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A Study on Reconstruction of Condominium in the Metropolitan Area using Real Estate Data

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Abstract

In Japan, there is concern about the impact of the growing stock of older condominiums on the buildings themselves and the surrounding environment, and immediate action is needed. While in other countries, repair, elimination, and retirement of aged condominiums are the mainstream methods, in Japan, reconstruction is sometimes used. This study proposes a new decision criterion using discriminant analysis to address the problem of the difficulty and long time required to build consensus for rebuilding older condominiums. Discriminant analysis used building attributes and other variables to differentiate and predict condominium properties that have been successfully reconstructed from those that were not. Simple and clear answers will enable non-expert judgment and aid in consensus building. Multiple discriminant formulas were obtained and compared for Tokyo and neighbouring cities, as well as by subdividing and adding up these subdivisions. At the same time, coefficients of variables were changed or added to increase the reliability of the equations. As a result, a new modified discriminant equation with a high degree of reliability that advances previous studies was obtained. In addition, through the process of creating the formula, we discovered a new option for determining whether or not to rebuild based on whether or not there is an excess floor-area ratio, which is generally considered to be the solution in Japan, by increasing the site area.

Keywords: Condominium, reconstruction, metropolitan area, discriminant analysis

1.0 INTRODUCTION

1.1 Significance of the Study

This study expands on the research methodology and discussion in Hanazato (2017) (hereafter: previous paper) regarding the proposal of a new indicator that contributes to consensus building for condominium reconstruction. In this study, the amount of data used in the process of creating the model equation was expanded. At the same time, the sample range was expanded. Previous papers were limited to the 23 wards of Tokyo. In this study, sample data from Saitama, Kanagawa, Chiba, and Ibaraki prefectures surrounding Tokyo were added. The reason for this re-examination is that the model equation changes depending on the range, amount, and timing of the sample selection. There is also an objective to expand the range to derive a more reliable equation. In Japan, there are differences in condominium building attributes between Tokyo and other prefectures. It is of great significance to develop model equations that include these differences, either separately or together, and to compare and verify them. Following previous studies, discriminant analysis, a type of multivariate analysis, was used as the research method. The reason and justifications for adopting discriminant analysis need not be based on the ease of understanding and interpretation. But rather, on the statistical suitability for the type of data and measurement scale, suitability to test hypothesis, answer research questions and achieve the research objectives. For instance, as discriminant analysis is often used to test for differences between two or more groups based on identified variables, it may be more meaningful to say that the reason or justification for adopting discriminant analysis lies on the fact that the study focuses on testing and analysing differences in re-constructability between two-groups of condominium (reconstructed and unreconstructed) based on identified attribute variables. In addition, the study hopes to identify the most important discriminant variables that explain or predict the re-constructability of the condominiums. Another justification could be that the dependent grouping variable (y-variable) is measured in nominal scale (represented in discrete form, 1 or 0). The uniqueness of this study lies in the fact that it proposes a new method of rebuilding condominiums by expanding the site area, as opposed to the conventional Japanese method of rebuilding condominiums by increasing the floor-area ratio, which relies on the profit from the sale of surplus area gained by the rehabilitated condominiums. This is a new finding. This will contribute to providing a more effective alternative to the difficult-to-consensus resolution for rebuilding.

1.2 Background of the study

In recent years, the number of older condominiums has been increasing in Japan. There is no clear definition of "older condominiums" based on age or other factors. It refers to condominiums that have been completed for a considerable period of time. In the industry, the term generally refers to condominiums that are 40 years old. The increase in the number of older condominiums means that the industry is under pressure to respond to the aging of buildings. There are several possible solutions, including repair, reconstruction, and retirement based on the law. As of April 2021, there were 263 condominiums in Japan that had already been reconstructed. As of April 2021, there were 263 condominiums in Japan that had already been reconstructed, which is only about 26,000 units as of the end of 2018. This represents only 0.4% of the total condominium stock in Japan.

In Japan, the approval of at least four-fifths of the condominium owners is required to rebuild a condominium. This is called a reconstruction resolution. The decision to rebuild is a difficult one. For example, it is difficult to determine whether there are future benefits for the unit owners. In addition, according to the Ministry of Land, Infrastructure, Transport and Tourism's 2016 survey on condominium revitalization methods and consensus building, the amount borne by compartmentalized owners at the time of reconstruction was approximately 3.4 million yen per unit in 1996, but this amount is increasing to approximately 11 million yen in 2016. As a solution to the economic problem, it is believed that a promising method is to utilize the reserved floor space (expected income) expected to be available in the reconstructed condominiums after reconstruction to cover the costs of reconstruction. However, it is questionable whether this method is equally effective for all properties under all conditions. For example, there are many cases where this method cannot be used for older condominiums because of differences in location between urban centres and rural areas, cases where it is difficult to achieve due to legal restrictions, and cases where the floor-area ratio becomes non-conforming to existing conditions due to urban planning revisions after construction is completed. In particular, this economic uncertainty is the reason why it takes a very long period of time to reach a consensus on rebuilding. It is estimated that it takes a minimum of 5 years and a maximum of 28 years, and an average of 8 to 10 years from the start of discussions on rebuilding to reconstruction.

These figures are based on examples of reconstructed properties. Thus, looking at past properties, much time and expense has been wasted in reaching a resolution to rebuild. Examining the individual specific problems of each property and carefully repeating repairs to keep the property inhabited for a long time is a highly valuable act in terms of creating a sustainable society. However, the study is aimed to be initiated at an early stage to prepare for the reconstruction or retirement of the property that will eventually occur. This study presents an evaluation method that adds economic characteristics to building attributes based on real estate data without specifics. This evaluation method can be used as a reference for decision making at the stage before entering the process of consensus building for rebuilding, or at the preparatory stage at the beginning of the rebuilding process, which will lead to a reduction in the time required to reach a resolution as a general solution.

Based on the above, the following will be presented: Based on a case study of a rebuilding property that includes economic items, it is possible to provide a new decision-making tool that contributes to the rebuilding of condominiums by presenting a highly reliable formula that clarifies the items necessary for rebuilding. Since this formula requires clarity, versatility, and reliability, discriminant analysis is used in this study.

1.3 International Positioning of Condominium Reconstruction

In Japan, discussions on rebuilding condominiums due to high aging are widely recognized as one of the methods of condominium revitalization. On the other hand, internationally, it is not common in some areas at this time. According to an international comparison of condominium unit ownership legislation by Kamano (2022), when looking at Western European countries, the German Civil Code, the Law on Joint Relationships and Common Dwelling Places, the French Law on Laws Determining the Status of Building Unit Ownership and Management Regulations, and the British Law on Joint Ownership and Property Leasehold Reform, all have in Germany, reconstruction is not a common practice among unit owners. In Germany, reconstruction is subject to the agreement of all unit owners, but there have been few cases where reconstruction has been discussed in the first place. In France, several cases of expropriation by public expropriation have been confirmed, but there have been no discussions by the unit owners or the management association, which is the main management body. In the United States, under the Uniform Condominium Code and the Uniform Community Property Ownership Act, it is reported that rehabilitation and reconstruction of poorly managed condominiums and damaged buildings that have lost their market value are being promoted, but there have been almost no cases of resolution by aging or majority agreement alone.

On the other hand, looking at Asia, there exist laws similar to Japan's condominium unit ownership laws, where a resolution for reconstruction by agreement of a certain number of condominium unit owners is legally established. In South Korea, in particular, the Urban Housing Act requires, as in Japan, the agreement of four-fifths or more of the unit owners to rebuild a building. However, in the case of apartment complexes, three-fourths or more of the owners must agree to the reconstruction of each building, making it more difficult than in Japan to reach a consensus. In China, the three-fourths agreement is lighter than in Japan and Korea. However, the direction of the reconstruction resolution differs significantly from that promoted by private management companies and management associations in Japan and Korea, because the land and building are divided as one, which is a characteristic of property rights law, and only the right of possession is recognized as to ownership. On the other hand, under Taiwanese law, although the land and building are traded independently, a resolution for rebuilding must be passed by unanimous consent, which promotes stability and active trading in the second-hand market but is not suitable for building rehabilitation. In Singapore, the percentage of agreement required for a resolution varies depending on the age of the building, with 90% of agreement required for reconstruction if the building is less than 10 years old, and 80% for reconstruction if the building is 10 years old or older. The ownership structure in Singapore is similar to that of Japan's public corporations, and there have been few cases of reconstruction, particularly due to the large economic burden, such as relocation costs, from planning for rebuilding condominiums. As in the U.S. and Australia, the main method is to sell the site in one lump sum.

Regarding the act of rebuilding, policies differ depending on the economic background and principles of each country, the frequency and scale of disasters, and the building structure. In Asia, there are laws and regulations similar to those in Japan, but there are few actual examples. In fact, most Western countries do not anticipate rebuilding due to deterioration. In fact, most of these countries sell the entire property at once. In Japan, the problem of aging is seen as one between the building and the owner, and research is underway to identify this as a major factor preventing consensus building for rebuilding. It is hoped that the findings of this study will be used in the future when attempting to rehabilitate buildings that require the agreement of their owners to address issues beyond the scope of repair and renovation, such as advanced land use planning and aging populations in urban centres.

1.4 Literature Review

In a previous paper, Hanazato (2017) refers to the prediction of rebuilding from various previous studies, describes the uniqueness and importance of extracting objective data, and performs a discriminant analysis after selecting covariates. The study focuses on the increase or decrease in the floor-area ratio that will be available after the reconstruction from the previous value. The results showed that properties with a large increase in floor-area ratio indicated reconstruction, while properties with a small increase indicated repair or renovation. In summary, the study concluded that the likelihood of reconstruction increases with; 1) the impact of an increase or decrease in floor-area ratio, 2) the size of the building, 3) the size of the underlying land (referring to the increase or decrease in floor-area ratio, the previous total floor area, and the previous site area), and 4) the economic characteristics of the property, such as its high assessed value (referring to the assessed value of the land property per unit). There are few direct studies on this type of reconstruction of condominiums, and the studies are particularly concentrated in Japan. According to a discussion on aging of condominiums by Ohtani and Hanazato (2020), two things are going on in condominiums: the aging of the building and the aging of the owner. It states that the need for a certain number of people to approve the renewal of the building is a hardship unique to condominiums. In confirming the physical aging of a building, one can consider measuring the aging and durability of the building materials used.

According to a study by Ohnuma et al. (2009), which focused on condominium reconstruction and capitalization rates, the authors analysed how the likelihood of reconstruction varies with land prices and construction costs, which are affected by economic factors. In this study, Ohnuma et al. (2009) calculated the rate of return for each year based on the fluctuating values of land prices and construction costs from 1980 to 2007, and analysed land prices, construction costs, surplus area, and the rate of change in these factors. The conclusion of the study is that it is basically difficult to establish a project that assumes a 100% rate of return and no burden on residents. The rebuilding project is more likely to be realized when; 1) the property faces a road with high road value, 2) the site area is small, there is excess floor space, and the dwelling unit area is small. The floor-area ratio is calculated based on the site area and the total floor area, and the smaller the site and the smaller the total floor area, the smaller the floor-area ratio will be, and as a result, the easier it will be to secure surplus floor area after reconstruction.

In a study by Ohki (2014), in describing the relationship between transaction prices and rebuilding, contract prices were compared with and without surplus floor-area ratio, and found that from an economic perspective, condominiums without surplus floor-area ratio are more likely to be very difficult to rebuild. The study also states that appropriate disclosure of information will increase the appropriateness of transaction prices, resulting in an increase in the stock of quality condominiums and progress in the rehabilitation process itself. The report states that it is important to take action on an individual property basis, such as expanding the contents of the Important Matters Explanation. It can be said that widely disclosing and providing information on these matters is also an act of informing owners of the current status of their buildings and can be said to provide a push for resolution. Whether the condominium is to be sold as a used condominium or to be rebuilt or retired, an accurate understanding of the current status of the property and a common understanding among condominium unit owners is necessary to form the basis for making a decision.

Both studies discuss the importance of excess floor-area ratio, reduction ratio, and reserved floor space, and state that the most important point for the establishment of a condominium reconstruction project is the creation of economic benefits. However, there is a strong possibility that environmental degradation caused by an excessive increase in floor-area ratio and disadvantages caused by larger and taller buildings will surface in the future. Whether increasing the floor-area ratio is the only solution to this problem must also be examined in this paper.

Previous studies have shown that one of the factors that make the decision to rebuild condominiums difficult is economic issues and have focused on the rate of return as a solution. The study states that one of the factors that make the decision to rebuild condominiums difficult is economic issues, and the rate of return is the amount of floor space that can be increased when the condominium is reconstructed. This means that the floor-area ratio should be increased under the assumption that the site remains the same. However, increasing the floor-area ratio requires meeting legal requirements and regulations, and depending on the site, the floor-area ratio may rather be reduced. In addition, a policy of increasing the floor-area ratio in a blanket manner is likely to have a negative impact on the surrounding environment.

There are few existing studies abroad due to the paucity of condominium reconstruction cases; Webb and Webber (2017) described long-term planning for condominiums through an interview survey. The study warns that revitalization of city blocks requires a change in stakeholder perceptions. The study stated that the ownership of subdivided city blocks (anti-commons) is an obstacle and hinders activities for long-term collective revitalization. These anti-commons obstacle is partly applicable to this study because the form of land ownership by condominium unit owners in Japan is proportionate to their exclusive area. Since a long-term perspective from dissolution to reconfiguration is considered, it is undeniable that extreme subdivisions are a concern in terms of consensus building. In addition, due to the aging of unit owners, etc., the anti-commons increase the possibility of falling into ownerlessness, and in this respect, too, it can be an obstacle to consensus building. Munneke and Womack (2015) examined partial renovation and retirement of older condominiums. It is similar to this study in that it refers to prior activities as a determinant of the resolution at the general meeting of the management association. It stated that price fluctuations due to large-scale repair work are highly correlated with land prices. At the same time, depending on the nature of the large-scale repair work, it may also be a cause of lower prices in existing transactions. When this verification is applied to reconstruction, it can be hypothesized that some activities leading up to the resolution of reconstruction may have the potential to affect the price of rehabilitated condominiums. Although refurbishment is not the topic of this study, the possibility of a favourable impact on prices cannot be ruled out in terms of activities during the preparation period and in terms of aiming to support the reduction of the required timeframe. The study by Yamazaki and Sadayuki (2017) has similarities to this study as an examination of the point where the decision-making of condominium unit owners hinders redevelopment. The study stated that the large number of units in any given condominium has a negative impact on the price in terms of rent. This suggests that building size may be one of the factors that negatively affect the economic issues in deciding to rebuild, for example. This study also uses building attributes as variables and describes the differences due to size, especially the impact of lot size.

1.5 Objective of the Study

This study uses discriminant analysis, a type of multivariate analysis. A model equation was created by adding "properties that have been reconstructed (hereafter referred to as "reconstructed properties")" and "properties that have not been reconstructed (hereafter referred to as "unreconstructed properties")" as objective variables, and building attributes and economic items as explanatory variables, in order to determine which group a given property is closer to and to provide decision-making information that may help in making a reconstruction decision. The purpose of this project is to provide a decision-making tool that can help in the decision to rebuild. At the same time, new possibilities for condominium reconstruction based on the findings obtained in the process of validating the equation will be considered.

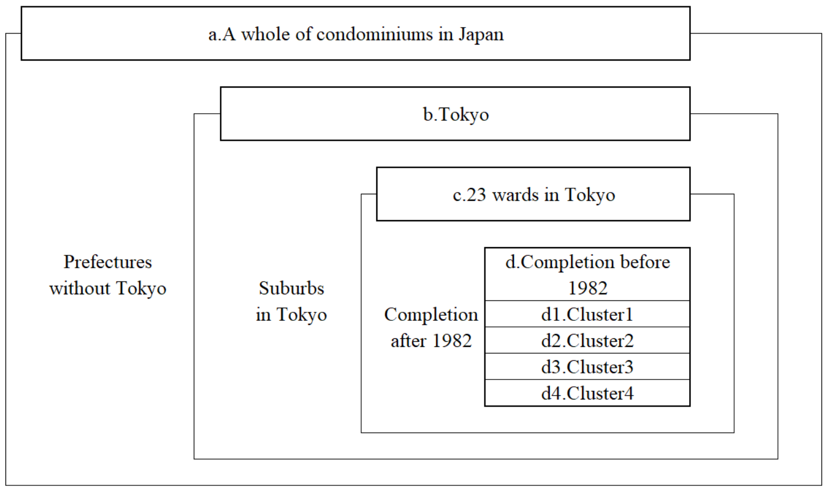

Figure 1 Classification

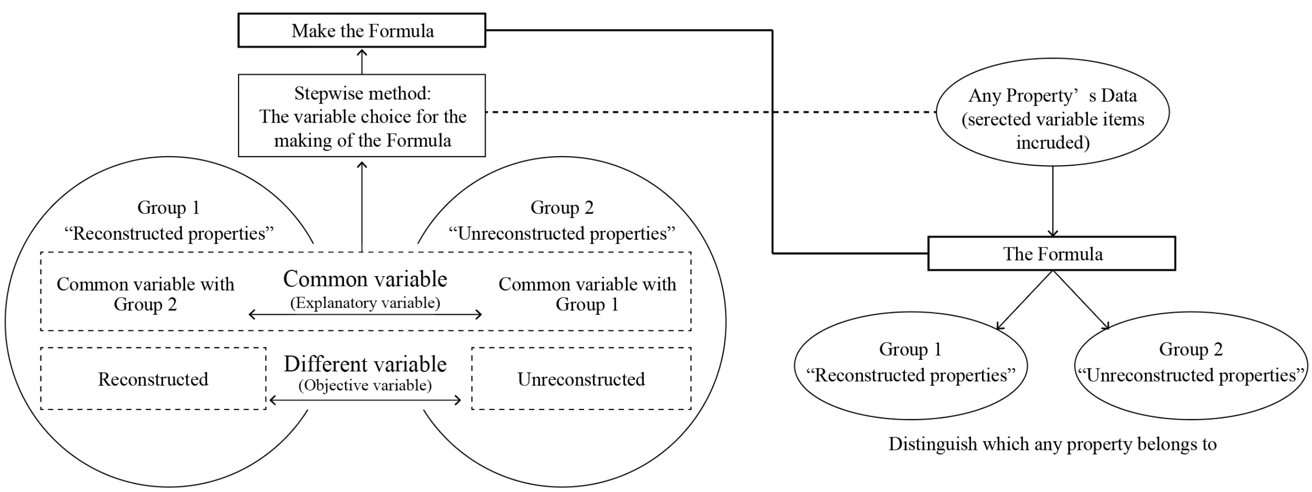

Figure 2 Schema of discriminant analysis

1.6 Research Methodology and Data

The data comprising the two groups were condominiums existing in Tokyo and nearby cities (Saitama, Chiba, Kanagawa, and Ibaraki prefectures). These were divided into two groups: reconstructed properties and unreconstructed properties. Reconstructed properties were selected based on data posted on the website of the Condominium Revitalization Council of Japan (Tokyo n=57, suburban cities n=21). Unreconstructed properties were selected as those older than 1982, when the Building Standard Law, the main building code in Japan, was revised regarding earthquake-resistant structures. In Japan, properties older than 1982 are treated as a special category of old earthquake-resistant properties. The selection criteria were chosen because they are close to 40 years old, which is the general age of older condominiums. Since many properties meet this selection criterion, 15% of these properties were selected using the random function (RAND) in Excel (Tokyo n=291, suburban cities n=36). This was obtained after several trials and is the rate that ensures the lowest number in the population n. Unreconstructed properties were checked against the property names listed in the Condominium Revitalization Council and confirmed that they had not been reconstructed as there were no duplicates.

Discriminant analysis was calculated by MAC Multivariate Analysis ver. 3 from Esmi. At the same time, a JMP trial was conducted using the same data. Variable selection using the stepwise method was based on the variable increase/decrease method, and variables were selected by inserting and removing variables based on the 2in2out principle. Based on Kawakami (1986), the distribution of variables was compared between real and log-corrected variables, and a normal distribution was assumed based on the judgment that they were similar. This method has the potential to produce different solutions depending on the population, population group, sample characteristics, sample range, and other factors. In this study, the formula was varied by dividing and combining various ranges, including Tokyo, Tokyo subdivided by cluster analysis, suburban cities, and the Tokyo metropolitan area, which is the sum of Tokyo and suburban cities.

In this paper, the research methods of the previous papers were critically inherited, changed or added the number of data, population, covariates, and range of coverage, and compared and discussed the results with the previous paper. Figure 3 shows the differences between the previous paper and this paper, and Table 1 shows the 12 covariates and the basis for their calculation referenced previous paper. All covariates obtained here are limited to those objectively available.

The study is conducted using the following methodology;

(1) The sample size is expanded from n=132 to 291 for Tokyo and 36 for suburban cities for properties that have not been reconstructed. The sample range was expanded by adding suburban cities to Tokyo.

(2) Discriminant analysis was conducted for Tokyo after variable selection using the stepwise method. Subsequently, Tokyo was subdivided by cluster analysis, and only suburban cities were added together to form the Tokyo metropolitan area, and then a discriminant analysis was conducted again.

(3) To the 12 covariates, five additional covariates that represent the environment surrounding the building were attempted.

(4) For the coefficient portion that assumed the floor-area ratio after reconstruction, the mean value, median value was substituted, and publicly indicated value, which are similar to the sample, and observe changes in these values as the reliability of the equation improves.

(5) Using the most reliable discriminant equation obtained from (1) to (4), discrimination using new property data picked up at random was performed, which is different from the time when the equation was created. At the same time, calculation of specific ideal values for these results was performed by changing variables and discuss the possibility of new reconstruction based on the findings obtained.

For the coefficient portion, the previous paper uses 1.282 as the coefficient for assuming the post-reconstruction floor-area ratio of un-reconstructed properties (i.e., by multiplying the previously used floor-area ratio by a coefficient, the post-reconstruction floor-area ratio is assumed), but this coefficient has no solid basis. Based on previous research (coefficient of 1.282) to determine the impact of changes in variables on the formula was used, and the coefficients (mean and median) were changed to those derived from the sample picked up this time and verified the results. In addition, two types of modified discriminant formulas with higher reliability are created using proxy coefficients based on the ratio of floor-area ratio in use before and after the 2010s, as shown in the reconstruction case study by the Ministry of Land, Infrastructure, Transport and Tourism.

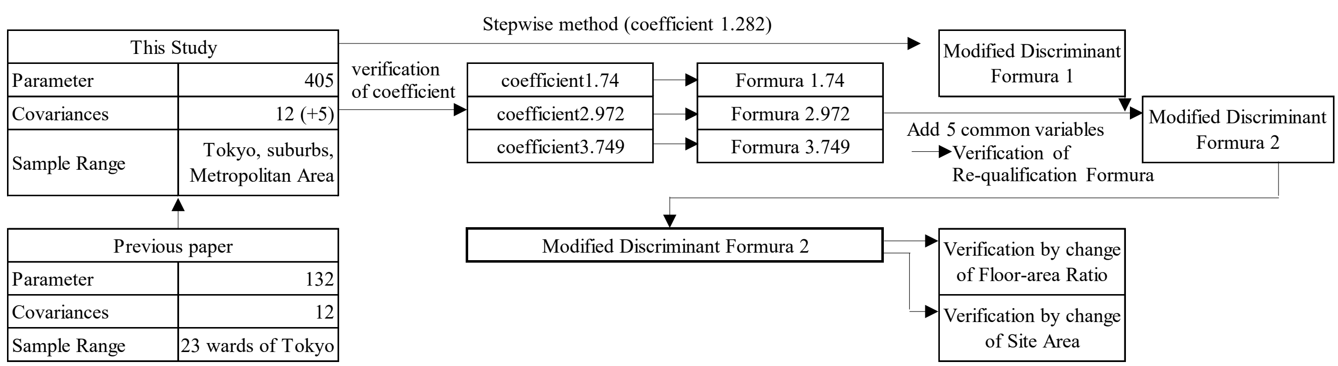

Figure 3 Structure of this study

■2.0 RESULTS OF DISCRIMINANT ANALYSIS OF CONDOMINIUM RECONSTRUCTION IN TOKYO, SUBURBS AND METRO-POLITAN AREA

2.1 Selection of variables in Tokyo

Variable selection was conducted for the explanatory variables in Tokyo using the stepwise method of variable increase/decrease. The five covariates listed in Table 3 were selected: "Increase/decrease of floor-area ratio," "Former floor-area ratio," "Former site area," "Architectural area/dwelling units," and "Age of a building at rebuilding". The variables " Increase/decrease of floor-area ratio" and " Former site area" were similar to those in the previous paper. The fact that "Increase/decrease of floor-area ratio" was selected indicates the rate of return that is considered important for rebuilding. In addition, the age of the building at the time of reconstruction, which was selected this time, indicates aging, but was not selected in the previous paper, and the selection of this variable increased the certainty of the background.

Table 1 Calculation Method of 12 Common Variables Referenced Previous Paper (Explanatory Variables)

Covariances	category of Covariances	23 Wards of Tokyo (A)								Suburbs (B)				Metropolitan Area (A+B)			
		total		reconstruc-ted	unreconstructed					total		reconstruc-ted	un-reconstruc-ted	total		reconstruc-ted	un-reconstruc-ted
					total	Cluster1	Cluster2	Cluster3	Cluster4								
		n=348		n=57	n=291	n=147	n=52	n=37	n=55	n=38		n=21	n=17	n=386		n=78	n=308
		ave.	SD.	ave.	ave.	ave.	ave.	ave.	ave.	ave.	SD.	ave.	ave.	ave.	SD.	ave.	ave.
Former site area (㎡)	Structure	1560.36	4163.09	5093.30	868.34	719.32	680.74	1626.18	934.18	3564.28	3528.50	4825.83	2005.89	2562.32	3845.80	4959.57	1437.12
Former architectural area (㎡)	Structure	3246.64	3623.19	5887.49	2729.37	2219.76	2157.21	4140.00	3683.37	4085.97	2572.04	4296.29	3826.17	3666.31	3097.62	5091.89	3277.77
Former floor area ratio (%)	Land use	386.98%	239.43%	247.57%	414.29%	415.12%	438.70%	321.58%	451.35%	232.50%	219.88%	143.50%	342.45%	309.74%	229.66%	195.54%	378.37%
Legal floor area ratio (%)	Land use	363.22%	154.89%	363.16%	363.23%	337.76%	384.62%	318.92%	440.91%	270.00%	109.14%	271.43%	268.24%	316.61%	132.02%	317.30%	315.74%
Floor area ratio after rebuilding (%)	Land use	475.00%	220.25%	522.69%	465.66%	433.00%	493.08%	408.85%	565.25%	362.29%	266.87%	300.09%	439.14%	418.65%	243.56%	411.39%	452.40%
Increase or decrease of floor area ratio(%)	Land use	88.02%	220.56%	275.11%	51.38%	17.88%	54.38%	87.27%	113.89%	129.77%	80.69%	156.59%	96.63%	108.90%	150.63%	215.85%	74.01%
Former total number of dwelling units	Structure	53.94	65.33	97.18	45.47	37.33	39.65	62.92	60.98	81.97	91.12	72.90	93.18	67.96	78.23	85.04	69.33
Architectural area / dwelling units	Scale of each dwellings	65.00	29.14	79.13	62.24	60.00	55.70	67.04	71.15	65.45	33.50	69.78	60.09	65.23	31.32	74.46	61.17
Site area / dwelling units	Scale of each dwellings	25.84	26.26	45.61	21.97	23.02	17.94	26.43	19.94	48.46	37.04	63.90	29.39	37.15	31.65	54.76	25.68
peripheral land price	real estate	130.69	192.38	135.67	129.72	115.54	60.39	40.70	293.03	30.57	37.81	38.06	21.32	80.63	115.10	86.87	75.52
Land price of each dwelling units	real estate	2899.44	5027.78	5340.41	2421.32	1939.07	1041.16	1079.40	5917.86	1259.51	1256.20	1806.83	583.4	2079.48	3141.99	3573.62	1502.36
Age of a building at rebuilding	passed years	42.12	6.95	47.91	40.99	41.63	39.88	39.24	41.53	40.63	9.09	38.00	43.88	41.38	8.02	42.96	42.44

Table 2 Outline of 12 Common Variables

Covariances (12)	**the basis for calculating**
Former site area (㎡)	Acreage from certified copy of register on Oct, 2021
Former architectural area (㎡)	Every architectural area from certified copy of register on Oct, 2021
Former floor-area ratio (%)	Former site area / Former architectural area
Legal floor-area ratio (%)	From website of every local governments at 31, Aug, 2021
Floor-area ratio after rebuilding (%)	Former floor-area ratio * 1.282
Increase or decrease of floor-area ratio (%)	Floor-area ratio after rebuilding - Former floor-area ratio
Former total number of dwelling units	total number of dwelling units registered in certified copy of register in Oct, 2021
Architectural area / dwelling units	Former architectural area / Former total number of dwelling units
Site area / dwelling units	Former site area / Former total number of dwelling units
peripheral land price	From website of Tochi.com and Tochidai DATA at 31, Aug, 2021
Land price of each dwelling units	Peripheral land price * ancient site area / Former total number of dwelling units
Age of a building at rebuilding	2021 - year of completion

Table 3 Stepwise Method Results of Tokyo

Covariances	discriminal coefficient	standard dc.	F value	P value	decision
Increase or decrease of floor-area ratio (%)	-2.524	0.413	140.77	2×0.1^{27}	**
Former floor-area ratio (%)	1.039	-0.118	81.93	0.1^{17}	**
Former site area (㎡)	-0.0002	-0.118	26.48	4.5×0.1^{7}	**
Architectural area / dwelling units	-0.033	0.160	20.26	9×0.1^{6}	**
Age of a building at rebuilding	-0.108	0.347	10.17	0.001	**
Constant term	10.412				

n.s. : p≧0.05、* : p＜0.05、 ** ; p＜0.01

2.2 Creation of Modified Discriminant

The equation obtained by discriminant analysis is shown below. Discriminant coefficients are used as coefficients.

$$Y=-2.524X_1 +1.039X_2 -0.00028X_3 -0.033X_4 -0.108X_5 +10.412 \quad (1)$$

[X_1 = Increase or decrease in floor-area ratio (%), X_2 =Former floor-area ratio (%), X_3 = Former site area (m²), X_4 = Architectural area / dwelling units (m²/unit), X_5 = Age of a building at rebuilding (years)].

Table 4 Result of discriminant analysis

Square χ	10878.21
Variance	21
P value	0.00000001
Decision	**

n.s. : p≧0.05、 * : p<0.05、 ** ; p<0.01

Wilks's Λ	0.469
Statistic	31.63
Variance 1	12
Variance 2	335
P value	0.000000004
decision	**

n.s. : p≧0.05、 * : p<0.05、 ** ; p<0.01

predictive value	
Unreconstructed	94.2%
Reconstructed	97.5%
estimated frequency	
Unreconstructed	99.7%
Reconstructed	68.4%

cross tabulation	
Distinction hitting ratio	94.5%
misjudgment ratio	7.6%
Mahalanobis's Square distance	8.2236
correlation ratio	0.531

Regarding the reliability of the equation, the results of the equal-variance and box M test in Table 4 confirmed that the p-value was less than the significance level of 0.05. Also, in the Wilks' Lambda test, the null hypothesis was rejected because the p-value was less than 0.01, which is below the significance level of 0.05. From these results, it can be assumed that the mother variances of the two groups (rebuilt and unbuilt properties) are different. Therefore, a discriminant analysis using the Mahalanobis distance was conducted in this study. When Y (the objective variable) is positive, the group is considered to be "close to the group that has not been reconstructed," and when it is negative, the group is considered to be "close to the group that has been reconstructed. The accuracy of the analysis is high at 94.5%, which is higher than the general frequency of 75%. The correlation ratio also exceeds the general frequency of 0.5. (The above test results and statements regarding the significance level have the same value in the discriminant analysis to be conducted later, unless otherwise noted.) When looking at the importance of each variable to the equation using the standard discriminant coefficients, the one that contributes the most to the result of negative discriminant scores is the increase or decrease in the floor area ratio. This is followed by the age of the building at the time of reconstruction and the total floor area/number of dwelling units. The higher these values are, the closer the property is to the group where the reconstruction took place. On the other hand, since the coefficient of the floor-area ratio for previous use is positive, the larger the value, the closer the property is to those that have not been reconstructed. In other words, the larger the excess floor-area ratio, the higher the reduction ratio, and the older the property is, the more likely it is to be identified as being close to a group that has been reconstructed. If there is already no room in the floor-area ratio at the time of considering rebuilding, the property is judged to be close to a group that has not been rebuilt.

2.3 Problems with Cluster Analysis and Inclusive Coverage

A cluster analysis was conducted on the properties that had not yet been reconstructed. The properties were divided into four groups (d1 to d4), which were classified according to location, and a discriminant analysis was conducted for each group. The purpose of this analysis was to confirm the reliability of the formula, given the inherent bias in the number and type of properties in each ward of Tokyo. Cluster analysis was performed on the subject properties using 36 variables, and after obtaining a tree diagram, the properties were classified by the most likely group (Table 5).

The results of the classification showed that the overall accuracy was low, with a result of 70.8% for group d3, which is lower than the typical 75%, indicating that this group is not appropriate as a discriminant formula. d3 is located in the relatively peripheral area of Tokyo and is characterized by large size but low prices. In addition, the d2 group has a higher rate of misclassification than the d1 group, even though the target and predicted values are higher in the d2 group. Thus, it was found that the number of n as the denominator was less than 20 cases, and the bias of the variables made the discrimination difficult and reduced the accuracy (Table 6).

Table 5 Result of Cluster analysis

d1.Cluster1	d2.Cluster2	d3.Cluster3	d4.Cluster4
Shinjyuku	Koutou	Katsushika	Minato
Suginami	Taitou	Edogawa	Shibuya
Setagaya	Ota	Arakawa	Chiyoda
Chuou	Kita	Adachi	
Nakano	Sumida	Itabashi	
Shinagawa	Nerima		
Bunkyou			
Toshima			
Meguro			

（Wards）

Table 6 Result of discriminant analysis of each Cluster

d1.Cluster1: predictive value		d2.Cluster2: predictive value		d3.Cluster3: predictive value		d4.Cluster4: predictive value	
Unreconstructed	89.0%	Unreconstructed	82.0%	Unreconstructed	70.8%	Unreconstructed	83.1%
Reconstructed	80.0%	Reconstructed	95.8%	Reconstructed	93.5%	Reconstructed	88.7%

d1.Cluster1: predictive value		d2.Cluster2: predictive value		d3.Cluster3: predictive value		d4.Cluster4: predictive value	
Unreconstructed	93.2%	Unreconstructed	96.2%	Unreconstructed	91.9%	Unreconstructed	89.1%
Reconstructed	70.2%	Reconstructed	80.7%	Reconstructed	75.4%	Reconstructed	82.5%

2.4 Discriminant Analysis in Suburban and Metropolitan Area

Discriminant analysis was performed for only the suburban cities (Saitama, Chiba, Kanagawa, and Ibaraki prefectures) and as the metropolitan area, which is the sum of Tokyo and the suburban cities. Table 7 shows the ranking in the equation using standard discriminant coefficients for the selected covariates. The only common variable among the three regions was an increase or decrease in floor-area ratio. The Age of a building at rebuilding was selected only for Tokyo, but not for other regions or categories, suggesting that the importance of the age at time of reconstruction will decrease as the target area moves away from the urban centre and toward the rural areas. On the other hand, in the Tokyo metropolitan area, the most important factor is the assessed value of land per unit, and the sign of the coefficient indicates that the larger the assessed value of the property, the closer it is to the group that has not been rebuilt. This means, for example, that properties built on sites where land is highly valued are difficult to rebuild, a result that is generally difficult to consider. Aggressively expanding the scope of inclusion may distort the analysis and may not ensure statistical reliability.

Table 7 Comparison the results of each discrimination analysis

Covariances	Tokyo	Suburbs	Metropolitan Area
Former site area (㎡)	5		2
Former architectural area (㎡)			
Former floor-area ratio (%)	4	2	
Legal floor-area ratio (%)			
Floor-area ratio after rebuilding (%)			4
Increase or decrease of floor-area ratio (%)	1	1	3
Former total number of dwelling units			
Architectural area / dwelling units	3		5
Site area / dwelling units			
peripheral land price			
Land price of each dwelling units			1
Age of a building at rebuilding	2		

2.5 Adding Covariates

In addition to the 12 covariates used so far, data quantifying the surrounding conditions are used to see changes in the discriminant equation. Previous paper has treated as covariates information sufficient to describe a building, such as building size, economic aspects, and legal aspects, but the influence of actual buildings in the surrounding area have not been taken into account. The surrounding conditions are related to "convenience," which is actually handled in the sale of condominiums, and compensates for commercial facilities, public facilities, parks, and other aspects related to daily life in the surrounding area. The Walkability Index is a joint study by the University of Tokyo and Nikken Sekkei Research Institute, Inc. that quantifies the convenience of nearby commercial facilities, public facilities, parks, and other amenities that are relevant to daily life. A walking range (15-minute radius) based on pedestrian routes centred on the property was calculated, and each facility within that area is evaluated as a score according to its proximity. In addition to the major categories given for each property, facility fulfilment and convenience of large commercial facilities, which are facilities of high importance, a total of five additional covariates were employed: distance (minutes) from the property to the nearest station.

As a result of the analysis, the added covariates were not selected at the stepwise stage, and the differences between the 12 covariates and the five covariates added this time were observed in the gap between each variable and the range of values between the rebuilt and unrebuilt properties, which were small and large. Therefore, if the gap between the covariates and the objective variable is not large enough, the covariates are not appropriate for discriminant analysis. However, since the surrounding environment is assumed to be an important variable in terms of purchase motivation and evaluation, we believe that the addition of a variable that satisfies the conditions will be important for the purpose of increasing the reliability of the equation in the future.

Table 8 Additional covariances

Added Covariances (5)	the basis for calculating
Facilities enhancement degree (a)	Convenience of the life: Supermarket, CVS, Postoffice, Clinic, Police box, etc.
Facilities enhancement degree (b)	Improvement of store: Shopping center, Bakery, Café, restaurants, etc.
Facilities enhancement degree (c)	Education: school, Child care facilities, etc.
Convenience of Commercial complex	The number of the facilities mainly on the article of radius 50M (area on foot)
Distance to the station	Minutes from an article to the nearest railroad station on foot

■3.0 MODIFICATION OF THE ASSUMED FLOOR-AREA RATIO COEFFICIENT AFTER RECONSTRUCTION OF CONDOMINIUMS AND CREATION OF A MODIFIED DISCRIMINANT FORMULA

The coefficient used in the previous paper for the assumed post-reconstruction floor-area ratio for un-reconstructed properties is 1.282, but this coefficient has no solid basis. Therefore, it is necessary to provide a credible background for the coefficient. The mean and median values of the coefficients for each of the target coefficients were calculated for the rebuilt properties in Tokyo, suburban cities, and the Tokyo metropolitan area that were selected. At the same time, based on the data presented by the Subcommittee on Condominium Policy of the Subcommittee of the Council for Social Infrastructure Development conducted by the Ministry of Land, Infrastructure, Transport and Tourism in February 2020, the coefficient of 1.74 for the 2010s was determined to be appropriate as a reference value. A discriminant analysis using these three coefficients was conducted and compared. In the 23 wards of Tokyo, the increase or decrease in floor-area ratio was most important when the coefficient was 3.749, the largest, but as the coefficient decreased, the increase or decrease in floor-area ratio was not selected, and the previously used floor-area ratio was selected when the coefficient was 1.74. However, the difference in the standardized scores is small, and the floor area ratio is considered to be of similar importance compared to other variables. Since the sign of both coefficients is negative, the floor-area ratio is close to that of the group where reconstruction took place due to a large increase in the floor-area ratio. 1.282 was used to select both the previous-use floor-area ratio and the increase or decrease in the floor-area ratio, and the increase or decrease in the floor-area ratio was more important than the other two variables. The results using 1.282 show that both the floor-area ratio in the previous use and the increase/decrease in the floor-area ratio were selected.

In suburban cities, the most important factor was the increase or decrease in floor area ratio when the coefficient of 1.282 was used, while the results using a coefficient other than 1.282 varied between site area and age of the building. A larger site area is discriminated as being closer to the group where the reconstruction took place, and the choice of age confirms the importance of the value related to aging. This confirms the difference from other ranges when more reliable publicly based figures were used.

Looking at the Tokyo metropolitan area, the increase or decrease in floor-area ratio and the floor-area ratio of previous use were picked up in both cases. The Tokyo metropolitan area has its own sample, with the Tokyo metropolitan area and the suburban area each having their own sample. This makes the importance of the reduction ratio increase due to the influence of the increase in floor-area ratio conditioned by the Tokyo sample data. At the same time, since the sample data includes urban and suburban areas, it is affected by the area of the existing lot and the age of the building. The results indicate that rebuilding becomes more difficult when the existing site area is large, or the age of the building is young. In any case, the results for the Tokyo metropolitan area are not reliable for this discussion, because the over-inclusive scope of the metropolitan area is too large and leads to unforeseen results. The numbers in Table 9 rank the importance of the variables to the equation when creating the discriminant equation, using standard discriminant coefficients. Changing the coefficients is the act of changing the assumed value of unbuilt properties while leaving the actual number of rebuilt properties unchanged. This trial will increase the likelihood of being selected as a significant variable because the gap between reconstructed and unreconstructed properties in terms of increase or decrease in floor-area ratio will be large or small. On the other hand, it is interesting to note that the results of this study differ from those of previous studies in that they show the importance of variables other than floor-area ratio by moving the focus away from the urban centre and toward the rural areas. Based on these results, we will again attempt to create the most reliable modified discriminant equation. The coefficient of the floor-area ratio after reconstruction was 1.74, as indicated by the Ministry of Land, Infrastructure, Transport and Tourism.

Table 9 Comparison as the rank of the results of each discrimination analysis with different coefficient number

Tokyo

Covariances	coefficient 3.749	coefficient 2.972	coefficient 1.74	coefficient 1.282
Former site area (㎡)	4	2	4	5
Former architectural area (㎡)				
Former floor area ratio (%)		4	1	4
Legal floor area ratio (%)	5		3	
Floor area ratio after rebuilding (%)	2			
Increase or decrease of floor area ratio(%)	1			1
Former total number of dwelling units				
Architectural area / dwelling units		3	5	3
Site area / dwelling units				
peripheral land price				
Land price of each dwelling units				
Age of a building at rebuilding	3	1	2	2

Suburban

Covariances	coefficient 3.749	coefficient 2.972	coefficient 1.74	coefficient 1.282
Former site area (㎡)	2	2	1	
Former architectural area (㎡)				
Former floor area ratio (%)				2
Legal floor area ratio (%)				
Floor area ratio after rebuilding (%)				
Increase or decrease of floor area ratio(%)				1
Former total number of dwelling units				
Architectural area / dwelling units				
Site area / dwelling units				
peripheral land price				
Land price of each dwelling units				
Age of a building at rebuilding	1	1	2	

Metropolitan Area

Covariances	coefficient 3.749	coefficient 2.972	coefficient 1.74	coefficient 1.282
Former site area (㎡)	2	2	3	2
Former architectural area (㎡)				
Former floor area ratio (%)		1	1	
Legal floor area ratio (%)	3	3	5	
Floor area ratio after rebuilding (%)				4
Increase or decrease of floor area ratio(%)	1		2	3
Former total number of dwelling units				
Architectural area / dwelling units	4	4	4	5
Site area / dwelling units				
peripheral land price				
Land price of each dwelling units				1
Age of a building at rebuilding				

$$Y=-0.00024X_1 -0.16X_2 -0.03X_3 +0.93X_4 -0.56X_5-0.62X_6 +10.85 \quad (2)$$

[X_1 = Former site area (m^2), X_2 = Age of a building at rebuilding (years), X_3 = Architectural area / number of dwelling units (m^2/unit), X_4 = Former floor-area ratio, X_5 = legal floor-area ratio, X_6 = increase or decrease in floor-area ratio]

Table 10 Result of discriminant analysis 2

Square χ	10878.21
Variance	21
P value	0.0001
Decision	**

n.s. : p ≧ 0.05、 * : p＜0.05、 ** ; p＜0.01

Wilks's Λ	0.643
Statistic	15.49
Variance 1	12
Variance 2	335
P value	5.6×0.1-26
decision	**

n.s. : p ≧ 0.05、 * : p＜0.05、 ** ; p＜0.01

predictive value

Unreconstructed	93.6%
Reconstructed	73.1%

estimated frequency

Unreconstructed	95.2%
Reconstructed	66.7%

cross tabulation

Distinction hitting ratio	90.5%
misjudgment ratio	15.8%
Mahalanobis's Square distance	4.0288
correlation ratio	0.357

■4.0 DISCRIMINANT ATTEMPTS USING ARBITLARY DATA

4.1 Input Results

To validate the equation using arbitrary property data, the data from 20 randomly selected condominiums completed before 1982 (T-1 through 20), covering the new Tokyo metropolitan area was used. Each variable was substituted into the equation, and five properties (T-1, 2, 3, 10, and 13) were negative and close to the group where reconstruction took place, while the remaining 15 properties were close to the group where reconstruction did not take place (Table 11).

Table 11 Result of the discriminant analysis with formula 2 and sign-reversing coefficients by the change of floor-area ratio

No.	Results of discrimination analysis (y)	addition to increase/decrease in floor area ratio (z)	ideal value of increase/decrease in floor area ratio (a)	ideal coefficient
T-1	-0.44811476			
T-2	-0.85495410			
T-3	-0.00741479			
T-4	1.03509614	1.670	3.433	2.441
T-5	0.94516318	1.524	3.586	2.287
T-6	0.79343421	1.280	4.139	2.071
T-7	0.00109632	0.002	4.213	1.740
T-8	1.66323531	2.683	7.186	2.181
T-9	1.56283563	2.521	6.673	2.189
T-10	-1.58140044			
T-11	0.77479580	1.250	4.073	2.067
T-12	1.31979569	2.129	3.804	2.680
T-13	-0.43443539			
T-14	2.17558732	3.509	4.953	3.538
T-15	1.98926790	3.208	5.465	2.792
T-16	0.91906949	1.482	4.393	2.117
T-17	1.17730243	1.899	8.347	1.958
T-18	1.85169227	2.987	6.945	2.298
T-19	1.44143617	2.325	4.680	2.470
T-20	1.32984544	2.145	5.453	2.220

4.2 Discussion of the Results of the Variation in the Increase or Decrease in the Floor-area Ratio

In Sections 4.2 and 4.3, the result of the 15 cases obtained in Section 4.1 from "close to the group that has not been reconstructed" to "close to the group that has been reconstructed" was changed. Among the variables that make up the equation, the increase or decrease in floor-area ratio is assumed to be the floor-area ratio after reconstruction by multiplying the previous floor-area ratio by a certain coefficient. Since it is possible to intentionally change the result by changing this coefficient, the result was reversed by changing the increase/decrease portion of the floor area ratio.

From the coefficient of X_6 in the modified discriminant Equation 2, the discriminant result for each property was divided by 0.62 to obtain the additional value of the increase or decrease in floor area ratio required to make the result negative. The obtained Z was referred to as the "addition to increase/decrease in floor area ratio. This value was added to the increase/decrease in floor area ratio to obtain the "ideal value of increase/decrease in floor area ratio (a). This (a) was substituted into the discriminant equation, and it was confirmed that all results were less than 0. As a result, it was found that a sign reversal occurs with an increase in the floor area ratio of approximately 343% to 834% only within the range of data used in this study.

Next, the coefficient of increase or decrease in floor area ratio that reverses the sign of the discriminant result was examined. The following equation was developed to calculate the ideal coefficient for each property.

$$b=y\div 0.62x+1.74 \tag{3}$$

The coefficient (b) was obtained by the discrimination result (y) and the previously used floor area ratio (x). Table 11 shows the results of the "ideal coefficient" for the 15 cases that were determined to be difficult to rebuild. In order to reverse the result of the 20 cases used for this verification, the 15 cases that were determined to be close to those that had not been reconstructed to be close to those that had been reconstructed, the post-use floor area ratio would need to be approximately 1.8 to 3.6 times the pre-use floor area ratio, or on average 2 to 2.5 times the pre-use floor area ratio. It can be understood that the required floor-area ratio increases in the 1970s was 434%, which is very high, and that the present results are within that range. While the verification results indicate that rebuilding plans that are contingent on securing excess floor-area ratio are still an effective means, the tendency of the figure to decrease with each passing year can be read from the same figure, suggesting that the excess floor-area ratio required in the future will tend to decrease.

4.3 Discussion of the Results of the Variation in the Increase or Decrease in the Area of the Existing Site

Here, instead of increasing or decreasing the floor-area ratio as done in 4.2, a sign reversal by changing the value of the site area in light of the possibility of a consolidation, joint project, or site sale was attempted. When the value of the former site area is changed, the floor-area ratio of the former use (former total floor area divided by the former site area), which is calculated using the former site area, and the increase or decrease in the floor-area ratio (floor-area ratio after reconstruction - floor-area ratio of the former use) also change simultaneously. The other variables, excluding these three, are assumed to remain unchanged, and the discriminant equation is organized as follows;

Discrimination result (Y) = -0.00024 ×previous site area (X_1) + 0.93 (previous total floor area / X_1) - 0.62 (previous total floor area / X_1 × 1.74 – previous total floor area / X_1) + C (4)

[C is the age of a building at rebuilding (years), Architectural area / dwelling units (m^2/unit), and the legal floor-area ratio portion in the modified discriminant formula].

Select a solution where X_1 by Equation 4 is greater than or equal to 0.

These results indicate that sign reversal requires an increase of approximately 1.0004 to 7.7 times the previous site area for the range of data used in this study. The average is 2.8 times, and Table 12 shows that in 8 out of 15 cases, the sign is reversed by a factor of about 1.5 to 2. In other words, this result can be expected to promote rebuilding through joint projects with neighbouring condominiums of about the same size. In addition, since the change in site area is a change in the fundamental part of the building, it has no small impact on areas other than those verified in this study. The benefits are significant, including the increased possibility of meeting floor-area ratio mitigation requirements, such as securing open space and wall setbacks, and maintaining a good relationship with the surrounding environment by keeping a good distance from neighbouring properties.

Table 12 Result of the discriminant analysis with formula 4 and sign-reversing rate by the change of site area

	Results of discrimination analysis (y)	C	after the change of former site area（㎡）	Increase in site area（㎡）	rate of increase
T-4	1.035096136	-0.046	815.781	640.381	4.651
T-5	0.945163177	-0.171	1790.639	971.129	2.185
T-6	0.793434206	-0.584	2721.648	872.808	1.472
T-7	0.001096319	-2.592	366.825	0.145	1.0004
T-8	1.663235311	-1.142	577.269	319.419	2.239
T-9	1.562835628	-0.975	964.622	524.312	2.191
T-11	0.774795804	-0.725	1891.848	650.858	1.524
T-12	1.319795689	0.461	3144.659	2278.849	3.632
T-14	2.175587317	1.702	7980.796	6124.646	4.300
T-15	1.989267898	0.662	3531.256	3074.826	7.737
T-16	0.919069488	-0.738	1410.013	591.303	1.722
T-17	1.177302431	-2.711	1236.412	330.622	1.365
T-18	1.851692266	-0.618	683.410	471.420	3.224
T-19	1.44143617	0.143	2605.183	1767.103	3.109
T-20	1.32984544	-0.601	1579.483	844.973	2.150
min				0.145	1.0004
max				6124.646	7.737
ave				1297.520	2.833

■5.0 CONCLUSION

With the aim of providing support for the decision to rebuild condominiums, an analysis using discriminant analysis, a type of multivariate analysis was conducted. A discriminant equation with the highest reliability at present was created, and the possibility of a new rebuilding was presented with its validation. The process of creating the equation revealed that in addition to the importance of floor-area ratio, which complements previous studies in Tokyo, the age of the building was selected to further increase the reliability of the equation. In the future, when the number of properties over 40 years old will increase, it will be necessary to consider rebuilding based on the age of the building as soon as possible. The formula is also affected by the area of the previous site, which also makes up the entire formula. This confirms the usefulness of a wider range of decision-making materials, rather than a centralized solution based on the reduction ratio. On the other hand, as for the reliability of the formula, the discriminant analysis by cluster and the results for the metropolitan area showed that it is important to set an appropriate inclusionary range. In the suburban cities with different ranges, the importance of variables related to floor-area ratio was lower than in Tokyo. Rather, the age of the building had a negative impact, making rebuilding more difficult as the number of years increases.

(1) The inclusion of covariates for increase/decrease in floor-area ratio in the discriminant equation suggests the importance of profit from the sale of surplus floor space (expected income) in previous papers and previous studies.
(2) The contribution based on the standard discriminant coefficient to the discriminant equation indicates that the age of the building plays a significant role in rebuilding in Tokyo. The older the building is, the more it should be rebuilt.
(3) In suburban cities, no change in the importance of the floor-area ratio was observed in response to trials from various angles, such as changing or replacing coefficients of variables related to the floor-area ratio. The floor-area ratio in suburban cities is less important than in Tokyo. The age of the building affects it in a negative way, making rebuilding more difficult as the number of years increases.
(4) From the creation of the equation when inclusive as the metropolitan area and the creation of the equation when subdivided by cluster analysis, it was found that a moderate inclusive range and a certain number of population or more were necessary for the analysis. The influence of an excessive or insufficient number of populations cannot be ignored in the ranking of covariates using standard discriminant coefficients and in the results of discriminant analysis with different volume ratio assumption coefficients.

The importance of the increase or decrease in floor-area ratio as an economic aspect, regional differences due to the length of the building's age, and the updating of coefficients in consideration of actual cases, etc., indicate that a certain answer was obtained to the tentative question, Based on a case study of a rebuilding property that includes economic items, it is possible to provide a new decision-making tool that contributes to the rebuilding of condominiums by presenting a highly reliable formula that clarifies the items necessary for rebuilding. Formulate a practically applicable discriminant equation for the future reconstruction of condominium. It is hoped that the two modified equations formulated from this study have practical significance as both can form good and effective decision support for future reconstruction of condominiums in Tokyo.

As a new finding obtained through the process of the provisional demonstration, the verification of the modified discriminant equation based on changes in the floor-area ratio and site area revealed that reconstruction can be promoted by changing more realistic numerical values, especially in the verification of the sign reversal caused by site area expansion. While encompassing the argument that the rate of return should be increased in the previous study, we believe that we were able to develop an argument for site expansion that can be expected to have more multifaceted effects. There are numerous secondary benefits such as securing public open space and wall setbacks, which will have a positive effect on the surrounding environment. It is important to start the study early and to unify the will to reach a consensus for the continued residence of the residents on their beloved land. The project has achieved a certain level of success in presenting the possibility of reconfiguration through a review of the use of the site and joint projects as a way of shaping the future of the town unit. As the number of properties to be reconstructed increases, it is hoped that a more reliable and reliable formula will be established and made known to the community and used in the future.

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References

Hanazato, T. (2017). Feasibility Evaluation for Condominium Reconstruction by Means of the Application of Discriminant Analysis on Real Estate Data. *Journal of the Real Estate Institute of Japan*, 31(3), 119-128. (DOI. https://doi.org/10.5736/jares.31.3_119).

Kamano, K. (2022). International Comparison of Condominium Unit Ownership Legislation, Japan, Taisei Press Co. ISBN978-4-8028-3465-0.

Kawakami, M. (1986). Research on a model to support housing demand-supply planning in the region (1), *Residential Building Research Institute Research Institute, 8516*, 119-128. DOI. https://doi.org/10.20803/jusokenjo.13.0_271.

Munneke, H. J. & Womack, K. S. (2015). Neighbourhood renewal: the decision to renovate or tear down. Regional Science and Urban Economics, 54, 99-115. DOI. https://doi.org/10.1016/j.regsciurbeco.2015.08.001.

Ohki, Y. (2014). Condominium Revitalization - Large scale by experienced practitioners' practical advice on repair, renovation and reconstruction, Japan, *PROGRESS, Inc*.

Ohtani, Y., Hanazato, T. (2020). Shadow and Lights of Highly Aged Condominiums – From Birth to Revitalization, Japan, PROGRESS, Inc.

Ohnuma, Yasuka et al. (2009). A Study About Rebuilding Possibility Evaluation of the Apartment Based on Land Prices Based on Accessibility and A Construction Cost, Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan, 1269-1270.

Webb, B. and Webber, S. (2017). The implications of condominium neighbourhoods for long-term urban revitalization. *Cities*, 61, 48-57. DOI. https://doi.org/10.1016/j.cities.2016.11.006.

Yamazaki, F., & Sadayuki, T. (2017). The Collective Action Problem in Japanese Condominium Reconstruction. *International Real Estate Review*, 20(4), 493-523.