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Determining the Construction Costs for Basic Type to Estimate the Sale Prices of New Multi-Family Housing Projects

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Abstract: Over the past two decades, the South Korean government has been regulating the supply and prices of multi-family housing (MFH) projects to stabilize the national population. Recently, active research has been conducted on the construction costs for basic type (CCBT) calculation to formulate appropriate policies. However, related previous studies have focused on improving the predictability of the construction cost in early stages based on existing house sale prices. In contrast, the CCBT calculation approach mainly requires policy implementation in practical fields, without considering the requirements of academics. Therefore, it is necessary to academically discuss a different approach for the estimation of sale prices of new MFH in the construction stage. This study aimed to calculate the CCBT to determine the appropriate sale price for new MFH. We selected four sample projects to calculate the CCBT, and a weighted average method was applied to correct regional deviations. Case application, which is a comparison between the CCBT-based sale price and actual case-based sale price, produced cost values in the range of 98–104%, and they included additional expenses. The results of this study demonstrate an extremely high level of cost estimation accuracy according to the Association for the Advancement of Cost Engineering study. Furthermore, this study can facilitate the stabilization of national housing by determining an appropriate sale price and can contribute to cost management research conducted during the construction phase.

Keywords: multi-family housing (MFH); construction costs for basic type (CCBT); sales price ceiling system; residential stability; cost management

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1. Introduction

1.1. Research Background

In recent years, the demand for multi-family housing (MFH) has significantly increased in South Korea, resulting in a consequent increase in MFH prices. This has led to social issues such as hindered livelihoods and instability. To address these issues, the Korean government has established standards for MFH construction projects based on the Housing act and instituted a Sale Price Ceiling System aimed at securing residential stability and new supply invigoration in the country [1]. The most crucial purpose of the sale price ceiling system is the implementation of a residential stability policy that allows people without house ownerships to purchase appropriate quality houses. This policy was implemented in March 2005 for small MFH projects (exclusive residential areas within 85 m^2) (exclusive residential areas within 85 m^2) constructed on public lands. In March 2006, this policy was expanded to cover mid-to-large MFH projects (exclusive residential areas over 85 m^2). Furthermore, in October 2019, the policy was expanded to MFH projects on private lands.

According to the Housing act, the sale price of an MFH project is determined by the sum of housing site preparation costs, construction costs, and adding expenses. Furthermore, the housing site preparation costs comprise land costs and adding expenses of the land cost, and the construction costs comprise the construction costs for basic type (CCBT) and the adding expenses of the construction cost. To ensure private and public residential stability, it is essential for the government to provide housing quality standards that can satisfy changing consumer requirements. Therefore, it is crucial to determine the sale price based on the calculations of construction costs for MFH that fit the latest trend.

Accordingly, the South Korean government selects and updates MFH sample projects every 4 years while considering the latest trends and determines the CCBT based on the sample MFH projects that are selected subject to strict criteria (such as the area, number of households, and latest facilities such as intelligent function); this is done because completed and sold sample projects are required to be representative. Upon selecting the sample project after sale completion, the CCBT is calculated based on the design drawings and bill of quantities. Moreover, the South Korean government officially issues a notice regarding the CCBT twice annually [1–3].

So far, several studies have been conducted to estimate the total construction costs [4–8]. However, most of these studies have examined the prediction accuracy based on limited information (areas and the number of floors) in the early construction stages [4–13]. In particular, because the sale price is determined after the detailed design plan is finalized, there is a limit to the application of methodologies (uncertainty method) adopted in these conventional studies that predict construction costs based on limited information in the early construction stage. Although previous studies have contributed academically, the development of a deterministic methodology is necessary because the sale price must be appropriately determined for consumers intending to purchase an MFH unit. Therefore, objective CCBT calculation is one of the factors that significantly influences the determination of sale prices.

1.2. Research Objectives and Scope

People in South Korea expect the quality of MFH facilities to be uniform nationwide. Therefore, the fluctuation in the CCBT should be less than the variations in the housing site preparation costs, and a reasonable CCBT should be calculated. Thus, this study aims to calculate an improved CCBT for new MFH construction projects to enable rational operation of the sale price ceiling system and to provide housing units that satisfy diverse consumer requirements.

As mentioned above, the sale price comprises the sum of the housing site preparation costs and the construction cost (Figure 1).

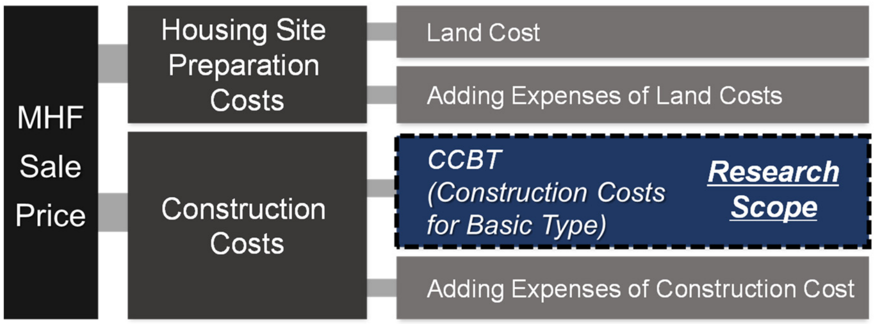

Figure 1. Composition of the MFH sale price and research scope.

Housing site preparation costs are one of the most important factors; this is because these costs vary significantly based on regional characteristics, and, in fact, they constitute a large proportion of the sale price in metropolitan areas with higher MFH market prices. Accordingly, owing to large variations within the same area, the importance of construction costs becomes relatively low (high housing site preparation costs). In particular, according to the Appraisal act, the housing site preparation costs are determined based on various factors, such as the removal of obstacles, accessibility to public transportation, and the number of households.

Therefore, it is necessary to construct a database of the housing site preparation costs while considering regional characteristics to determine the sale price; however, securing the related data as a whole in South Korea is not very feasible. Therefore, this study limits the scope of its research to propose a method for CCBT calculation.

2. Literature Review

2.1. Sales Price Ceiling System and Construction Costs for Basic Type

The South Korean government has implemented a housing policy to address the rise in new MFH demand. The sale price ceiling system is a representative policy that prevents a rapid rise and fall in new MFH sale prices [1,2]. The sale price ceiling system limits the sale price by placing a cap on the construction costs required for MFH projects. Table 1 details the composition of sale price components.

Table 1. Composition of sale price (refer to Housing Act Article 57, as modified by Cha et al. [3]).

Category			Component	Description
Housing site preparation costs		Land cost	Public MFH supply price	Price of MFH land developed by a public institution
			Private MFH appraised price	Appraisal price of MFH land developed by a private corporation
		Adding expenses of land costs	Pre-stressed high-strength concrete pile cost	Pile construction cost under building foundation or a similar construction method
			Retaining wall	Construction cost of the retaining and barrier walls for the foundation of a building
			Sound-proof work	Structural wall for noise reduction around the MFH
Construction costs	CCBT	Ground floor cost	Architectural, mechanical, electronic, landscape, community facility works	Direct costs of the main building and facilities built on the ground floor such as roads, landscaping, and community facilities
		Basement floor cost	Parking area, electrical pip shaft (EPS)/air duct (AD)/telecommunication pipe shaft (TPS)/pit space	Direct cost of ground floor facilities built on the underground floor such as parking lots, EPS, TPS, machine room facilities, and other equipment.
		Design/Construction Management fee		Design and construction management service fee
		Incidental expenses	Display home, registration fee	MFH display costs and installed lifelines such as electricity, gas, water, and sewage
	Adding expenses of construction costs		Structure type	Adding expenses incurred depending on the type of structures, such as a flat-plate structure (~3%), reinforced concrete rigid-frame structure (5%), steel and reinforce concrete (SRC, 10%), and steel structure (SC, 16%), obtained by multiplying a certain ratio with the CCBT.
			Degree of performance for MFH	Adding expenses pertaining to the performance grade recognized based on the Housing act obtained by multiplying a certain ratio (1–4%) with the CCBT
			Balcony extension	Adding expenses incurred for expanding a balcony to be used as an indoor space. (2–3%)
			Intelligent facilities	Costs of smart facilities (home-network and high-speed communication network) and automation facilities (mechanical ventilation and automatic waste collection system)

As mentioned above, the sale prices are determined based on a summation of the housing site preparation costs, construction costs, and the adding expenses. At public sites, the land owned by public owners is made available for public projects; therefore, the land cost is calculated as an input construction cost. In contrast, at private sites, private companies acquire lands for private projects; therefore, the land cost is calculated based on appraisals according to the Appraisal act. However, private sites are mostly loacted in metropolitan areas, and hence, land costs of private sites vary significantly. Moreover, the additional expenses of components (that is PHC-pile, retaining wall, etc.) required for housing construction are included in the housing site preparation costs.

The construction costs comprise the CCBT and adding expenses of the construction costs. The CCBT is composed of the costs for ground and basement floors, design, construction management (CM) fee, and incidental expenses, which represent the basic elements necessary for new MFH. Additionally, attempts to improve the quality of housing and residential environments may incur additional expenses; these may involve improving the structure type, installation of welfare facilities for resident convenience, construction of eco-friendly residential complexes, and improvement in the housing quality. Because the required input cost is different for each type of adding expense, the Housing act provides an independent adding expense rate.

Meanwhile, it is important to ensure the provision of housing qualities that can satisfy occupants and to calculate fair construction costs so that the sale price does not increase significantly. However, if the construction costs are highly restrictive (low construction costs), they could result in poor-quality MFH. Accordingly, the Ministry of Land, Infrastructure, and Transport in South Korea issues a notice stating an appropriate price for new MFH twice every year; this is because the CCBT is often influenced by social factors such as the inflation rate, unit cost of wages, and material costs.

2.2. Related Research

2.2.1. Construction Cost Prediction

Several studies have been conducted on construction cost prediction in the CM field. Therefore, over the past two decades, researchers have investigated construction cost prediction methods in the early stage of a project based on various methodologies [14] such as square foot prices and statistical analysis methods, including regression analysis (RA) [4,5,15,16]. Recently, several artificial intelligence (AI) methods such as artificial neural networks (ANN), genetic algorithms, and case-based reasoning (CBR) have been applied for cost estimation in construction [7,10,17]. These existing studies have primarily focused on two perspectives for construction cost forecasting.

First, the construction costs are predicted based on limited information in the early stages of the project, when details required for the direct calculation of the construction costs are typically absent. Numerous related studies have been conducted to predict the construction costs based on information that can be obtained in the initial stages of the project (gross floor area, structure type, and foundation type) [6,8,9,13]. Second, a majority of the research has focused on improving the accuracy of construction cost predictions using statistical and AI techniques (CBR and ANN) based on massive amounts of data [7,10–12,18]. Although several studies are still underway, most of them focus on the initial stages of a project.

Thus, previous studies predicted the construction cost based on limited information available during the early stages of the project. Thus, only high-level early-stage data were used in existing research, limiting direct calculations of the construction cost. Thus, in this study, the target CCBT is calculated based on the detailed design drawings and bill of quantity (items that can enable direct calculations of the construction cost) of the MFH. Moreover, considering the unceratinity in the early stages of a project, the application of existing methodologies is rather limited as the CCBT used in calculating the objective sale price must be accurate.

Therefore, this study focuses on calculating the objective construction costs from a rational perspective, rather than focusing on the prediction and accuracy. In other words, the CCBT is calculated appropriately as it is an important factor in determining the sale price. Finally, we verify whether the sale price is reasonably determined (Table 2).

Table 2. Literature review.

Authors	Utilization Stage		Utilization Information		Method	
	Early Stage	Sale Stage	Project Overview	Project Details	Statistical Analysis	Data Mining
Trost et al. [4], Lowe et al. [5], Jin et al. [6], Sonmez [7,16], Kim et al. [15]	•		•		•	•
Ji et al. [9], Ji et al. [10], Dǒgan et al. [11,18], Jin et al. [13], Jin et al. [8]	•		•			
This study		•		•	•	

2.2.2. Housing Sale Price Prediction

In this section, we analyze studies focusing on the estimation of housing prices and the factors influencing housing prices.

First, so far, studies investigating housing prices have been generally conducted from a macroscopic perspective based on factors such as the wage level, labor force, unemployment rate, and the accessibility of public transportation. [19]. Furthermore, a few studies have been conducted considering environment factors such as land surrounding the facilities, which significantly impact housing prices [20–22]. Moreover, a few studies have been conducted focusing on the factors affecting housing prices while simultaneously considering regional characteristics such as industrial and commercial areas and the environmental characteristics of cities [23,24]. Second, studies related to housing price prediction differ based on the methodology applied. In that regard, several studies have been conducted based on the hedonic and regression models [25–27], whereas few studies have focused on using statistical approaches [28,29]. Moreover, in recent years, several studies have been conducted to improve the prediction accuracy by applying AI and machine learning techniques [30,31].

Within the scope of this study, the CCBT is an important factor in determining the sale price of new MFH. This is different from the scope of previous studies that use data on the sale prices of existing housing. Moreover, as mentioned above, herein, the CCBT is calculated after completion of the design, which makes our study different from previous studies that predict construction costs or existing housing sale prices based on variables.

3. Research Procedure

In this study, we calculated the CCBT based on the detailed bill of quantities of the sample projects with completed designs. Accordingly, the research procedures were conducted in six steps, as described below (see Figure 2).

(i) Sample project selection criteria were selected based on the latest design trends, regions, number of households, and customer satisfaction; (ii) a sample project was selected from the southern region area, central region area, eastern part of the metropolitan area, and the western part of the metropolitan area according to the selection criteria; (iii) a detailed design bill of quantities for the sample projects was designed. The items resulting in adding expenses (structure type and intelligent facility) were removed from the bill of quantities and classified as included in the CCBT. Additionally, the construction costs of the ground and basement floors were categorized; (iv) a synchronization of the construction cost for each sample project was necessary because the construction cost was estimated at different times. In other words, the construction cost of each project had to be calculated based on the value at a given instant owing to changes in prices, productivity, labor costs, and material costs. Therefore, the construction cost of each sample project was converted to the present value based on the construction cost index; and (v) the direct construction cost of the sample projects (converted to the present value) was multiplied by the rate to calculate the indirect cost, design fee, and CM fee.

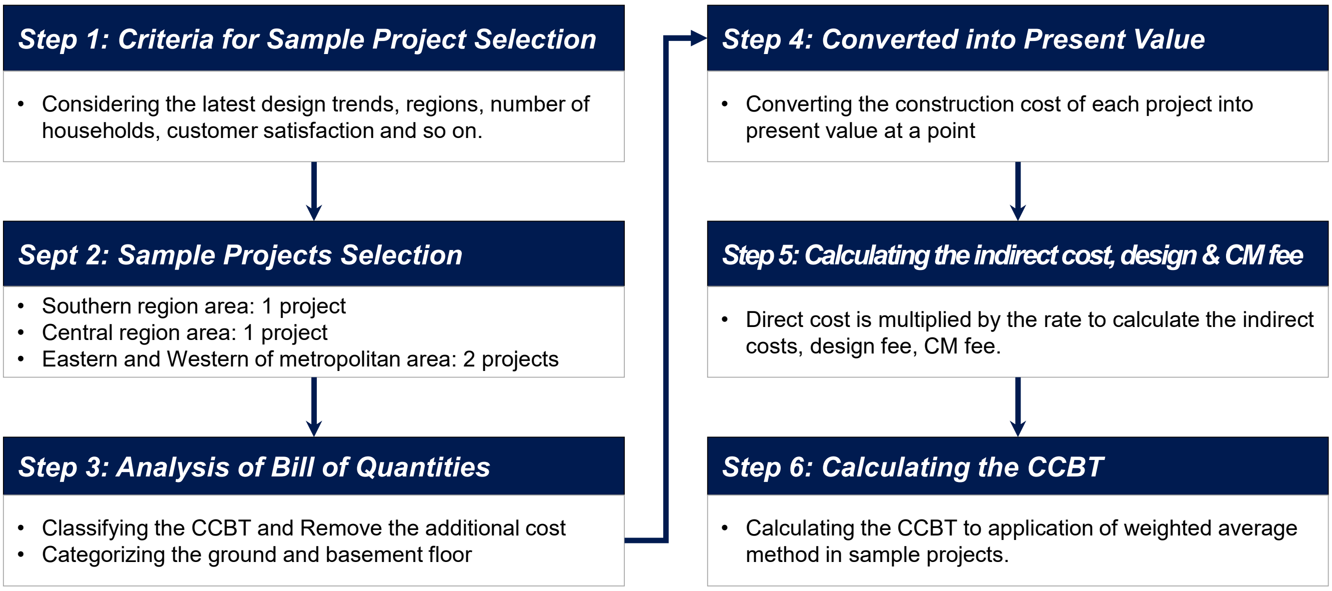

Figure 2. Research procedure.

Notably, in South Korea, the construction cost index is announced at the national level, whereas in North America, the construction cost index is released at the state level. Although South Korea is small compared to North America, the construction cost inevitably varies depending on the number of houses based on regions owing to variations in the material cost, equipment cost, and shipping expenses. Therefore, the regional weighted average method was applied to reflect the number of MFH supplied in the sample projects.

4. Calculation of the Construction Costs for Basic Types of MFH

4.1. Sample Project Selection

Notably, sample projects are important for calculating the CCBT. However, to calculate the construction cost, sample projects must be selected considering reasonable housing quality levels, consumer preferences, and the latest housing trends, instead of barely satisfying minimum standards.

This study expanded the target scope and number of sample projects used in the calculation of CCBT [2] to reflect more diverse characteristics while considering market conditions such as the expanded implementation of the sale price ceiling system. Table 3 lists the sample project selection criteria.

Table 3. Sample project selection criteria.

Category	Criteria
Unit scale	More than 500 units
Area	60–85 m^2
Type of structure	Wall type
Regional	1 metropolitan, 1 central, 1 south
Substitute	19 regional projects

Four cases were selected based on the sample project selection criteria presented in Table 4. The sample project selection procedures are as follows:

Table 4. Sample project information.

Category	Project 1	Project 2	Project 3	Project 4
Unit Scale	More than 1000	More than 900	More than 600	More than 700
Type of Floor	3~4 Bay L type/ 6 houses (2 + 2 + 2)	4 Bay L type/ 5 houses (2 + 3)	3~4 Bay L&Flat type/ 5 houses (2 + 3)	4 Bay L type/ 4 houses (2 + 2)
Regional	South	Central	Capital 1	Capital 2
No. of Floor	21 GF, 1 BF	21~25 GF, 1 BF	19~25 GF, 1 BF	25 GF, 2 BF

(1) Step 1: Select 19 public MFH projects sold within the past 3 years

Projects with available design statements that were drafted according to the Act on Contracts, to which the state is a party, and the Public Construction Cost Calculation Standards System were selected. The projects sold within the past 3 years were selected to reflect the recent housing design trends and quality standards.

(2) Step 2: Select seven projects that represent the CCBT

To ensure that the sample projects reflected diverse housing design standards, projects with over 500 units were selected. Given that the calculation of the CCBT is based on housing units, the selected projects primarily featured housing units with reinforced concrete wall structures, 20–25 floors, and areas of 60–85 m^2. Notably, the selected projects should not have excessively expansive auxiliary facilities such as day care, parks, and other welfare facilities; therefore, they must also not be prioritized based on their appearance and landscape.

(3) Step 3: Select four projects that reflect various residential characteristics (sample projects should also consider the regional spread)

The sample projects selected in Step 2 were further processed in terms of the project location to reflect diverse housing preferences and other elements that impacted the CCBT. Consequently, two projects in the metropolitan and non-metropolitan regions each (South and Central) were selected. Table 4 presents the sample project information.

4.2. Construction Costs of Each Sample Project

Before calculating the CCBT, the construction costs of the sample projects were calculated for the ground and basement floors.

The construction costs for ground floors were calculated for MFH facilities with 16–25 floors and housing units with exclusive residential areas (living room, dining room, bathroom, and bedroom) with dimensions between 60 and 85 m^2. Note that the construction costs for ground floor units include costs for residential facilities, as well as other public facilities, welfare facilities, landscaping, and roads (direct and indirect construction costs). Additionally, the ground floor CCBT includes design, supervision, and other incidental expenses. Therefore, the ground construction costs for each sample project included these factors. The following results were obtained for the ground floor construction costs for each sample project (Table 5).

Table 5. Ground-floor construction costs of each project.

Category	Existing	Project 1	Project 2	Project 3	Project 4
Direct cost	961	956	967	963	951
Indirect cost	376	375	371	377	370
Sub-total ①	1337	1331	1339	1340	1321
Design and CM ②	51	45	38	57	38
Incidental expenses ③	87	93	93	94	93
CCBT (① + ② + ③)	1475	1470	1470	1491	1452
Ratio	-	99.64%	99.64%	101.09%	98.42%

Unit: \$/m^2, supply area.

The basement floor construction costs include the costs of constructing and installing various underground facilities (underground parking lots, electrical rooms, mechanical rooms, sewage purification tanks, underground water tanks, and pit layers), as well as the costs for setting up mechanical equipment for maintaining such facilities. The following results were obtained for the basement floor construction costs for each sample project (Table 6).

As shown in Tables 5 and 6, the CCBT of the sample project tends to be usually slightly lower than the existing CCBT [2]. This trend is particularly noticeable on the basement floor owing to the fact that the existing CCBT [2] includes the costs of the 15 m long PHC-pile with a diameter of 500 mm. However, this study excluded the cost of the PHC-pile from the basement floor CCBT; particularly, it appears reasonable to only consider the actual construction costs in the sale price because the number and length of the PHC-pile to be constructed may vary depending on the ground conditions at the construction site. Therefore, we adopted a method for calculating the adding expenses rather than the CCBT.

Table 6. Basement-floor construction cost of each project.

Category	Existing	Project 1	Project 2	Project 3	Project 4
Direct cost ①	592	522	472	541	485
Indirect cost ②	228	203	181	211	184
CCBT (① + ②)	820	726	653	752	669
Ratio	-	88.50%	79.61%	91.69%	81.58%

Unit: $\$/m^2$, supply area.

4.3. Weighted Average Method for Improving the CCBT

A method for CCBT calculation that considers a larger number of sample projects and wider regional spread was adopted. Notably, a previous study [2] did not consider regional differences; the authors decided to use a weighted average method that considered the per-supplied area construction cost of each sample project and the number of housing units sold in each region over the past 3 years based on expert interviews (Table 7).

Table 7. Number of new MFH units.

Category	Metropolitan	South	Central
No. of new MFH units (2019 to 2021.)	247,154	176,056	88,583

As mentioned above, the supply prices of various materials and equipment vary depending on the number of new MFH units in each region. In addition, a continuity with the existing method of calculating CCBT must be considered. Thus, herein, two sample projects were selected for the metropolitan region and were assigned twice the weight of other projects on top of the weight value determined by the number of housing units sold. The detailed construction costs (direct costs, indirect costs, design/supervision costs, and incidental expenses) were calculated via a weighted average method. The weighted average method developed for the CCBT can be expressed as

$$C_n = \frac{2(f_n \times x1) + (f_n \times x2) + (f_n \times x3)}{(x1 \times 2) + x2 + x3} \tag{1}$$

where C_n is the construction cost for each factor, C_1 is the direct cost, C_2 is the indirect cost, C_3 is the design fees, C_4 is the CM fees, and C_5 is the incidental expenses; x is the number of MFH units sold in the past 3 years; x_1 is in the metropolitan region (247,154); x_2 is in the southern region (176,056); and x_3 is in the central region (88,583); f_n is the detailed construction cost factor; f_1 is the materials cost; f_2 is the labor cost; f_3 represents the overhead expenses f_4 is the design fee; f_5 is the supervision fee; and f_6 represents the incidental expenses.

$$y = \sum_{n=1}^{6} C_n \tag{2}$$

where y is the CCBT and C_n is the construction cost for each factor.

The improvement CCBT is presented in Table 8. The ground floor CCBT was calculated as 1468 $/m^2, and it included a direct cost of 957 $/m^2 (that is, material costs: 494 $/m^2, labor costs: 436 $/m^2, and overhead expenses: 27 $/m^2), an indirect cost of 373 $/m^2, a design fee of 32 $/m^2, a CM fee of 13 $/m^2, and an incidental expense of 93 $/m^2. Additionally, the direct cost for the basement floor was 510 $/m^2 (material costs: 269 $/m^2, labor costs: 224 $/m^2, and overhead expenses: 16 $/m^2), and the indirect cost was 197 $/m^2; thus, the CCBT of the basement floor was calculated to be 706 $/m^2.

Table 8. Improving the CCBT.

CCBT Component			Existing [2]	This Study
Ground floor	Direct costs	Material costs	961	494
		Labor costs		436
		Overhead Expenses		27
	Indirect costs		376	373
	Design fee		36	32
	CM Fee		15	13
	Incidental expenses		87	93
	CCBT		1475	1468
Basement floor	Direct costs	Material costs	592	269
		Labor costs		224
		Overhead expenses		16
	Indirect costs		228	197
	CCBT		820	706

Unit: $/m^2, supply area.

As explained above, in this study, the CCBT was calculated by excluding the PHC-pile, which is why it demonstrated a slight decrease. Notably, even though the PHC-pile was excluded from the CCBT, quality and structural problems of the MFH did not occur as it was considered as an adding expense item. Cha et al. [3] argued that the PHC-pile costs were found to be 2–3% of the CCBT. Moreover, the new CCBT is expected to reflect latest design trends that do not differ significantly from those in the previous CCBT.

4.4. Improving the CCBT Description

The CCBT differs based on the number of floors in an MFH project. For the existing The CCBT differs based on the number of floors in an MFH project. For the existing method of calculating the CCBT, the highest floor category involves 36 or more floors. However, because the heights of MFH projects have increased in recent years, more segmented floor categories are required. Consequently, herein, the CCBT calculation method was proposed by extending the maximum number of floors to 49.

The CCBT was calculated based on exclusive residential areas. With the recent increase in the number of one- and two-person households, more housing units with exclusive residential areas of 60 m^2 or less are being constructed. Moreover, with the diversification of the floor plans in small housing units, more resources are being committed to the construction of windows, doors, bathrooms, and kitchens using various types and quantities of materials and equipment, leading to an increase in the per-unit area construction costs. Therefore, this study used per-area construction cost records provided by certain private constructors and public owners to analyze the per-supplied area construction costs. Our analysis revealed the existence of large errors in the per-area construction costs. Furthermore, the immediate implementation of this idea in the overall construction cost calculation was anticipated to create a large burden on the consumers.

The results of CCBT calculation based on the floor number and area applied according to the above-mentioned criteria are shown in Table 9. The CCBT variable rate for each supply area calculated based on the 16–25 floor 60–85 m^2 Type was 98.5–109.5%, and the

CCBT variable rate for each floor was calculated as 100–102.8%. Additionally, the basement floor CCBT was calculated to be 706 $/m^2.

Table 9. Improving the CCBT based on the area and floor.

Ground Floor CCBT							(Unit: \$/m^2, Supply Area)	
Floor	**~40m^2**	**~40–50 m^2**	**~50–60 m^2**	**~60–85 m^2**	**~85–105 m^2**	**~105–125 m^2**	**~125 m^2**	**Variable**
~5F	1480	1509	1472	1446	1486	1467	1448	98.5%
~6–10F	1585	1615	1575	1548	1590	1571	1550	105.4%
~11–15F	1487	1515	1478	1452	1492	1473	1455	98.9%
~16–25F	1503	1532	1495	1468	1509	1490	1471	100.0%
~26–30F	1527	1556	1518	1491	1533	1514	1494	101.6%
~31–35F	1552	1582	1543	1515	1557	1538	1518	103.2%
~36–40F	1575	1607	1566	1539	1581	1562	1541	104.8%
~41–45F	1597	1628	1587	1559	1603	1582	1562	106.2%
~46–49F	1646	1678	1636	1607	1652	1632	1611	109.5%
Variable	102.4%	104.4%	101.8%	100.0%	102.8%	101.5%	100.2%	-
Basement-floor CCBT							**(Unit: \$/m^2, supply area)**	
Basement floor							706	

5. Case Study and Discussion

To validate the CCBT calculation method developed in this study, a case study was conducted, wherein we selected an MFH project recently sold by a public owner. We selected cases with conditions similar to those of the sample projects for calculating the CCBT. With regard to case details, the project had an exclusive area of 84 m^2 (standard for CCBT calculation) and was located in a metropolitan area; it had 15–16 ground floors, one basement floor, and 700 households (refer to Tables 10 and 11).

Table 10. Case summary.

Category	**Case Information**	
Bird's-eye view		
Types	 84 m^2 B type	 114 m^2 type
Unit	795 units	
Region	Metropolitan	
No. of Floors	15–16 GF, 1 BF	

Table 11. Case information for each type.

Type	Supply Area	Basement Area	No. of Households	Floor
84 m^2 A	115.71 m^2	59.70 m^2	120ea	16–25
84 m^2 B	116.02 m^2	59.64 m^2	32ea	16–25
84 m^2 C	115.41 m^2	59.37 m^2	64ea	16–25
114 m^2	155.97 m^2	80.70 m^2	128ea	16–25
84 m^2 A	115.71 m^2	59.70 m^2	56ea	11–15
84 m^2 B	116.02 m^2	59.64 m^2	240ea	11–15
84 m^2 C	115.41 m^2	59.37 m^2	75ea	11–15
59 m^2	82.82 m^2	42.02 m^2	80ea	11–15

The CCBT calculation method proposed in this study was applied to the selected case, and its accuracy was examined by comparing the results with the actual construction cost base sale price for the MFH. To compare the proposed CCBT base sale price with the actual construction cost, the base sale price had to be first determined according to the construction costs. For this, the ground floor and basement construction costs were calculated by multiplying the supply area with the ground CCBT and the basement area with the basement CCBT (Equation (3)), respectively.

$$Construction\ Cost = \sum\begin{bmatrix}(Ground\ floor\ supply\ area \times \text{ Ground floor } CCBT\ by\ floor) \\ +(Basement\ floor\ area \times \text{ Basement floor } CCBT)\end{bmatrix} \tag{3}$$

For instance, to explain the 84 m^2 B type depicted in Table 10, the exclusive area per household was 84.95 $m^{2\cdot}$, and the public area (stair hall, community area, security office, etc.) was 30.76 m^2. Therefore, the supply area was 115.71 m^2 (84.95 + 30.76), and the basement floor area was 59.7 m^2. Here, 60 and 28 households were built in a building with 25 floors and 15 floors, respectively. By applying Equation (3) mentioned above, the construction cost of a building (84 m^2 A–C, 16–25 floors) was calculated based on the CCBT (60–85 m^2, 16–25 floors). Similarly, the construction cost was calculated using Equation (3) for all types of buildings.

$$\begin{aligned}&\left[\left\{\left(115.71\mathrm{m}^2 \times \$1468/\mathrm{m}^2\right) + \left(59.70\mathrm{m}^2 \times \$706/\mathrm{m}^2\right)\right\} \times 120\mathrm{ea}\right] + \left[\left\{\left(116.02\mathrm{m}^2 \times \$1468/\mathrm{m}^2\right)\right.\right. \\ &\left.\left. +\left(59.64\mathrm{m}^2 \times \$706/\mathrm{m}^2\right)\right\} \times 32\mathrm{ea}\right] + \left[\left\{\left(115.41\mathrm{m}^2 \times \$1468/\mathrm{m}^2\right)\right.\right. \\ &\left.\left. +\left(59.37\mathrm{m}^2 \times \$706/\mathrm{m}^2\right)\right\} \times 64\mathrm{ea}\right] = \$45,764,374.4\end{aligned}$$

Table 12 lists the construction costs for the sale prices of MFH in terms of the floor and area, which are calculated as described above. The CCBT calculation method proposed in this study was applied to this case, and the construction cost in the sale price of MFH per supply area was found to be approximately 1833.51 $.

Table 12. CCBT base sale price per supply area.

Floor	Area	Supply Area (m^2)	CCBT ($/$m^2$)
16 to 25 floors	60–85 m^2	24,984.08 m^2	45,764,374.40 $/$m^2$
	105–125 m^2	19,964.16 m^2	37,418,615.04 $/$m^2$
11 to 15 floors	60–85 m^2	42,980.31 m^2	78,016,752.42 $/$m^2$
	50–60 m^2	6625.6 m^2	12,165,926.40 $/$m^2$
Summary		94,554.15 m^2	173,365,668.26 $/$m^2$
Sale price per supply area		-	1833.51

Meanwhile, although public owners have focused on providing MFH facilities to secure national residential stability, they have refused to disclose construction costs owing to the adequacy of the sale prices calculated by public owners. This behavior has stemmed from insinuations that public owners imparted with the responsibilty of stabilizing national housing pursue excessive profitability. Nevertheless, as the status of national housing remains unstable owing to various international factors (inflation, war, and interest rates), affecting MFH prices in South Korea, the need to disclose actual construction costs has increased. Therefore, public owners have attempted to stabilize national housing by disclosing the actual construction costs. Table 13 presents the actual sale price construction cost that constitutes the basis for calculating the sale price of MFH and the cost excluding the land construction and interest costs during the construction period. Consequently, the construction costs per supply are approximately 1995.22 $; however, they include the adding expenses (land and construction costs).

Table 13. Base sale price per supply area with adding expenses.

Category	Actual Construction Cost
Constriction costs (direct and indirect)	166,271,176
Design and CM fee	6,870,547
Incidental expenses	15,514,543
Summary	188,656,266
Actual sale price per supply area	1995.22/ m^2

This section presents a comparative analysis of the results of our CCBT calculation method with the actual costs when construction costs as disclosed. Accordingly, the CCBT base sale price found in our analysis is 91.9% (1833.51 $/m^2$/1995.22 $/m^2$); of the actual sale price (however, the CCBT base sale price excludes the land development and interest costs).

However, as described above, the cases include the adding expenses of construction, as well as the adding expenses of land costs. As described in Table 1, the cases can include adding expenses of construction costs such as the expenses of structure types (0–5%), degree of performance for MFH (1–4%), balcony extension (1–2%), and intelligent facilities. In actual cases, 5% of the rigid-frame structure (incorporating the structure type) and 2% of the degree of performance certification are added (refer to Figure 3), and the other added ratio items such as the PHC-pile and intelligent facility costs remain undisclosed. Furthermore, as shown in Table 1, the actual cases also include the PHC-pile costs that represent adding expenses within the land costs. Cha et al. [3] argued that PHC-pile costs account for 2–3% of the CCBT. Therefore, the construction adding expense ratio is approximately 5–10%, and the PHC-pile adding expenses are 2–3% [3], thereby accounting for 7–13% of the CCBT.

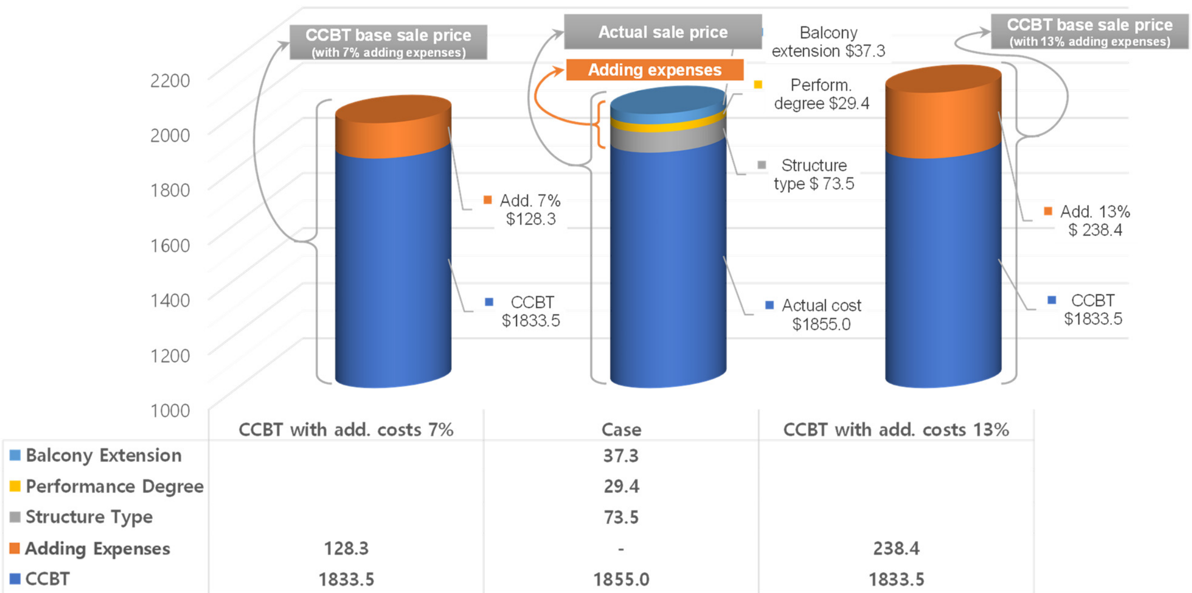

Figure 3. Composition of the CCBT and the actual case base sale price.

Owing to the application of the case given in Table 14, the CCBT base sale price obtained in this study was in the 98.3–103.84% range of the actual construction base sale price accounting for the adding expenses (however, the actual case also includes PHC-pile and intelligent facility cost). According to the Association for the Advancement of Cost Engineering International (AACE International), Class 1 represents the construction phase, when a cost estimation accuracy of +3–15% denotes the high expected actual cost, and a cost estimation accuracy of −3–10% denotes the low expected actual cost [32]. Although some deviation may be noted in the results of the application case, the CCBT calculated based on the proposed method appears relatively accurate. Therefore, this study contributes toward the calculation of objective sale prices to ensure national housing stability and can contribute to cost analysis.

Table 14. Result of comparison of the CCBT and the actual cases sale price.

Category	Sale Price ($)	Ratio	Deviation ($)
CCBT with added expenses 7%	1961.8	98.33%	−33.36
Actual case	1995.2	100%	-
CCBT with added expenses 13%	2071.9	103.84%	+76.66

6. Conclusions

This study improved the existing CCBT calculation method, which was proposed shortly before 2018, by adopting a practical and academic perspective while considering the effects of COVID-19 and Ukraine–Russia war circumstances. We believe that this study presents a novel CCBT calculation approach based on latest sample projects while considering the recent domestic and international circumstances.

To ensure the appropriateness of the CCBT, four recent sample projects were selected based on strict selection criteria (number of households, areas, number of floors, and region). The detailed bill of quantities and drawings of the four sample projects were analyzed and classified into ground floor CCBT, basement floor CCBT, and adding expenses that constituted the sale price. Compared to the previous CCBT [2], the CCBT of the ground floor was 99.5% ($1475/$1468) and that of the basement floor was 86.1%. ($820/$706). For the basement floor CCBT, a large cost deviation was noted because the PHC-pile was excluded as an adding expense; however, the results were similar to the results of a previous study [3]. To validate the proposed CCBT calculation approach, it was applied to a recently built MFH unit. In this application, we compared the sale price obtained based on the new CCBT with the actual case construction cost (excluding housing site preparation costs and interest cost). In general, the proportion of adding expenses in the sale price was in the 7–13% range; however, the CCBT base sale price was in the 98.3–103.84% range compared to the actual case. Therefore, the results of this study are within the range of the Class 1 AACE cost estimate [32], thereby indicating high accuracy. Thus, we verified that the CCBT value obtained in this study falls within the range of the internationally accepted value. Overall, this study contributes from both practical and academic aspects to the field of construction cost management.

Despite these practical and academic contributions, this study has certain limitations. First, the CCBT needs to be further validated for various cases. However, it can be applied when public owners disclose construction costs; therefore, we can expect public owners to play a role in stabilizing the national housing needs. Second, it is necessary to select more sample projects from each state to ensure representativeness. However, numerous samples are not required because the design criteria differ across design periods and regions. Instead, the number of samples should be increased based on strict criteria for sample project selection. Finally, if the consideration of adding expenses can facilitate determination of the CCBT ratio, more accurate comparative analysis results can be obtained.

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