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Relationship of public preferences and behavior in residential outdoor spaces using analytic hierarchy process and principal component analysis—a case study of Hangzhou City, China

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Abstract: This study examined public attitudes concerning the value of outdoor spaces which people use daily. Two successive analyses were performed based on data from common residents and college students in the city of Hangzhou, China. First, citizens registered various items constituting desirable values of residential outdoor spaces through a preliminary questionnaire. The result proposed three general attributes (functional, aesthetic and ecological) and ten specific qualities of residential outdoor spaces. An analytic hierarchy process (AHP) was applied to an interview survey in order to clarify the weights among these attributes and qualities. Second, principal factors were extracted from the ten specific qualities with principal component analysis (PCA) for both the common case and the campus case. In addition, the variations of respondents' groups were classified with cluster analysis (CA) using the results of the PCA. The results of the AHP application found that the public prefers the functional attribute, rather than the aesthetic attribute. The latter is always viewed as the core value of open spaces in the eyes of architects and designers. Furthermore, comparisons of ten specific qualities showed that the public prefers the open spaces that can be utilized conveniently and easily for group activities, because such spaces keep an active lifestyle of neighborhood communication, which is also seen to protect human-regarding residential environments. Moreover, different groups of respondents diverge largely in terms of gender, age, behavior and preference.

Key words: Public preference, Open space, Analytic hierarchy process (AHP), Principal component analysis (PCA), Cluster analysis (CA)

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INTRODUCTION

Nowadays, as a large number of residential blocks and college campuses are being constructed nationwide in China, improvement in the quality of residential community becomes a rising issue of city policy and urban planning. Layouts of open spaces in residential areas are predicated on their ability to deliver both a mechanism to maintain the viability of citizens' outdoor lives and a treatment to alleviate the high-density of urban constructions. What kinds of residential open spaces are desired by the masses? This question may be regarded as a valuable topic concerning the quality of life in residential environments.

Much urban research concerns the breakdown of community, without corresponding inquiries into mechanisms, such as neighborhood space design, which can enhance the quality of life in the community (Altman and Wandersman, 1987; Stokols, 1995). Generally, social contacts between neighbors can be enhanced by the presence of three neighborhoods activities: necessary activities, optional activities, and social activities (Gehl, 1987). The present study fo-

cuses on the second and third activities, in an attempt to disentangle various public attitudes towards the attributes of residential outdoor space.

In this paper, outdoor spaces located near or in residential areas call for much attention because of their convenience and humanism in the eyes of the masses. For years, however, research on environmental design has been concentrated on architectural forms, spatial relationship, material texture and visual landscape (Marus and Francis, 1998). Consequently, large-scale open spaces, e.g. city plazas, pedestrian shopping streets and city parks, dominate popular topics among architects and environmental designers. In contrast, the daily utilization of common outdoor spaces, e.g. neighborhood parks and campus spaces, is excluded from the mainstream of architectural forums. As such, public preferences for the value of residential outdoor spaces appeal to few designers' interest.

The popularity of open space projects undoubtedly also derives from their collateral benefits, including the provision of landscape, leisure places, and wildlife habitats. Open spaces, therefore, internalize some of the social benefits that go beyond the nominal boundary of the pricing system of real estate (Gardner, 1977; Kline and Wichelns 1994; 1998). In the aggregate, public preferences concerning the value of residential outdoor spaces may be characterized by three general attributes: function, aesthetics, and ecology. Compared with some economic research in the field of real estate, the three attributes may be classified to the non-market value of open spaces.

Developed by Saaty (1980), analytic hierarchy process (AHP) is a flexible yet structured methodology which enables an individual or a group to define a specific problem and derive a solution based on the individual's (or the group's) own experience. As a widely used multi-criteria decision-making methodology, herein, AHP offers a tool to the hands of decision makers and researchers to compare the public's understanding of the value of open spaces, i.e. functional, aesthetic, and ecological attributes. Furthermore, some specific qualities, which explain the aforementioned attributes respectively, are also compared within each group. Moreover, a principal component analysis (PCA) is also applied to explore the result of the AHP and to classify several distinctive types of users of outdoor spaces.

OBJECTIVES

As mentioned above, there are three worthwhile attempts to improve the Chinese residential environment. They are: (1) to examine the difference between designers' concepts and residents' preferences regarding the value of residential outdoor spaces, and to offer public opinion to designers; (2) to investigate two main types of outdoor spaces in common residence and on campus, and to discover their common ground and diversity; (3) to propose from the public side a quantification framework of analytical factors regarding the value of residential outdoor spaces.

The next section reviews previous studies and the fourth section introduces the AHP conceptual model, exemplifying the responses from the masses and students of Hangzhou City, China. The analytical methods are explained in the fifth section. The sixth section then describes the survey procedure and reports the basic information provided by the samples. Sequentially, the seventh section discusses the analytical results of the AHP and the PCA. The final section draws conclusions for the effective application of AHP with PCA to analyze people and residential outdoor spaces (Fig.1).

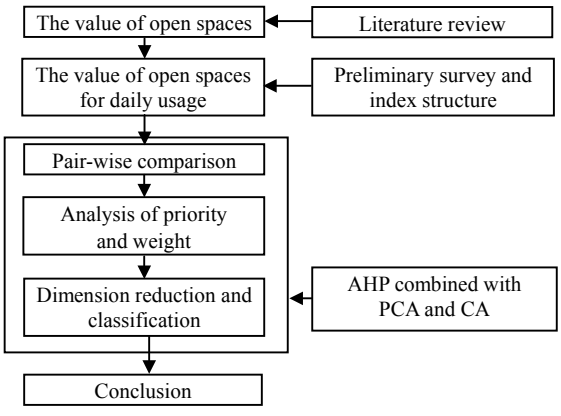

Fig.1 Framework of the AHP and PCA applied into the value of outdoor spaces in residential area
AHP: analytic hierarchy process; PCA: principal component analysis; CA: cluster analysis

LITERATURE REVIEW

Value of open spaces

As an important garden designer of the Ming Dynasty in China, Ji (1631) offered a classical design guideline for private gardens in Chinese style, discussing the basic principle for garden design. The non-native speaking reader is encouraged to refer to the English translation by Hardie (1988). Private gardens are regarded as the rudiment of residential outdoor spaces in China. Ji (1631) stressed that the value of gardens is to express designers' aesthetics and classified the design principles into six interdependent aspects: (1) field analysis, (2) building construction, (3) detail decoration, (4) horticulture, (5) rocks and water setting and (6) spatial interaction. At that time, the masses' demands for open spaces were out of designers' consideration. The philosophy of harmony between the nature and the master (i.e. the garden designer) was pursued as the supreme goal of environmental design.

As with urban construction and social development during the last two decades, Chinese designers began to refer to the western mode. Prior to the 1980's, research in this area classified various values provided by open spaces. Berry (1976) discussed six highly interdependent sources of value: utility, function, contemplation, aesthetics, recreation, and ecology. Berry (1976), in effect, distinguished active value (e.g. recreational value) from passive value (e.g. aesthetic value) and nonuse value (e.g. contemplative value). Effort was also made to distinguish ecological value that is readily valuable to humans (related to functional value) from that which is not (related only to natural environment).

Similarly, environmental psychology literature highlighted three main, successive neighborhood evaluative aspects: spatial (architectural and town-planning features), functional (services and facilities) and human (socio-relational features). The first and second aspects were considered as the physical settings of the last (Canter, 1983).

Cybriwsky (1999) reviewed trends in the design of urban public spaces in Japan and the USA by examining their changing patterns: how they are used. A comparison indicates that new public spaces enhance the quality of urban life and add aesthetic appeal, but also reflects certain social problems. In the Tokyo area, there is a curious trend to create large, landscaped open areas near new development projects that few people use. They can be called "planned wastelands" or "new urban deserts". New York City, on the other hand, has succeeded in having more people come together for enjoyment in parts of the city that were once all but abandoned.

The comparison studies used several methods to measure public preferences for preserved open spaces, especially agricultural land, on a county or town level. Kline and Wichelns (1994) used an indirect approach employing referenda data in Rhode Island and Pennsylvania to distinguish three attributes of preserved open space, including environmental, agricultural, and growth control (open space was included in the environmental attribute). In a study most directly motivating the research presented in this paper, Duke and Rhonda (2002) used a general population survey to develop a list of four attributes and eight qualities of preserved open space in Delaware.

A hint deriving from the above studies is that the non-market value of open spaces should be given more consideration in an open space project, i.e. functional, aesthetic and ecological attributes, because they endow open spaces with abundant appeal for citizens and the whole society.

In China, much research in residential environment evaluation focuses on the general evaluation system at a city level, which is mainly related with the subjective satisfaction evaluation. Wu *et al*.(1995) and Xu and Yang (1996) conducted general surveys of residential environments in Southeast China and Shanghai City respectively. In fact, residential environment is closely connected with concrete components, e.g. building quality, shopping convenience, transportation and open spaces, influencing people's daily lives. As a result, it is necessary to deepen the residential environment evaluation of some specific topics. In this paper, residential outdoor spaces located in residential areas will be examined. In the limited literature on this type of open space, the focus is mainly on the spatial formation, cultural atmosphere and landscape. Zhu and Wu (2002) built up a multi-level evaluation model considering building quality, transportation, landscape and so on. Wang (1996) and Wu (2002) examined the relationship of human perception of satisfaction and utilization of facilities of parkways in Taiwan. Previous research

mainly applied satisfaction evaluation into public preferences. In this paper, AHP is used as a central method to study the public's preferences for the value of daily usage open spaces located in residential zones and campuses. The purpose is to offer a supporting tool for open space designers who will understand the masses' demands for their works.

Applications of AHP

How can people best deal with complexity? Herbert Simon, Nobel laureate and expert of artificial intelligence, write in (Simon, 1960): Large organizations are almost universally hierarchical in structure. That is to say, they are divided into units which are subdivided into smaller units, which are, in turn, subdivided and so on. An organization will tend to assume hierarchical form whenever the task environment is complex relative to the problem-solving and communicating powers of the organization members and their tools. Hierarchy is the adaptive form for finite intelligence to assume in the face of complexity.

Developed by Saaty (1980), AHP is a multiple criteria decision-making tool, which facilitates choosing among alternative action courses or designs in order to achieve a final goal and objectives (Fig.2).

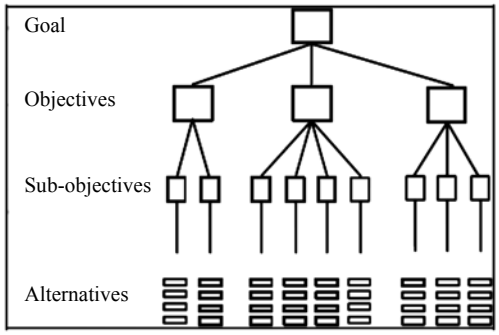

Fig.2 A demonstration of hierarchical structure

AHP applies an eigenvalue approach to the pair-wise comparisons matrix. It also provides a methodology to calibrate the numeric scale for the measurement of quantitative as well as qualitative performances. Normalized weights for each attribute can be calculated according to the maximum eigenvalue (λ_{max}). Meanwhile, the consistency index (CI) and the consistency ratio (CR) test the consistency of the whole matrix. Saaty (1980) proposed the right eigenvector method that constructs the vector of priority weights and facilitates testing for inconsistency. Value of CR is desired to be smaller than 0.1.

In this study, the decision maker is actually a group of 425 randomly selected survey respondents in Hangzhou City. In a case of group decision making, Duke and Rhonda (2002) suggested the geometric mean as a method of calculating the overall average comparison rating across all respondents. Aczel and Saaty (1983) proved that the geometric mean is consistent and upholds the four axioms underlying the AHP process.

AHP, since its invention, has been one of the most widely used multiple criteria decision-making tools in different fields such as planning, selecting a best alternative, resource allocations, resolving conflict, optimization, numerical extensions of AHP, etc. (Zahedi, 1986; Vargas 1990; Forman and Selly, 2001; Vaidya and Kumar, 2006).

However, there exist relatively few applications of AHP to residential outdoor spaces, especially for daily usage. The main extension of the present paper is to apply AHP with PCA to a general survey with a good number of respondents in order to explicate public preferences for daily places.

HIERARCHY OF ITEMS

Collection of items

In order to cover the facets and levels of the value of residential outdoor spaces, it is necessary to broaden the objectives of the problem or consider all factors and its outcome. As discussed in the section of review, the value can be understood from different viewpoints in terms of the interest of different people. For example, traditional garden artists showed an appreciation of spatial and architectural aesthetics; land and estate agents express an anxiety of the cost-benefit optimization; meanwhile the masses call for a more humanistic open space to enjoy life. Therefore, a preparative interview or survey is absolutely required.

Before the AHP survey, some useful information was collected at Hangzhou City, concerning the citizens' perspectives on open spaces they use daily near their residences. In order to acquire a general consciousness, both common residents and college students were selected around Hangzhou City for this case

study. The objectives evaluated by those respondents consist of two types of open spaces in residential area, i.e. the open space in mass communities and that on campus respectively. In the preparative interview with 31 designers, 45 residents and 25 students, the respondents were asked what kinds of attributes made up the value of residential outdoor spaces. We obtained the following information (Table 1):

(1) Generally, the value of residential outdoor spaces includes three aspects, which are: available places of leisure activities; landscape amenity; and ecological conditioners.

(2) There are some differences between the residents and designers. The residents mention the leisure value frequently, while the designers put the landscape, especially visual amenity on the first consideration.

(3) The factors mentioned by residents are more general than those by designers. Residents' perspectives almost cover all the aspects concerning open space, while designers argue that there are some factors which cannot be dealt with through design. For example, environmental cleanness, fresh air, creature inhabitability, activity, harmful gas, garbage disposal and fire accident.

(4) There are some differences between campus and common community. On campus, students consider both group activities and public activities, while the residents in community mainly consider individual and small group activities, and exclude large public activities.

Structured hierarchy of items

According to the AHP, the problem can be structured with a hierarchy of different levels constituting goal, objectives, sub-objectives and alternatives. Based on the above interview we structure a hierarchy of the indices constituting the value of open spaces for daily usage. The hierarchical structure is decomposed into two levels, i.e. general attributes and specific qualities, underlying the total goal (Fig.3). The general attributes include functional, aesthetic, and ecological factors; and the specific qualities are described as follows.

1. The functional attribute: facilitating users' leisure activities

According to users' behavior, there are three categories of leisure activities in open spaces. The first one is individual activities, e.g. strolling, reading, musing, fishing and so on. The second one is interactive activities in a group, e.g. chatting, discussing, sports game, party, picnic and so on. The third one is interactive activities in crowds, e.g. speech listening, exposition, flea market and so on.

Table 1 Comparison of frequently mentioned attributes between designers, common residents and college students

Sequence	Designers		Common residents		College students	
	Description	Percentage*	Description	Percentage*	Description	Percentage*
1	Landscape formation	19.4% (188:970)	Facility for group activity	20.3% (301:1485)	Facility for group activity	21.0% (211:1003)
2	Architectural style	18.1% (176:970)	Landscape formation	17.8% (265:1485)	Facility for public activity	17.9% (180:1003)
3	Biologic diversity	15.9% (154:970)	Facility for individual activity	15.8% (234:1485)	Landscape formation	14.4% (144:1003)
4	Community culture	13.5% (131:970)	Service buildings	13.7% (203:1485)	Aural amenity	12.3% (123:1003)
5	Facility for group activity	12.1% (117:970)	Tactual amenity	11.3% (168:1485)	Biologic diversity	9.2% (92:1003)
6	Microclimate	8.4% (81:970)	Microclimate	7.7% (115:1485)	Facility for individual activity	8.3% (83:1003)
7	Facility for individual activity	6.1% (59:970)	Aural amenity	5.7% (84:1485)	Campus culture	5.6% (56:1003)
8	Water-soil retention	2.3% (22:970)	Biologic diversity	3.9% (58:1485)	Water-soil retention	4.9% (49:1003)
9	Facility of service	1.3% (13:970)	Facility for public activity	2.2% (32:1485)	Service buildings	3.2% (32:1003)
10	Others	3.0% (29:970)	Others	1.7% (25:1485)	Others	3.3% (33:1003)

*: the percentage of mentioned terms among all terms. The former number in the bracket denotes the times of mentioned terms; the latter denotes the total times of all terms

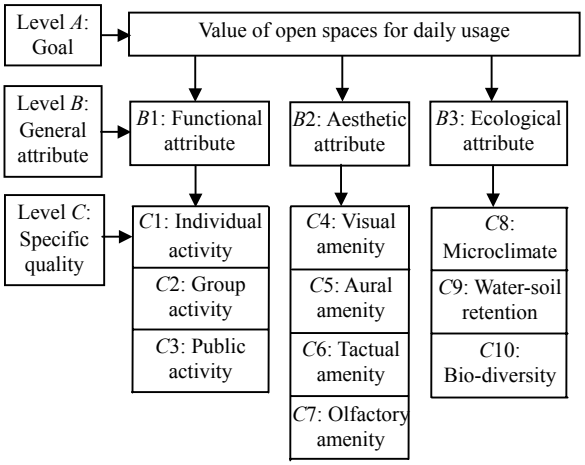

Fig.3 Structured hierarchy of the indices regarding the value of daily used open space

Correspondingly, an open space is subjected to the requirement of the three categories of activities. They are defined as three specific qualities, i.e. facilitating individual, group and public activities. Proper location, space, and facilities are required to provide material conditions for residents' daily usage.

2. The aesthetic attribute: providing amenity of landscape

Conventionally, the concept of landscape is mainly relative to visual perception. With the development of the research on landscape design and environmental psychology, some new concepts, e.g. sound-scape, are introduced frequently to understand comprehensively human perception of surrounding environment. In this research, we defined the amenity of landscape as the properties that offer comfortable perception for residents in open spaces.

There are four specific qualities of the amenity of landscape. The first one is visual amenity, e.g. architectural styles, natural scenery and so on. The second one is aural amenity, e.g. human songs and voice, wind or rain sound, creatural songs and so on. The third aspect is tactual amenity, e.g. sunshine, wind flick, material sense of benches, water surface, and vegetal contiguity and so on. The fourth one is olfactory amenity, e.g. fresh air, aroma, smell of picnic food, outdoor tea or coffee and so on.

Correspondingly, an open space near a residence is subjected to the requirement of these four qualities. Designers should create beautiful buildings, plantation, and natural environment to meet residents' daily aesthetics.

3. The ecological attribute: preserving local ecology

Although much research has highlighted the ecological significance of open spaces for local environment, especially wetland at the urban fringe and rural green land, most residents underrate, not ignore, the ecological attribute of open spaces for their daily life.

For residents, there are three specific qualities of open spaces for local ecology. The first aspect is creatural diversity, e.g. planting various vegetation and attracting more birds and insects with a livable habitat. The second aspect is the improvement in microclimate, e.g. diluting density of buildings and increasing sunlight rate. The third aspect is preservation of natural resource, e.g. conserving a natural pond or creek and keeping vacant land from being occupied by buildings.

Correspondingly, an open space near a residence is subjected to the requirement of these three qualities. Sufficient space, plantation and natural surface features are required to alleviate the intensity of ecological impact imposed by the construction.

METHODS

The main extension of the present paper is to apply AHP to reveal relative weights on the functional, aesthetic, and ecological attributes of open spaces. AHP is also used to identify relative weights on ten specific qualities within each of the three general attributes. Generally this consists of a questionnaire for comparison of each factor and geometric mean to arrive at a final solution of all the factors' weights. The survey data are then compared between two different groups of respondents (one is the group of common residents and the other is the group of college students). Subsequently, principal component analysis is applied to extract principal components from the ten specific qualities with the PCA applied for both the common case and the campus case. Finally, the variations of respondents' groups were classified with a cluster analysis (CA) using the results of the PCA.

DATA COLLECTION

Survey procedures

After structuring the hierarchy of three general attributes and ten specific qualities, 301 residents living in common residential communities and 124 college students in Hangzhou City were interviewed to reveal their collective preferences for open spaces. The enumerators solicited the participation of respondents and then offered a clear statement for respondents to understand the meanings of the three key concepts (i.e. open space, daily usage, and pair-wise comparison) and the hierarchical structure of all the attributes (qualities). The survey concluded with several demographic and opinion questions concerning frequency, accompaniers and the first preference of place and activity. The surveyor recorded the respondents' comparison ratings via pencil and paper. As such, each respondent provides 15 pair-wise comparisons with intensity rankings: 3 comparisons among the general attributes at Level *B* and 12 comparisons at Level *C*.

Basic information of respondents in the sample

A sample of 398 valid responses from the total 425, resulting in 5970 usable pair-wise comparisons (15 comparisons per respondent), was obtained in the spring of 2005 by a questionnaire survey at Hangzhou City, China. Table 2 shows the descriptive statistical data resulted from the survey.

In this survey, most of the questionnaires were answered with a face-to-face interview. The percentage of valid respondents is approximately 90%. During the interviews, the enumerators paid attention to the respondents and answered their questions. As a result, the percentage of the respondents without inconsistency in all the valid responses was approximately 50%.

RESULTS AND DISCUSSIONS

Weight rankings of public preferences

Overall, the local residents are demanding all the aspects of residential outdoor spaces. Nonetheless, marked preferences exist for the functional attribute regarding the capability of facilitating leisure activities. The AHP result is presented in terms of the type of the survey areas in Table 3.

As an important tourism city, until 2002, Hangzhou City had been one of the geographically smallest, but highest-densely populated provincial cities in China. After the administrational amalgamation of Hangzhou City and a few satellite counties in 2002, it is also one of the fastest growing cities in East China, with the residential floor area increasing 184% from 2002 to 2004 (Hangzhou Bureau of Statistics, 2005).

In this case study, respondents living in common residences allocated 51.2% of their preferences to the functional attribute. The aesthetic attribute was weighted middle (34.3%), whereas the ecological attribute was the least important (14.5% merely). Almost on the scale of common residences, campus residences have been experiencing an extensive relocation from the city center to the suburban areas in recent years (Shi *et al*., 2005). Campus residents also rank the functional attribute as the most important (44.9%), followed by the aesthetic (39.7%) and ecological attributes (15.4%).

Hence, across the city, the functional attribute seems to be the most important, carrying approximately half the weight in the total balance. Following in importance is the aesthetic attribute with a little more than one-third weight, and only one-seventh weight is on the ecologic attribute. In contrast with the traditional perspective regarding the Chinese classical theory of the garden design (Ji, 1631), the approximate ratio of 7:5:2 (functional:aesthetic:ecological)

Table 2 Sample selection statistics

	Male				Female				Total			
	PT	VR	Total	PT (%)	PT	VR	Total	PT (%)	PT	VR	Total	PT (%)
Common residence	59	138	147	42.8	51	140	154	36.4	110	278	301	39.6
Campus residence	40	69	72	58.0	35	51	52	68.6	75	120	124	62.5
Total	99	207	219	47.8	86	191	206	45.0	185	398	425	46.5

Note: PT denotes consistency-test-passed respondents; VR denotes valid respondents; PT (%) denotes percentage of consistency-test-passed respondents in the valid respondents

Table 3 AHP results and priority rankings in terms of the community type

Valuable attribute		Weight of priority							
Level *B*: General attribute	Level *C*: Specific quality	Common residence				Campus residence			
		Within group		Total		Within group		Total	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank
*B*1: Leisure activity				0.512*	1			0.449*	1
(Functional attributes)	*C*1: Individual activity	0.371	2	0.190	2	0.335	2	0.150	2
	*C*2: Group activity	0.546	1	0.280	1	0.384	1	0.172	1
	*C*3: Public activity	0.083	3	0.042	9	0.281	3	0.126	4
*B*2: Landscape amenity				0.343*	2			0.397*	2
(Aesthetic attributes)	*C*4: Visual amenity	0.375	1	0.129	3	0.375	1	0.149	3
	*C*5: Aural amenity	0.268	2	0.092	4	0.292	2	0.116	5
	*C*6: Tactual amenity	0.137	4	0.047	8	0.106	4	0.042	9
	*C*7: Olfactory amenity	0.220	3	0.075	5	0.227	3	0.090	7
*B*3: Ecology				0.145*	3			0.154*	3
(Ecological attributes)	*C*8: Microclimate	0.333	2	0.048	7	0.293	2	0.045	8
	*C*9: Water-soil retention	0.196	3	0.028	10	0.098	3	0.015	10
	*C*10: Biological diversity	0.471	1	0.068	6	0.609	1	0.094	6
Total				1.000**				1.000**	

*: the sum of the percentages of the same *B* level; **: the total value of *B*1~*B*3

proves there exists a change of public preferences for open spaces that residents utilize daily. The rapid development of urbanization is invading the land used for open spaces so that human outdoor leisure is losing its indispensable supports of places and facilities.

The sharpness of the AHP results is marked; assuming one believes that the sample is sufficiently large and representative of Hangzhou City, then the results showed, for instance, that the public is almost 3.5 times as interested in the functional services of open spaces as the ecological effects. In general, the two results closely correspond to the current trend regarding public preferences for open spaces.

Further, a fuller picture emerges from the results on the relative importance among the various specific qualities of residential outdoor spaces. By multiplying the specific weight by the general weight, an overall weight for each specific quality emerges. The sample places the most importance on (1) providing places for group activities (28%, 17.2%), keeping neighborhood communication as a part of daily lives, and (2) providing places for individual activities (19%, 15%), an outdoor environment where people can relax. The sample expresses the least interest in water-soil retention (2.8%, 1.5%). The top three qualities (group activity, individual activity and visual amenity) contribute 59.9% (the common case) and 47.1% (the campus case) of the overall weight, while the bottom three qualities account for only 11.7% (the common case) and 10.2% (the campus case).

Principal component analysis using the AHP results of ten specific qualities

In order to examine the variations of public preferences for both cases, a dimension-reducing process was performed by PCA. Based on the AHP results (n=110 for the common case; n=75 for the campus case, Table 2), the ten variables of weights (i.e. *C*1~*C*10) representing public preferences were subjected to PCA. Furthermore, the residents/students were classified into several groups in terms of individual scores on the extracted factors.

1. Common case

The PCA solution (Table 4) extracted four factors labeled: (1) ecology−group activity, (2) non-visual landscape, (3) individual activity−visual amenity and (4) public activity. This solution yielded ten communalities ranging from 0.735 to 0.965.

The items in the first factor mainly referred to various ecological qualities of microclimate, water-soil retention, and biologic diversity inside or in the immediate surroundings of the residence, but negatively referred to the group activity. The second factor referred to manifestations of the non-visual landscapes

Table 4 Four-factor PCA solution for the common case, using 10 variables of the AHP result

Rotated component matrix	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Ecology−Group activity*					
*C*10: Biological diversity	0.957	−0.046	−0.079	0.134	0.943
*C*9: Water-soil retention	0.927	−0.009	0.142	0.264	0.949
*C*2: Group activity	−0.792	−0.506	−0.247	0.052	0.947
*C*8: Microclimate	0.717	0.342	−0.235	−0.294	0.772
Non-visual landscape*					
*C*5: Aural amenity	−0.079	0.934	−0.016	0.218	0.926
*C*7: Olfactory amenity	0.453	0.818	−0.108	−0.094	0.895
*C*6: Tactual amenity	−0.198	−0.590	0.398	0.436	0.735
Individual activity−Visual amenity*					
*C*1: Individual activity	0.070	−0.030	0.965	0.165	0.965
*C*4: Visual amenity	0.034	0.629	−0.648	0.212	0.861
Public activity*					
*C*3: Public activity	−0.178	−0.135	−0.061	−0.954	0.964
Eigenvalue	3.205	2.679	1.668	1.406	
Variance (%)	32.05	26.785	16.678	14.055	
Cumulative (%)	32.05	58.836	75.513	89.569	

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization. *: definition of each factor whose name is assigned by the authors

of open spaces, such as aural, tactual, olfactory amenity. The third factor contained items referring to positively visual amenity and negatively to individual activity. The fourth factor referred to public activity. The cumulative percentage of variance showed that the above four principal components explained residents' preferences quite well, with the cumulative 89.6%, in which the first two factors constituted 58.8%.

For the common case, therefore, the 110 pairs of scores on the four components were taken as the data variables for use in the subsequent CA, in order to classify the residents according to individual preferences. The CA results showed that eight groups of residents were classified among all the 110 samples. To illustrate the cluster distribution clearly, the scatter plot in terms of the scores on the first and second factors is shown in Fig.4 and Table 5.

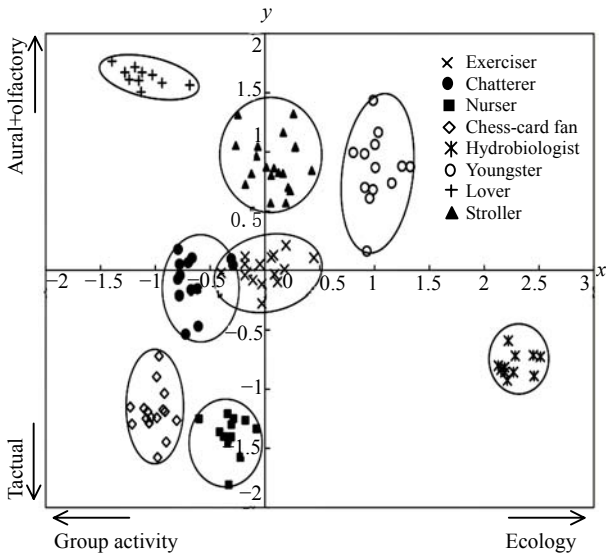

Fig.4 Scatter plot of common residents' cluster in terms of PCA scores

Analysis of variance between groups in terms of personal demographic attributes and behavioral features showed that three aspects have different significance, including gender, age, and behavior. Consequently, the corresponding characteristics of the eight groups are described as follows.

(1) Type 1 mainly refers to aged exercisers (15 respondents, 13.6%). Their average age is 62.5 and the gender is balanced. They utilize small squares in neighborhood parks to take exercise every morning for approximately 40 min. The weight on *C*3 (public activity) is assigned 22.2%, the highest rank among the eight types. On the contrary, the weights on *C*6

Table 5 Weight scores of the eight (or six) types' preferences on the ten specific qualities, using the AHP result

	*C*1	*C*2	*C*3	*C*4	*C*5	*C*6	*C*7	*C*8	*C*9	*C*10
Common case										
Exerciser	0.093	0.288	0.222**	0.107	0.058	0.011*	0.067	0.072	0.010*	0.072
Chatterer	0.243	0.312	0.068	0.097	0.066	0.079**	0.052	0.041	0.006	0.036
Nurser	0.089	0.449**	0.040	0.121	0.041	0.078	0.021	0.043	0.027	0.091
Chess-card fan	0.148	0.558	0.071	0.033*	0.041*	0.061	0.021*	0.023*	0.013	0.033
Hydro-biologist	0.286**	0.057*	0.025	0.029	0.046	0.056	0.057	0.069	0.167**	0.208**
Youngster	0.078*	0.181	0.020*	0.155	0.115	0.032	0.103**	0.096**	0.094	0.125
Lover	0.256	0.257	0.035	0.100	0.159**	0.045	0.076	0.031	0.019	0.022*
Middle-aged	0.107	0.244	0.028	0.197**	0.108	0.021	0.080	0.052	0.058	0.105
Campus case										
Sports people	0.126	0.189	0.368**	0.093	0.042*	0.016*	0.052	0.029*	0.008*	0.076
Talker	0.100	0.305**	0.149	0.123	0.091	0.082	0.047*	0.030	0.010	0.063
Landscapist	0.070*	0.102	0.025*	0.300**	0.072	0.088	0.101**	0.098**	0.026	0.117
Scholar	0.230	0.120	0.027	0.051*	0.210**	0.132**	0.061	0.060	0.011	0.097
Hydro-biologist	0.151	0.085*	0.062	0.068	0.068	0.051	0.082	0.045	0.098**	0.290**
Lover	0.245**	0.191	0.044	0.159	0.111	0.044	0.091	0.047	0.023	0.046*

*: the lowest rank; **: the highest rank within the eight groups (or the six groups)

(tactual amenity) and *C*9 (water-soil retention) are assigned 1.1% and 1.0% respectively, the lowest and second lowest ranks among the eight types (next only to Type 2: aged chatterers).

(2) Type 2 mainly refers to aged chatterers (13 respondents, 11.8%). Their average age was 68.1 and the female was the majority. They utilize various spaces of neighborhood parks for chatting or gossiping from 9:00 to 11:00 a.m. or from 3:00 to 5:00 p.m. for approximately 60 min per day. The weight on *C*6 (tactual amenity) is assigned 7.9%, the highest rank among the eight types. On the contrary, the weight on *C*9 (water-soil retention) is assigned 0.6%, the lowest rank among the eight types.

(3) Type 3 mainly refers to private nursers (12 respondents, 10.9%). Their average age was 23.4 with all being female. They utilize grassland and paths inside neighborhood parks for playing, basking in the sunlight or viewing landscape from 9:00 to 11:00 a.m. or at about 5:00 p.m. for approximately 30 min, 5~6 times per week. The weight on *C*2 (group activity) is assigned 44.9%, the second highest rank among the eight types (next only to Type 4: chess-card fans). On the contrary, the weight on *C*1 (individual activity) is assigned 8.9%, the second lowest rank among the eight types (next only to Type 6: youngsters). In addition, *C*5 (aural amenity) and *C*7 (olfactory amenity) are assigned 4.1% and 2.1% respectively, the second lowest rank among the eight types (both next only to Type 2: aged chatterers).

(4) Type 4 mainly refers to chess-card fans (16 respondents, 14.5%). Their average age is 55.7 with the male being the majority. They utilize playrooms inside neighborhood parks and small corners between buildings for intellectual games from 12:00 to 1:00 p.m. or from 3:00 to 5:00 p.m. for approximately 60 min, 3~4 times per week. The weight on *C*2 (group activity) is assigned 55.8%, the highest rank among the eight types. On the contrary, the weights on most of the aesthetic and ecological qualities (*C*4, *C*5, *C*7, *C*8 and *C*10) are assigned low values, the lowest or second lowest rank among the eight types.

(5) Type 5 mainly refers to the people who are attracted to water, named hydrobiologists (11 respondents, 10.0%). Their average age is 48.2 with the male being the majority. They stay around waterfronts in the vicinity of the neighborhood for fishing and walking with a birdcage from 8:00 to 11:00 p.m. or from 1:00 to 5:00 p.m. for approximately 120 min, 3~4 times per week. The weights on *C*1 (individual activity), *C*9 (water-soil retention) and *C*10 (bio-diversity) are assigned 28.6%, 16.7%, and 20.8% respectively, the highest rank among the eight types. On the contrary, the weights on *C*4 (visual landscape) are assigned 2.9%, the lowest rank among the eight types.

(6) Type 6 mainly refers to young students and

workers (13 respondents, 11.8%) with average age of 16.6 and balanced gender. They usually utilize grassland inside neighborhood for reading, talking and viewing landscape with friends after lunch or at about 3:00 p.m. for approximately 30 min, for less than 1 time per week. The weights on most of the aesthetic and ecological qualities (*C*4, *C*5, *C*7, *C*8, *C*9 and *C*10) are assigned high values, with the highest or second highest rank among the eight types. On the contrary, the weights on *C*1 (individual activity) and *C*3 (public activity) are assigned 7.8% and 0.2% respectively, the lowest rank among the eight types.

(7) Type 7 mainly refers to lovers (10 respondents, 9.1%) with average age of 25.4 and balanced gender. They usually utilize shady places under trees inside neighborhood for intimate meetings from 3:00 to 4:00 p.m. or after supper, for approximately 45 min, 1~2 times per week. The weights on *C*5 (aural amenity) and *C*1 (individual activity) are assigned 15.9% and 25.6% respectively, the highest and second highest rank among the eight types (next only to Type 5: hydrobiologists). On the contrary, the weights on *C*10 (bio-diversity) and *C*8 (microclimate) are assigned 2.2% and 3.1% respectively, the lowest or second lowest rank among the eight types (next only to Type 4: chess-card fans).

(8) Type 8 mainly refers to middle-aged strollers (20 respondents, 18.2%). Their average age is 43.8 and the gender is balanced. They usually pass through the neighborhood park for meeting neighbors off duty or stroll along walkways after supper, for approximately 15 min, 3~4 times per week. The weights on *C*4 (visual amenity) and *C*7 (olfactory amenity) are assigned 19.7% and 8.0% respectively, the highest or second highest rank among the eight types. On the contrary, the weight on *C*5 (aural amenity) is assigned 2.1%, the second lowest rank among the eight types (next only to Type 1: aged exercisers).

2. Campus case

A similar analytic process was performed for the campus case. The PCA solution (Table 6) extracted four components labeled: (1) landscape+microclimate, (2) ecology−group activity, (3) non-visual landscape, and (4) individual−public activity. This solution yielded ten communalities ranging from 0.690 to 0.983.

The items in the first factor mainly refers to visual and olfactory aesthetic qualities, with the microclimate

Table 6 Four-factor PCA solution for the campus case, using 10 variables of the AHP result

Rotated component matrix	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Landscape+Microclimate*					
*C*4: Visual amenity	0.894	−0.092	0.003	−0.366	0.941
*C*7: Olfactory amenity	0.881	0.261	−0.090	0.187	0.887
*C*8: Microclimate	0.833	0.122	0.316	−0.220	0.857
Ecology−Group activity*					
*C*10: Biological diversity	−0.041	0.961	0.060	−0.232	0.983
*C*9: Water-soil retention	0.093	0.928	−0.070	0.098	0.885
*C*2: Group activity	−0.449	−0.684	−0.123	−0.074	0.690
Non-visual landscape*					
*C*6: Tactual amenity	0.124	0.045	0.969	−0.142	0.976
*C*5: Aural amenity	−0.111	−0.110	0.812	0.525	0.959
Individual−Public activity*					
*C*3: Public activity	−0.575	−0.224	−0.636	−0.301	0.876
*C*1: Individual activity	−0.124	−0.040	0.094	0.972	0.971
Eigenvalue	2.854	2.410	2.142	1.619	
Variance (%)	28.541	24.099	21.422	16.189	
Cumulative (%)	28.541	52.640	74.062	90.251	

Extraction method: principal component analysis; Rotation method: varimax with Kaiser normalization. *: definition of each factor whose name is assigned by the authors

quality being regulated by open spaces near residences. The second factor refers to two ecological qualities of water-soil retention and biologic diversity inside or in the immediate surroundings of the residence, but is negatively referred to the group activity. The third factor refers to manifestations of the aural and tactual aesthetic qualities of open spaces. The fourth factor contained items referring to positively individual activity and negatively public activity. The cumulative percentage of variance showed that the above four principle components explained residents' preferences quite well, with a cumulative 90.3%, in which the first two components occupied 52.6%.

Similar to the common case, therefore, the 75 pairs of scores on the four factors were taken as the data variables for use in the subsequent CA, in order to classify the students according to individual preferences. The CA results showed that six groups of students can be classified among all the 75 samples. To illustrate the cluster distribution clearly, the scatter plot in terms of the scores on the first and second factors is shown in Fig.5 and Table 5.

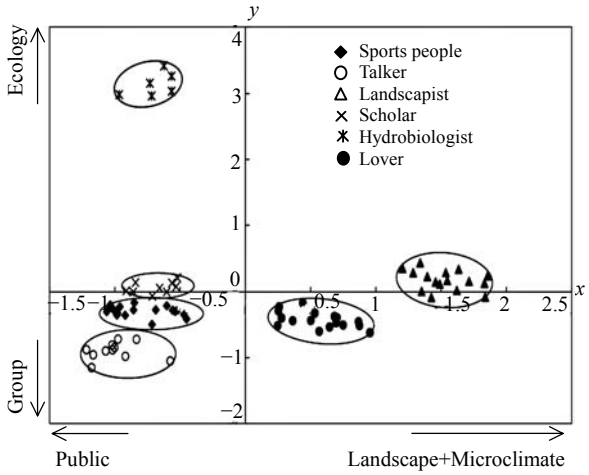

Fig.5 Scatter plot of students' cluster in terms of PCA scores

Consequently, the corresponding characteristics of the six groups are described as follows.

(1) Type 1 mainly refers to sports people (16 respondents, 21.3%) with average age of 20.7 years old and the male being a little less than 70%. They utilize playgrounds to take exercise every morning, for approximately 20 min, 5~6 times per week, who are fond of ball games in the afternoon, for approximately 50 min, 3~4 times per week. The weight on *C*3 (public activity) is assigned 36.8%, the highest rank among the six types. On the contrary, the weights on most of the aesthetic and ecological qualities (*C*5, *C*6, *C*7, *C*8 and *C*9) are assigned low values, the lowest or second lowest rank among the six types.

(2) Type 2 mainly refers to talkers (11 respondents, 14.7%) with average age of 21.3 years old and balanced gender who utilize various spaces near classrooms for chatting or discussion at about 10:00 a.m. and 3:00 p.m. with a short break of approximately 10 min per day. The weights on *C*2 (group activity) and *C*3 (public activity) are assigned 30.5% and 14.9% respectively, the highest and second highest rank among the six types (next only to Type 1: sports people). On the contrary, the weights on *C*1 (individual activity), *C*7 (olfactory amenity) and all the ecological qualities are assigned low values, the lowest or second lowest rank among the six types respectively.

(3) Type 3 mainly refers to students who like landscapes, named landscapist (16 respondents, 21.3%) with average age of 22.2 and female being the majority. They usually utilize grassland or scenery-facing ground on campus for reading and viewing landscape alone in the afternoon, for approximately 60 min, 3~4 times per week. The weights on *C*4 (visual amenity), *C*7 (olfactory amenity) and *C*8 (microclimate) are assigned 30.0%, 10.1%, and 9.8% respectively, the highest rank among the six types. On the contrary, the weights on *C*1 (individual activity) and *C*3 (public activity) are assigned 7.0% and 2.5% respectively, the lowest rank among the six types.

(4) Type 4 mainly refers to students who enjoy outdoor studying, named scholars (9 respondents, 12.0%) with average age of 19.4 and balanced gender who utilize (semi) open spaces with good seating environment on campus for reading and studying, from 9:00 to 11:00 a.m. and from 2:00 to 4:00 p.m. for approximately 40 min, 3~4 times per week. The weights on *C*5 (aural amenity) and *C*6 (tactual amenity) are assigned 21.0% and 13.2% respectively, the highest rank among the six types. In addition, the weight on *C*1 (individual activity) is assigned 23.0%, the second highest rank among the six types (next only to Type 6: lovers). On the contrary, the weights on *C*2 (group activity), *C*3 (public activity) and *C*4 (visual amenity) are assigned low values, the lowest or second lowest rank among the six types respec-

tively.

(5) Type 5 mainly refers to people who like water, named hydrobiologists (6 respondents, 8.0%), with average age of 21.1 years old and the male being the majority. They stay around waterfronts on campus for fishing and boating from 1:00 to 5:00 p.m. for approximately 50 min, 1~2 times per week. The weights on *C*9 (water-soil retention) and *C*10 (bio-diversity) are assigned 9.8% and 29.0% respectively, the highest rank among the six types. On the contrary, the weights on *C*2 (group activity), *C*4 (visual amenity) and *C*5 (aural amenity) are assigned low values, the lowest or second lowest rank among the six types respectively.

(6) Type 6 mainly refers to lovers (17 respondents, 22.7%). Their average age is 23.6 and the gender is balanced. They usually utilize interior places, e.g. marginal or isolated sections on campus for intimate trysts after supper, for approximately 90 min, 5~6 times per week. The weights on *C*1 (individual activity) and *C*2 (group activity) are assigned 24.5% and 19.1% respectively, the highest and second highest rank among the eight types (next only to Type 2: talkers). In addition, the weights on most of the aesthetic qualities (*C*4, *C*5 and *C*7) are assigned high values, the second highest rank among the six types. On the contrary, the weights on *C*10 (bio-diversity) and *C*6 (tactual amenity) are assigned 4.6% and 4.4% respectively, the lowest or second lowest rank among the six types (next only to Type 1: sports people) respectively.

3. Relationship of the PCAs between the two cases

As mentioned above, a PCA solution extracted four factors of the common case (Table 4), labelled: (1) ecology−group activity, (2) non-visual landscape, (3) individual activity−visual amenity, and (4) public activity. Another similar PCA was performed for the campus case (Table 6), extracting four components labeled: (1) landscape+microclimate, (2) ecology−group activity, (3) non-visual landscape, and (4) individual−public activity. The result clarified the common grounds and differences between the two cases. The components of ecology, group activity and non-visual landscape can be regarded as the shared components that explain perceptional differences among the eight groups (the common case) and among the six groups (the campus case). That means the designers should consider the diversity of public demands on ecology, group activity and non-visual landscape, whether for common residential zones or for university campuses. On the other hand, the two cases show some differences of the preferences on visual amenity, individual activity, public activity and microclimate. That means the designers may treat their works differently for common residential open spaces and for campus open spaces, in terms of the mentioned aspects above.

CONCLUSION

Importance of the functional attribute

As a whole, the public is demanding many valuable attributes from residential outdoor spaces. The importance of the functional attribute is consistent between common residents and college students. The results suggest that the public is less interested in several ecological services of open spaces, including the provision of microclimate, wildlife habitat and water-soil retention, which are usually provided via other types of open spaces planned for forestland and wetland. These results also tend to prove that a cost-effective design for open spaces should include at least two approaches, one for common residential areas and one for other special areas, e.g. campuses. The study reinforces Marus and Francis (1998)'s argument that open space programs should focus on criteria associated with leisure activities in open spaces over visual landscape. Consequently, further research on activity-supporting space is needed.

Diversity of public preferences

As mentioned in the last part, the public seems to prefer specific spaces to take different kinds of activity. The characteristics of each type also diverge on the scales of gender, age and behavior mode. It becomes an ever-growing challenge facing designers that they should make an effort to create various spatial-physical provisions for different groups.

Potential application of the AHP into the design process

The survey suggested that the concepts of designers diverge, in a way, from the public's demands on daily used urban spaces. The users' demands and evaluation derive from their subjective perception,

while the designers deal with controllable objective factors. Users' demands and their evaluation on open space are the basis of environmental design. Designers should consider their designs according to the demands of users and improve the designs to increase the users' evaluation. The AHP results can offer designers useful information: what kinds of attributes and qualities are important in public opinion. In the process of environmental design, alternative designs can be compared with each other according to weighted marks of all items.

Future work

Evidence is now accumulating that the public demands many services from residential outdoor spaces. Clearly, human interaction will not emerge in the space that only targets visual impression or that only appeals to house purchasers, while paying slight attention to the functional attributes. More work is needed to reconcile the public's demands on functional attributes. Such a recommendation has been made before; Marus and Francis (1998) argued that behavior modes in leisure activities show diversity of the public's demands. As a consequence, it is necessary to clarify the relationship between spatial-physical elements and people's behaviors (preferences) before formulating a design policy. Efficient administration of open space programs requires that the varied benefits should be balanced.

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