QUANTITATIVE EVALUATION METHOD OF THE CAPACITY OF SKELETONS USED IN SI HOUSING

Kozo KADOWAKI, Seiichi FUKAO
Department of Architecture, Tokyo Metropolitan Univ., 1-1, Minami-osawa, Hachioji, Tokyo
Kazuo KAMATA
Tokyo Gas Co., 26F, Shinjuku Park Tower BLD., 3-7-1, Nishishinjuku, Shinjuku-Ku, Tokyo
Hideki KOBAYASHI, Hidekazu FUJIMOTO
Building Research Institute, 1, Tachihara, Tsukuba, Ibaraki
Shunji MIYAMOTO
Urban Development Corporation, 1-14-6, Kudankita, Chiyoda-Ku, Tokyo

Abstract: *The SI housing, which separates the skeleton and infill, is regarded as a construction system, which is capable of adjusting to the individual requirements of residents continuously, has drawn considerable attention. And also an evaluation method to quantify the capacity of skeletons is required. This research shows the result on the evaluation of the skeletons operated by specialists. The characteristic items of skeleton were compared with the evaluation, and the influence of each item on the "ease of renovation" was revealed. Using the results, multiple regression analyses were operated, and the evaluation formulas of the capacity of skeletons were proposed.*

1. INTRODUCTION

1.1 Background and Objectives

Recently considerable attention is paid to the SI housing, which separates the skeleton (support or structural elements) and infill (interior and equipments), as a desirable construction system, which is capable of adjusting to the individual requirements of the residents. It is necessary that the skeleton allow the alteration or replacement of the infill, in order for SI housings to operate effectively on such requirements. And the evaluation of the capacity of skeletons often provides subject for debate. Also at the time of planning renovations of multiunit residential building stocks built after 1970, an evaluation method to quantify the capacity of skeletons for repair or improvement is required.

The objectives of this research are to establish a quantitative evaluation method for the "ease of renovation" of skeletons for multiunit residential buildings, and to reveal the influence of each characteristic property on the "ease of renovation" of the structure, or what degree of renovation the skeleton can allow.

1.2 Outline of Research

This research was conducted through three phases to accomplish the objectives mentioned above.

First, the evaluation of the capacity of various types of skeleton was operated by thirty-one specialists in multiunit residential building, by questionnaire. And the reliability in that evaluation was verified. (Chapter 2)

Then, the correlation of each characteristic item, which is assumed to have considerable influence on the "ease of renovation" such as story height or concrete wall length ratio of skeleton, with the evaluation by specialists, was studied by comparing both data. (Chapter 3)

Finally, multiple regression analyses were operated using the evaluation by specialists as the criterion variable and the characteristic items as the dependent variables. And the weight of each characteristic item on the evaluation of the capacity of skeletons was revealed. Using the results of the analyses, two types of the evaluation formula of skeleton were obtained. (Chapter 4)

2. EVALUATION OF THE CAPACITIES OF SKELETONS OPERATED BY SPECIALISTS

2.1 Definitions of the Capacities of Skeletons on this Research

The skeleton capacities concerning the four types of renovation, which are thought important to adjust to the requirements of the residents, are analyzed in this research: water section renovation of an individual unit and of a whole building, floor plan alteration of an individual unit and of a whole building. Below is a table indicating each definition of them. In addition, the renovation of a whole residential building, which was built in the mass-housing era, is called “super reform”, and “super reform” has begun to be carried out in Japan.

Table 1 Definition of the Skeleton Capacities concerning the Four Types of Renovation

WH; Skeleton Capacity concerning Water Section Renovation of an Individual Unit The term “WH” is defined as the capacity of skeletons concerning water section renovation such as bathroom, dressing room, lavatory and toilet room (except kitchen), of an individual unit. Still more, this renovation includes the case of enlarging such water section, but removing the water section. Moreover, although it is possible that enlarging water section area follows the floor plan alteration, the ease of floor plan alteration is excluded.
WS; Skeleton Capacity concerning Water Section Renovation of a Whole Building The term “WS” is defined as the capacity of skeletons concerning water section renovation likewise “WH”, of a whole building.
LH; Skeleton Capacity concerning Floor Plan Alteration of an Individual Unit The term “LH” is defined as the capacity of skeletons concerning floor plan alteration of an individual unit. Still more, this renovation includes the case of removing the water section such as bathroom, dressing room, lavatory, toilet room and kitchen. Moreover, such renovation is carried out in the representing area of a unit, excluded the case of combining some units.
LS; Skeleton Capacity concerning Floor Plan Alteration of Whole Building The term “LS” is defined as the capacity of skeletons concerning floor plan alteration likewise “LH”, of a whole building.

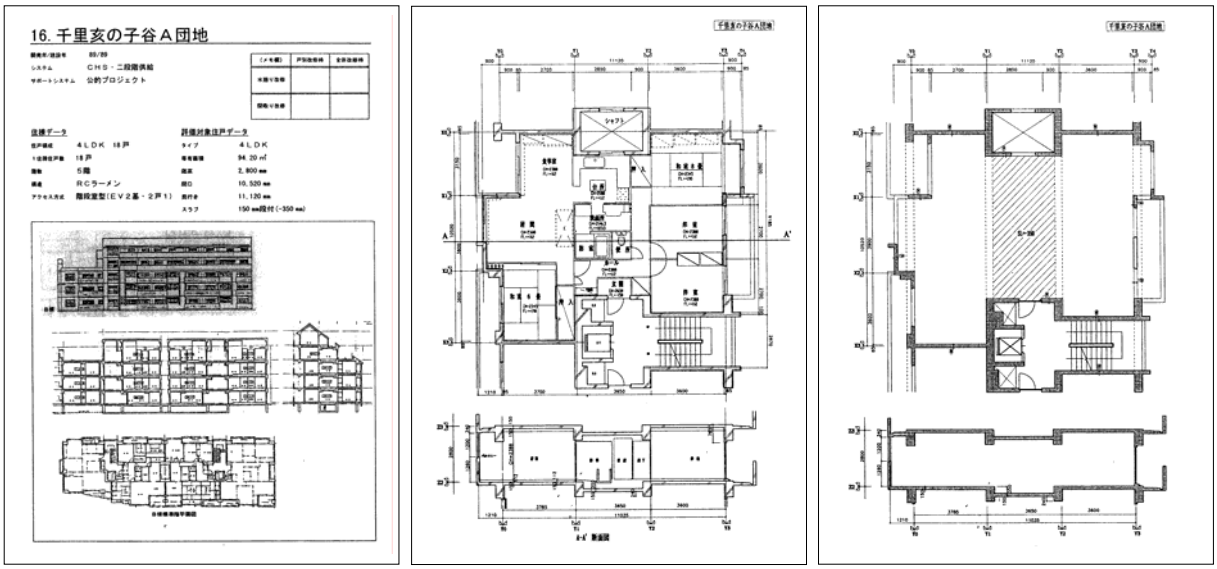


Figure 1 Example of Database (Senri-Inokodani Apt., CHS, Osaka)
*1/100-scale drawings were shown to the specialists.

2.2 Questionnaire on the Capacities of Skeletons to Specialists

Drawings for most common types of skeleton, which was built by Japan Housing Corporation (now the Urban Development Corporation or UDC), and new proposals of multiunit residential buildings were collected. The total number of projects amounted to eighty. Then, the special housing types were excluded: low-rise terrace house, duplex apartment and super high-rise housing. Thirty representing projects were selected among them, and the drawings (floor detail plan, sectional detail plan, skeleton plan, skeleton section of the principal unit and drawings of a whole residential building) in the same form were made as database an example of which is shown in Figure 1.

The skeleton capacities concerning the four types of renovation were evaluated. The evaluations were

operated by thirty-one specialists in multiunit residential building with the prepared database, by questionnaire. They may be divided into four types of attribute according to their business as follows.

A: Architect whose Major Work is Housing Design	8 persons
B: Architect or Researcher of General Contractor or Subcontractor	9 persons
C: Person who belongs to Housing Supply Organization such as UDC	7 persons
D: Researcher of University or Other Institutes	7 persons

2.3 Result of the Evaluations

The evaluations were operated on a scale of one hundred. As the method of evaluation had only a few guidelines, the range of the scores of each evaluator varied widely, for example evaluator A scored from 40 to 60, on the other hand evaluator B scored from 0 to 100. For such reason, the scores were standardized on each individual evaluator, using each one's average and standard deviation of the thirty projects scores. These results are made into box-whisker graph as Figure 2. They are set in chronological order in this graph, while the projects had been listed according to their property and their housing supply organization when the questionnaire had been carried out.

Evaluation Scores in case of "WH"	Ave.	Project Name / Year of Completion		Ave.	Evaluation Scores in case of "LH"
	-1.563	Model 66-4N-3DK, JHC	1966	-1.743	
	-1.597	Higashi-Kurume Apt., JHC	1967	-1.360	
	-0.487	Pilot House, Shimizu Co.	1971	-0.361	
	-0.857	Pilot Hpuse, Tokyu Prefab Co.	1971	-1.010	
	-1.398	Takashimadaira E-1, JHC	1972	-0.842	
	-0.651	Model Pub.-74-5PC-3DK, JHC	1974	-1.184	
	-1.011	Model 74-8CS-3DK-W, JHC	1974	-1.074	
	-0.673	Senboku-Momoyamadai Apt., Osaka	1982	-0.072	
	-0.618	Tama N.T. 15-2 Apt., HUDC	1983	-0.553	
	0.823	Tsurumaki-3, Free-Space, HUDC	1983	0.686	
	-0.160	Kengun Apt., CHS, Kumamoto	1984	-0.674	
	-0.050	CI Heitz Matida, CHS, Takenaka Co.	1984	-0.436	
	0.120	Hikarigaoka Apt., Free-Plan, HUDC	1985	0.112	
	-0.113	Eifuku-Cho Apt., CHS, Shimizu Co.	1985	-0.113	
	0.612	Terada-Cho Apt., CHS, Osaka	1986	0.703	
	0.869	Senri-Inokodani Apt., CHS, Osaka	1986	0.774	
	-0.845	Promenade Tama-Chuo, HUDC	1987	-0.685	
	0.260	Shin-Tokorozawa 1, HUDC	1988	0.327	
	0.028	Rune Koiwa, CHS, Haseko Co.	1988	-0.048	
	-0.432	Verde Akibadai, Corporative, HUDC	1990	-0.240	
	0.974	Utsugidai Apt., HUDC	1992	0.899	
	0.616	Nagamachi Apt., Ibaraki	1995	0.330	
	0.171	Makuhari Patios 6, Shimizu Co.	1995	0.306	
	1.220	Sanda Apt., Hyogo 100 years House	1997	1.367	
	0.493	Matsuyama Apt., Takenaka Co.	1997	0.596	
	0.255	Toka-Ichiba Apt., Flat-Beam, HUDC	1998	0.025	
	0.820	KSI Building, Original Plan, HUDC	1998	0.934	
	1.075	Matsubara Apt., Tsukuba Method	1998	1.245	
	0.983	Yoshida Apt., Osaka	1999	1.006	
	1.137	Tsurumi Apt., Renace System	1999	1.082	
-3 -2 -1 0 +1 +2 +3					-3 -2 -1 0 +1 +2 +3

Figure 2 Standardized Evaluation Scores of the Capacities of Skeletons operated by Specialists

Each evaluation of the capacities concerning four types of renovation had been assumed that the differences of evaluation tendency would have appeared conspicuously. On the contrary, there were little differences among them on the whole, especially between the case of an individual unit and of a whole building. However, some of the specialists evaluated each case differently.

2.4 Reliability of the Evaluation by Specialists

The results show that the correlation of the evaluation by the individual specialists was very high, and it was proved that the evaluations were operated effectively. And also the correlation of the average of the evaluations of each skeleton among the specialists who belong to the same attribute group defined at the beginning of this chapter was too high to find out the characteristic evaluation tendency of each attribute group

(See Table 2 and Figure 3). It is no exaggeration to say that the average of the evaluations of several specialists is enough to confide the scores. Therefore the average score of all evaluators' is adopted as a typical value of the capacity of a skeleton in following analyses.

Table 2 Correlation Coefficients among Specialist Groups

	A	B	C	D
A		0.947	0.938	0.956
B			0.965	0.946
C				0.956
D				

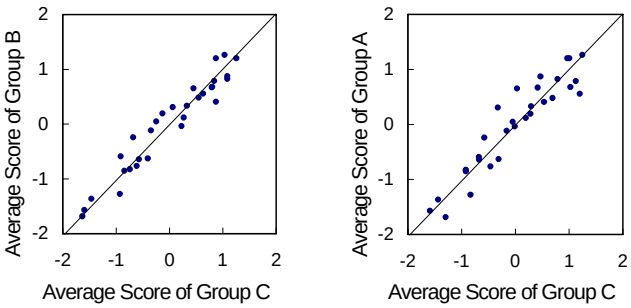
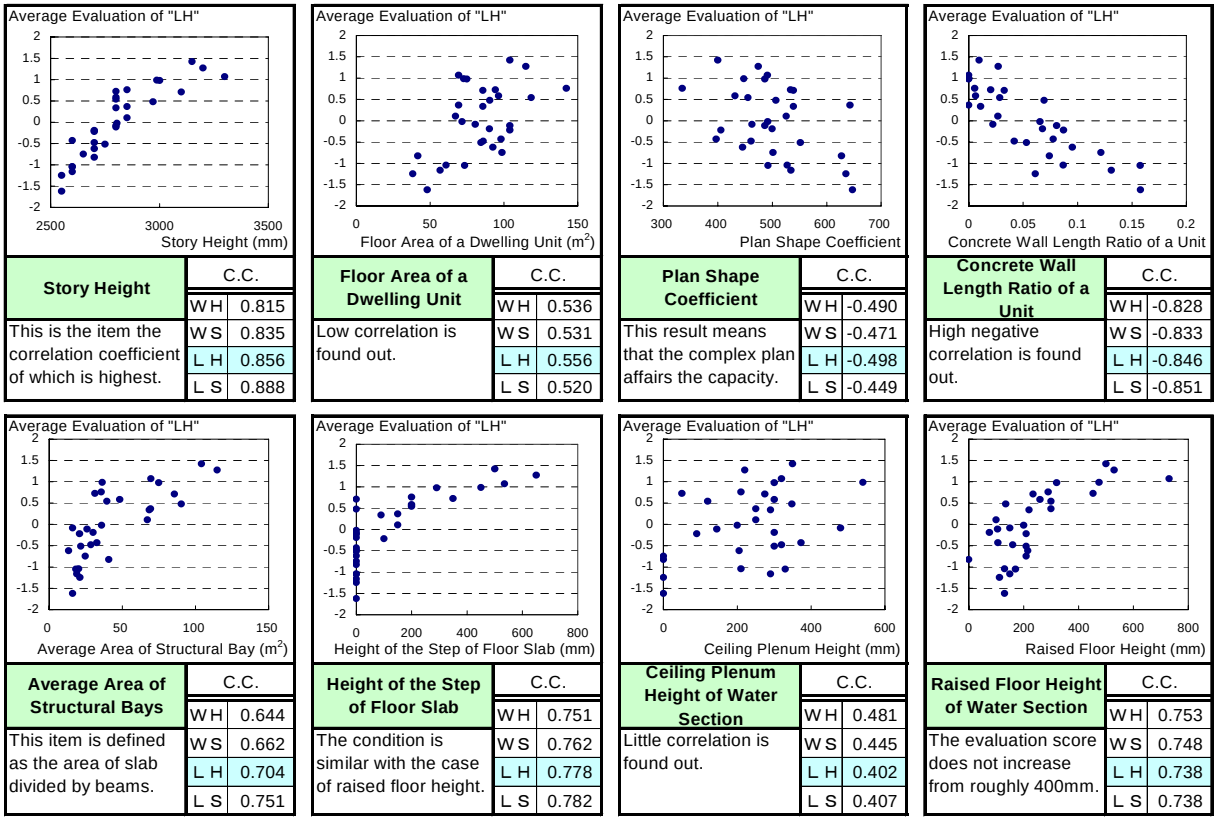


Figure 3 Examples of Conditions of Correlation among Specialist Groups

3. RELATIVITIES OF CHARACTERISTIC ITEMS TO THE CAPACITY OF SKELTONS

About fifty characteristic items of skeleton, which are assumed to have considerable influence on the "ease of renovation", were selected. Then, the items, which are impossible to read from database shown to specialists, were excluded. And these selected items were examined as which data we should have dealt with: quantitative data or qualitative data.

The relative relation of the values of each characteristic item of skeleton to the average evaluation scores of the capacity was considered, with scatter diagram in case of quantitative item, or with stratified histogram in case of qualitative item. Then, correlation coefficients between values of each characteristic item, and the average evaluation scores of the capacity were calculated. In addition, the correlation coefficients in case of quantitative item were obtained by operating quantification method Ⅰ. The examples of these results are shown in Figure 4 and Figure 5.



Story Height	C.C.	Floor Area of a Dwelling Unit	C.C.	Plan Shape Coefficient	C.C.	Concrete Wall Length Ratio of a Unit	C.C.
This is the item the correlation coefficient of which is highest.	W H 0.815 W S 0.835 L H 0.856 L S 0.888	Low correlation is found out.	W H 0.536 W S 0.531 L H 0.556 L S 0.520	This result means that the complex plan affairs the capacity.	W H -0.490 W S -0.471 L H -0.498 L S -0.449	High negative correlation is found out.	W H -0.828 W S -0.833 L H -0.846 L S -0.851
Average Area of Structural Bays	C.C.	**Height of the Step of Floor Slab**	C.C.	**Ceiling Plenum Height of Water Section**	C.C.	**Raised Floor Height of Water Section**	C.C.
This item is defined as the area of slab divided by beams.	W H 0.644 W S 0.662 L H 0.704 L S 0.751	The condition is similar with the case of raised floor height.	W H 0.751 W S 0.762 L H 0.778 L S 0.782	Little correlation is found out.	W H 0.481 W S 0.445 L H 0.402 L S 0.407	The evaluation score does not increase from roughly 400mm.	W H 0.753 W S 0.748 L H 0.738 L S 0.738

Figure 4 Examples of the Relativities (Quantitative Items)

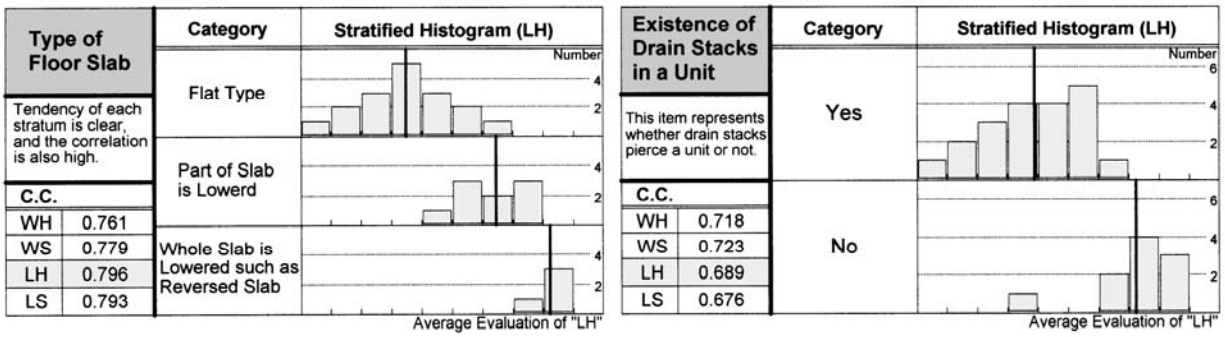


Figure 5 Examples of the Relativities (Qualitative Items)
*Bold lines on the histograms show the average on a stratum.

There were some items that have low correlation with the average evaluation of the capacity although it had been assumed to have had high correlation, such as the frontage width of a unit or the beam quantity in a unit. In case of the frontage width, one explanation for this result is that there were many wide-frontage samples among the common skeletons built in the 1960's to 70's, evaluation scores of which were relatively low.

These results lead to the conclusion that the items, which have significant correlation with the average evaluation of the capacity and have important means, were twenty-four shown in Figure 6. The story height, the concrete wall length ratio of a unit, the raised floor height of water section and the type of floor slab had especially high correlation with the average evaluation of the capacity among them. The story height is effective towards "ease of renovation", so that the correlation with the average evaluation of the capacity was positive; on the other hand, the concrete wall length ratio affects the "ease of renovation", so that the correlation was negative.

Characteristic Item of Skeletons	C.C. (WH)	C.C. (LH)	Absolute Value of Average on C.C.s of 4 cases
Quantitative Item			0.2 0.5 0.8
Story Height	+0.815	+0.856	
Floor Area of a Dwelling Unit	+0.536	+0.556	
Plan Shape Coefficient	-0.490	-0.498	
Concrete Wall Length Ratio of a Unit	-0.828	-0.846	
Concrete Wall Length Ratio of the Toilet Room	-0.699	-0.613	
Concrete Wall Length Ratio of the Bathroom	-0.813	-0.741	
Concrete Wall Length Ratio of Water Section	-0.752	-0.634	
Average Area of Structural Bays	+0.644	+0.704	
Area of Lowerd Floor Slab	+0.667	+0.706	
Height of the Step of Floor Slab	+0.751	+0.778	
Height of the Principal Beam	-0.412	-0.446	
Structural Rate of Exterior Walls of a Unit	-0.456	-0.469	
Ceiling Plenum Height of Habitable Room	+0.425	+0.422	
Raised Floor Height of Habitable Room	+0.445	+0.467	
Ceiling Plenum Height of Water Section	+0.481	+0.402	
Raised Floor Height of Water Section	+0.753	+0.738	
Rate of the Number of ELVs per Unit	+0.426	+0.461	
Qualitative Item			0.2 0.5 0.8
Type of Structure System	+0.640	+0.713	
Type of Floor Slab	+0.761	+0.796	
Type of Water Section Position	+0.447	+0.386	
Existence of Drain Stacks in a Unit	+0.718	+0.689	
Type of Drain Stack System	+0.623	+0.654	
Type of Principal Pipe Shaft	+0.430	+0.378	
Access System for a Unit	+0.319	+0.390	

Figure 6 Correlation Coefficients between Values of Characteristic Items and Average Evaluations Scores

4. EVALUATION FORMULAS OF THE CAPACITY OF SKELETONS

4.1 Weights of the Characteristic Items of Skeleton on the Evaluation of the Capacity

Having just considered the influences of the characteristic items on the average evaluation of the capacity, we investigate about their weights.

The weights are obtained by operating multiple regression analysis using the average evaluation as the criterion variable and the characteristic items as the dependant variables in this chapter. When the multiple regression analysis is operated, the dependant variables should have low correlation with each other. Therefore the "multi-variable correlation matrix" and the "correlation coefficient matrix" were studied. Table 3 is an example of the "correlation coefficient matrix".

Table 3 Example of the "Correlation Coefficient Matrix"

Characteristic Items of Skeletons	Story Height	Floor Area of a Dwelling Unit	Plan Shape Coefficient	Concrete Wall Length Ratio of a Unit	Height of the Step of Floor Slab	Height of the Principal Beam	Structural Rate of Exterior Walls	Raised Floor Height of Water Section
Story Height	1.000	0.304	-0.256	-0.720	0.771	-0.635	-0.626	0.772
Floor Area of a Dwelling Unit	0.304	1.000	-0.775	-0.300	0.294	0.101	0.190	0.296
Plan Shape Coefficient	-0.256	-0.256	1.000	0.263	-0.293	-0.231	-0.187	-0.286
Concrete Wall Length Ratio of a Unit	-0.720	-0.300	0.263	1.000	-0.628	0.371	0.453	-0.614
Concrete Wall Length Ratio of Water Section	-0.586	-0.248	0.262	0.656	-0.496	0.432	0.474	-0.511
Average Area of Structural Bays	0.823	0.190	-0.053	-0.562	0.612	-0.843	-0.749	0.497
Area of Lowered Floor Slab	0.763	0.287	-0.271	-0.511	0.909	-0.540	-0.536	0.780
Height of the Step of Floor Slab	0.771	0.294	-0.206	-0.628	1.000	-0.424	-0.468	0.905
Height of the Principal Beam	-0.635	0.101	-0.231	0.371	-0.424	1.000	0.797	-0.311
Structural Rate of Exterior Walls of a unit	-0.626	0.190	-0.187	0.453	-0.468	0.797	1.000	-0.362
Ceiling Plenum Height of Water Section	0.389	0.124	-0.426	-0.409	0.214	-0.133	-0.241	0.241
Raised Floor Height of Water Section	0.772	0.296	-0.286	-0.614	0.905	-0.311	-0.362	1.000
Rate of the Number of Elevators per Unit	0.462	0.380	-0.180	-0.425	0.494	-0.166	-0.064	0.400
					Absolute Value of Correlation Coefficient	under 0.5	over 0.5	over 0.7

The criteria to select some characteristic items were set up as follows, in order for the analysis to be operated effectively.

a. Combination of the selected characteristic items should reflect the property of the skeleton adequately.
b. Selected characteristic items should have low correlation with each other.
c. Evaluation formula obtained by this analysis should represent a more accurate evaluation score.

The correlations between each characteristic item were studied, and there were some couples of items of which the correlation showed high values. For example, the height of the step of floor slab and the area of lowered floor slab had high correlation. In case of this example, the reason for the high correlation was assumed to be that the inclination of the branch drain is restricted. In such case, one item was adopted and another one was omitted. This analysis brought nine characteristic items as dependant variables. However, the multiple regression analysis using this combination as dependant variables was deficient in statistical confidence, as the number of dependant variable was too many. Therefore, another analysis, the items as dependant variable of which are less, was also operated, and both results were compared. In this paper, we use the term "M9" as the former, and the term "M5" as the latter. The average evaluation concerning "LS" was used as a criterion variable in both analyses, since there were no significant differences among the results in four cases. It is for this reason that the average evaluation scores operated by specialists had little differences among them. The capacities of skeletons, which were taken up on these analyses, can be interpreted as the capacity comprehending the four cases of capacity; that is to say, the capacity for the water section renovation and floor plan alteration without assuming a pragmatic process. This is a rather abstract notion, but should be regarded as one of the indexes concerning the capacity of skeletons.

Outlines and results are shown on the next page. The results show that five characteristic items on "M9" did not reach the significant level, however, the result of "M9" was not very different from the result of "M5". The standardized partial regression coefficient of the story height was relatively lower than the case of correlation coefficient. The main reason is that the correlation of the story height with the other characteristic items was high, since the high-story project tends to be ambitious towards the "ease of renovation".

M9

Multiple Correlation Coefficient 0.980
Coefficient of Determination 0.960
Squared Multiple Coeeficient adjusted for the Degrees of Fredom 0.942

Characteristic items of skeletons, which were selected as dependant variable, reflect the property of skeletons well, however, the statistical confidence is rather low.

Characteristic Items as Dependant Variables	S.P.R.C.	Absolute Value of Standardized Partial Regression Coefficient
Story Height	+0.287	
Floor Area of a Dwelling Unit	+0.252	
Plan Shape Coefficient	-0.051	
Concrete Wall Length Ratio of a Unit	-0.371	
Average Area of Stractural Bays	+0.096	
Height of the Step of Floor Slab	+0.107	
Height of the Principal Beam	-0.018	
Stractural Rate of Exterior Walls	-0.085	
Existence of Drain Stacks in a Unit	+0.033	

0.1 0.2 0.3

M5

Multiple Correlation Coefficient 0.979
Coefficient of Determination 0.958
Squared Multiple Coeeficient adjusted for the Degrees of Fredom 0.949

Aithough the statistical confidence is high, the selected items do not reflect the property of skeletons well.

Characteristic Items as Dependant Variables	S.P.R.C.	Absolute Value of Standardized Partial Regression Coefficient
Story Height	+0.340	
Floor Area of a Dwelling Unit	+0.312	
Concrete Wall Length Ratio of a Unit	-0.367	
Height of the Step of Floor Slab	+0.134	
Stractural Rate of Exterior Walls	-0.137	

0.1 0.2 0.3 0.4

Figure 7 Outlines and Results of the Multiple Regression Analyses
*Both graphs are illustrated, as the lines of Story Height are equal in length.
**The items, which do not reach the significant level (α=0.05), are colored on above graph.

Two types of evaluation formula of the capacity of skeletons were obtained using the results of the multiple regression analyses as (1) and (2). The scores of the thirty projects, which were the objects on the questionnaire mentioned in Chapter 2, were calculated using these formulas. The evaluation scores calculated with each formula and the average evaluation scores operated by specialists were made into the scatter diagrams. Figure 8 is the scatter diagram. Also the correlation coefficients (multiple correlation coefficient) were obtained to discuss the effectiveness of the formulas. The correlation between the evaluation score of formula and that of specialists was very high, and their effectiveness was proved.

Evaluation Formula obtained by operating "M9"

$$C_{M9} = +1.214\times a +0.009\times b -0.563\times 10^{-2}\times c -0.316\times 10^{-2}\times d +0.277\times 10^{-2}\times e +0.464\times f -0.050\times g -0.357\times h +0.057\times A -3.544 \quad -(1)$$

Evaluation Formula obtained by operating "M5"

$$C_{M5} = +1.441\times a +0.011\times b -0.312\times 10^{-2}\times d +0.579\times f -0.575\times h -4.382 \quad -(2)$$

Provided, a: Story Height,
b: Floor Area of a Dwelling Unit,
c: Plan Shape Coefficient,
d: Concrete Wall Length Ratio of a Unit,
e: Average Area of Structural Bays,
f: Height of the step of Floor Slab,
g: Height of the Principal Ream,
h: Structural Rate of Exterior Walls of a Unit,
A (: Existence of Drain Stacks in a Unit) = (yes, no) = (1, 2)

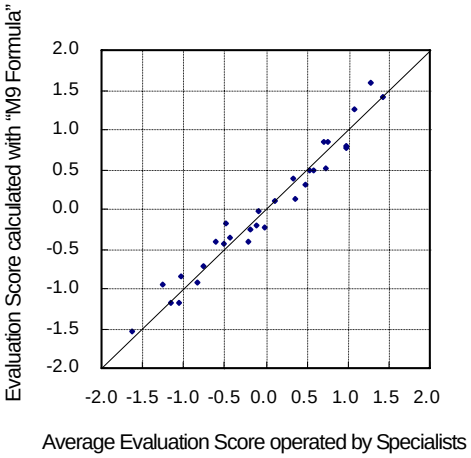


Figure 8 Correlation between Evaluation with Formula and Evaluation by Specialists

4.2 Evaluation of a New Project using the Evaluation Formulas

The project, Flexsus House 22, which was built in March 2000, was evaluated using the evaluation formulas. The outline of the project and the results of the evaluations are shown on the next page. Flexsus House 22 is an ambitious project towards "ease of renovation"; high evaluation score had been expected. And the evaluation scores of "M9 formula" and "M5 formula" were both extremely high, 1.494 and 1.526. They are higher than the scores of any other projects, which were shown in Chapter 2. And the scores evaluated by both formulas corresponded to each other very closely. These results also show the effectiveness of the evaluation formulas.

Flexsus House 22	
Score calculated with Evaluation Formura	
"M9 Formula"	**1.494**
"M5 Formula"	**1.526**
Data of Charactristic Items	
Story Height (m)	3.350
Floor Area of a Dwelling Unit (㎡)	98.18
Plan Shape Coefficient	0.489
Concrete Wall Rength Ratio of a Unit	0.104
Average Area of Structural Bays (㎡)	83.52
Height of the Step of Floor Slab (m)	0.250
Height of the Principal Beam (m)	0.000
Structural Rate of Exterior Walls of a Unit	0.195
Existence of Drain Stacks in a Unit	No

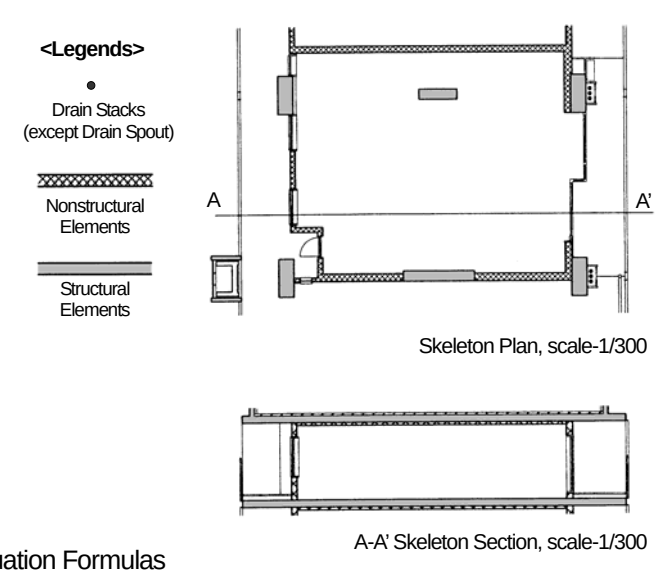


Figure 9 Evaluation of a New Project using Evaluation Formulas

5. CONCLUSION

This research investigated how the characteristic items of the skeleton influence its capacity. The results are as follows:

a) The evaluation of the capacity of thirty representing skeletons operated by specialists was revealed. And it was proved that the average evaluation has high confidence. These are efficient to seek the ideal way of carrying out the renovation or development of the multiunit residential building stocks.

b) The relativity condition of the characteristic items with the evaluation of the capacity was revealed with scatter diagrams or stratified histograms. And also the quantitative influence of the characteristic items on the capacity of skeletons was revealed by calculating the correlation coefficient. It is an outcome that the quantitative influence was found out.

c) Operating multiple regression analyses, the weight of each characteristic item on the capacity of skeletons was found out. Furthermore, two types of evaluation formula were proposed using the results of the analyses. And the effectiveness of them was proved.

Considering the results mentioned above, the objectives shown in the early part of the paper were almost accomplished. However, it should be noted that this research did not more than analyze the evaluation of the capacity of skeletons operated by specialists. To grasp the capacity of the skeleton more accurately, further researches from many other viewpoints are necessary.

This research was conducted as part of the General Technology Development Project of the Ministry of Construction, “Development of Technology for Building and Recycling More Investment-Efficient and Longer-Lasting Urban Collective Housing”.

Lastly, we would like to thank all the persons, who gave us the generous cooperation. Our special thanks are due to the evaluators for their valuable works.