A Mathematical Approach to Measure Attractiveness of a Local Park

Sung Kwon, Hong

Dept. of Landscape Architecture, Chonnam National Univ.

都市公園 魅力度 測定의 數學的 接近 :

Ewing and Kulka의 모델응용

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全南大學校 農科大學 造景學科

요 약

기존의 많은 연구가 도시공원의 중요성을 밝히고 있지만, 보다 만족스런 공원조성을 위한 기본 자료의 부족으로 전통적인 설계방법은 경험이나 설계기준(standard)에 크게 의존하는 것이 현실이다. 그러나 전통적인 설계방법은 시간적, 사회적으로 변화하는 이용자의 욕구 충족과 창의성의 제고에는 문제점이 있다. 이러한 현상의 부분적인 이유는 객관적이고 보편성이 있는 공원 매력도 측정 방법의 결여로, 각 공원에서의 이용자 만족도의 그 이유를 체계적으로 분석하여 실제상황에의 적용이 어렵기 때문이다.

이에 본 연구는 공원의 매력도가 같다면 가장 가까운 공원을 이용할 것이라는 가정하에서 가장 논리적인 수학적 방법을 통해 기존 도시공원내의 매력도를 산출할 수 있는 모델을 제시하였다. 제시된 모델은 두개 이상의 공원이 존재해야 하며, 응답자의 거주지가 확인되어야 측정이 가능하다.

Ⅰ. INTRODUCTION

There are two factors determining park use-intensity, which are so called "facilitation factor" and "constraint factor." As many researchers suggest, constraint factors include many items, uncontrollable by landscape architects, such as lack of time, physical inability, lack of companionship, lack of awareness about service available, parent control, or lack of mobility(Jackson, 1986 ; Godbey, 1985 ; Searle and Jackson, 1985 ; Howard and Crompton, 1984 ; Jackson, 1983 ; Dee and Liebaman, 1970). The importance of these factors are variable depending on age, sex, race and income etc. However, facilitating factors can often be controlled and can be provided by landscape architects or park and recreation authorities under given conditions and a limited budget (Howard and Crompton, 1984). Therefore, a focus on attractive qualities to enhance park use-intensity would be a more reasonable research direction. Instead of researching uncontrollable factors, the landscape architect… as an environmental designer… should investigate those fac-

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tors he can control.

Unfortunately, little research has been conducted to investigate the relationship between the attractiveness of a local park and its use-intensity. Difficulty in measurement of the attractiveness of a park was the main deterrence against this type of investigation. Therefore, the purpose of this study is to direct toward identifying a scientific way of measurement of park attractiveness, which will contributes to make researches of this area empirically verifiable.

II. RELATED RESEARCH

Recently, there has been increasing need to operationalize the attractiveness of a certain place, mainly due to estimate volume of trips between origin and destinations(McAllister and Klett, 1976 ; Cesario and Knetch 1976 ; Freund and Wilson, 1974 ; Cheung, 1976 ; Cesario, 1973). Cheung (1976) developed a model to measure the attractiveness of a park for day-use based upon the concept of importance-performance analysis.

$$T(j) = \Sigma S(e) \cdot (\Sigma R(m)\ Q(m))$$

$T(j)$: attractiveness of a park j
$S(e)$: relative popularity rating of activity e
$R(m)$: the relative importance rating of facility m
$Q(m)$: score of facility m, according to its quantity or quality

Also, Cesario and Knetch(1976) proposed a following model to measure attractiveness of a state park.

$$A_j = \Sigma U_\ell(Z_\ell) q_\ell(Z_\ell) a_\ell\ ;\ \Sigma U_\ell = 1$$

A_j : attractiveness of park j
U_ℓ : apparent utility of having activity Z_ℓ available, as indicated by popularity weights obtained from the survey
q_ℓ : quality of the facility for activity Z_ℓ, subjectively rated by a team of researchers on a scale ranging from 1 to 10
a_ℓ : 0 if activity Z_ℓ not offered
1 if activity Z_ℓ offered

Most of research stated above has a common drawback. They predetermined important attributes affecting attractiveness of a park such as size of a park, size of waterbody, number of camp site, etc. As Howard and Crompton(1980) stated, product-- which might be interpreted as a park-- is a bundle of want-- satisfying attributes. Such want- satisfying attributes of a park are variable depending upon given situation and visitors' personality. Moreover, attractiveness of a park is determined by the comprehensive evaluation of all possible attributes of the park.

Ross(1973) suggested a model which can be applied to calculate attractiveness of a park in a regional area by use of an imaginative use of distance decay curve. Noting that different facilities of the same type in the same region often exhibit different distance decay curve, he speculated that the cause of these difference is variation in the attractiveness of the facilities.

$$A_{jk} = T_{jk} / (T_{jk} + T_{kj})$$

A_{jk} : the relative attractiveness of the site actually visited(j) to all other sites(k)
T_{jk} : number of times travellers chose j over k
T_{kj} : number of times travellers chose k over j

This model overcomes the weak point of the previous models, but it still have structual problem to measure the attractiveness : biased estimates of the attractiveness of one or more destinations can be produced because the attractiveness fail to account for the total number of trips from all origins to any given destination. To adjust for this, Ewing and Kulka(1979) added a weighting component to the equation.

III. AN EXPLANATION OF MEASUREMENT OF PARK ATTRACTIVENESS

Ewing and Kulka(1979) suggested a model to compare relative preference of ski resorts, which is a version of Ross' work(1973).

$$P'_{jk}=\frac{C_{jk}/N_{jk}}{C_{jk}/N_{jk}+C_{kj}/N_{kj}} \quad \text{for } N_{jk} \text{ and } N_{kj}>0$$

P'_{jk} : relative preference of resort j over re sort k

C_{jk} : number of times that resort j is chosen over resort k although resort j is more distant than resork k

N_{jk} : the number of respondents for whom resort j is more a distant alternative than resort k

Two factors determining the skier's preference of one resort over another are distance relative to the other resorts and attractiveness relative to others : skiers will visit the nearest resort if the attractiveness of all resorts is the same. Same concept can be applied to measure attrativeness of a local park by switching the term resort in the equation to park. Therefore, relative preference of park j over park k can be calculated by the following equation :

$$P'_{jk}=\frac{C_{jk}/N_{jk}}{C_{jk}/N_{jk}+C_{kj}/N_{kj}} \quad \text{for } N_{jk} \text{ and } N_{kj}>0 \quad \cdots\cdots (1)$$

P'_{jk} : relative preference of park j over park k

C_{jk} : number of times that park j is chosen over park k although park j is more distant than park k

N_{jk} : the number of respondents for whom park j is a more distant alternative than park k

Because the matrix of P_{jk} are inferred paired comparisons, it is impossible to calculate the attractiveness of each park. Therefore, it is necessary to make certain assumptions in order to calculate the difference of the attractiveness score in park j and park k, the previous step to calculate attractiveness of individual park, from the values of the P_{jk}. Thurstone(1959) suggested that so called just noticeable difference is contingent on the fact that an observer is not consistent in his comparative judgements from one occasion to the next. In other words, the observer gives different comparative judgements on successive occasions about the same pair of stimuli. Specifically, he assumed that the psychological continuum is so defined that the frequencies of the respective discriminal processes for any given stimulus form a normal distribution on the psychological scale. He suggested the following equation to measure the differences of psychological scale values of two compared stimuli :

$$(S_j-S_k)'=X'_{jk}\sqrt{\sigma^2_j+\sigma^2_k-2r\sigma_j\sigma_k}$$

$(S_j-S_k)'$: the psychological scale value of the two compared stimuli

X'_{jk} : the sigma value corresponding to the proportion of judgement $P'_{j>k}$. When $P'_{j>k}$ is greater than 0.5, the numerical value of X'_{jk} is positive. When $P'_{j>k}$ is less than 0.5, the numerical value of X'_{jk} is negative.

σ_j : discriminal dispersion of stimulus R_j

σ_k : discriminal dispersion of stimulus R_k

r : correlation between the discriminal deviations of R_j and R_k in the same judgement

Calculating σ_j, σ_k and r is infeasible, at least, in this study. Therefore, the most practical Thurstone's Case V is adapted. This Case V allows the constant discriminal dispersion and zero correlations between pairs of stimuli sensations. The reduced equation under Case V is :

$$(S_j-S_k)'=X'_{jk}\sigma\sqrt{2} \quad \cdots\cdots (2)$$

Since the assumed constant discriminal dispersion is the unit of the measurement, Equation (2) can simplified further as follow :

$$(S_j-S_k)'=X'_{jk}$$

Thurstone's equation can be interpreted as following equation to apply for calculating the difference of attractiveness of each park.

$$(A_j - A_k)' = X'_{jk} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

$(A_j - A_k)'$: difference of attractiveness between park j and park k

Mosteller(1951) discovered that of two assumptions in Case V if the constant dispersion between pairs is true then the zero correlation between pairs of stimuli sensations is a weak assumption. In other words, if a single assumption is true, it can be used without an alteration in method. Further, he suggested the method to solve psychological scale value (S'_j) from P'_{jk} in Case V by use of least squares which minimize $\sum_{j=1}^{n}\sum_{k=1}^{n}[X'_{jk} - (S'_j - S'_k)]^2$.

$$F = \sum_{j=1}^{n}\sum_{k=1}^{n}[X'_{jk} - (S'_j - S'_k)]^2 \quad \cdots\cdots\cdots\cdots \quad (4)$$

$$= (\sum_{j=1}^{n}\sum_{k=1}^{n} X'^2_{jk}) + (\sum_{j=1}^{n}\sum_{k=1}^{n} S'^2_j) + (\sum_{j=1}^{n}\sum_{k=1}^{n} S'^2_k)$$

$$- (2\sum_{j=1}^{n}\sum_{k=1}^{n} S'_j S'_k) - (2\sum_{j=1}^{n}\sum_{k=1}^{n} X'_{jk} S'_j)$$

$$+ (2\sum_{j=1}^{n}\sum_{k=1}^{n} X'_{jk} S'_k)$$

$$\partial F / \partial S'_j = 2(\sum_{k=1}^{n} S'_j - \sum_{k=1}^{n} S'_k - \sum_{k=1}^{n} X'_{jk})$$

$j = 1, 2, \cdots\cdots\cdots, n$

To get a soultion which minimizes the equation (4), partial derivative with respect to S'_j has to be equal to zero.

$$n\, S'_j = \sum_{k=1}^{n} X'_{jk} + \sum_{k=1}^{n} S'_k$$

$j = 1, 2, \cdots\cdots\cdots, n$

$$S'_j = (\sum_{k=1}^{n} X'_{jk})/n + (\sum_{k=1}^{n} S'_k)/n \quad \cdots\cdots\cdots\cdots \quad (5)$$

$$= 1/n \sum_{k=1}^{n} X'_{jk} + \bar{S}' \qquad j = 1, 2, \cdots\cdots\cdots, n$$

The equation (5) can be simplified because $\bar{S}'$ is constant.

$$S'_j = 1/n \sum_{k=1}^{n} X'_{jk} \qquad j = 1, 2, \cdots\cdots, n$$

S'_j : mean of sensation evoked by j^{th} stimuli

n : number of compared stimuli

Finally, Mosteller's equation can be interpreted as follows.

$$A'_j = 1/n \sum_{k=1}^{n} X'_{jk} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (6)$$

$j = 1, 2, \cdots\cdots\cdots, n$

A'_j : attractiveness of park j

n : number of compared parks

This least squares solutions are not entirely satisfactory because the P'_{jk} tend not to represent correct value when extreme stimuli are compared : unsatisfactory big numbers are introduced in X'_{jk} table(Fig. 1). This difficulty can be solved by excluding all numbers beyond 2.0 from the X'_{jk} table.

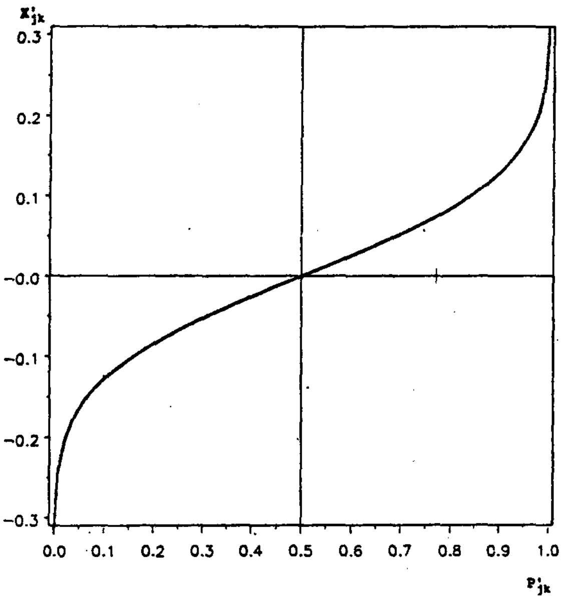

Fig. 1. Relationship between P'_{jk} and X'_{jk}

Ⅳ. AN ILLUSTRATIVE EXAMPLE

(1) Parks Studied

All of forty-three parks in two adjacent cities in Texas--Bryan and College Station(C.S.)--were selected. Two cities are different in terms of administrative district, but they are conjoined like one city.

(2) Sampling

Three-hundred forty-eight households were selected only in Bryan by a three stage stratified cluster sampling. The main reason for excluding residents in the C.S. was to obtain more generalized result. Texas A&M University is located in the C.S. so that demographic distribution of this town is severely skewed. Cluster sampling was used because of economical purpose, and stratification was utilized to obtain samller variance with same numbers of samples. Also, respondents were asked to rank the parks by frequency they had visited.

(3) Data Collection

Data collection was conducted by a personally delivered, self-administered questionnaire. This method had dual purposes. One purpose was to achieve a higher response rate to reduce sampling error. The other purpose was to identify the exact location of respondents' houses. They were marked on a subdivision map of Bryan. Two-hundred completed questionnaires were returned. Therefore, the response rate was 57.8 percent.

(4) Measurement

Measurement of park attractiveness was calculated by the three equations mentioned above. Equation (1) was needed to measure the four variables : C_{jk}, C_{kj}, N_{jk}, N_{kj}. The exact locations of two hundred respondents, which were marked on the subdivision map during the data collection, were used to measure the distance from a respondent's house to each of forty-three parks of Bryan and the C.S.A "Map Wheel" was the device used to measure the distance. There might be three different ways to measure the distance from a respondent's house to parks : (i) direct distance, (ii) the shortest distance by side roads, and (iii) the shortest way to get to the thoroughfare plus the distance of the thoroughfare. Both the second and the third methods were used. If parks were located within a relatively short distance or there was no thoroughfare to use to get to the parks from the respondents' houses, method (ii) was used because respondents were assumed to know the shortest way to get there. If parks were located relatively far away, and there was a thoroughfare to use to get to the parks, method (iii) was used because it was a reasonable guess for users to drive through the main thoroughfare to get some places when they had to drive a long distance.

The number of times that a park is chosen over the other parks although the park is more distant (C_{jk}) was counted by the rank respondents stated in their questionnaires. Then, a Fortran program was utilized to calculate P'_{jk} because it posed a great risk for making mistakes to calculate P'_{jk} by hand. However, N_{jk} and N_{kj} was programmed to be calculated when j was more than five percent farther away than k, and k was more than five perent farther away than j, respectively. The reasons for such a flexibility were that : (1) it is almost impossible for respondents to guess exactly which park is farther away than the others ; and (ii) there might be error in the measurement of distance from a respondent's house to a park on the subdivision map. As a result, a 43×43 P'_{jk} matrix without a diagonal was developed.

Equation (3) was used to calculate the difference in the attractiveness between park j and park k. A table of the normal curve area was employed to calculate the sigma value corresponding to the proportion of judgement $P'_{jk}(X'_{jk})$. Next, equation (6) was used to get the results of the least squares of given X'_{jk}. The following table is results calculated.

Theoretically, the attractiveness value of all parks had to be calculated. However, the attractiveness values of thirty-two parks out of forty-three were calculated. The reason for this problem was due to a lack in numbers of samples. In some cases either N_{jk} or N_{kj} was zero because only the residents of Bryan were sampled while parks in the C.S. were considered in calculating the attrac tiveness value. In another case, both C_{jk} and C_{kj} were zero because two parks might not be used at all for some reasons.

Table 1. Attractiveness Values of Selected Parks

Parks	Attrac-tiveness	Pakrs	Attrac-tiveness
Astin	0.280	Lincoln	−0.832
Anderson	−0.091	Oaks	−0.249
Bee Creek	−0.014	Reaearch	−0.430
Bonham	−0.337	San Jacinto	−0.434
Brazos County	−1.021	Scurry	−0.177
Brison	−0.248	Southwood Athletic	−0.542
Brothers Pond	−0.720		
Bryan Golf Course	0.708	Sports Complex	0.212
		Sue Haswell	0.983
Burton Creek	−0.643	Sul Ross	0.420
Castel Height	−0.408	Tanglewood	1.087
Central	0.529	Thomas(Bryan)	0.401
Gabbard	−0.867	Thomas(C.S.)	−0.124
Henderson	−0.528	Travis Ball	0.035
Hensel	0.040	Washington	0.641
Lemontree	−0.775	Williams	−0.620
Lions	−0.603	Williamson	0.148

V. DISCUSSION

The traditional approach to understanding people's park use has been directed toward a single concern, the presence of physical environments. As a result, most of the research has been conducted in predetermined study sites with existing facilities(Kruas and Washington, 1985 ; Johnson, 1978). However, an individual's environmental preference is a joint function of the importance of psychological attributes and the degree to which the attributes are present in the environments under consideration(Guadagnolo, 1985 ; Cooksey et al., 1982 ; Swan and Coombs, 1978). Such a traditional approach is not exhaustive. Whenever a researcher determines the attributes involved in a study, he may inject his own biases. To avoid a weakness such as this, a comprehensive approach, attractiveness of a park, needs to be introduced. Although sample size for this study was not large enough to validate the methodological advantages of these calculations, the combination of three suggested equations could contribute to the measurement of attractiveness of a park objectively.

In order to improve a accuracy of the measurement of park attractiveness, following is suggested for future studies.

Analysis in this study reveals the possibility for mistake in the measurement of the distance from a respondent's house to a park(N_{jk}). It was almost impossible to guess which routes the respondents would travel to reach a park. Also, N_{jk} and N_{kj} was programmed to be calculated when park j was more than five percent farther away than park k, and park k was more than five percent farther away than park j, respectively. A five percent flexibility assumption in this analysis is somewhat arbitrary. As an alternative, the amount of time a respondent needs to spend for reaching a park from his house might be a more appropriate variable in calculating relative perference of a park over another park (P'_{jk}) than the distance from his house to a park (N_{jk}). Thus, further studies might consider replacement of the distance variable with a time variable in opera-tionalization of P'_{jk}.

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