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Development of Impact Table and optimum combination dedication module for green-remodeling advance business value assessment

Choi, Jun-Woo* · Kim, Gyoung-Rok** · Ko Jung-Lim*** · Shin, Jee-Woong**** · Lee, Keon-Ho*****

* *Division of New Business Dev. & Abroad Business, EAN Technology, Seoul, Korea (cjw@eantec.co.kr)*
** *Sustainable Engineering Division 2, EAN Technology, Seoul, Korea (kgr@eantec.co.kr)*
*** *Division of New Business Dev. & Abroad Business, EAN Technology, Seoul, Korea (jlko@eantec.co.kr)*
**** *EAN Technology, Seoul, Korea (sjw@eantec.co.kr)*
***** *Division of Public Architecture, Korea Institute of Construction Technology, Gyeonggi-do, Korea (lee1ncdh@kict.re.kr)*

ABSTRACT

Purpose: In case of existing building, A lot of attempts are being made like changing thermal system or using high efficiency products to decrease energy load and increase energy efficiency. However, (1) Absence of systemed database of green-remodeling technology and products. (2) Absence of comparative analysis system and qualitative/quantitative evaluation method of energy performance and energy reduction cost. (3) Existing remodeling was very hard to access for non-experts. So, in this paper, the authors developed data base for green-remodeling(Impact Table A, Impact Table B) and optimum combination dedication tool for user convenience. Accordingly, purpose of this paper validate usefulness of Impact Table and optimum alternative dedication tool. **Method:** For validate the usefulness of Impact Table and optimum combination dedication tool, the authors selected five test model office buildings. Next, through research investigation, the authors diagnosed the present state of buildings. In base of diagnosis results, select technologies for remodeling by qualitative comparison (Impact Table A). Next, evaluate quantitative price and performance technologies that selected in Impact Table A (Impact Table B). Lastly, through final evaluation of Impact Taba A and Impact Table B, determine the direction of the green-remodeling. **Result:** Impact Table and optimum combination dedication tool can use relative indicator for green-remodeling, especially through ROI by detail field.

KEYWORD

Green-remodeling
Energy performance
Impact Table
Optimum combination

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1. Introduction

1.1. Research Background and Purpose

Nowadays, people have more interest in low-energy buildings due to worsened environmental pollution and thus increased value of ecological conditions. Accordingly, various policies and systems are being enforced to reduce energy load. Particularly for old buildings, attempts have been made to remodel them by replacing old system or using energy-efficient materials to reduce existing energy load and increase energy efficiency old buildings.

As for Korea, it has also made several efforts to activate green-remodeling market at the dimension of policy and system: information sharing through integrated energy DB of buildings (Korea Energy Economics Institute, 2015), setting green-remodeling guideline through demonstration or pilot projects and phased compulsory implementation, attraction to green-remodeling using private finance and interest preservation (Green-Remodeling Creation Center, http://www.green remodeling.or.kr/).

However, such problems as followings prevent from making preliminary feasibility decision, which is necessary to remodel existing old buildings. First, there is no systemized database of the elemental technology of green-remodeling by sector. Second, quantitative, qualitative, integrated comparison, and analysis system are absent for the evaluation of energy performance and cost of energy reduction. Last, since existing green-remodeling techniques heavily depend on expert's subjective judgement and expertise, non-experts have difficulty having access to them and it is also hard to obtain and derive objective and quantitative data out of them through objective and quantitative data analysis.

In this respect, this study developed a plan for qualitative and quantitative evaluation of old structure remodeling by element (exterior envelope, lighting, thermal source·air conditioning, new and renewable energy) and by use of existing building (large/small office facility, and apartment house) and Impact Table in which performance/cost database is provided by sector. In addition, this study developed preliminary study checklist and optimum combination dedication module (tool) in order to increase the usability of Impact Table and user's convenience.

And then Impact Table and optimum combination dedication module, which were developed in this study, were applied to 5 actual test models as pilot project to verify the usability and applicability of the proposed method. Last, the results from the evaluation of

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optimum combination dedication module were used to determine the suitability of preliminary business feasibility evaluation based on Impact Table for the decision making of green-remodeling project and limitations and the need of further study were pointed.

1.2. Method and Scope

This study was conducted in the following order. First, Impact Table, preliminary study checklist for Impact Table, the components of optimum combination dedication module were analyzed. And then, 5 pilot project models (5 physical places) were chosen; a preliminary study checklist for each model was prepared; and the technological elements for green-remodeling were selected based on the checklist (using optimum combination dedication module). Last, the performance and cost of the chosen technological elements were analyzed to find an optimum combination for green remodeling. Then, the optimum green remodel was evaluated and the results were analyzed and verified to determine the suitability of preliminary business feasibility evaluation based on Impact Table for the decision making of green-remodeling project. Limitations and the need of further study were pointed out. (Fig 1).

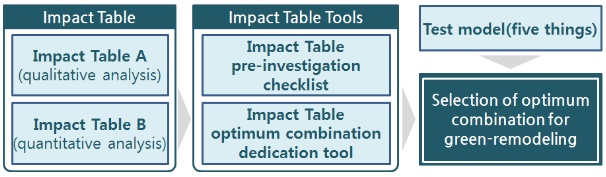


Fig 1. Study process of optimum alternative for green-remodeling

2. Outline and Composition of Impact Table

2.1. Outline of Impact Table

Impact Table is the database of performance and cost of green remodeling project by sector (exterior envelope, lighting, thermal source·air conditioning, new and renewable). Therefore, it facilitates to review various alternatives in the stage of pre-design or schematic design of green remodeling project, and helps a client or a designer reduce trials and errors in the process of intial decision making.

Impact Table consists of Impact Table A where qualitative evaluation is carried out in pre-design stage and Impact Table B where quantitative evaluation is carried out in schematic design stage. In Impact Table A, energy efficiency, cost (disposal, production, construction, and so on), and performance of technological elements are compared by sector and classified into 3 classes (high, middle and low). Meanwhile, Impact Table B provides specific numbers (such as reduction ratio of energy, cost of energy reduction, construction cost) of technological elements by sector through the comparison with Reference Model[1)] (Table 1).

Table 1. Comparison of Impact Table A and B

	Impact Table A	Impact Table B
Evaluation items	• energy efficiency, performance • cost (disposal, production, construction)	• reduction ratio of energy • total construction cost
Comparison standard	• qualitative comparison • relative comparison	• quantitative comparison • absolute comparison
Application stage	• pre-design stage	• schematic design stage

2.2. Composition of Impact Table

Criteria for alternative selection of green remodeling according to Impact Table are composed on the basis of five classification systems as below. The first classification system is separate implementation by construction type. The second classification system is by the scope of replacement. The third and fourth classification system are by construction classification and the scope of detailed construction. Last, the 5th classification system is selection of element technology and material by construction type. Figure 2 shows as example the alternative selection for exterior envelope according to 5 classification systems described above: then general low-e glass (low-emissivity coated glass) was selected as a technological element for partial replacement.

Fig 2. Impact Table classification system (ex: exterior envelope)

After 5 steps of classification, Impact Table A (Figure 3) consists of constraints, applicable performance (qualitative), cost and constructability, and cost efficiency and Impact Table B (Figure 4) is composed of applicable performance (quantitative), energy consumption using reference model (qualitative), and cost.

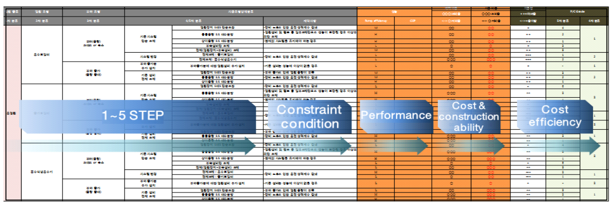


Fig 3. Composition of Impact Table A

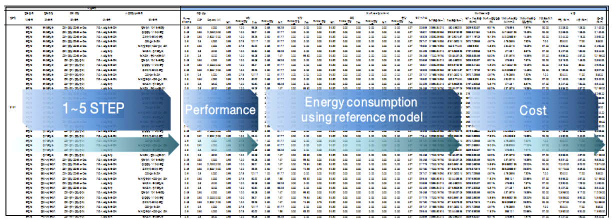


Fig 4. Composition of Impact Table B

1) The bulling is assumed as a structure built in early 1990s. For the performance of window and exterior envelope, the data of then-building facility standard was applied (Kim Kyung-rok, 2014)

Table 2 and Table 3 show the evaluation results of Impact Table A and Impact Table B composed by the selection of general low-e glass as partial replacement element in Figure 2 (based on total floor area 4,700m^2).

Table 2. Drawing contents from Impact Table A

Evaluation items		Evaluation result
Performance	Thermal	mid
	Watertight/Airtight	low
Cost	Disposal	low
	Production	mid
	Construction	low
Construction period		low
Interior construction		none
Constraint factor		• exposed bar(low cost • non exposed bar(high cost) • glass exchange: laminated/single glass >> double glass (whole exchange with frame and window)

Table 3. Drawing contents from Impact Table B

Evaluation items	Contents
Energy consumption cost (₩)	139,529,236.88
Reduction ratio of energy cost	5.10
Reduction of energy cost (₩)	7,499,271.14
Construction cost (₩)	13,848,422.29

As seen above, Impact Table A shows qualitative results of evaluation while Impact Table B shows quantitative results of evaluation on the technological elements a user chooses.

3. Checklist of Preliminary Research and Optimum Combination Dedication Module

3.1. Preliminary Research Checklist of Impact Table

To perform reasonable selection of alternatives of existing building for green-remodeling based on Impact Table, it is necessary to examine the current status of target building for remodeling. Accordingly, this study made preliminary research checklists on exterior envelope, lighting, and thermal source·air conditioning of a target building. Each checklist is composed as seen in Figure 5. Figure 6 shows the checklists of lighting and thermal source·air conditioning sector as example.

Key input variables by sector include as follows: wall·roof·floor·window thermal transmittance, standard thermal transmittance, type of exterior and interior material and etc. for exterior envelope; lighting source type, lighting control type, control hour, control system, and etc. for lighting; and type and capacity of thermal source facility, air conditioning type, building operating hour, status of occupants, etc. for thermal source·air conditioning.

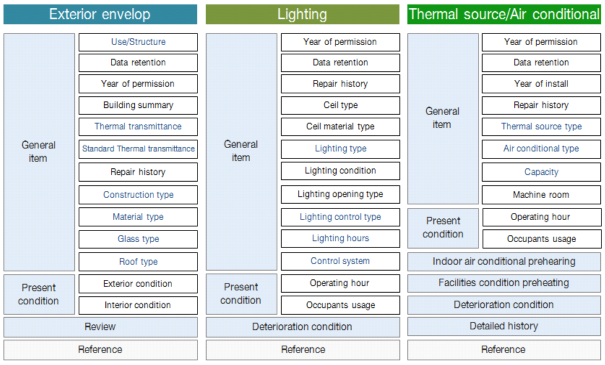


Figure 5. Composition of check list

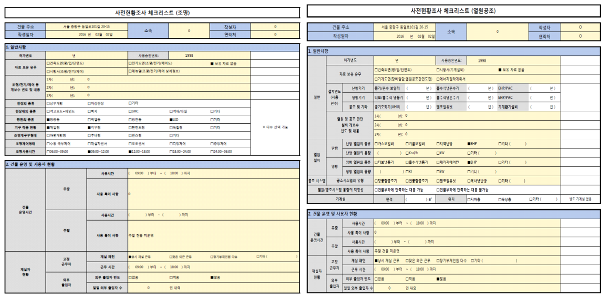


Figure 6. Check list sample, Lighting(left), Thermal source/ Air conditioning(right) - partial omission

3.2. Optimum Combination Dedication Module of Impact Table

Impact Table A and B are made in Excel format. Since the classification systems are complicate and the data are bulky in size, however, it takes a long time to compare technological elements by sector one by one and choose an alternative. In addition, it is also not intuitive to do so. To tackle this issue, this study developed stand-alone softwares for Impact Table A and B: GRIS (Impact Table A in Figure 7) GRIT-OD (Impact Table B in Figure 8).

In addition, as for GRIS, a web version was developed to increase user's accessibility. The optimum combination dedication module of Impact Table has the following characteristics. It was designed to let a user select 5 stages of technological classification sequentiality using icons rather than exploring all the checklists, which is aimed to increase readability (visuality) and intuitiveness for non-experts. Second, comparison of alternatives are presented not in numbers alone but in graph and numbers together, so users can see the difference in performance/cost of alternative combinations. Third, optimum alternative dedication modules can be saved and printed out so database for green remodeling of a target building can be built and easily managed on regular base.

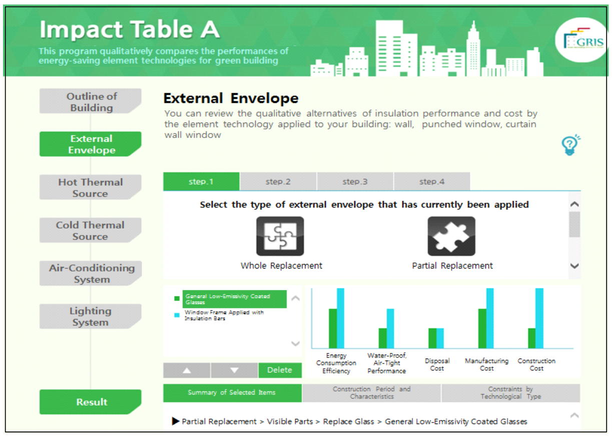


Figure 7. Captured image in GRIS (based Impact Table A)

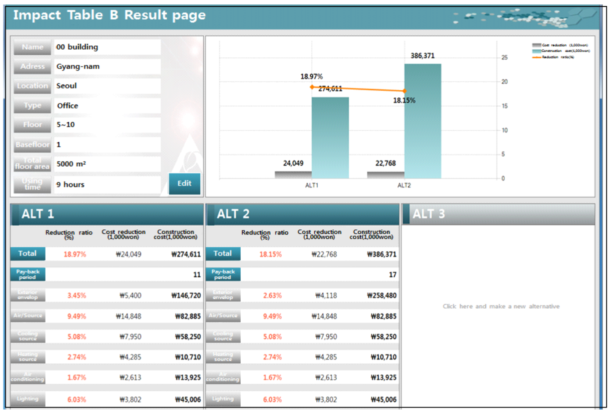


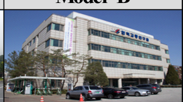
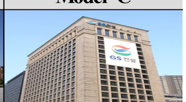
Figure 8. Captured image in GRIT-OD (based Impact Table B)

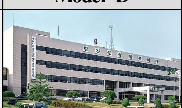
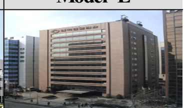
4. Test Model and Preparing Preliminary Research Checklist

4.1. Selection of Test Model

To verify Impact Table A and B and optimum combination dedication modules, this study selected 5 office facilities as test model. Each test model is summarized in Table 4.

Table 4. Test buildings for energy efficiency/cost evaluation

Name	Model A	Model B	Model C
Image			
Location	Daejeon	Goyang	Seoul
Purpose	office	office	office
Floor	7F, BF1	5F, BF1	19F, BF2
Total floor	30,147.63 m²	6,477 m²	32,488.14 m²

Name	Model D	Model E
Image		
Location	Mungyeong	Seoul
Purpose	office	office
Floor	4F, BF1	12F, BF3
Total floor	9,361 m²	11,880 m²

4.2. Preparing Preliminary Research Checklist

Table 5 shows the items of each building to check by sector through a preliminary research. Other items worth checking for aging are also described in the checklist. besides those items in Table 5, such as aging status index, operational and acceptancy status, contents of preliminary hearing. Followed are the findings from the preliminary research checklists.

Evaluation of Test Model A: as for exterior envelope, it turned out all of external wall, roof, bottom floor, thermal transmittance of window system did not meet the standard. Therefore, it is necessary to improve external wall and window thermal performance with thermal insulation boards and double pane window, and also to install wind-proof structure at the main entrance when remodeling it because wind-proof structure is absent. As for lighting, embedded louvers of fluorescent lights were applied to the building and they turned out bright enough as a whole. No damaged lighting equipment was found. As for thermal source·air conditioning, the building is equipped with gas boiler, package air-conditioner and EHP as heating and cooling source. Constant air volume conditioning units are used for cooling air conditioning. On the first floor, the building showed large cooling load due to frequency travels of people from outside (heavy influx of external air).

Evaluation of Test Model B: as for exterior envelope, it turned out that the state of external and interior wall finish was satisfactory, but thermal insulation boards were deteriorated by heat. Coated glass was used for windows (in aluminum frame) and the sealing state was so poor that the performance of thermal insulation and air-tightness of the boards were very low. Therefore, it is necessary to replace the deteriorated external thermal insulation boards and reinforce the sealing on the metal joints of the windows and ceiling to increase the performance of thermal insulation and air-tightness of the boards. As for lighting, it is open-embedded type with reflectors (plates). Therefore, it is necessary to add louvers to increase lighting efficiency. As for thermal source·air conditioning, it is necessary to check the working conditions of a hot water boiler and probe the causes for low thermal comfort. As occupants request ventilation, it is recommended to install a heat recovery ventilator during remodeling work. In addition, hot water pipes were not buried in some areas. Therefore, it is necessary to check the overall status of hot water piping.

Evaluation of Test Model C: as for exterior envelope, it was very difficult to diagnose the performance of thermal insulation boards of external walls thoroughly due to insufficient data. Therefore, general improvements are applied here (adding outside thermal insulation boards or inside thermal insulation boards to improve the performance of thermal insulation board of external walls). As for lighting, this building uses embedded louvers of fluorescent lights. It is necessary to review replacing them with LED fluorescent lights to improve lighting performance. Last, the thermal source·air conditioning of the building is short of load capacity and aged. Therefore, it is considered to replace facility system as a whole and increase load capacity. As for air conditioning, the building does not operate it now. Therefore, it is necessary to replace it in remodeling construction.

Evaluation of Test Model D: the preliminary research checklist found that Test Model D failed to meet all standards for exterior envelope (wall, roof, bottom floor, thermal transmittance of window system). Therefore, it is necessary to review replacing existing ceramic tile finish with stone-finished envelope and apply outside thermal insulation board system to improve exterior envelope performance. In addition, the performance of existing window thermal insulation boards needs improving by replacing them with low-e glass windows. For lighting, embedded and low-open fluorescent lights are applied to the building now and the brightness is evaluated to be generally satisfactory as a whole at bare-eye inspection. No damaged lighting equipment was found. Therefore, review for improvement is limited to only increasing lighting performance by louver installation. Lack of load capacity was found in thermal source·air conditioning. Therefore, it is necessary to increase load capacity by extending facility system. On the first floor, the building showed large cooling load due to frequency travels of people from outside (heavy influx of external air). Therefore, it is necessary to consider installing additional facility to increase load capacity.

Evaluation of Test Model E: exterior envelope turned out to be excellent in window performance. But the thermal transmittance of external wall, roof, and bottom floor failed to meet the standard . Therefore, it is necessary to improve the performance of thermal insulation boards of external walls by installing additional outside thermal insulation boards or inside thermal insulation boards. As for lighting, embedded louvers of fluorescent light are currently applied to the model. It is necessary to consider replacing them with LED fluorescent lights to improve lighting performance. As for thermal source·air conditioning, the efficiency of heating boilers was relatively low and it was found that air was supplied excessively due to inaccurate control of air volume for fuel volume. In addition, only one freezer was in use due to restriction of peak load to reduce the base rate of electricity, so the 1st cooling supply capacity was insufficient. Therefore, it is necessary to replace a whole system of heating source to improve thermal performance. For cooling source, installation of additional facility needs considering for increased load volume.

5. Application of Impact Table - Optimum Combination Module

5.1. Results of Application of Optimum Combination Modules for Impact Table A

Using GRIS, which is the tool for the optimum combination module of Impact Table A, the alternative technological elements for remodeling of each test model were derived by sector (based on the elements derived by the preliminary research checklists in 4.2). And then, as seen in Figure 9, optimum alternative was selected by sector through qualitative comparison.

Table 5. Check list of test buildings

		Model A	Model B	Model C	Model D	Model E
Exterior envelope	Exterior wall thermal transmittance (W/m^{2}k)	0.46	0.58	-	0.76	0.57
	Roof thermal transmittance	0.34	0.41	-	0.66	1.05
	Floor thermal transmittance	0.42	0.58	-	2.22	1.65
	Window thermal transmittance	2.40	3.30	-	4.00	0.70
	Insulation method	outside insulation	outside insulation	outside insulation	inside insulation	outside insulation
	Exterior material	stone	stone	stone	tile	stone
	Interior material	plaster board, paint	mortar, paint	plaster board, paint	plaster board, paint	plaster board, paint
	Window	double glass	double glass	single glass	single glass	single glass
	Frame	metal	metal	metal	metal	metal
Thermal source/ Air conditioning	Heating source	gas boiler	district heating	EHP	EHP	gas boiler
	Cooling source	package air conditional	absorption chiller	EHP	EHP	turbo refrigerator
	Air conditioning	constant air volume	constant air volume	fan-coil unit	fan-coil unit	constant air volume
Lighting	Light	fluorescent light	fluorescent light	fluorescent light	fluorescent light	fluorescent light
	Set-up type	recessed	recessed	recessed	recessed	recessed
	Opening type	louver	bottom opened	louver	bottom opened	louver
	Time	09:00-18:00	09:00-18:00	09:00-18:00	09:00-18:00	09:00-18:00

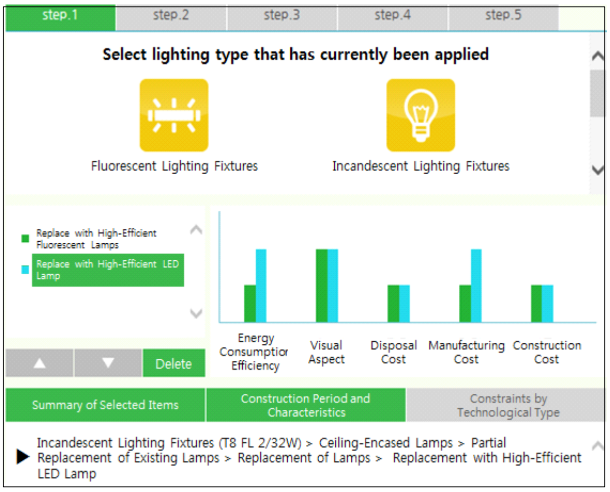


Figure 9. Comparison of alternatives about light in GRIS (captured in optimum combination module of Impact Table A dedication tool)

Table 6 shows the final alternatives. In addition, Figure 10 lets us know the results of exterior envelope sector of Test Model A among the combinations derived by GRIS as example.

▶Insulation reinforcement beside urethane filling	punched-win type > partial replacement > invisible area > Wall-(insulation beside existing method) > Insulation reinforcement beside urethane filling		
Energy Performance	High	Waterproof/Air-tight Performance	Middle
Disposal Cost	Low	Manufacturing Cost	Low
Installation Period	Middle	Cleaning Cost after Work	-
Construction Period	Low	Interior Work (Yes or No)	None
Characteristics	* In case that insulator, which is filled (in form of foam) between existing finishes and outer wall, degrades due to aging or/and heat, reinforce insulation with additional urethane filling		
▶High-Insulation Glass	punched-win type > partial replacement > visible area > glass replacement > high-insulation glass		
Energy Performance	High	Waterproof/Air-tight Performance	Low
Disposal Cost	Low	Manufacturing Cost	High
Installation Period	Low	Cleaning Cost after Work	Middle
Construction Period	Low	Interior Work (Yes or No)	None
Characteristics	* Method (glazing or others) and cost depend on aluminum type (protruding bar or non-protruding bar) - Protruding bar: work only on glazing weather seal - Non-protruding bar: Norton tape + structure caulking (more expensive than protruding bar) * Most of the buildings in 70s and 80s use single-layer glass or laminated glass. In this case, it is difficult to insert pair glass into the window frame. Whole frame needs replacing.		

Figure 10. Evaluation result of exterior envelop of Model A in GRIS (captured in optimum combination module of Impact Table A dedication tool)

For exterior envelope (wall), reinforcement of outside thermal insulation boards, replacement of outside thermal insulation boards, reinforcement of inside thermal insulation boards were selected by test model. For exterior envelope (window), doubling of high thermal insulation glass, addition of high thermal insulation bar frame, and replacement with low-e glass were selected. For lighting, replacement with high-efficiency fluorescent lights, replacement with high-luminance reflectors (plates), and replacement with high-efficiency LED lamps were selected. As for thermal source, one-to-one exchange and addition of thermal source facility construction were selected as alternative technological elements for remodeling. Last, for air conditioning, one-to-one exchange of aged air conditioning system with constant air volume system unit and variable air volume system unit, respectively.

5.2. Results of Application of Optimum Combination Modules for Impact Table B

To derive the quantitative evaluation figures of the optimum combination module of Impact Table A, this study entered technological elements selected in Table 5 into GRIT-OD, which is the tool for the optimum combination module of Impact Table B, and produced the graphs and tables like in Figure 11. Reduction ratio of energy, cost of energy reduction, and cost of initial investment of each test model were compared by sector (Table 7). And then the results of each sector were combined and years to take until recovering the cost of initial investment (payback period) were compared (Table 8). Test Model A was found most excellent in reduction ratio of energy and payback period of initial investment while and cost of energy reduction and initial investment were highest cost in Test Model C. Particularly, Test Model A showed excellent rate of energy reduction and payback period for cost of initial investment. Therefore, when technological elements selected in Table 6 are employed for green-remodeling, its effectiveness is expected to be high. On th contrary, Test Model C showed the lowest rate of energy reduction and the highest cost of initial investment. Therefore overall review is necessary for the selected technological elements of remodeling by sector.

Figure 12 shows cost of initial investment and cost of energy reduction of Test Model C whose payback period for cost of initial investment rank on 5th on percentage base. Since it expresses the percentage of cost of initial investment and cost of energy

Table 6. Selected items in Impact Table A

Name		Model A	Model B	Model C	Model D	Model E
Exterior envelope	Wall	outside insulation adding	outside insulation change	inside insulation adding	outside insulation adding	outside insulation adding
	Window	high insulation glass adding	insulation bar frame adding	-	Low-e glass change	-
Thermal source	heating	1:1 simple change	additional installation	1:1 simple change	additional installation	1:1 simple change
	cooling	additional installation	additional installation	1:1 simple change	additional installation	additional installation
Air conditioning		system change (VAV)	system change (VAV)	system change (CAV)	system change (CAV)	1:1 simple change
Lighting		high efficiency fluorescent change	high luminance reflecting plate change	high efficiency LED lamp change	high luminance reflecting plate change	high efficiency LED lamp change

reduction, it is very easy to catch technological elements that need reconsidering. As for Test Model C, lighting, exterior envelope, and cooling thermal source take higher cost of initial investment than other elements. On the other hand, Figure 13 shows the percentages of cost of initial investment and cost of energy reduction of Test Model B whose payback period for cost of initial investment rank on 4th among the test models. When the results of Test Model B (Figure 13) are compared with those of Test Model C (Figure 12), it is known that the former has lower percentage of cost of energy reduction for exterior envelope, but much higher percentage of cost of energy reduction for cooling thermal source than the latter. As a result, payback period for (cost of) initial investment is shortened.

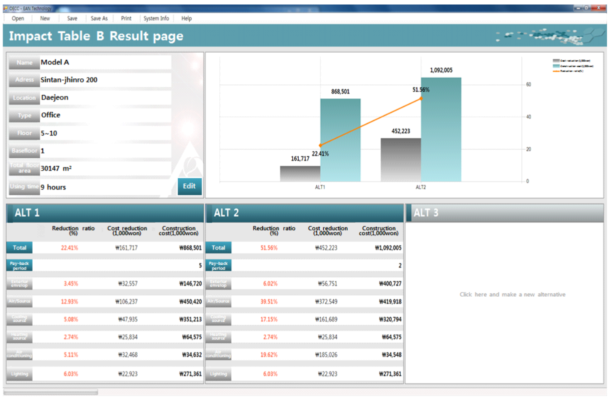


Figure 11. Evaluation result of Model A in GRIT-OD (captured in Impact Table B optimum combination dedication tool)

Table 7. Drawing contents from Impact Table B

		Reduction ratio of energy cost	Reduction of energy cost (₩1,000)	Investment cost (₩1,000)
Model A	Exterior envelope	6.02	56,751	400,727
	Heating source	2.74	25,834	64,575
	Cooling source	17.15	161,689	320,794
	Air conditioning	19.62	185,026	34,548
	Lighting	6.03	22,923	271,361
Model B	Exterior envelope	4.24	8,592	308,727
	Heating source	2.90	5,866	19,392
	Cooling source	17.15	34,738	68,922
	Air conditioning	3.44	6,972	7,423
	Lighting	6.03	4,925	58,301
Model C	Exterior envelope	3.43	6,941	91,735
	Heating source	2.74	5,550	13,874
	Cooling source	5.08	10,299	75,457
	Air conditioning	3.44	6,972	7,423
	Lighting	4.86	984,770	11,659,255
Model D	Exterior envelope	4.24	12,418	166,327
	Heating source	2.90	8,478	28,027
	Cooling source	17.15	50,206	99,610
	Air conditioning	3.44	10,077	10,728
	Lighting	6.03	7,118	84,261
Model E	Exterior envelope	3.43	12,731	174,172
	Heating source	2.74	10,180	25,447
	Cooling source	17.15	63,716	126,415
	Air conditioning	1.67	6,208	33,086
	Lighting	6.03	9,033	106,935

Table 8. Drawing contents from Impact Table B

	Reduction ratio of energy cost	Reduction of energy cost (₩1,000)	Investment cost (₩1,000)	payback period (year)	Rank
Model A	51.56	452,223	1,092,005	2.41	1
Model B	33.76	61,093	462,765	7.57	4
Model C	19.55	1,014,532	11,847,744	11.68	5
Model D	33.76	88,297	388,953	4.4	2
Model E	31.02	101,870	466,055	4.57	3

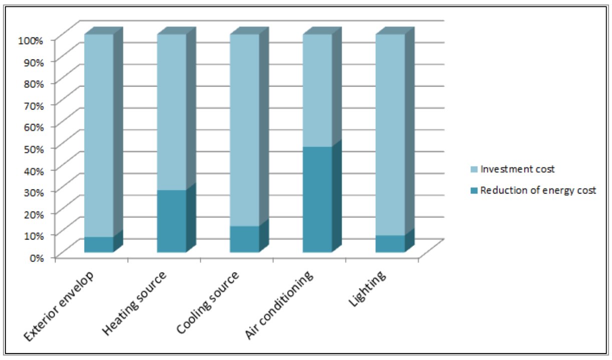


Figure 12. Ratio of investment cost and energy reduction cost (Model C)

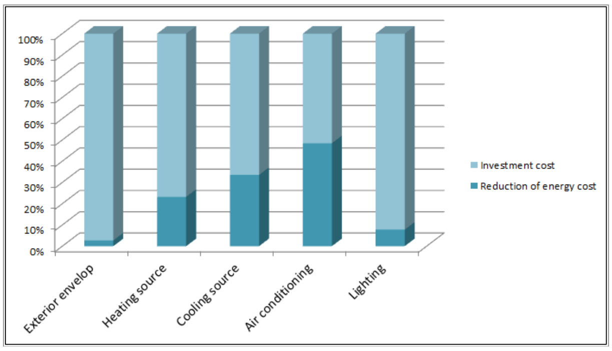


Figure 13. Ratio of investment cost and energy reduction cost (Model B)

Like this, since the evaluation of optimum combination tool based on Impact Table can propose percentage of cost of initial investment and cost reduction of remodeling elements by sector, it can show a direction and guideline to efficient green-remodeling business.

6. Conclusion and Implication

This study designed the database of performance/cost, a guideline to use of Impact Table, preliminary research checklist, and optimum combination dedication tool of Impact Table as means of evaluating preliminary business feasibility to efficiently implement green-remodeling by sector (exterior envelope, lighting, thermal source · air conditioning, new and renewable energy).

In addition, it conducted quantitative/qualitative evaluation on the technological elements of 5 green-remodeling test models. Upon optimum combination module of Impact Table A, qualitative and relative evaluation was carried out on alternative technological elements based on the checklist. And then, in combination module of Impact Table B, quantitative evaluation was conducted on technological elements selected from Impact Table A. Resultantly, this study proposed the cost of energy reduction and cost of investment of technological elements required for green-remodeling.

Through these processes, the applicability of Impact Table and optimum combination modules were verified in this study as follows. First, a systemized database was built for element technology of green-remodeling by sector of domestic construction and a plan for qualitative, quantitative evaluation on energy performance and cost of energy reduction were prepared. Second, this study examined a way to review business feasibility of green-remodeling in advance; proposed a guideline to the review of technological elements unfit to user's direction to remodeling; and suggested a method to reduce trials and errors in the process of decision making and to enable efficient implementation of green-remodeling business. Third, Exclusive software was developed for Impact Table to strengthen marketability and user's convenience/accessibility to Impact Table.

However, this study has some limitations. performance and cost data in Impact Table are not inclusive of all technological elements and reference models are not standard models. Therefore, there could be difference between the evaluation results of this study from those from actual remodeling on site. In this respect, it is expected that the analytic results of Impact Table and optimum combination dedication modules will be used as rough relative index for remodeling. For more detail evaluation of remodeling business feasibility, experts are asked to intervene.

In the meantime, this study will keep supplement these Impact Table and optimum combination dedication modules with additional research as follows and secure extendability and user's convenience of the modules. First, it will keep updating performance and cost DB of the latest (newly developed) technology and carry out a study on a plan to provide users most recent data of price information by sector of remodeling (exterior envelope, thermal source・air conditioning, lighting, and new and renewable energy). Second, this study will expand and develop applicable scope of Impact Table A and B to educational facility and factories as well as existing large-scale/small office facility and apartment house. Third, it will integrate alternative combinations to select (number of all possible cases) by sector in a database and conduct a study on the development of algorithm of automatic selection of alternative satisfying target and standard. Last, it will build integrated version of software (web version + software) of Impact Table A/B optimum combination dedication model in order to increase user's accessibility.

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