 0\ 1\ 0)$$

The assessment matrix for this parameter is obtained by matrix multiplication of $\mathbf{D}_7$ with $\mathbf{M_7}$.

$$\mathbf{A}_{P,7} = \mathbf{D}_7 \mathbf{M_7} = (0.00\ 0.00\ 0.50\ 1.00\ 0.50)$$

and is given in row seven of the assessment matrix – columns 10 to 14 in Table 5.

Among the several mathematical models used in fuzzy logic applications, the weighted mean model was preferred for this study due to its simplicity and capability of holding useful information concerning all assessment evaluation parameters.

The process of assessment was carried out by direct multiplication of the fuzzy weight and assessment matrices, resulting in two weighted assessment matrices $\mathbf{K}_P$ and $\mathbf{K}_H$ for the factors P and H, respectively, as:

$$\mathbf{K}_P = \mathbf{W}_P \mathbf{A}_P \text{ and } \mathbf{K}_H = \mathbf{W}_H \mathbf{A}_H.$$

The final assessment matrix **R** (1 × 5) was obtained from the following matrix multiplication

$$\mathbf{R} = \mathbf{W_F} \mathbf{K}$$

where the matrix **K** is formed from the matrices $\mathbf{K}_P$ and $\mathbf{K}_H$ as its rows. The absolute values of the entries (membership grades) of the final assessment matrix **R** are not significant, but the entry with the maximum membership grade and its relative differences with the other entries is the decisive factor for the assessment.

For Little Haven, UK (Table 5), the final assessment matrix is given by the following steps. As a first step the fuzzy weighted average matrix $\mathbf{K}_P$ for the physical parameters is:

$$\downarrow$$

$$\mathbf{K_P} = \mathbf{W_P} \mathbf{A_P} = (0.074\ 0.126\ 0.385\ 0.468\ 0.372)$$

As stated previously, the absolute values of the elements of the fuzzy matrix has only a meaning relative to each another. In the above matrix, the maximum entry is on the fourth column implying that the beach assessed may be graded by the attribute 4 with respect to its physical characteristics. Similarly, the fuzzy weighted average matrix $\mathbf{K}_H$ for the human parameter is:

$$\downarrow$$

$$\mathbf{K}_H = \mathbf{W}_H \mathbf{A}_H = (0.000\ 0.000\ 0.141\ 0.468\ 0.608)$$

where the maximum entry is in the last column, implying that when human parameters are considered this beach may be graded as 5.

As a second step and synthesizing all factors of the first step, one arrives at the final assessment matrix **R**:

$$\mathbf{R} = \mathbf{W_F} K = (0.5\ 0.5)\begin{bmatrix} 0.074 & 0.126 & 0.385 & 0.468 & 0.372 \\ 0.000 & 0.000 & 0.141 & 0.468 & 0.608 \end{bmatrix}$$

$$\downarrow$$

$$= (0.037\ 0.063\ 0.263\ 0.468\ 0.490)$$

As in the previous assessment matrices, the i'th element of assessment matrix **R** is the membership grade of the i'th attribute. In this example, according to the principle of maximum membership grade, this is a grade '5'.

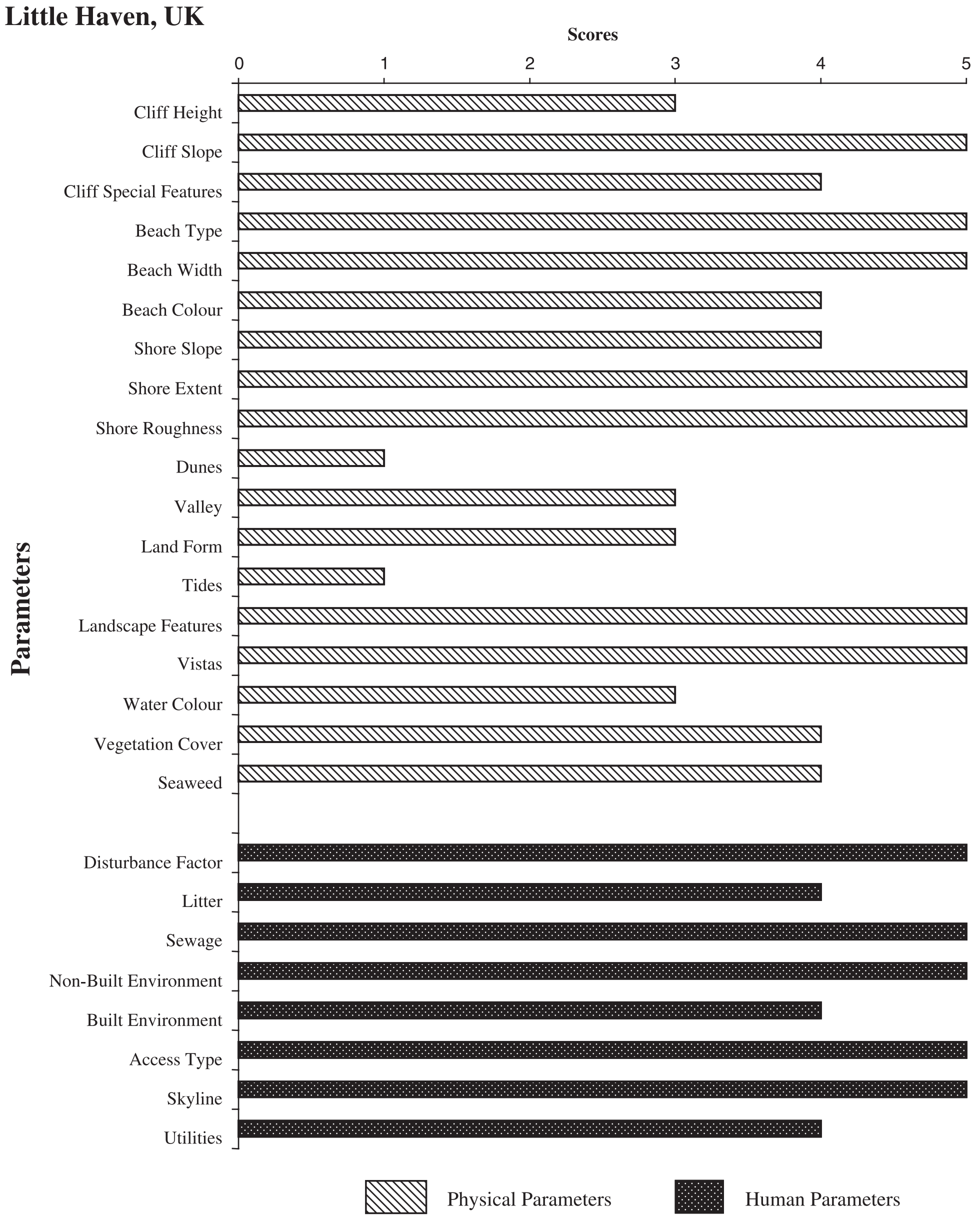

Figure 1 Scenic evaluation score histogram for Little Haven, UK

Data presentation

Coastal scenic assessments of the sites and scenic evaluation carried out by the fuzzy methodology were presented by:

1 *Scenic Evaluation Score Histograms*: The histogram was produced by plotting the scores taken from the 'Coastal Scenic Evaluation System' (Table 1) on the *y*-axis versus scenic evaluation parameters on the *x*-axis. The *x*-axis was further grouped into physical and human sub-sections. A scenic evaluation score histogram for Little Haven, UK, is given as an example in Figure 1.

2 *Fuzzy Weighted Average Matrices of Physical and Human Factors*: Weighted averages are given as examples in Tables 3, 4 and 5 for Little Haven, UK.

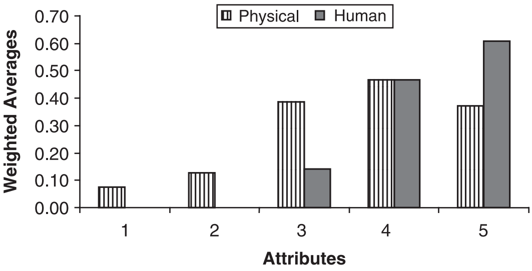

Figure 2 Weighted averages histogram, Little Haven, UK

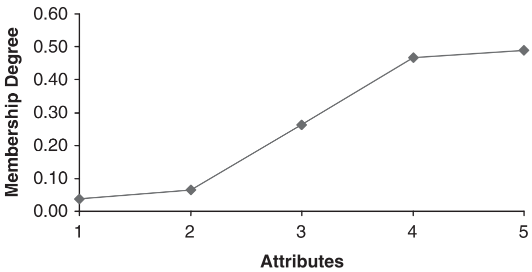

Figure 3 Membership degree curve, Little Haven, UK

3 *Membership Degrees of Physical and Human Factors*: Membership degrees are the final assessment matrix R of attributes (from 1 to 5), as given in (Table 5) for Little Haven, UK. Weighted Averages and Membership Degrees were presented in graphical forms as:

- The histogram of weighted average of attributes grouped into physical and human parameters versus attributes for each site. An example is given in Figure 2.
- The graph of membership degrees of attributes (R) for each site. An example is given in Figure 3.

Data interpretation

With respect to the weighted averages vs attributes histograms, high weighted averages at lower attribute values such as 1 and 2 reflect the adverse impact of the physical or human parameter. The reverse holds true for high attribute values, such as 4 and 5, which reflect the positive influencing impact of the physical/human parameter as given in Figure 2 for Little Haven, UK. With respect to coastal management issues, high human parameters at low attribute values may be interpreted, for example, as having too much litter present, etc. Most sites have physical parameters for which managers can do little to alleviate their scenic impact, so perhaps emphasis should be given to assessing ways of upgrading the human parameter scores.

With respect to membership degree vs attribute curves, a right hand skew (RHS) indicates a high scenic rating as given in Figure 3 for Little Haven, UK, compared to a low scenic rating epitomized by a left hand skew (LHS) curve (Ergin et al. 2002 2003 in press).

For comparison between sites, decision parameters (D1–D3) were defined – see below. Decision parameter computations were considered for several computational scenarios from the *Membership Degree versus Attributes* curves (Figure 3) and included:

D1 $= \frac{A_{35}}{A_T}$ The higher the D1 value, the better the scenic value.

D2 $= \frac{A_{35}}{A_{13}}$ The higher the D2 value – as above.

$$\mathbf{D3} = \frac{(-2 \times A_{12}) + (-1 \times A_{23}) + (1 \times A_{34}) + (2 \times A_{45})}{A_T}$$

The higher the D3 value – as above.

where the area under the curve between attributes i and j is named A_{ij} with: i = 1, 2, 3, 4 and j = 2, 3, 4, 5. The total area under the curve is A_T.

It can be seen that:

For **D1** $A_{13} + A_{35} = A_T \Rightarrow 1 \geq \frac{A_{35}}{A_T} \geq 0$

$\Rightarrow$ That is **D1** = 0 when $A_{35} = 0$
and **D1** = 1 for $A_{13} = 0$.

For **D2** $\frac{A_{35}}{A_T} + \frac{A_{13}}{A_T} = 1 \Rightarrow \frac{A_{35}}{A_{13}} = \frac{1}{\frac{A_{35}}{A_T}} - 1$

$\Rightarrow$ It is clear that $\infty > \frac{A_{35}}{A_{13}} \geq 0$

For **D3** $A_{12} + A_{23} + A_{34} + A_{45} = A_T$

$$\Rightarrow 2 \geq \frac{(-2 \times A_{12}) + (-1 \times A_{23}) + (1 \times A_{34}) + (2 \times A_{45})}{A_T} \geq -2$$

Calculations were carried out for all 57 evaluated sites using Di decision parameters. Among the proposed decision parameters Di, criteria D3 was chosen as a decision tool since it reflected all attributed values in terms of weighted areas, with negative and positive weights referring respectively to the sequence of attributes from 1 to 5. These were applied in order to distinguish the attributes'

Table 6 Site sequence with respect to D criteria

k	Sites (UK, Turkey, Malta)	D	k	Sites (UK, Turkey, Malta)	D
1	Çıralı Mid-section (TR)	1.31	28	Tenby N (UK)	0.26
2	Çıralı Karaburun (TR)	1.26	29	Antalya Old Harbour (TR)	0.19
3	Phasalis Small Bay (TR)	1.08	30	Tekirova North (TR)	0.19
4	Little Haven (UK)	1.00	31	Tekirova South (TR)	0.18
5	Dingli Cliffs (MT)	0.97	32	Kercem Cliffs (MT)	0.16
6	Phasalis Large Bay (TR)	0.91	33	Saundersfoot (UK)	0.15
7	Poppit (UK)	0.91	34	Konyaaltı West (TR)	0.10
8	Tisan Back Bay Mersin (TR)	0.83	35	White Towers Coastline (MT)	0.10
9	Fungus Rock (MT)	0.77	36	Konyaaltı East (TR)	0.09
10	Nash (UK)	0.74	37	Xwieni Point (MT)	0.08
11	St Govans (UK)	0.69	38	Xlendi Bay (MT)	0.07
12	Tisan Tample, Mersin (TR)	0.68	39	Alata East, Mersin (TR)	0.07
13	Whitesands (UK)	0.68	40	Llantwit (UK)	0.04
14	Karaburun Akyar Mersin (TR)	0.67	41	Konyaaltı Middle (TR)	0.04
15	Newgale (UK)	0.66	42	Ogmore (UK)	0.03
16	Göksu Hurma, Mersin (TR)	0.61	43	Porthcawl (UK)	0.02
17	Tenby S (UK)	0.57	44	Antalya Waterfalls (TR)	−0.01
18	Ghajn Tuffieha (MT)	0.56	45	Mgarr ix-Xini (MT)	−0.02
19	Manikata (MT)	0.56	46	Ramla Bay (MT)	−0.06
20	Southerndown (UK)	0.54	47	Amroth (UK)	−0.08
21	Calypso Cave (MT)	0.48	48	Ghallis Rocks coastline (MT)	−0.12
22	FreshWater West (UK)	0.46	49	Antalya Lara Barınak (TR)	−0.16
23	Blue Lagoon (UK)	0.45	50	Antalya Dedeman Hotel (TR)	−0.21
24	Mellieha (MT)	0.37	51	Lara Beach (TR)	−0.28
25	Wisemans Bridge (UK)	0.34	52	Marsalforn (MT)	−0.37
26	Broadhaven (UK)	0.34	53	Bahar Ic-caghaq (MT)	−0.41
27	Angle (UK)	0.33	54	Kız Kalesi Mersin (TR)	−0.58
28	Alata West, Mersin (TR)	0.31	55	St. George's Bay (MT)	−0.64
29	Alata Mid, Mersin (TR)	0.29			

impact on the evaluation of the coastal scenery. The D3 parameter was termed the Evaluation Index (D). Sequence figures/curve for D are given in tabular form in Table 6, together with a graphical form in Figure 4, for all 57 sites investigated in this project.

Discussion

Landscape value refers to the relative value or importance attached to a landscape, which expresses national or local consensus because of its quality, special qualities including scenic beauty, tranquillity or wildness, cultural associations or other conservation interests (LIIEA 1995). It must be emphasized that landscape scenery assessment is personal and should always be so, and that 'environmental aspects (landscape, ecology, archaeology and geology) cannot be given monetary values that fully and accurately reflect their value' (GCDLVI 2001, 18). However, planners and coastal managers demand a more rigorous and structural methodology on which to base decisions that can affect many people in a myriad of ways. DEFRA (2001) has argued that shoreline management plans (SMP) must take account of the landscape setting. The DEFRA (2001) report has also argued that formal EIA insists upon landscape and visual baseline studies. This requires research, classification, analysis and description of all landscape components including analysis of principal representative viewpoints and key viewpoints for carrying out visual impact assessments. As regards significance levels, some coastal sites can have distinctive strong characters, others a weak character (LIIEMA 2002). The technique outlined in this paper answers all these points.

The close of the twentieth century saw a swing in landscape studies from a more formal quantitative approach to a more aesthetic subjective viewpoint.

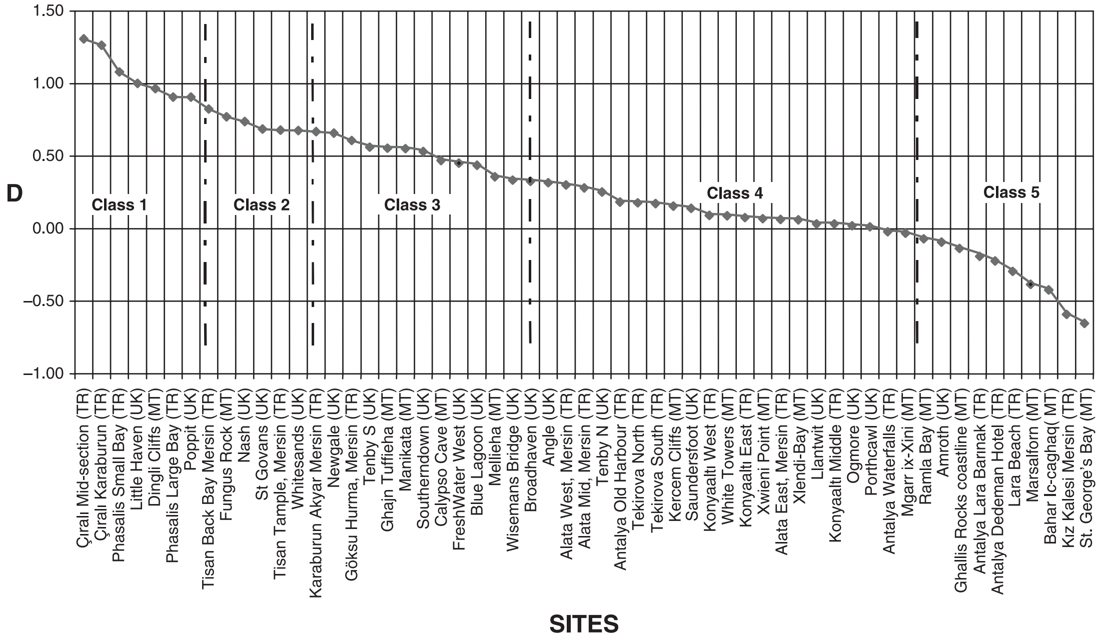

Figure 4 Evaluation index curve for 57 sites

This paper brings to the fore the semi-quantitative approach and the checklist technique owes much to the classic landscape paper of Leopold (1969). The fuzzy logic technique embodies detailed site-specific assessments of scenery. As such, it could represent, for example, the 5th stage of the CCW (2001) LANDMAP approach. LANDMAP 'hones down' components of the natural and cultural landscapes. Stage 1 is a very broad-brush approach, which will eventually feed into the detail exemplified by level 5. Currently it is at level 3. It is worthy of note that Appleton's (1975) paper proposed the viewpoint that landscape studies lacked a theoretical and philosophical base. This is still true as the current paper simply illustrates a novel technique on which the theoretical underpinnings have still to be fully finalized. It is field based and repetitive – after Linton (1968) – and the perception studies agree with those formulated by Penning-Rowsell (1982). The NAW (2002) has stressed that one aspect of information needed for scenic studies is professional evaluations or studies on the landscape within the study area. The application of fuzzy logic mathematics makes such evaluations easier, precise and more objective.

Site classifications were made on the final sequence curve produced, based on the Evaluation Index D (Figure 4). Curve break points based on the midpoint change of slope allowed a division of sites into five main classes (Figure 5). This simple rule is also compared to the percentile values of the D criteria on a normal plot (Figure 5), where Class 1 and Class 5 were within the lowest 15th percentile and top 85th percentile, respectively. The normal plot of the cumulative percentages versus the D criteria was almost linear, as shown in Figure 5**.** The break-point statistical distributions were also tested for Gaussian (normal) distribution that would indicate study unbiasedness. For this purpose, normality tests using chi-square and Kolmogorov-Smirnov tests were performed at the 5 per cent significance level, confirming normality of the break-point distributions. Classes obtained were as follows:

Class 1: Extremely attractive natural site with a very high landscape value, having a D-value above 0.85, e.g. Cirali and Phasalis Bay, Turkey (Plate 1).

Class 2: Attractive natural site with high landscape value, having a D-value between 0.65 and 0.85, e.g. St Govans, UK and Tisan Back Bay, Turkey (Plate 2).

Class 3: Mainly natural with little outstanding landscape features and a D-value between 0.4 and 0.65, e.g. Manikata, Malta; Southerndown Bay, UK (Plate 3); or urban sites with exceptional scenic characteristics, e.g. Tenby, UK.

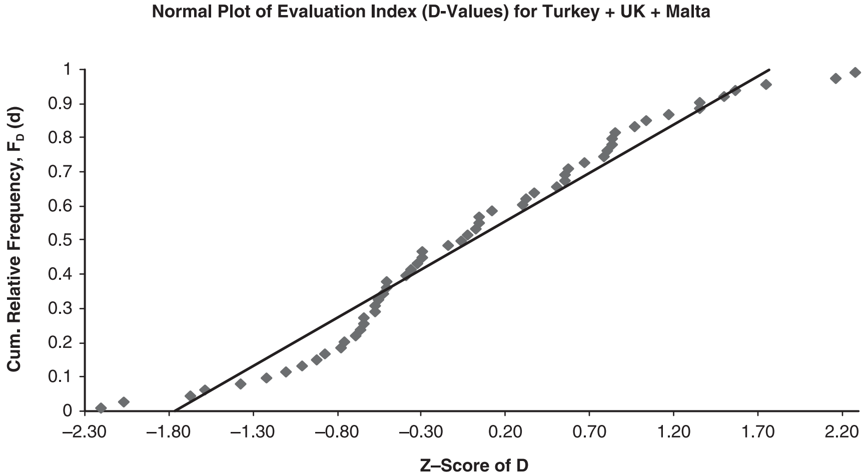

Figure 5 Normal plot of evaluation index (D values) for Turkey, UK and Malta sites

($\text{Z-score} = \dfrac{\text{D} - \text{Average of D}}{\text{Standard Deviation of D}}$ and Cumulative Relative Frequency, $F_D(d) = \dfrac{n - k + 0.5}{n}$, where k is the order of D-values in descending form (Table 6) and n is the total number of sites)

Plate 1 Phaselis Small Bay, Turkey: coastal embayment with a pebble beach backed by maquis vegetation and stunning imposing mountainous scenery in the background (Class 1)

Plate 2 Tisan Back Bay, Mersin, Turkey: a good example of natural scenery uninterrupted by anthropogenic impact (Class 2)

Class 4: Mainly unattractive urban, with a low landscape value and a D-value between 0 and 0.4, e.g. Xlendi Bay, Gozo, Malta (Plate 4).

Class 5: Very unattractive urban, intensive development with a low landscape value and a D-value below 0, e.g. Kizkalesi, Turkey and St Georges Bay, Malta (Plate 5).

Examples of Class 1 sites would include Cirali (Turkey), Dingli Cliffs (Malta) and Little Haven (UK). These sites rate highly due to outstanding features represented by natural and human parameters. The top five rated parameters obtained from perception studies were: absence of sewage/litter, water colour/clarity, absence of noise, quality of the built environment and landscape features (e.g. caves, water-falls etc.), all having attributes at the 4 or 5 level. Other parameters that rated highly included beach type together with the natural vegetation cover.

Class 2 sites included Fungus Rock (Gozo, Malta), Nash Point (UK) and Tisan Temple (Turkey). These sites rated lower than Class 1, due to a lower scoring of the parameters given above for Class 1 sites. For example, watercolour and clarity at Nash Point (UK), due to high turbidity associated with limestone cliffs and Severn estuarine sediment inputs, lower landscape features and a pebble (rather than sand) beach. While Fungus Rock scored highly on spectacular cliff scenery, the presence of litter and the absence of beaches and natural vegetation cover detracted from its overall assessment. Spectacular Roman historical features plus a luxuriant vegetation cover influenced the Tisan Temple site rating, but negative aspects of this site included much litter and a tourism housing development well out of harmony with the environment.

Class 3 sites included Tenby South (UK), Goksu Hurma (Turkey) and Ghajn Tuffieha (Malta). In spite of intensive urban development, Tenby South represented the highest rated urban beach in the study. Positive features at this site included sensitive urban development in keeping with the surrounding natural environment, a wide golden sand beach backed by dunes, and edged by a Napoleonic fort. The beach also faced an island housing an ancient monastery. Negative features at this site, that

Plate 3 Southerndown, UK: example of cliff, pebble beach and rock platform (Class 3)

presented a Class 3 rating, included poor water colour and clarity and a macro tidal range. At Ghajn Tuffieha, a very narrow sand beach with considerable amounts of litter and a partially demolished hotel represented negative aspects preventing a higher classification. Positive aspects included good natural vegetation cover, a very attractive pocket beach embayment and an absence of noise and urban environment. The Goksu Hurma site was located at the mouth of a river delta. No urban environment occurred in the area, but the absence of any topography, difficulty of access and considerable amounts of litter indicated a Class 3 rating.

The Class 4 category included the largest number of sites. Examples were Xlendi Bay (Gozo, Malta), Konyaaltı (Turkey) and Saundersfoot (UK). Typically in these sites, negative aspects were dominated by creeping urbanization with its associated problems of utilities, litter, poor skyline quality, noise disturbance and a degeneration of natural features present. The presence of adequate buffer zones was noted to mitigate such negative features. This class also included interesting but complex harbour sites such as Antalya Old Yacht Harbour – a World Heritage site that despite intensive development had many aesthetically pleasing features such as traditional housing and historical fortifications.

Class 5 sites included St Georges Bay (Malta), Amroth (UK) and Kizkalesi, Mersin (Turkey). Typically, these sites tended to be developed in a piecemeal fashion, with unattractive urbanization dominant at Kizkalesi, ugly coastal structures, e.g. at Amroth, and intensive tourism (hotels) development at St Georges Bay. Other negative features included high amounts of litter, high noise levels and an absence of any type of buffer zone. Degraded natural environments, e.g. loss of beach arising from anthropogenic developments, were common.

Conclusions

An innovative coastal scenic evaluation (CSE) technique was developed incorporating:

- Eighteen physical and eight human parameters, sub-divided into a five-scale attribute rating system.
- A weighting index derived from a perception study, which ranked parameter importance.

Plate 4 The beach at Xlendi Bay, Malta: unattractive intensive tourism development at the back of a beach (Class 4)

- A fuzzy logic approach utilizing a mathematical model.
- Management tools reflecting strengths and weaknesses of evaluated sites based on data presentation in the form of assessment histograms and weighted averages versus attributes. The latter reflects the effect of physical and human parameters on a scenic assessment, which can be used as a tool by coastal planners.
- Membership degree vs attribute curves, for identification of the most appropriate D (Evaluation index) criteria. The skew of the membership degree vs attribute curve reflects the scenic value of assessed sites.
- A Coastal Scenic Classification Curve, determined for all 57 evaluated sites based upon calculated Evaluation index values (D). The latter reflected the importance of attribute values in terms of weighted areas.
- A five-class evaluation system for coastal scenery was developed.

Class 1: having a D-value above 0.85, e.g. Cirali, Turkey.
Class 2: having a D-value between 0.65 and 0.85, e.g. St Govans, UK.
Class 3: having a D-value between 0.4 and 0.65, e.g. Manikata, Malta; or urban sites with exceptional scenic characteristics, e.g. Tenby, UK.
Class 4: having a D-value between 0 and 0.4, e.g. Xlendi Bay, Gozo, Malta.
Class 5: having a D-value below zero, e.g. Kizkalesi, Turkey.

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