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An Analysis of the Characteristics of the Environmental Impact of Residential Facilities in Korea

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Abstract

The study analyzes the characteristics of the environmental impact involving residential-commercial buildings, which have rapidly emerged lately as the major residential facilities in city centers, and conducts a comparative analysis involving apartment buildings, the subject for earlier studies. By using the results from the current study and those earlier studies, I have presented a method for assessing the environmental impact involving the major residential facilities of Korea. The study has analyzed the environmental impact from residential-commercial buildings as 4.62E-02pe·yr/㎡ on average, which is about 50% higher compared to apartment buildings. Also, the selection and evaluation of principal construction materials, which has included an analysis of sensitivity to environmental impact for respective construction materials for specific targets, has resulted in an average error rate of 4.1%.

Keywords: Residential-Commercial Building, Apartment Building, Life Cycle Assessment, Environmental Impact, Input-Output Analysis

1 Introduction

The Korean studies that assess the environmental impact of the construction industry have focused on buildings representing different uses, due to the local presence of diverse buildings. Studies on residential facilities have focused on apartment buildings that take up 58%[1], but lately, owing to Korean government policy and the interests of construction companies and consumers, residential-commercial buildings that mix commercial and residential facilities have rapidly emerged[2], thus establishing themselves as the city center's representative residential facilities.[3]

Thus, with a view to an environmental impact assessment for Korea's major residential buildings, the study has tapped into the results of earlier studies[4] conducted on apartments to perform a comparative analysis of the characteristics of environmental impact involving residential-commercial buildings, and has used earlier studies and the results of the current study to present a method for assessing the environmental impact involving Korea's major residential buildings.

2 Methodology

2.1 Overview and Composition of LCA

LCA is defined as a method for listing all inputs and outputs for all the stages of a product's life and assessing the potential environmental impact related to them.[5] LCA includes the four stages of Goal and Scope Definition, Life Cycle Inventory analysis (LCI), Life Cycle Impact Assessment (LCIA), and Life Cycle Interpretation. So, implementing an LCA on a building must presuppose[6] the creation of LCI DB on the construction materials that constitute the specific building. Korea has so far 417 databases created through a government-led process analysis, with a focus on basic materials and basic industries.[7] With 26 construction materials included among them, however, it is difficult to conduct an LCA on a building that is made up of countless materials. Inasmuch as process analysis is a method for creating an LCI DB on types and quantities of all materials put in a product, and environmental loads and by-products by guessing a series of production processes, it is impossible to create a database on all materials that make up buildings, as it requires a lot of time, cost, and manpower.

In this regard, the study has created an LCI DB on deployed construction materials by using input-output analysis[8][9] that performs an indirect estimation of the input & output quantities in a broad scope. Here, using the LCIA DB[10] specific to different environmental loads in the earlier studies, I have performed environmental impact assessment for residential-commercial buildings.

2.2 Environmental Impact Assessment Method Specific to Building Characteristics

While input-output analysis is used to perform Environmental Impact Assessment (EIA) for buildings, an analysis of construction materials deployed into a building takes a long time and a lot of money. As a solution to this problem, this study suggests a method for performing EIA through the analysis of the characteristics of environmental impact from the construction materials deployed in various residential-commercial buildings.

For EIA specific to the characteristics of residential-commercial buildings, the environmental impact for different deployed construction materials is assessed while the sensitivity to the environmental impact from deployed construction materials is analyzed for different buildings. Deployed construction materials are classified into principal and other materials, based on the analysis of the characteristics of environmental impact. Here, for principal construction materials, those materials that register large variation with different buildings instead of those that register big environmental impact are selected while others that don't belong to the principal group are classified into other construction materials, thus creating a DB.

As for a method for evaluation specific to the characteristics of environmental impact, principal construction materials are analyzed to calculate environmental impact, to which the unitary area (/㎡) of other construction materials that register small or no variations is applied for evaluation.

3 Analysis Result

3.1 Results of the Selection of the Scope of Construction

The buildings analyzed for this study belong to eight residential-commercial building compounds (with 31 buildings) newly built in large cities of Korea between 2004 and 2015, which are classified into the five work types of construction, mechanical, electrical & communications, civil engineering, and landscaping, with 44 types of detailed work.

3.2 Results of Environmental Impact Assessment

Through input-output analysis, I have calculated the discharge of environmental load from different construction materials deployed into the construction of the 31 residential-commercial buildings in the eight compounds, through which EIA has been conducted.

Table 1 below shows the results of EIA for different work types of residential-commercial buildings in comparison with the apartment buildings in the results of earlier studies.

Table 1. Results of Work Type-Specific EIA for Residential-Commercial Buildings and Apartment Buildings

Category		Construction	Mechanical	Electrical & communications	Civil	Landscaping	Total
Residential-commercial	Building	3.20E-02	8.42E-03	5.73E-03	-	-	4.62E-02
	(pe·yr/㎡)	69.3%	18.2%	12.4%	-	-	
	Site	-	-	-	3.72E-02	1.33E-02	5.05E-02
	(pe·yr/㎡)	-	-	-	73.7%	26.3%	
Apartment building	Building	2.62E-02	3.91E-03	9.89E-04	-	-	3.11E-02
	(pe·yr/㎡)	84.3%	12.6%	3.2%	-	-	
	Site	-	-	-	2.92E-03	1.73E-03	4.65E-03
	(pe·yr/㎡)	-	-	-	62.8%	37.2%	

※pe·yr is a unit that indicates the environmental impact generated in a specific area (the sphere of influence commanded by environmental load) per population (1 person) to ensure comparison, and it applies weighted value to [(environmental load x characterization coefficient)/normalization coefficient].

As shown on Table 1, the results of EIA per unitary area (/㎡) of residential-commercial buildings show in the descending order of construction, civil engineering, landscaping, mechanical, and electrical & communications. Also, when compared to the environmental impact from the Korean apartment buildings as treated in the earlier studies, residential-commercial buildings have been analyzed as registering about 50% more. And this has proven to be because residential-commercial buildings, which tend to be higher and larger than 15F to 20F apartment buildings, use structural materials (reinforcing bars and steel frames) that register big environmental load. It has also proven to be because high-grade finishing materials and various latest facilities and systems have been applied in accordance with the trend for preferring upscale buildings. In civil works that have site area calculated against buildings, high floor area ratio peculiar to residential-commercial buildings necessitates it to secure underground parking and neighbor living facilities, which results in deeper underground floors, thus showing its big environmental impact compared to apartment buildings.

3.3 Environmental Impact Assessment Specific to Building Characteristics

1) Results of the Selection of Principal Construction Materials

For the selection of principal construction materials, sensitivity analysis was performed by calculating the environmental impact from construction materials deployed in the residential-commercial buildings selected for the analysis. Sensitivity analysis conducted three-stage selection. The first selection, which is designed to select principal construction materials, chose only those materials that were overlapped among minimum one third (minimum 10) of 31 buildings. Second selection tapped those materials among the ones included in the first selection that

varied greatly with buildings. Third selection minimized the number of principal construction materials among the ones included in the second selection.

Table 2 below shows the comparison of the final selection of principal materials for residential-commercial buildings and the results of the selection of principal construction materials for apartment buildings in earlier studies.

Table 2. Results of the selection of principal construction materials for residential-commercial buildings and apartment buildings

Classification	Residential-commercial building						Apartment building			
	Name of materials	Average environmental impact (pe·yr/㎡)	Ratio (%)	Variation (pe·yr/㎡)	Work type	Detailed work	Name of materials	Average environmental impact (pe·yr/㎡)	Work type	Detailed work
Building	deformed reinforcement	1.06E-02	23.0	3.02E-03	Construction	Reinforced concrete work	High strength reinforcing bar	9.52E-03	Construction	Reinforced concrete work
	Kitchen furniture	1.33E-03	2.9	5.23E-04	Construction	Furniture work	Pile	9.57E-04	Construction	Land leveling
	Tile	2.32E-03	5.0	4.81E-04	Construction	Tile work	Ultra high strength rebar	1.63E-03	Construction	Reinforced concrete work
	Built-in wardrobe	8.63E-04	1.9	4.38E-04	Construction	Furniture work	Ready-mixed concrete	4.53E-03	Construction	Reinforced concrete work
	AL windows	1.43E-03	3.1	4.29E-04	Construction	Windows installation	Gangform	5.97E-04	Construction	Reinforced concrete work
	Ready-mixed concrete	2.30E-03	5.0	4.07E-04	Construction	Reinforced concrete work	AL windows	1.06E-03	Construction	Windows installation
	Shoe storage	3.50E-04	0.8	3.42E-04	Construction	Furniture work	Plastic windows	1.05E-04	Construction	Windows installation

	Alform	6.50E-04	1.4	2.75E-04	Construction	Reinforced concrete work	Metal windows	2.80E-04	Construction	Windows installation
	Double layer color glass	4.78E-04	1.0	1.73E-04	Construction	Glass work	Prefab PD	1.13E-03	Mechanical	Fire extinguishing installation
	Marble floor	1.56E-04	0.3	9.39E-05	Construction	Stonemasonry	Home door	3.00E-04	Construction	Windows installation
	Metal windows	3.67E-04	0.8	5.93E-05	Construction	Windows installation	Euroform	1.03E-04	Construction	Reinforced concrete work
	Gangform	2.74E-04	0.6	4.43E-05	Construction	Reinforced concrete work	Kitchen furniture	5.97E-04	Construction	Kitchen utensil installation
	Cabinet	8.85E-05	0.2	2.93E-05	Construction	Kitchen furniture	Shoe storage	1.91E-04	Construction	Furniture work
	Alsheet	1.60E-04	0.3	2.46E-05	Construction	Metal work	Dry mortar	8.29E-04	Construction	Plaster work
	Plywood	5.18E-05	0.1	1.35E-05	Construction	Interior woodworking	Alform	1.04E-03	Construction	Reinforced concrete work
Civil	High strength reinforcing bar	1.08E-02	28.6	5.57E-03	Civil	Principal materials	deformed reinforcement	9.80E-04	Civil	Drainage work
	Ready-mixed concrete	8.30E-03	22.3	2.74E-03	Civil	Principal materials	High strength reinforcing bar	6.82E-04	Civil	Utility tunnel construction
	deformed reinforcement	8.12E-04	2.1	1.46E-03	Civil	Principal materials	High strength reinforcing bar	5.64E-04	Civil	Underground reservoir construction

	-	-	-	-	-	-	Earth anchor	5.60E-04	Civil	Earth retainment work
	-	-	-	-	-	-	deformed reinforcement	4.73E-04	Civil	Waste water work
	-	-	-	-	-	-	deformed reinforcement	4.51E-04	Civil	Retaining wall installation
	-	-	-	-	-	-	Ultra high strength rebar	3.56E-04	Civil	Underground reservoir construction
	-	-	-	-	-	-	H-steel	3.54E-04	Civil	Earth retainment work
	-	-	-	-	-	-	Round water pipe	3..47E-04	Civil	Drainage work
	-	-	-	-	-	-	Ready-mixed concrete	2.24E-04	Civil	Retaining wall installation
Landscaping	Vegetation	4.48E-03	33.7	1.70E-03	Landscaping	Vegetation Work	Vegetation	5.83E-04	Landscaping	Vegetation Work

For residential-commercial buildings (construction, mechanical, electrical & communications), total 15 principal materials were selected for construction alone, which took up about 46% of the environmental impact involving the buildings. Unlike apartment buildings, no more principal materials were selected for mechanical and electrical & communications for residential-commercial buildings.

Since detailed work with such materials as are commonly adopted in specifications, three construction materials were selected for civil works in contrast with apartment buildings, which took up about 53% of the environmental impact for civil works. For landscaping, as for apartment, vegetation alone was selected as a principal material.

Other materials except the principal ones are classified as other construction materials, and the average environmental impact per unitary area (/㎡) as compiled into the database is compared with apartment buildings as shown on Table 3 below.

Table 3. Results of the Assessment of Average Environmental Impact for Principal and Other Construction Materials

Classification		Principal materials		Other materials	
		Environmental impact(pe·yr/㎡)	Ratio (%)	Environmental impact(pe·yr/㎡)	Ratio (%)
Residential-commercial	Building (construction + mechanical + electrical & communications)	2.14E-02	46.4	2.48E-02	53.6
	Site (civil works+landscaping)	2.44E-02	48.3	2.61E-02	51.7
Apartment	Building (construction + mechanical + electrical & communications)	2.10E-02	67.3	1.02E-02	32.7
	Site (civil works+landscaping)	2.03E-03	43.7	2.61E-03	56.3

2) Results of Environmental Impact Assessment Specific to Characteristics of Buildings

A comparison of the actual EIA that put area in the analyzed building and the assessment that applied the database for principal and other construction materials is presented in Fig. 1 below.

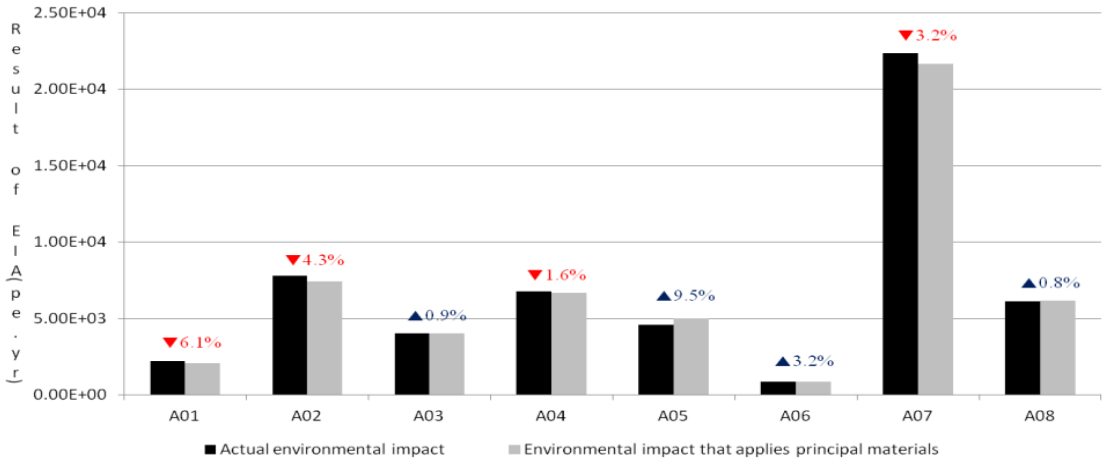

Fig 1. Results of EIA that Applies Principal Construction Materials

The EIA that took into account principal construction materials for residential-commercial buildings showed that margin of errors was maximum 9.5% and minimum 0.8%, while average error rate was 3.7%, which was smaller than 4.1%, the average error rate for apartment buildings as treated in earlier studies.

4 Conclusion

With a view to conducting an EIA for Korea's major residential buildings, this study has analyzed the characteristics of environmental impact involving residential-commercial buildings in comparison with the results of earlier studies on apartments. In the study, I have tapped into the results from the earlier studies and the current study to present a method for assessing the environmental impact of Korea's major residential buildings.

1) The analysis of the project specifications for 31 residential-commercial buildings of Korea (in 8 compounds) shows that environmental impact from the construction materials deployed in the five work types showed in the descending order of civil works, construction, landscaping, mechanical, and electrical & communications, while the environmental impact from residential-commercial buildings showed about 50% bigger than that from apartment buildings.
2) The analysis of sensitivity for different construction materials in surveyed buildings, which was conducted using the above results in order to conduct EIA according to the characteristics of residential-commercial buildings, has selected 15 principal materials including three in civil works and one in landscaping for buildings that comprise construction, mechanical, and electrical & communications.
3) The comparison of the results of actual EIA for surveyed buildings with the EIA that applies the DB on principal and other construction materials came up

with an average margin of error at 3.7%, which is smaller than 4.1%, the average margin of error for apartment buildings. The analysis suggests that using the evaluation method to survey residential-commercial buildings and apartment buildings, which are major residential facilities of Korea, will secure a high reliability with an average margin of error at 5% with small effort.

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References

[1] Statistics Korea, "2010 Population and Housing Census", http://www.census.go.kr
[2] J.S. Yang, "Investigation of Residential Conditions and Proposlas for Preserving Residential Uses in Downtown Seoul", Seoul Development Institute , (2001)
[3] W.K. Lee, "A Study on the Locational Characteristics of the 'Mixed Use Building Development' – the case of Seoul -", master's thesis, University of Seoul, (2007)
[4] D.S. Choi, H.C. Jeon and K.H. Cho, "Study on Environmental Impact through Analysis of Materials Used for Apartment Complex", journal of the Architectural Institute of Korea, 30, 9, (2014), 195-204
[5] ISO, "ISO14040 Environmental management - Life Cycle Assessment - principles and frame", (2006)
[6] ISO "ISO14044 Environmental management - Life Cycle Assessment - Requirements and guidelines", (2006)
[7] Korea LCI Database Information Network, http://www.edp.or.kr/
[8] The Bank of Korea, "2010 Input-Output Tables", (2014)
[9] D.S. Choi, H.C. Jeon and Y.H. Jung, "Proposal of Simplified LCA Technique for Potential Environmental Impact Assessment of The Construction Materials", Journal of Korean Society of Living Environment System, 20, 6, (2013), 755-768
[10] M.J. Ko, H.C. Jeon, K.H. Cho, J.H. An and D.S. Choi, "A Trend analysis on the Environmental Impact of Construction Industry in Korea", International Journal of Applied Engineering Research, 9, 24, (2014), 24827-24835
[11] Y.C. Choi, H.C. Jeon and H.D. Kim, "A Study on Environmental Impact Assessment of Residential-Commercial Building through the Analysis of Construction Material Input in Korea", Workshop on Architecture and Civil Engineering 2015, SERSC, 89, (2015), 15-19