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Residential environment index system and evaluation model established by subjective and objective methods

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Abstract: In this research, the residential environment index system and evaluation model were established by means of subjective and objective methods. The methodology for establishing the evaluation system for residential environment was first analyzed; then the subjective evaluation data-base was established by questionnaire survey; and at the same time, the objective evaluation data-base was constructed by Geographic Information System (GIS); and then the related equation system between subjective and objective system was developed by multiple regression analysis. This research could benefit evaluation of the residential environment quality for various purposes, and also provide important rudimentary data-base for the development and improvement of residential environment for officials. Furthermore, the index system and evaluation model established in this research could construct a strong relation between subjective evaluation and objective data; and thus could provide a comprehensive, efficient and effective methodology for the evaluation of residential environment.

Key words: Residential environment, Index system, Evaluation model, Geographic information system (GIS)
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BACKGROUND AND OBJECTIVES

With the rapid development of society and economy, and the growing demands on lift quality, the development, improvement and management of residential environment are becoming more and more important. In researches on residential environment, the evaluation system is one of the rudimentary and important topics. Several researches have been done on the database, index system, methods and models of residential environment evaluation (Naito and Morita, 1995; Asami, 2001). There are mainly two types of index systems and evaluation methods: experiment-based and questionnaire-based; in other words, objective and subjective methods. The former one is based on experiments on environment conditions, and can be measured physically with device according to a standardized procedure. The main problem in this method is the weak relationship between measurements and effects. The later one is commonly based on the subjective perception of "satisfaction" which can be grasped by means of interviews or questionnaires. The main problem in this kind of method is its subjective nature.

METHODOLOGY

The establishment of residential environment index system and evaluation model is mainly divided into three parts. Part I: to establish the subjective evaluation index system and model by means of questionnaire survey and analysis; Part II:

to establish the objective evaluation data-base by means of Geographic Information System (GIS); Part III: to establish the relation equation system between the subjective and objective data by means of multiple regression analysis. The flow chart of the research is shown in Fig.1.

ESTABLISHMENT OF SUBJECTIVE EVALUATION SYSTEM

Hierarchical multi-attribute index system

In order to analyze the factors influencing residential environment comprehensively, three residential areas in Saga City and two areas around the city were chosen as the sample areas, and a questionnaire survey was conducted in 1999 as the rudimentary research (Yoshimoto, 2000). As the result, 44 items on residential environment qualities were set up and five principal components were abstracted, which were convenience, amenity, health, safety and community. WHO (World Heath Organization) first presented the four concepts of residential environment to satisfy the basic living requirements of human beings in 1961, which were safety, health, convenience and amenity. The first four components obtained by our rudimentary research were exactly the same as the concepts presented by WHO, and one more concept of "Community" was added from our research, standing for the spiritual needs beyond the basic material needs of residential environment. According to this result and also by interviewing experts, officials and citizens for revision of indexes, the hierarchical multi-attribute index system for subjective residential environment evaluation was established with four levels as described in Fig.2.

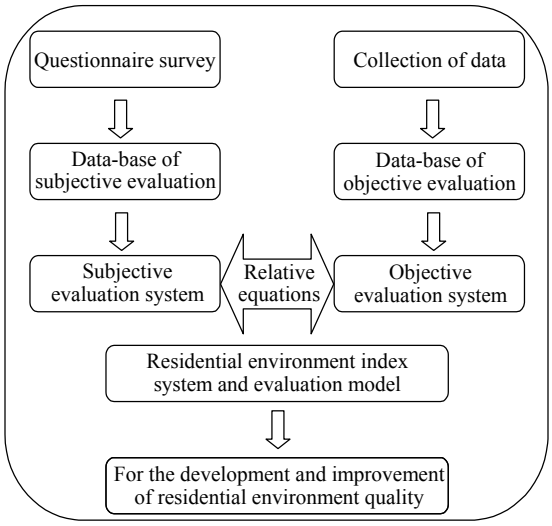
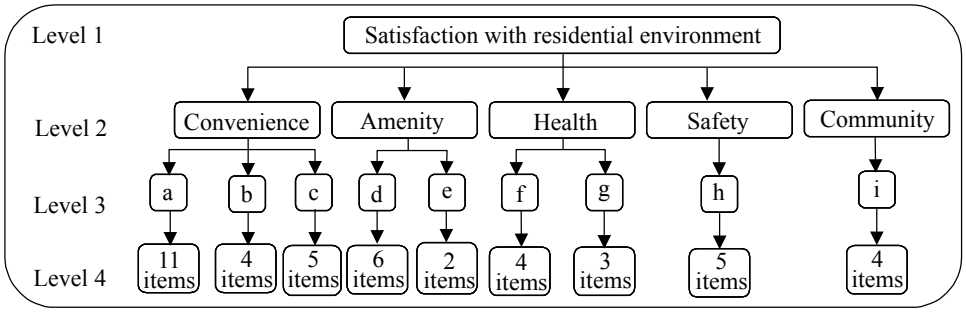


Fig.1 Flow chart of the establishment of residential environment index system and evaluation model

In this system, residential environmental quality in terms of "Satisfaction with Residential Environment" (level 1) depends on satisfaction with "Convenience", "Amenity", "Health", "Safety" and "Community" (level 2). Attributes of level 2 are assumed to depend on satisfaction with nine attributes ("a" to "i") of level 3. Furthermore, each of the nine attributes of level 3 is decomposed into some attributes of level 4. For instance, "b" of level 3 (efficiency of access to work and study site) is assumed to depend on such four attributes of level



a: efficiency with living facilities; b: efficiency of access to work and study site; c: efficiency with access to nearby cities; d: comfort with natural living environment; e: comfort with landscape; f: health with sanitary; g: health with no pollution; h: residential safety; i: residential community

Fig.2 Hierarchical multi-attribute index system

4 as "distance to work", "distance to school", "convenience of transportation to work" and "convenience of transportation to school". (For information of all 44 items of level 4, please see our homepage http://toshi1.civil.saga-u.ac.jp/hokao/index-j.html)

Besides, the questionnaire included such question as: "Are there any other items not mentioned in the questionnaire that will affect your residential environment quality?" Almost all of the answers considered that the items we presented could explain well the residential environment quality.

Questionnaire survey

A questionnaire survey was conducted in all of the 19 residential areas of Saga City in November 2001. From all the 63353 households of Saga City 3802 households were randomly selected and sent a questionnaire. The total valid response number was 1882, or 49.5%. Residents were asked to evaluate their present residential situation with multi-attributes according to the index system shown in Fig.2. Evaluations were given in terms of satisfaction elicited on 5-point scales: 1 (very satisfied); 2 (satisfied); 3 (ordinary); 4 (dissatisfied); and 5 (very dissatisfied).

The result of overall evaluation of all the samples revealed that residents were fairly satisfied with the quality of residential environment, with the average score (standard deviation) of 2.34 (0.81), which is close to the midpoint of the 5-point scale. The average scores for Convenience, Amenity, Health, Safety and Community are 2.83 (1.02), 3.03 (0.82), 2.91 (0.92), 3.19 (0.81) and 3.01 (0.66) respectively.

Subjective residential environment evaluation model

The subjective residential environment model was established through hierarchical multiple regression analysis by means of software SPSS 10.0. Evaluations of higher-level attributes could be regressed by the evaluations of the lower-level attributes.

Level 1:

$$\begin{aligned} Satisfaction &= 0.558Convenience + 0.248Amenity \\ &\quad +0.137Health + 0.308Safety \\ &\quad +0.02Community \\ r^2 &= 0.804 \end{aligned}$$

Level 2:

$$Convenience = 0.241a + 0.293b + 0.500c \qquad r^2 = 0.925$$

$$Amenity = 0.022d + 0.923e \qquad r^2 = 0.619$$

$$Health = 0.296f + 0.857g \qquad r^2 = 0.870$$

The relative importance of each residential attribute was given by standardized regression coefficient β. Satisfaction with "Convenience" appeared to be the most important attribute (β=0.558), then came the attributes of "Safety", "Amenity" and "Health" (β=0.308, β=0.248, β=0.137, respectively). The fifth attribute of "Community" did not appear to affect residential satisfaction to an important extent (β=0.02).

Three attributes a, b and c (level 3) were found to contribute significantly to the satisfaction with "Convenience" (level 2). Inspection of the β value revealed that convenience with "access to nearby cities" (β=0.500) appeared to be more important than that of "living facilities" (β=0.241) and "access to work and study" (β=0.293). Between the two attributes d (natural environment) and e (landscape) of level 3, "landscape" (β=0.803) seemed to be much more important than "natural environment" (β=0.022). As to the satisfaction with "Health" (level 2), attribute g (no pollution) (β=0.857) seemed to be more important than f (sanitary) (β=0.296).

Through the regression analysis in level 4, the regression equations of all the 44 attributes of level 4 to explain the satisfaction with the attributes of level 3 were also obtained respectively.

The model fitness was determined by the proportion of explained variance r^2, which could vary from 0~100%, with 100% indicating perfect fitness. The analysis results showed that r^2 in level 1 was 0.804, in level 2 were 0.925, 0.619, 0.870,

0.612, 0.914, and in level 3 was 0.895 in average, which meant that the model fitness was quite good, and the hierarchical multi-attributes model applied in this study seemed to offer a promising and valuable theoretical framework for modeling residential environmental quality. By this model, evaluations from on-site residents might provide fairly valid indicators for evaluation of residential environmental quality.

ESTABLISHMENT OF OBJECTIVE EVALUATION SYSTEM

Geographic Information Systems (GIS) is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations (Takasaka, 1998). In this research, GIS was applied in the collection, revision and calculation of objective data conveniently, accurately and effectively. The high efficiency of renewing data, and the vivid expression of maps or graphs made it suitable for the construction of objective index system. Compared with conditional method of objective data collection and management, GIS has great advantages in the selection of suitable indexes, reduction of budget and calculation time.

The process of establishing objective index system for residential environment evaluation by GIS is shown in Fig.3. First, according to the structure of the subjective index system, together with consideration of the characteristics of GIS data, we selected the possible objective indexes, and calculated them by software ArcView GIS 3.2.

Then relative analysis was conducted between the subjective evaluation scores obtained by questionnaire survey and the objective indexes. With the results, we selected the indexes having high relative coefficients with the subjective evaluation scores, which mean the strong co-relationship with each other. The objective index system was then established as shown in Table 1.

There are mainly two kinds of GIS indexes in this system, one is facility cover rate; another is area ratio. Facility cover rate is the ratio of the facility area to the whole residential area. For instance, the bus stop 200 m cover rate is defined as the ratio of the area from which the distance to the bus stop is shorter than 200 m to the whole residential area. By GIS, the calculation of various cover rate can be performed easily and rapidly; for example the 100 m, 200 m, 500 m and 1000 m cover rate of the facility, and their relative coefficients with subjective evaluation scores could also be calculated conveniently, so that the index with highest relative coefficient can be selected into the objective index system, in order to raise the accuracy of the evaluation model. On the other hand, the area ratio, for example green area ratio, is defined as the green area divided by the whole area. These kinds of indexes could be calculated by GIS conveniently and accurately.

RELATIVE EQUATION SYSTEM BETWEEN SUBJECTIVE AND OBJECTIVE EVALUATION SYSTEM

We conducted a multiple regression analysis between the objective index system and the subjective evaluation scores obtained by questionnaire survey, to establish the relative equation system between them, which could serve as the bridge be-

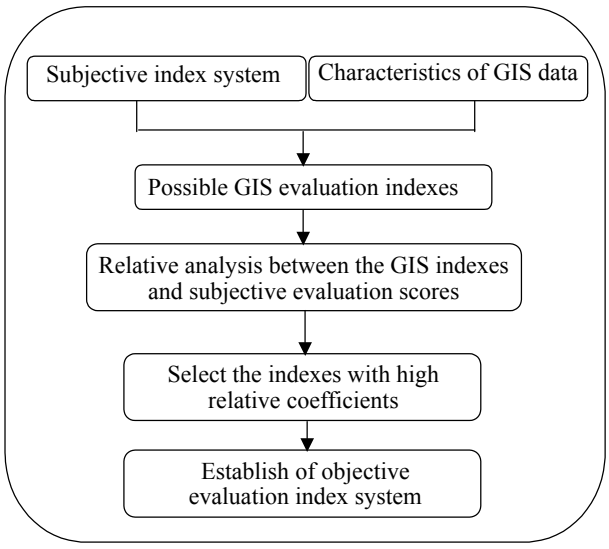


Fig.3 Establishment of objective index system

Table 1 Structure of objective index system

Convenience	Distance to school	Elementary school 800 m cover rate
		Middle school 800 m cover rate
		High school 800 m cover rate
	Convenience of public transportation	Bus stop 200 m cover rate
		Railway station 800 m cover rate
	Distance to popular shops	Supermarket 500 m cover rate
		Food shop 800 m cover rate
		Convenience store 800 m cover rate
		Commercial land rate
	Distance to post office and banks	Post office 1000 m cover rate
		Bank 1000 m cover rate
	Preparedness of nearby cultural facilities	Culture facilities 1500 m cover rate
	Preparedness of nearby sports facilities	Sports facilities 1800 m cover rate
	Preparedness of nearby medical and welfare facilities	Medical facilities 500 m cover rate
Amenity	Abundance of neighborhood greening	Green rate
		Land use rate (farm)
		Land use rate (forest)
		Field 10 m cover rate
		Farm 10 m cover rate
		Forest 10 m cover rate
	Waterfront environment of the neighborhood	Mix rate (50 m)
	Preparedness of open space	Park area ratio
Health	Clearness of the air	Road rate
		Industrial land rate
		Main road 10 m cover rate
		Factory 10 m cover rate
	Noise and vibration	Main road 50 m cover rate
		Factory 20 m cover rate
	Sunshine and ventilation	Nonbuilding-to-land ratio
Safety	Safety from crimes	Fire office cover rate
	Safety from transportation accidents	Main Road 50 m cover rate
	Safety from disasters	Road rate
		Medical facilities 500 m cover rate
		Nonbuilding-to-land ratio
Community	Regional activities	Community hall cover rate
		Number of community hall

tween the subjective and objective system. During the regression analysis, the variables taken into regression were decided by objective index system shown in Table 1. The regression analysis was conducted by means of SPSS 10.0; and the method for selecting independents was "backward". The calculation results are listed in Table 2, and the model fit of the analysis were quite good.

On the other hand, the regression analysis also showed that the relative equation of the attribute "Community" could not be established well. The problem could be that the evaluation of "Community" environment not only depend on the "hardware" such as community halls, but mainly on the

Table 2 Relative equation system between subjective and objective evaluation

	Attributes (Y)	Regression equation	Variables (X_i)	r^2	T Test
Convenience	Distance to school	Y=0.016X_1+2.560	X_1: Elementary school (800 m cover rate)	0.826	[**]
	Convenience of public transportation	Y=0.008X_1+0.016X_2+1.423	X_1: Railway station (3000 m cover rate) X_2: Bus stop (200 m cover rate)	0.756	[**]
	Distance to well-going shops	Y=0.013X_1+0.015X_2+1.283	X_1: Convenience store (1200 m cover rate) X_2: Bus stop (200 m cover rate)	0.641	[**]
	Distance to post offices and banks	Y=0.009X_1+2.982	X_1: Bank (1200 m cover rate)	0.715	[**]
	Preparedness of nearby cultural facilities	Y=0.011X_1+2.460	X_1: Cultural facility (1500 m cover rate)	0.602	[**]
	Preparedness of nearby sports facilities	Y=0.008X_1+1.917	X_1: Sports facility (1800 m cover rate)	0.744	[**]
	Preparedness of nearby medical and welfare facilities	Y=0.010X_1+0.009X_2+1.460	X_1: Medical facility (500 m cover rate) X_2: Welfare facility (1800 m cover rate)	0.935	[**]
Amenity	Abundance of neighborhood greening	Y=0.040X_1+3.309	X_1: Green (10 m cover rate)	0.924	[**]
	Waterfront environment of the neighborhood	–	–	–	–
	Preparedness of open space	Y=0.104X_1+2.686	X_1: Area of parks	0.813	[**]
Health	Clearness of the air	Y=–0.039X_1–0.007X_2+4.218	X_1: Road rate X_2: Main road (300 m cover rate)	0.631	[**]
	Noise and vibration	Y=–0.013X_1–0.015X_2+3.988	X_1: Main road (300 m cover rate) X_2: Road rate	0.745	[**]
	Sunshine and ventilation	–	–	–	–
Safety	Safety from crimes	Y=0.156X_1–0.017X_2+4.381	X_1: Firestation (100 m cover rate) X_2: Police office (2500 m cover rate)	0.607	[**]
	Safety from transportation accidents	Y=–0.009X_1+3.127	X_1: Main road (150 m cover rate)	0.573	[**]
	Safety from disasters	Y=–0.014X_1+0.062X_2 +0.003X_3+3.064	X_1: Road rate X_2: Firestation (100 m cover rate) X_3: Nonbuilding-to-land ratio	0.814	[**]

Note [**] Analysis accuracy is good under the tolerance of 0.01 (99% confidence); [*] Analysis accuracy is good under the tolerance of 0.05 (99% confidence); [ ] Analysis accuracy is not good

"software" such as community network, community activities and so on; however, these kinds of indexes are not suitable for GIS calculation. The same condition could also be found in such indexes as "the beauty of the street fronting the house" and "the beauty of the landscape", because of their subjective property. This might show to some extent the weak point or limitation of GIS in the objective index system, which should be taken into consideration and revised in future research.

CONCLUSION

In this research, a comprehensive evaluation model combining both subjective and objective system for residential environment quality is established through the case study of Saga City. The model includes three parts: in Part I, the subjective index system and evaluation model were established by means of questionnaire survey and statistical analysis; in Part II: the objective evaluation data-base was constructed by means of Geographic Information System (GIS); and in Part III, the relative equation system between subjective and objective data was developed by multiple regression analysis. This model is expected to combine the merits of both questionnaire-base method and experiment-base method for residential environment evaluation, and can be applied to the development and improvement of residential environments comprehensively, effectively and efficiently.

In the future, the more detailed objective index system would be studied, especially the attributes unsuitable to be obtained by GIS. Furthermore, we also propose to apply this model to other local cities besides Saga to prove its general adaptability and accuracy.

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