博士論文

Decision-Making Processes of Retrofitting Designs in a Small-scale Building Construction System in Taiwan: Case study on energy-efficient retrofits of building envelopes

（台湾の小規模な建築生産システムにおける改修設計の
意思決定プロセスに関する研究
－ファサードの省エネルギー改修事例に着目して－）

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Chapter 1:
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CHAPTER 1

1.1 Research background

1.1.1 Renovating buildings for energy conservation

Lin (2011)[1] pointed out that more than 70% of current environmental crisis result from energy-related issues. Therefore, energy problems must be resolved to achieve sustainable development.

Buildings require a huge amount of energy for electrical and mechanical systems to reach interior comfort in most climates.[2] The report of international energy agency shows that the building sector accounts for 32% to 40% of total final energy use and approximately 40% CO2 emissions.[3] Moreover, 60%~50% of total CO2 emission in a building life cycle occur in its operation stage.[1]

Gelfand & Duncan (2012)[4] proposed that within the building sector the existing building stock has the greatest opportunity for energy conservation. Thorpe (2010)[5] also argued that retrofitting a building is usually a better option than demolish-and-rebuild to higher standard due to the embodied energy in the existing buildings, especially when compared to the energy cost of demolishing and replacing it.

Furthermore, utilizing the existing building stock can reduce natural resource consumption and wastes generated from rebuilding. Therefore, recently, renovating buildings for energy conservations has gained wider attention globally.

1.1.2 Improving building envelope for energy conservation

Gelfand & Duncan (2010)[4] pointed out that a well-designed envelope can greatly reduce the energy requirements for external sources of heating, cooling, ventilating, or lighting in existing buildings. Moreover, several researches indicate that improving a building's envelope will affect functional performance more than any other aspects of sustainable renovation. [6-9]

Currently, a large number of existing building envelopes are considered to perform poorly because building envelopes are not required by previous building regulations due to lack of maintenance. Hence, adopting energy-efficiency retrofits when building envelopes are being renovated would be environmentally friendly.

1.1.3 Planning a building renovation

Planning building renovations is unlike planning new building constructions, especially because requirements for players and design proposals of retrofitting projects are subject to

fewer building regulations. Types of players and the quality of design proposals vary in retrofitting projects, particularly for projects planned under a small-scale building construction system.

Preliminary studies have shown that the small-scale building construction system is commonly used in retrofitting projects which usually have small-scale buildings, smaller areas for improvement or low budgets. In general, the projects implemented under the small-scale building construction system have several planning problems.

1.1.4 Planning "energy-efficient building envelope retrofits" in a small-scale building construction system

To decide a suitable retrofitting method for energy efficiency, comprehensive review of existing building conditions, confirmation of limitations in their application, and careful assessment for improving performance of the retrofitting methods is crucial. Decision-making processes of energy-efficiency retrofitting designs are complicated and need assistance of professionals from different fields.

Decision makers in a small-scale building construction system are commonly from different field and compositions, and have different levels of experience on energy-efficiency retrofits. Energy-efficient building envelope retrofits planned by a small-scale building construction system are known to have the following issues. (see Chapter 2 for details)

(1) The adopted retrofitting methods of energy-efficient building envelope retrofits vary and are not exactly the same as the theoretically promoted ones.

(2) Multiple building-envelope retrofits had to be executed in some cases due to ineffective retrofitting results in improving indoor thermal environment

It is assumed that the decision makers in a small-scale building construction system might have different approaches or difficulties to plan a proper energy-efficiency retrofits.

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1.1.5 Necessity of studying practical decision-making processes for "energy-efficiency retrofitting designs" in a small-scale building construction system

How the decision makers decide energy-efficiency retrofitting designs is still unclear from current researches. To ensure the quality of energy-efficient building envelope retrofits and to assist these decision makers to choose a suitable retrofitting methods, studying practical decision-making processes in a small-scale building construction system is necessary.

1.2 Research objective

In this research, decision-making processes of retrofitting designs in a small-scale building construction system are the main focus. The research objective is to clarify what cause the variability of decision-making processes by understanding considerations, interactions, working contents and assessment approaches of decision makers with different attributes and compositions. Furthermore, proposals for decision makers in the small-scale building construction system to enhance quality of adopting energy-efficiency retrofits are also tried to suggest.

The specific aims of this research are two-fold and described as follows:

[Part 1: To elucidate practical situation of retrofitting designs in a small-scale building construction system]

(1) Understand current situations and issues of adopting energy-efficient building envelope retrofits in a small-scale building construction system (Chapter 2)

(2) Clarify attributes of decision makers in a small-scale building construction system (Chapter 3)

(3) Clarify practical decision-making processes of retrofitting designs in a small-scale building construction system (Chapter 4)

[Part 2: To provide suggestions for quality enhancement of adopting energy-efficiency retrofits in a small-scale building construction system]

(4) Evaluate quality of different decision-making processes for energy-efficiency retrofits and then provide suggestions for enhancing the quality of adopting energy-efficiency retrofits in a small-scale building construction system. (Chapter 5)

(5) Verify usefulness of the suggestions regarding quality enhancement of adopting energy-efficiency retrofit in the small-scale building construction system (Chapter 6)

1.3 Research subject

[Type of studied cases]

The cases relating to energy-efficiency retrofits of building envelopes that were planned by a small-scale building construction system were chosen for investigation in this research.
(Fig. 1-1)

[Research area]

Although retrofitting projects planned by a small-scale building construction system can be found in several countries, Taiwanese retrofitting cases were selected due to the following reasons:

(1) Energy-efficiency retrofits of existing buildings which have improved hundreds of buildings have been highly promoted by the Taiwanese government.

(2) A large number of the improved buildings found are executed by a small-scale building construction system.
(Fig. 1-1)

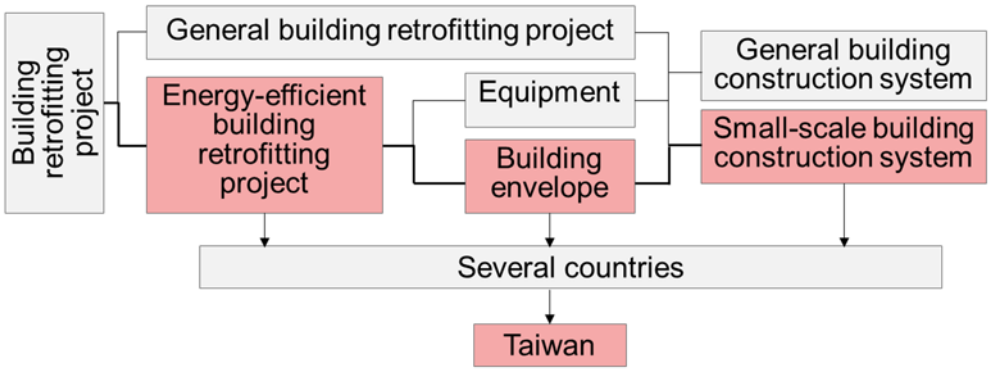

Figure 1-1 Research subject

1.4 Research content and framework

This research consists of seven chapters. An overview of this research is introduced in Chapter 1. The planning situations and issues related to building envelope retrofits for energy-efficiency in Taiwan are described in Chapter 2. The composition of decision makers and the practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system are explained in Chapter 3 and Chapter 4. The decision-making processes executed by decision makers with different specialties are evaluated as well as suggestions are provided in Chapter 5. In Chapter 6, the verification results of the suggestions (provided in Chapter 5) are narrated. Finally, all the research results are concluded in Chapter 7. (Fig. 1-2)

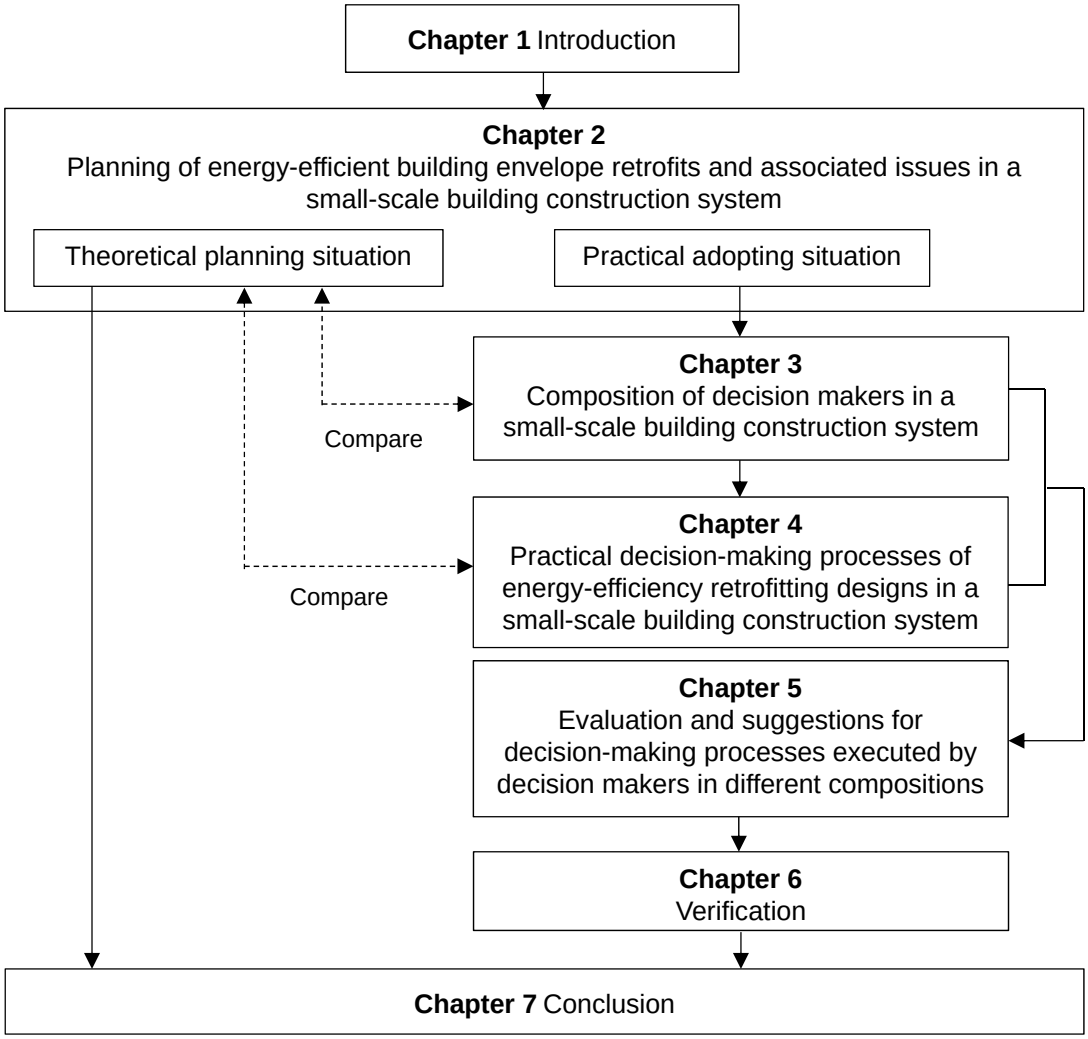

Figure 1-2 Research framework

1.5 Research methodology

1.5.1 Research contents and methods

Data for this research were collected through literature review, interview surveys, case studies, comparative analyses, and observation surveys. Research content and methodologies for each aim are described as below. (Table 1-1)

(1) To understand planning situations and issues related to energy-efficient building envelope retrofits in a small-scale building construction system (Chapter 2)

Planning situations are clarified by understanding the theoretical and practical planning situations of energy-efficient building envelope retrofits. The data were collected by literature reviews, document analyses, and interview surveys.

[Theoretical planning situation]- Literature review & Interview survey

Theoretical planning situations included standard planning approaches in current researches, suggested retrofitting methods in design guidelines, and promoted retrofitting methods by experts. The research data were collected by literature review and interview surveys.

The literature reviews included reference books and design guidelines relating to energy-efficient building designs.

Regarding interview surveys, the interviewees included 10 experts specializing in indoor environmental controls. The interviewing questions related to: problems in existing buildings, the retrofitting methods suitable for Taiwanese climate, and their relative advantages.

[Practical adopting situation]- Case study & Document analysis

Practical planning situation includes adopting results of retrofitting methods in practical energy-efficiency retrofitting projects. The research data were collected by studying 688 cases (selected from governmental incentive programs) and reviewing their adopted retrofitting methods.

(2) To define attributes of the decision makers in a small-scale building construction system (Chapter 3)

Attributes of the decision makers in a small-scale building construction system were defined by understanding decision makers' profession types, relevance, and compositions. The data were collected through case studies and interview surveys.

Thirty-two retrofitting projects were selected from incentive and non-incentive programs as cases to be studied.

Regarding interview surveys, decision makers from the 32 cases were interviewed to collect data on the profession types and relevance. Subsequently, based on these data, decision makers' combinations were categorized.

(3) To elucidate features of practical decision-making processes of retrofitting designs in a small-scale building construction system (Chapter 4)

In this chapter, the decision-making processes of retrofitting designs in small-scale building construction system were clarified by understanding what decision makers think and how decision makers arrive at the decisions during decision-making processes.

What decision makers think and how decision makers arrive at the decisions were clarified by interviewing decision makers in the 32 cases about the following research questions:

(a) What decision makers think during decision-making processes?

The questions regarding the decision makers' thought process included decision-making considerations, priority orders of final decision-making considerations, and development processes of decision-making considerations.

(b) How decision makers arrive at the decisions during decision-making processes?

The questions regarding the decision makers' actions included interactions between decision makers, decision makers' working content for assessments, and assessment approaches for improving effectiveness of energy-efficiency.

Furthermore, research results were categorized to define features of practical decision-making processes of retrofitting designs in the small-scale building construction system.

(4) To evaluate the decision-making processes of retrofitting designs executed by decision makers with different compositions and provide suggestions (Chapter 5)

The decision-making processes of retrofitting designs executed by decision makers specializing in different fields were evaluated according to research results in Chapters 3 and 4. By observing "what decision makers think" and "how decision makers arrive at the decisions" in different combinations of decision makers, the level of their awareness with regards to improving energy-efficiency and their level of rigor during the discussions and assessment were evaluated.

Subsequently, suggestions for raising the level of awareness for improving energy-efficiency and level of rigor in discussion and assessment were provided according to research results from Chapter 5.

(5) To verify usefulness of the suggestions (Chapter 6)

The suggestions provided in Chapter 5 were verified by two practical retrofitting projects. The verifying methods comprised applying the suggested strategies and checklists to check for

adoption of promoted retrofitting methods in the two cases.

Table 1-1 Research contents and methods

Research content	Method
Theoretical planning situation of building envelope retrofit for energy conservation	Literature review and interview surveys with government officers, research scholars and government-assigned counselors
Current implement situation of building envelope retrofit for energy conservation in Taiwan	Analyze adopted retrofitting methods of 688 case in their application documents
Types and relevance of decision makers' professions	Interview decision makers in 32 cases
Practical decision-making processes of retrofitting designs	Interview decision makers in 32 cases
Suggestions according to feature of decision-making processes executed by different specialties of decision makers	Comparative analysis
Verification of suggestions	Observation surveys of two cases

1.5.2 Field survey

Field surveys for document collection, interview surveys, and observation surveys were carried on eight times in several cities in Taiwan including Taipei city, Kaohsiung city, Taichung city, and Yilan city. The investigations relating to current implement status of building envelope retrofit for energy conservation in Taiwan were conducted in September, 2011 and February, 2012. The investigations relating to practical planning processes of retrofitting strategies of building envelopes were executed in August, 2012, February, 2013, and August, 2013. The investigations relating to planning participants' considerations regarding different decision-making approaches and planning leaders were carried out in October, 2014, February, 2015, and August, 2015. (Table 1-2)

Table 1-2 Information of field survey

Date	Location	Research content	Interviewee
September, 2011; February, 2012	Taipei, Kaohsiung, Yilan	Current implement situation of building envelope retrofit for energy conservation in Taiwan	Government officers, research scholars and government-assigned counselor
August, 2012, February, 2013, August, 2013	Kaohsiung, Taichung, Taipei	Professions of participants and practical decision-making processes of retrofitting designs	Participants of retrofitting designs in studied cases
October, 2014, February, 2015, August, 2015	Kaohsiung, Taipei,	Professions of participants and practical decision-making processes of retrofitting designs	Participants of retrofitting designs in studied cases

1.5.3 Research flow

The analysis methods and research flows from Chapter 2 to Chapter 6 are illustrated in Figures 1–3. The content for different chapters is as follows.

[Chapter 2]
Firstly, the current status of building envelope retrofits for energy-efficiency in Taiwan are introduced. Subsequently, theoretical planning for building envelope retrofits for energy-efficiency and practically adopted methods of building envelope retrofits for energy-efficiency are identified. By comparing the theoretical planning situations and the practically adopted results of energy-efficiency retrofitting designs, issues related to planning building envelope retrofits for energy-efficiency in a small-scale building construction system are defined.

[Chapter 3]
Secondly, attributes of decision makers are defined by understanding decision makers' professions and relevance, combinations of decision makers, and how decision makers' combinations were decided.

[Chapter 4]
Practical decision-making processes of retrofitting designs for energy efficiency were clarified by investigating what decision makers think and how decision makers decide. To understand what decision makers think, contents of decision makers' considerations, priority orders of decision makers' considerations, and development processes of decision makers' considerations were investigated. To understand how decision makers decide, decision makers' interactive relationships, interactions between decision makers, decision makers' working contents for assessments, and assessment approaches for improving effectiveness were investigated. Further, the features of decision-making processes in a small-scale building construction system and some of the issues (mentioned in Chapter 2) were are clarified.

[Chapter 5]
After elucidating clarifying the practical decision-making processes of retrofitting designs for energy efficiency, qualities of the decision-making processes executed by decision makers in different combinations were evaluated by assessing (1) the level of awareness regarding improving effects of energy efficiency, and (2) the level of rigor in discussion and assessment. Moreover, the level of awareness regarding improving effects of energy efficiency was defined as "what decision makers think" and the level of rigor in discussion and assessment was defined as "how decision makers carry out decision-making".

After defining the qualities of the decision-making processes executed by decision makers in different combinations, suggestions were proposed to decision makers. The suggestions included the following: (1) strategies for raising the level of awareness on improving the effects of energy efficiency, (2) checklists for enhancing the level of rigor in discussion and assessment, and (3) an evaluation reference of energy-efficiency retrofitting methods for finding suitable decisions.

[Chapter 6]
Finally, the possibility of enhancing quality of decision-making processes executed by decision makers in a small-scale building construction system were verified by applying suggestions (proposed in Chapter 5) to two practical building envelope retrofitting projects.

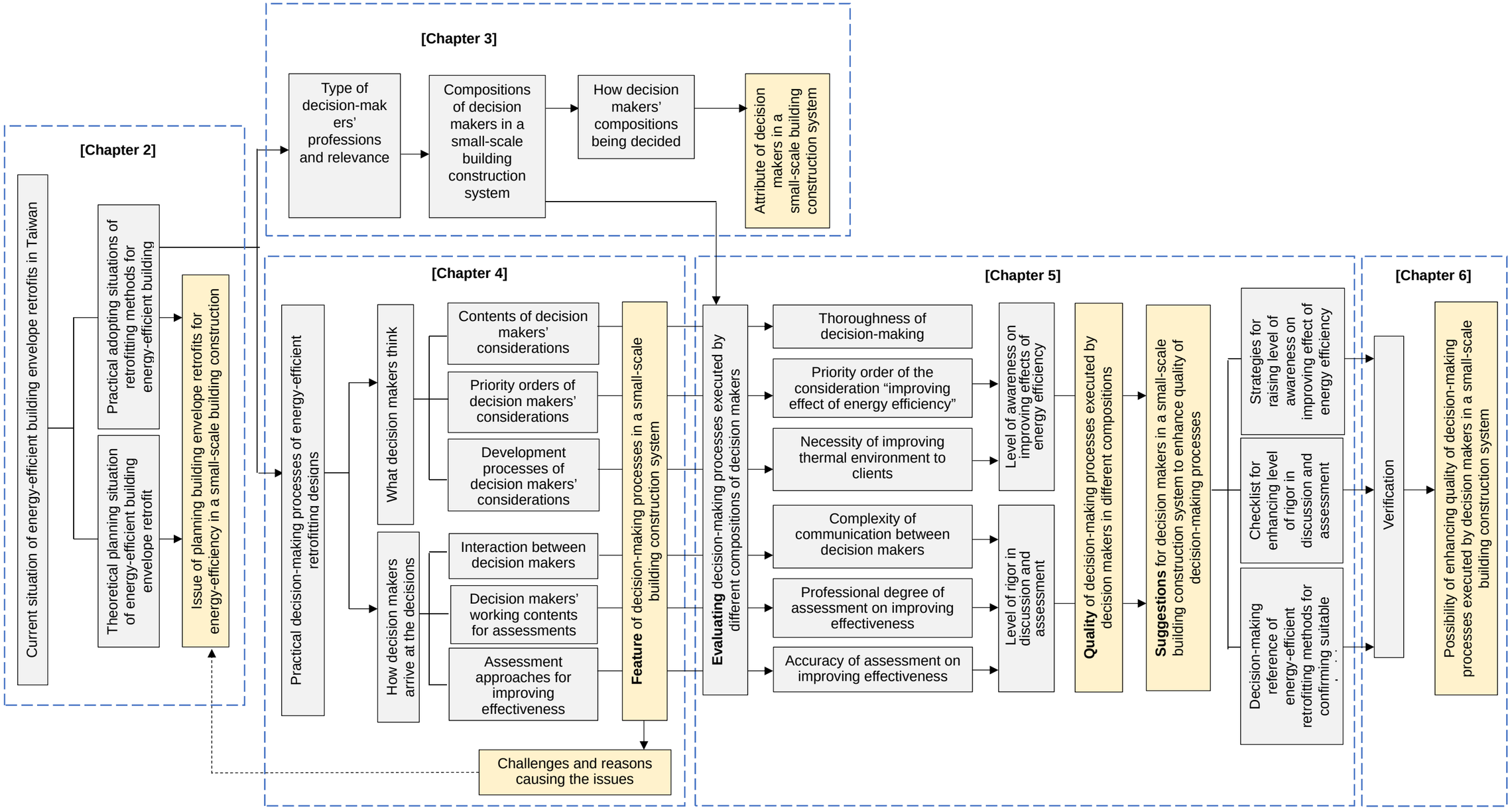

Figure 1-3 Research flow

1.6 Definition of Terminology

(1) Building envelope

A building envelope is also referred to as a building enclosure and a building shell. Lin (2011)[10] defined the function of a building envelope in his book as “human’s third protecting layer against climate changes besides skin and clothes”. Other papers also define a building envelope as the physical separator between the conditioned and the unconditioned environment of a building including the resistance to air, water, heat, light, and noise transfer.[11-12]

There are several definitions of the components of a building envelope which comprise roofs, openings, exterior walls, floors, foundations, and ceilings.[13~20] In this research, the components of a building envelope are defined as roofs, openings, and external walls which form the outermost layer of a building and directly connect to the outdoor environment. (Fig. 1-4)

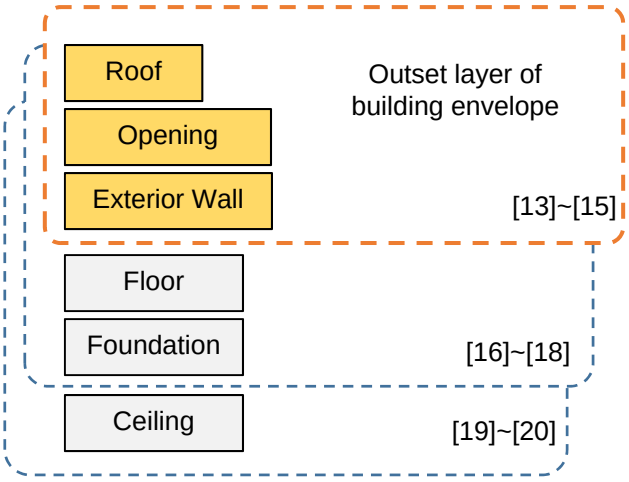

Figure 1-4 Definition of building envelope

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[13] Gelfand, L., and Duncan, C. (2012) Sustainable renovation: Strategy for commercial building system and envelope, USA: Wiley, 77
[14] *Building Technical Regulations*, Taiwan: CHAN’S ARCH-PUBLISHING CO., LTD., 2011
[15] Green Architects Group (2013), *Designing A Good House- Lesion from Green Architects (綠領建築師教你設計好房子)*, Taiwan: YEREN Publishing House, 55
[16] NOIKE, M (2011), *Ultimate Manual for Energy Conservation and Eco Housing Design*, Tokyo: X-Knowledge, 73-78 (野池政宏, *省エネ.エコ住宅設計究極マニュアル*)
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(2) Energy-efficiency retrofit

The term “energy-efficiency retrofit of building envelope” refers to the role of retrofits for enhancing the operating performance of an existing building to reduce its energy uses for cooling and heating. The retrofitting strategies include replacements of equipment and improvements of building envelopes. In this research, improvements of building envelopes for energy efficiency are the main focus.

(3) Decision maker

A decision maker (or player) in this research refers to people who participate in deciding retrofitting designs.

(4) Decision-making process of retrofitting design

The term “decision-making process” may cover several phases during building constructions: planning, deciding players, design, construction, completion inspection, and maintenance. In this research, decision-making process during the design phase is the main focus. Moreover, the term also refers to the processes of deciding design proposals for improving parts, methods, and aesthetic designs.

(5) Small-scale building construction system

The term “building construction system” may have multiple meanings: players, construction processes, and construction methods.[21] In this research, the term “building construction system” especially means the players involved in the design phase.

Moreover, members in a “general building construction system” are usually composed by well-integrated and professional groups from several fields. The term “small-scale building construction system” in this research means the members by a small number of people from a few or single fields.

(Fig. 1-5)

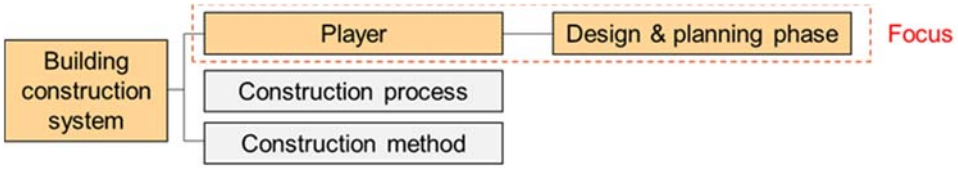

Figure 1-5 Definition of small-scale building construction system

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1.7 Past research and orientation of this research

1.7.1 Past research

[Past researches relating to building construction system]

The existing researches relating to building construction systems are found have following theme: (1) development of advance building construction system, (2) management of building construction system, and (3) investigation of practical building construction system. These researches are mostly about discussing middle and big scale of building construction systems and developing advance building construction systems, but few of them are investigating small-scale building construction systems in practical situations.

[Researches relating to energy-efficiency retrofits]

The existing researches relating to energy efficient retrofit of existing building have seen including the following topics: (1) estimations and verifications of improving effectiveness, (2) developments of evaluating methods after retrofits and diagnosing methods before retrofits, (3) current implement situations and results of retrofitting strategies being adopted, (4) retrofitting plan for applying energy efficient retrofit, (5) retrofitting approaches, and (6) verification of workability.

Within these topics, the estimations and verifications of improving effectiveness is the most theme to be discussed; planning and design procedure is the least one. Decision-making approaches, decision-making processes and interactive between participants in actual planning situations are rarely seen in existing researches.

[Past researches relating to decision making process of energy-efficiency retrofits]

The existing researches relating to decision making processes of building designs include following themes: decision making methodologies before retrofits, decision making process of building retrofit and design processes. These researches are mostly about changes of design proposals, but rarely discussing interactions between players.

Regarding “decision making methodologies before retrofits”, Liao (2014)[22] suggested a calculation formula to decide whether to implement an energy-efficient renovation on existing housing or not.

Regarding “decision-making process of building retrofit”, Tsai (2017) [23] clarified decision-making considerations of adopting energy-efficiency retrofitting methods on openings

in Taiwan, and Lai (2007)[24] followed the activity theory and hierarchical analysis process to understand the decision making process of space renovation executed by experts from different fields.

Regarding “design process”, TOYOKAWA (2016)[25] clarified decision-making considerations during design processes of building façade from designers’ point of view, SENO (2012)[26] clarified relationship between designers’ types and design processes of sustainable building façade, SASADA (2014)[27] clarified types of designers according to their consulting works during passive design processes of houses, and Liou (2000)[28] developed a modified Decision Process Flow Chart base on existing Decision Process Flow Chart for a design team to take a proper action in different design situations.

[22] Liao, T. C. (2014), *Decision making methodologies considering uncertainty in LCC evaluation: case study of energy-saving condominium refurbishment*, Unpublished master’s thesis, The University of Tokyo, Japan

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[Past researches relating to small-scale building construction system]

The existing researches relating to small-scale building construction system include following themes: (1) players and working contents, (2) production process, and (3) quality assurance.

Regarding “players and working contents”, TSUNODA (1989)[29] investigated production and supply system for small urban buildings and categorized the players into six types; contents of designs and constructions are different in the six types, AKIYAMA (1998) [30] investigated designs and supervision works of detached houses in different types of regional small architect firms, and SUNAGA (2003)[31] investigated small and medium-scale construction works to clarify current problems and improvement plans for streamlining construction works.

Regarding “production process”, TSUNODA (1990)[32] clarified production process of exterior wall cladding for small urban buildings.

Regarding “quality assurance” in a small- scale construction system, AKIYAMA (2001)[33] studied meaning of quality records in a small-scale housing construction system for ensuring quality, and OTA (2001)[34] proposed and evaluated quality records in a small-scale housing construction system.

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[33] AKIYAMA, T., et al. (2001) 「Study on Quality Securing of Detached Houses: Meanings of Quality Records」 Summaries of Technical Papers of Annual Meeting, AIJ, No. 2001, 1087-1088

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1.7.2 Orientation of this research

According to the contents of existing researches, the orientation of this research is defined as Figure 1-6. Regarding decisions of retrofitting designs, the diagram shows the past researches relating to different procedures of decision making for planning retrofits in theoretical context and practical context; the procedure including approaches of decision making, previews of decision making, process, processes of decision making, results of decision making, review of decision making and post-evaluation of decision making. It is found that decision-making processes of players in practical situations are rare in existing researches, especially lack of the discussions in a small-scale building construction system. Hence, the processes of decision making and results of decision making in a small-scale building construction system are the parts investigated in this research.

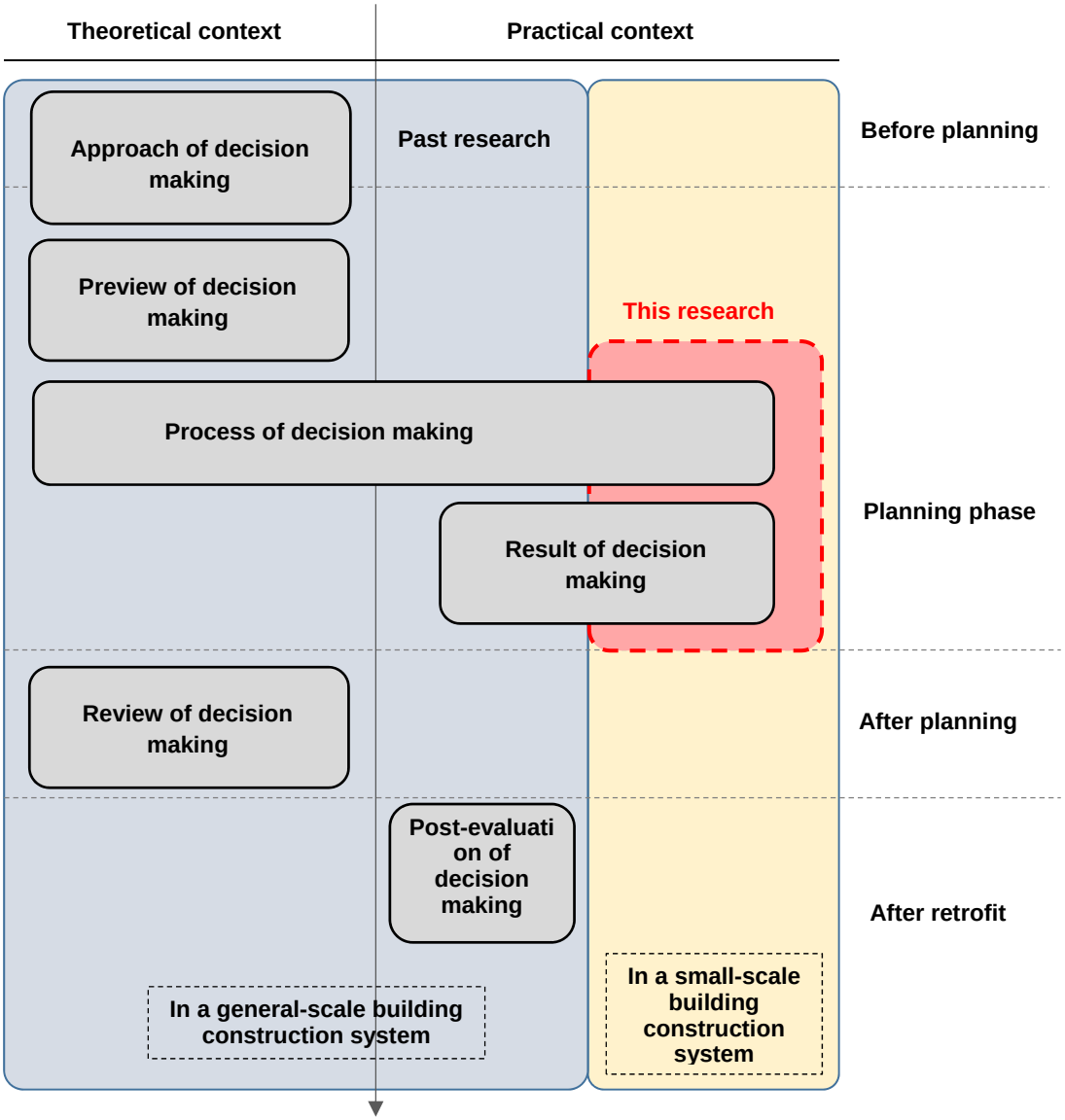

Figure 1-6 Orientation of this research

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太田 隆次郎，秋山 哲一「戸建住宅の品質確保に関する研究: その 2. 小規模住宅生産組織における品質記録の提案と評価」学術講演梗概集 No. 2001，pp1089-1090，2001 年 7 月

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Chapter 2:
Planning situations of energy-efficient building envelope retrofits and associated issue in a small-scale building construction system

2.1 Overview
2.2 Current situation of energy-efficient building envelope retrofits in Taiwan
  2.2.1 Climate type in Taiwan
  2.2.2 Problems of existing buildings relating to energy consumption
  2.2.3 Energy consumption of existing buildings
  2.2.4 Introduction of governmental incentive programs
2.3 Theoretical suggestions of energy-efficient building envelope retrofit
  2.3.1 Ideal planning process
  2.3.2 Ideal decision makers' types
  2.3.3 Retrofitting methods of energy-efficient building envelope in Taiwan
  2.3.4 Promoted retrofitting methods of energy-efficient building envelope in Taiwan
2.4 Practical application of energy-efficient building envelope retrofit
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2.5 Conclusion of Chapter 2
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2.1 Overview

To elucidate practical situation of retrofitting designs in a small-scale building construction system, research contents firstly are to understand current situations and issues of adopting energy-efficient building envelope retrofits in a small-scale building construction system.

Hence, the research purposes in this chapter aims to clarify current situations of energy-efficient building envelope retrofit in theoretical planning situations and practical adopting situations; and then, to define the issue of adopting energy-efficient building envelope retrofits in a small-scale building construction system according to research results.

The issue of adopting energy-efficient building envelope retrofits in a small-scale building construction system is defined by comparing the theoretical planning situations and practical adopting situations. The research framework of Chapter 2 show as the diagram below.

(1) Part 1 is to understand current situation of energy-efficient building envelope retrofits in Taiwan including problems of existing buildings relating to energy consumption and related governmental incentive programs.
(2) Part 2 is to clarified theoretical planning situation of energy-efficient building envelope retrofits including ideal planning processes, ideal decision makers' types, retrofitting methods and promoted retrofitting methods.
(3) Part 3 is to analyze practical adopting situations of retrofitting methods for energy-efficient building envelopes including adopting results of all retrofitting methods and promoted retrofitting methods.
(4) Part 4 is to define the issue of adopting energy-efficiency retrofitting methods on building envelopes in a small-scale building construction system according to the research results in Part 2 and Part 3.

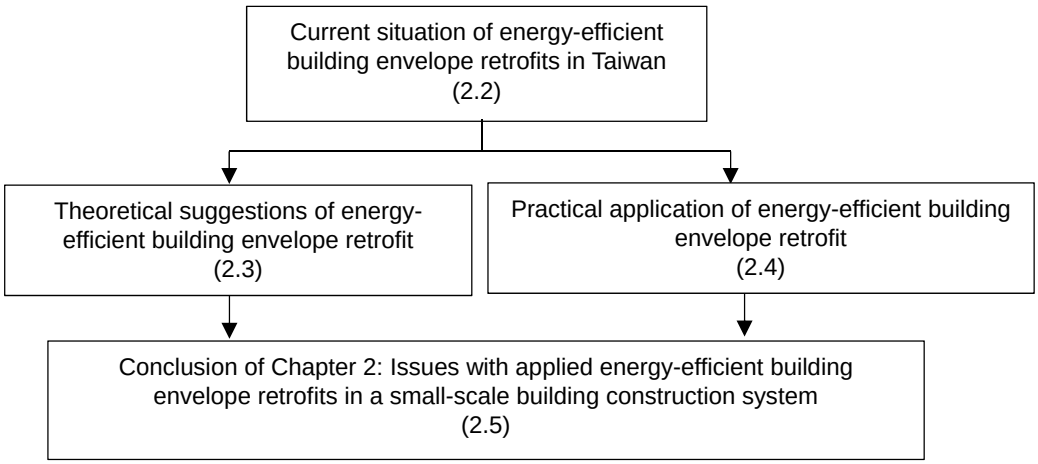

Figure 2-1 Research framework of Chapter 2

2.2 Current situation of energy-efficient building envelope retrofits in Taiwan

2.2.1 Climate type in Taiwan

Taiwan is located in the coast area of East Asia. The climate types in Taiwan are belonging to the subtropical monsoon climate and the tropical monsoon climate which is divided by the Tropic of Cancer. The weather data are as follows: the average temperature is approximately 29℃ during summer, the average sunshine hours per year is around 1788 hours, and the average percentage of humidity is about 77 percent.[35-36]

Hence, generally, the feature of the climates in Taiwan is considered hot and humid in most of the days of the year.

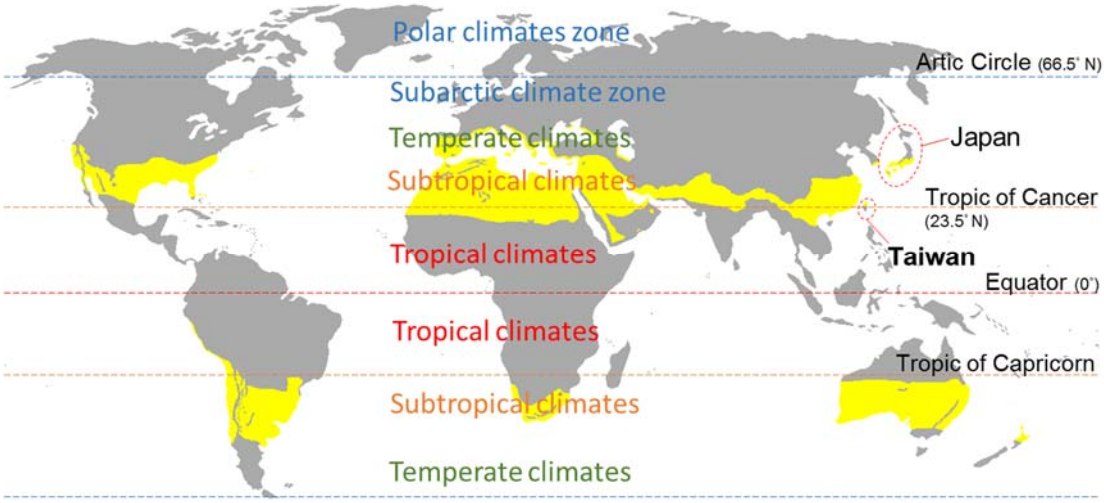

Figure 2-2 Map of climate zone

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[35] Weather data system [online]. Taiwan: Central Weather Bureau of Taiwan. Available from: http://www.cwb.gov.tw/V7/climate/monthlyMean/Taiwan_tx.htm [Accessed October 30, 2012]

[36] "Energy Statistics Handbook 2011", Taiwan: Bureau of Energy, Ministry of Economic Affairs, 2011

2.2.2 Problems of existing buildings relating to energy consumption

According to literature reviews and observations on sites, problems of existing buildings relating to energy consumption of cooling are clarified. Material and improper building designs result overheated problems on existing buildings in Taiwan. The contents are described as follows.

(1) Materials of existing building are easily absorbing solar heat

In Taiwan, the most common material of existing building was reinforced concrete (RC) over the last two decades according to the statistics by Construction and Planning Agency.

However, the concrete block is well known that easily absorbs and maintains solar heat during the day, and radiates the heat out at night.

Therefore, the building problem in Taiwan regarding building materials is that the existing buildings are mostly built by concrete. The situation would easily happen over-heated problems in indoor space.

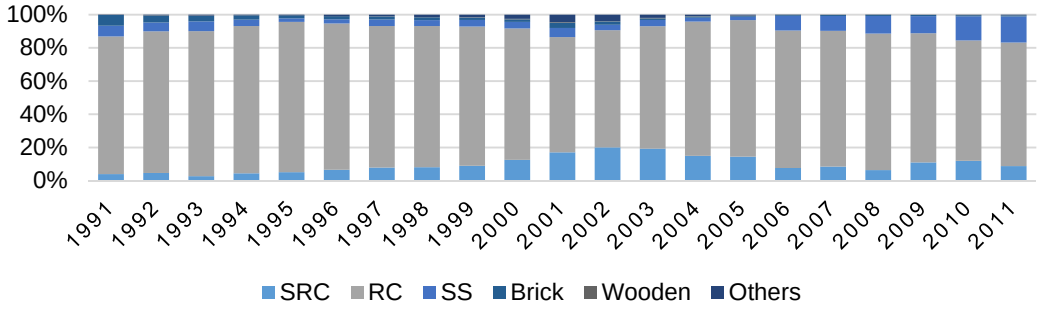


Figure 2-3 Number of the usage license by building materials (1991~2011)

(2) Improper building designs for energy conservation

(A) Oversized opening area

Oversized opening areas are commonly seen designed on existing buildings which were built before the establishment of building regulation regarding opening ratio in 1995.

		
Chung Cheng University	Office building	Office building

Figure 2-4 Images regarding issue of oversized opening area

Source: Picture from governmental report regarding implementation results of incentive programs

(B) Lack of insulating layer and shading design

Insulation and shading performances of building envelopes were not paid attentions before building regulations being established. Therefore, lack of insulating layers and shading designs are one of the problems commonly seen on existing buildings in Taiwan.

		
Lack of shading design	Lack of insulation on wall	Lack of insulation on roof

Figure 2-5 Images regarding issue of lack of insulating layer and shading design

The research results regarding problems of existing building show the most common problems of existing buildings are overheat absorption of building envelopes, oversized opening areas and lacks of insulting layers and shading designs. Hence, over-heated indoor environment is the common problems of existing buildings. Moreover, the building problems would result huge energy consumption for cooling.

2.2.3 Energy consumption of existing buildings

In Taiwan, the energy consumption for generating electricity in Taiwan was about 48.60% in 2010.[37] Moreover, the energy consumption on cooling is accounted for 30% of total building energy consumption in residential buildings and 45% of total building energy consumption in non-residential buildings.[38] Hence, the fact shows that the energy generates for cooling is considered main resource of energy consumption in existing buildings of Taiwan.

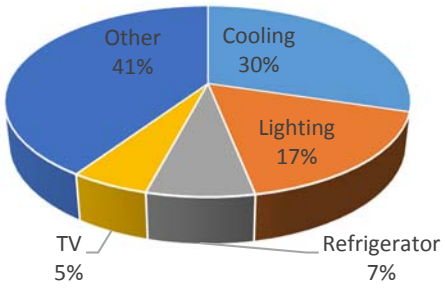
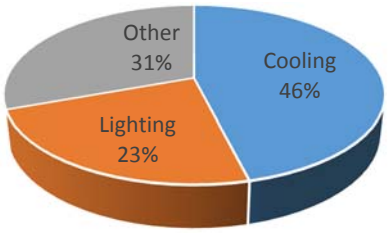
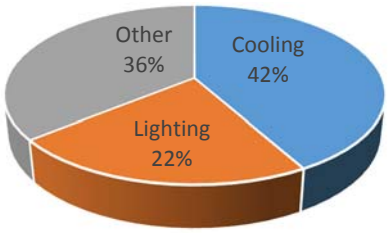


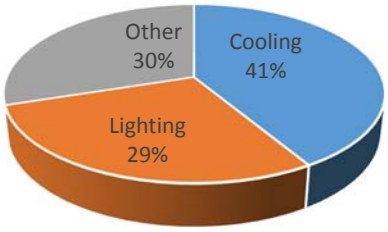
Figure 2-6 Use of electricity in residential buildings



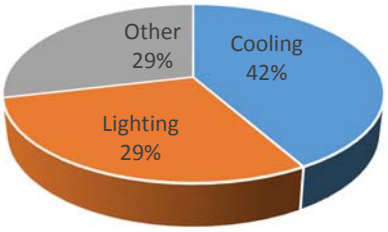
Use of electricity in office building (2011)



Use of electricity in government agencies (2011)



Use of electricity in school building (2011)



Use of electricity in department store (2011)

Figure 2-7 Use of electricity in commercial buildings

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[37] Wei, B. T., "Retrospect and Prospect of Taiwan's energy market supply and demand", in Proc. The Ninth Trade and Culture Forum, Nanning, China, 2013

[38] BEMAP, Building Energy Use According to Building Sector [online]. Taiwan: ITRI. Available from: http://www.bemap.org.tw

2.2.4 Introduction of governmental incentive programs

The seven governmental incentive schemes are introduced according to their conducting periods, incentive building types, amount of subsidy and incentive parts as below.

(1) Scheme A

Scheme A is a green remodeling incentive project for governmental buildings. The incentive project was implemented from 2002 to 2007 and aimed to improve government offices, public institutes and schools. The incentive parts are including openings, walls and roofs.

(2) Scheme B

Same as Scheme A, Scheme B is a green building renew and reform incentive project for public buildings. The incentive project was implemented since 2008 and the amount of subsidy is less than 500,000 NTD (1,800,000 JPY) for each of applied case. The incentive parts are including openings, walls and roofs.

(3) Scheme C

Scheme C is an incentive project to promote installations of exterior shading device on windows and to pave insulation layers on roofs of public and private buildings. The incentive project was implemented from 2002 to 2007. The amount of subsidy for applied cases installing shading devices on windows are no more than 1,000,000 NTD (3,600,000 JPY); the amount of subsidy for cases paving insulation layers on roofs are no more than 500,000 NTD (1,800,000 JPY). The incentive parts are including openings and roofs.

(4) Scheme D

Scheme D is a green building renovation and demonstration incentive project for improving private buildings (including offices, schools, health and welfare, residential and care buildings). The incentive project was implemented from 2004 to 2011. The amount of subsidy for each of applied case are around 250,000 NTD~2,000,000 NTD (900,000 JPY~7,200,000 JPY) and should be no more than 49% of construction cost. The incentive parts are including openings, walls and roofs.

(5) Scheme E

Scheme E is a building façade retrofit project for residential buildings built for over 20 years in Kaohsiung city. The incentive project was conducted from 2006 to 2014. The amount of subsidy for each of applied case are less than 250,000 NTD (900,000 JPY) and 1/2 or 1/3 of construction cost depending on applied retrofitting methods. The incentive parts are including openings and walls.

(6) Scheme F

Scheme F is a building façade retrofit project for private buildings damaged in a gas explosion area of Kaohsiung city. The incentive project was conducted in 2014. The amount of subsidy for each of applied case are less than 6000/m^2. The incentive parts are including openings and walls.

(7) Scheme G

Scheme G is a green façade and roof project for public and private buildings. The incentive project was conducted since 2011. The amount of subsidy for each of applied case to grow plant on walls and roofs are no more than 100,000 NTD (360,000 JPY) or 800,000 NTD (2,880,000JPY) depending on building types and less than 49% of construction cost. The incentive parts are including walls and roofs.

Table 2-1 Introduction of Taiwanese Governmental incentive programs

Name	Period	Incentive building type	Subsidy amount (NTD)	Incentive part
Scheme A Green Remodeling Project for Governmental Building	2002~ 2007	■Public: Government office, Public institutions, School	Unknown	Opening, Wall, Roof
Scheme B Green Building Renew & Reform Project	2008~	■Public: Government office, Public institutions, School	≦500,000/per	Opening, Wall, Roof
Scheme C Exterior shading device of window & insulation of roof installation project	2002~ 2007	■Public: Office, School ■Private: Office, Commerce, School, Health & Welfare, Residential & care	Sunshade: ≦1,000,000 Roof Insulation: ≦500,000	Opening, Roof
Scheme D Green building renovation and demonstration project	2004~ 2011	■Private: Office, School, Health & Welfare, Residential & care	250,000~2,000,000 and ≦ 49% construction cost	Opening, Wall, Roof
Scheme E Building façade retrofit project in Kaohsiung city	2006~ 2014	■Private: Residential, Office (Has built over 20 years old.)	1/2 or 1/3 of construction cost and less than 250,000	Opening, Wall
Scheme F Building façade retrofit project in gas explosion area of Kaohsiung city	2014	Private Buildings damaged due to gas explosion	100% construction cost, but less than 6000 / m^2	Opening, Wall
Scheme G Green façade and roof project	2011~	Public & Private buildings	≦ 49% construction cost and less than 100,000 or 800,000	Wall, roof

2.3 Theoretical suggestions of energy-efficient building envelope retrofit

2.3.1 Ideal planning process

According to literature reviews [39-42], the workflows and contents of retrofits in a planning and design stage are found can be concluded into following six steps:

(1) Pre-retrofit survey: collections of existing building-related data, investigation of existing conditions, understand of client's demands and criteria.

(2) Building performance assessment: check the performance on each part of building (airtight, insulation, thermal environment etc.), general physical deterioration diagnosis by tool or visual observation.

(3) Decide retrofit strategy: decide retrofitting scale, retrofitting part, retrofitting measure and establishment of retrofitting target and goal

(4) Retrofitting plan and design: schematic design of retrofitting part, constructing measures and design.

(5) Estimate retrofitting effect: amount of energy save, life cycle cost (Initial cost, construction cost, running cost, cost reduced from energy save), environmental friendliness (amount of CO_2 reduction).

(6) Suggest a retrofit proposal: suggest an energy-efficiency retrofit proposal, and sometimes the construction work combines with a deterioration retrofit.

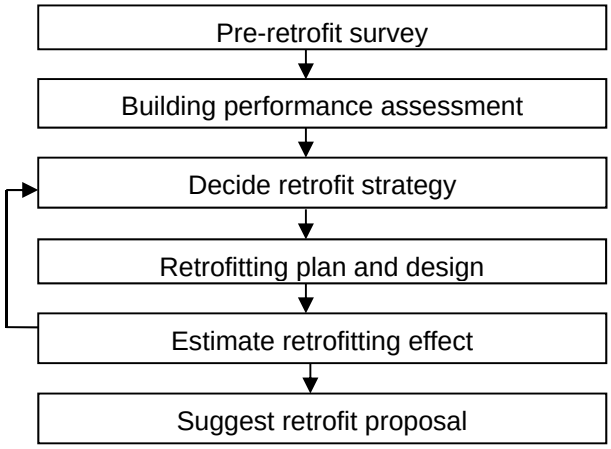

Figure 2-8 Theoretical planning process of sustainable retrofitting design

It is found that an energy-efficiency retrofitting plan and design is expected to be decided after estimating performances of existing buildings and retrofitting effects. Moreover, "Improving effects of energy efficiency" are the main focus for decision makers to decide effective retrofitting methods in a theoretical situation.

2.3.2 Ideal decision makers' types

For deciding effective energy-efficiency retrofitting methods in a theoretical situation, the following ideal situations are expected.

(1) Decision makers have professional and technical abilities

(2) A design team includes consultants and experts from several fields

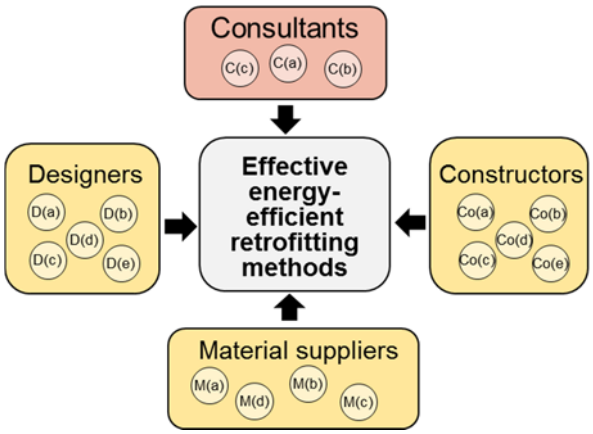

Figure 2-9
Theoretical specialties of decision makers in a general building construction system

[39] Ma, Z., Cooper, P., Daly, D., Ledo, L. (2012), 'Existing building retrofits: Methodology and state-of-the-art', *Energy and Building* 55: 889-902

[40] 自立循環型住宅開発委員会 (2010) *既存住宅の省エネ改修ガイドライン*, Tokyo: IBBC, pp. 10

[41] 自立循環型住宅開発委員会 (2017), 自立循環型住宅への設計ガイドライン: 要素技術の手法と省エネルギー効果 [online]. Tokyo: IBBC. Available from: http://www.jjj-design.org/?page_id=78 [Accessed 21 May 2017]

[42] 南早紀 (2011), 戸建住宅の省エネルギー改修に関する研究, 修士論文, 東京大学, 18-20

2.3.3 Retrofitting methods of energy-efficient building envelope in Taiwan

According to design guidelines, improving methods for reducing electricity usage on cooling are clarified as enhancing shading, insulating and airtightness of building envelopes.
The improving methods of building envelopes for reducing electricity generating for cooling can be categorized into 18 types for openings, walls and roofs.[43-49] The six improving methods for each part of building envelopes are introduced as follows.

A. Retrofitting methods for opening part

(1) Adding external shading device (O1)

Adding external shading devices on openings is the method can enhance shading capability of openings by installing devices outside of existing windows.

(2) Window replacement (O2)

Window replacements is the method can enhance shading and insulating capability of openings by replacing existing windows by higher performed windows, such as windows have low-e glazing and insulated frames.

(3) Moving position of window (O3)

Moving position of windows is the method can enhance shading capability of openings by create a shading space.

(4) Adding window film (O4)

Adding window films is the method can enhance shading and insulating capability of windows by pasting a layer of glass film on existing window glazing.

(5) Adding internal shading device (O5)

Adding internal shading device on openings is the method can enhance shading capability of openings by installing devices inside of existing windows.

(6) Adding second window (O6)

Adding second window is the method can enhance insulating capability of openings by installing new windows on the outside or the inside of existing windows.

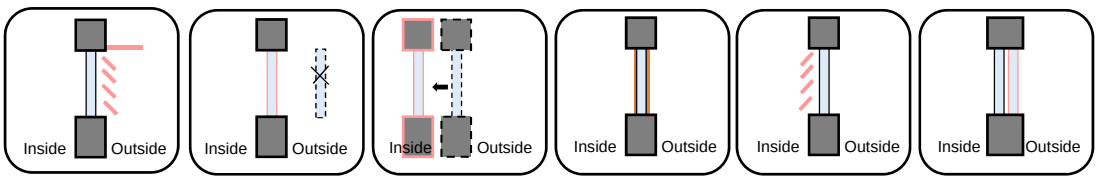

Figure 2-10 Retrofitting methods for opening part

B. Retrofitting methods for wall part

(7) Adding external shading device on wall (or second wall) (W1)

Adding external shading devices on walls (or second walls) is the method can reduce heat absorptions of walls by installing devices or second layer on the outside of existing walls.

(8) Adding insulation material externally (W2)

Adding insulation material externally on walls is the method can enhance insulating capability of walls by installing an insulating layer on the outside of external walls.

(9) Adding insulation material internally (W3)

Adding insulation material internally on walls is the method can enhance insulating capability of walls by installing an insulating layer on the inside of external walls.

(10) Covering heat reflective or insulating paint externally (W4)

Covering heat reflective or insulating paint externally is the method can enhance insulating capability of walls by coated with a layer of paint with light color on the outside of existing walls.

(11) Replacement of finishing material (W5)

Replacement of finishing material is the method can enhance insulating capability of walls by replacing existing finishing layers of walls to a new finishing layer with higher performances.

(12) Adding greenery vertically (W6)

Adding greenery vertically on walls is the method can reduce heat absorptions of walls by growing plants as a second layer to shade existing walls.

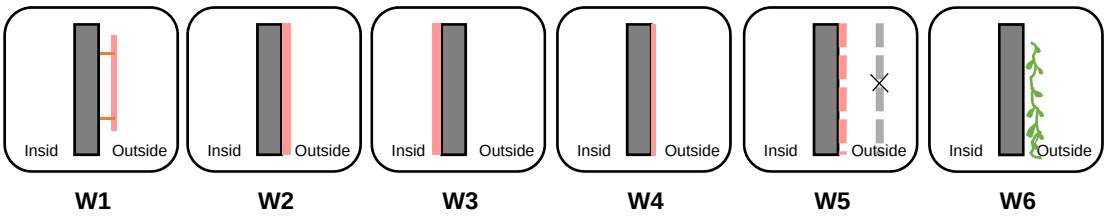

Figure 2-11 Retrofitting methods for wall part

C. Retrofitting methods for roof part

(13) Adding second roof or canopy (R1)

Adding second roof or canopy is the method to increase a layer to shade existing roofs.

(14) Adding insulation material externally (R2)

Adding insulation material externally on walls is the method can enhance insulating capability of roofs by paving a new insulated layer on the outside of existing roofs.

(15) Adding heat reflective or insulating paint externally (R3)

Adding heat reflective or insulating paint externally on roofs is the method can reflect sunlight away and reduce solar heat absorption on existing roofs.

(16) Adding greenery (R4)

Adding greenery on roofs is the method can reduce heat absorptions of roofs by growing plants to shade existing walls and to be an insulating layer.

(17) Watering (R5)

Watering on roofs is the method to cool down the surface temperature of roofs by evaporation.

(18) Adding insulation material internally (R6)

Adding insulation material internally is the method can enhance insulating capability of roofs by paving a new insulated inside the existing roofs.

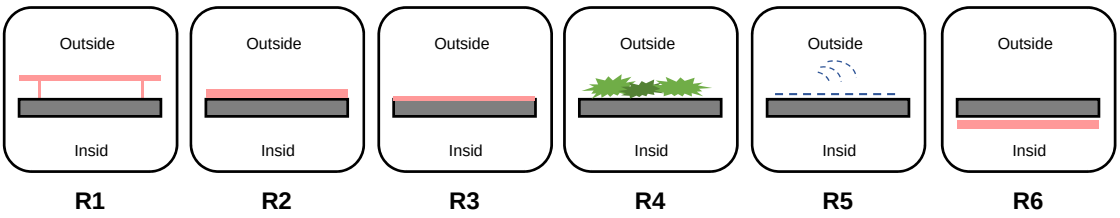

Figure 2-12 Retrofitting methods for roof part

2.3.4 Promoted retrofitting methods of energy-efficient building envelope in Taiwan

With the 18 improving methods, some of them are especially promoted by Taiwanese government [47-49] and expert to achieve the best improving effects of energy efficiency according to existing building problem, Taiwanese climate type and building energy consumption type. The promoted retrofitting strategies are expressing as follows.

(1) Opening

The promoted improving methods for openings include adding external shading devices on openings (O1). The method adding external shading devices on openings (O1) are encouraged to apply in Scheme A, Scheme B, Scheme D, Scheme E and Scheme F, and are required to apply in Scheme C.

(2) Wall

The promoted improving methods for walls include adding external shading device in walls or second walls (W1), adding insulation material externally on walls (W2) and adding greenery vertically (W6). These methods are encouraged to apply in Scheme E and Scheme F.

(3) Roof

The promoted improving methods for roofs include adding second roofs or shading device on roofs (R1), adding insulation material externally on roofs (R2), and adding greenery (R4). All these methods are encouraged to apply in Scheme A, Scheme B, Scheme C and Scheme D; the method R4 is required to apply in Scheme G.

Table 2-2 Promoted retrofitting methods (pink part)

	Improving methods for openings						**Improving methods for walls**						**Improving methods for roofs**					
Improving method	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
	Adding external shading device	Window replacement	Moving position of window	Adding window film	Adding internal shading device	Adding second window	Adding external shading device or second wall	Adding insulation material externally	Adding insulation material internally	Covering heat reflective or insulating paint externally	Replacement of finishing material	Adding greenery vertically	Adding second roof or shading device	Adding insulation material externally	Adding heat reflective or insulating paint externally	Adding greenery	Watering	Adding insulation material internally

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[43] 自立循環型住宅開発委員会 (2010) *既存住宅の省エネ改修ガイドライン*, Tokyo: IBBC (Institute for Building and Energy Conservation), P26

[44] 既存住宅の省エネ改修ガイドライン: 省エネルギー改修手法 [online]. Tokyo: IBBC. Available from: http://www.jjj-design.org / eco_repair/ technique/ index.html [Accessed 30 June 2013]

[45] Thorpe, D. (2010), *Sustainable home refurbishment: the Earthscan expert guide to retrofitting homes for efficiency*, UK: Earthscan

[46] Chou, Z., (2009), *Good house*, Taiwan: Yeren Publishing House (邱繼哲, *好房子*, 野人文化股份有限公司*)*

[47] Annual report of exterior shading device of window & insulation of roof installation project, Taiwan: Nation Taiwan University of Science and Technology, 2004~2007

[48] Annual report of green building renovation and demonstration project, Taiwan: Taiwan architecture and building center, 2004~2010

[49] Annual report of building façade retrofit project in Kaohsiung city, Taiwan: Kaohsiung city government, 2006~2014

2.4 Practical application of energy-efficient building envelope retrofit

2.4.1 Application of all energy-efficiency retrofitting methods

Cases in the seven incentive projects are utilized for analyzing adopting situations of retrofitting strategies. There are 688 cases in total are investigated about their retrofitting parts and selected retrofitting methods.

2.4.1.1 Selected retrofitting part

Regarding retrofitting parts of building envelopes, the research results show: (a) an opening is relatively the most common part improved in all incentive projects, (b) a roof is the secondary most part seen improved in Scheme A, Scheme B, Scheme C, Scheme D, Scheme G, and (c) a wall is the least part only seen improved in Scheme E and Scheme F. Moreover, the research result shows that retrofitting parts in most of cases are single component of building envelopes and small proportions of building envelopes.

Table 2-3 Application regarding improving part

Incentive scheme	Number of case			
	Total	**Opening**	**Wall**	**Roof**
Scheme A	50	43	1	12
Scheme B	17	6	-	11
Scheme C	336	56 (Public) + 60 (Private)	-	36 (Public) +184 (Private)
Scheme D	38	15	-	19
Scheme E	238	179	198	-
Scheme F	5	5	5	-
Scheme G	4	-	-	4
Total	688	364	204	266

2.4.1.2 Selected retrofitting method

The adoption situations of retrofitting methods are described according to the three components of building envelopes: opening, walls and roofs.

A. Opening

Regarding retrofitting methods of openings, adding external shading (O1) and window replacement (O2) are found the relatively popular improving strategies. Moreover, adding external shading (O1) is the strategy especially adopted greatly in Scheme A, Scheme B, Scheme C and Scheme D; window replacement (O2) is the strategy especially mostly in Scheme E and Scheme F. These two strategies are both common seen in non-incentive cases.

B. Wall

Regarding retrofitting methods of walls, replacement of finishing material (W5) and covering

heat reflective or insulating paint externally (W4) is the relatively popular improving strategies in Scheme E and Scheme F.

C. Roof

Regarding retrofitting methods of roofs, adding second roof or shading device (R1), adding insulation material externally (R2), and adding greenery (R4) are the relatively popular improving strategies. Moreover, adding second roof or shading device (R1), is the method commonly applied in cases of Scheme A, Scheme B and non-incentive one. Adding insulation material externally (R2) is the method seen a lots in cases of Scheme A, Scheme C and Scheme D. Adding greenery (R4) is the method applied greatly in cases of Scheme B, Scheme D and Scheme G.

Summary

It is found the 18 methods are almost adopted in the 688 cases, except the methods W3, W6, R5 and R6. The most adopted methods in the opening part are O1 and O2, in the wall part is W5 and in the roof part is R2.

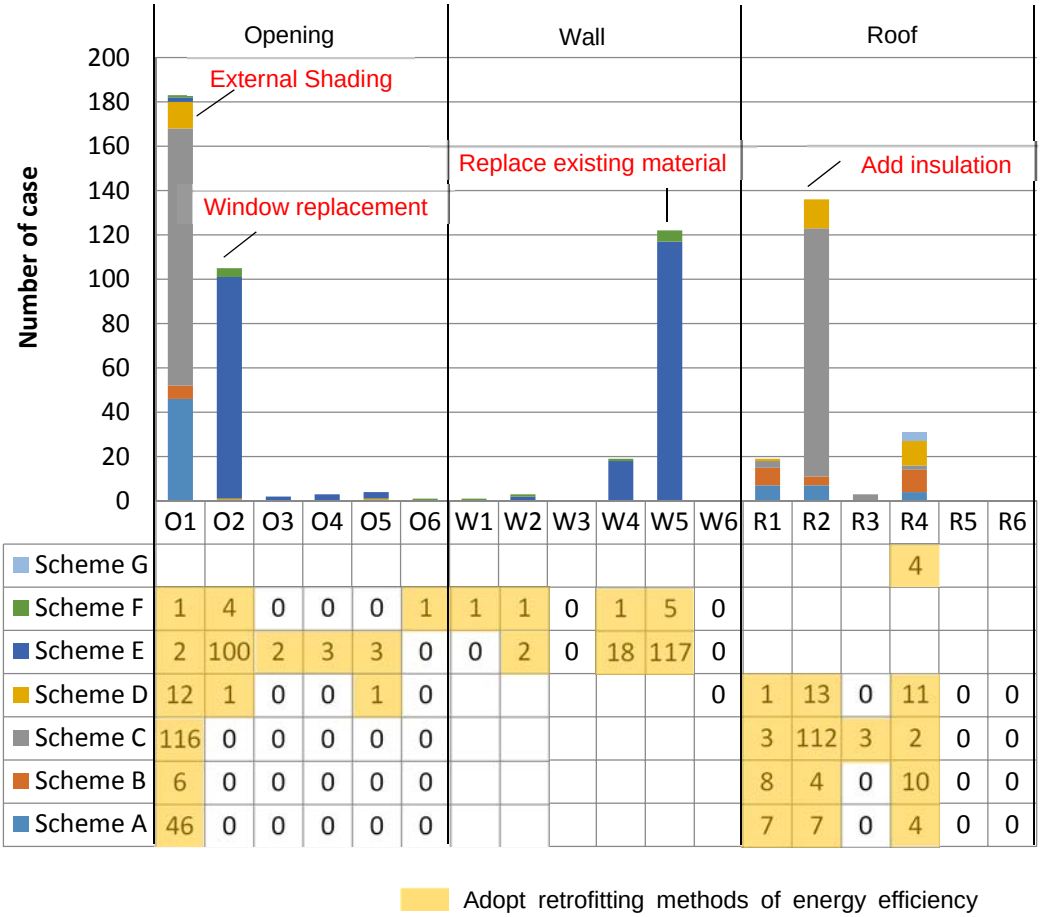


Figure 2-13 Application of all retrofitting methods

2.4.2 Application of promoted energy-efficiency retrofitting methods

2.4.2.1 Application of promoted retrofitting methods in all cases

The adopting situations of promoted improving methods (O1, O2, W1, W2, W6, R1, R2 and R4) are described and discussed in this part.

(1) Adding external shading on opening (O1)

Adding external shading on openings is the improving method seen adopted popularly in cases belonging to Scheme A, Scheme B, Scheme C and Scheme D. However, this strategy is rarely applied in the cases belonging to Scheme E and Scheme F.

(2) Window replacements (O2)

Window replacements is the improving method seen adopted popularly in cases belonging to Scheme E and Scheme F. The number of cases adopted this improving method on openings is more than the cases adopted the method adding external shading devices on opening (O1).

(3) Adding external shading device or second wall (W1)

Adding external shading device or second wall is the strategy seen adopted rarely in the cases belonging to Scheme E and Scheme F.

(4) Adding insulation material externally on walls (W2)

Same as the strategy W1, adding insulation material externally on walls is the strategy seen adopted rarely in the cases belonging to Scheme E and Scheme F.

(5) Adding greenery vertically on wall (W6)

None of cases adopted adding greenery vertically on walls as a retrofitting strategy.

(6) Adding second roof or shading device on roof (R1)

Adding second roof or shading device on roof is the strategy seen applied popularly in the cases belonging to Scheme A and Scheme B. However, this strategy is rarely applied in the cases belonging to Scheme C and Scheme D.

(7) Adding insulation material externally on roof (R2)

Adding insulation material externally on roof is the strategy seen applied popularly in the cases belonging to Scheme A, Scheme C and Scheme D. However, this strategy is rarely applied in the cases belonging to Scheme B and none of cases applied in non-incentive program.

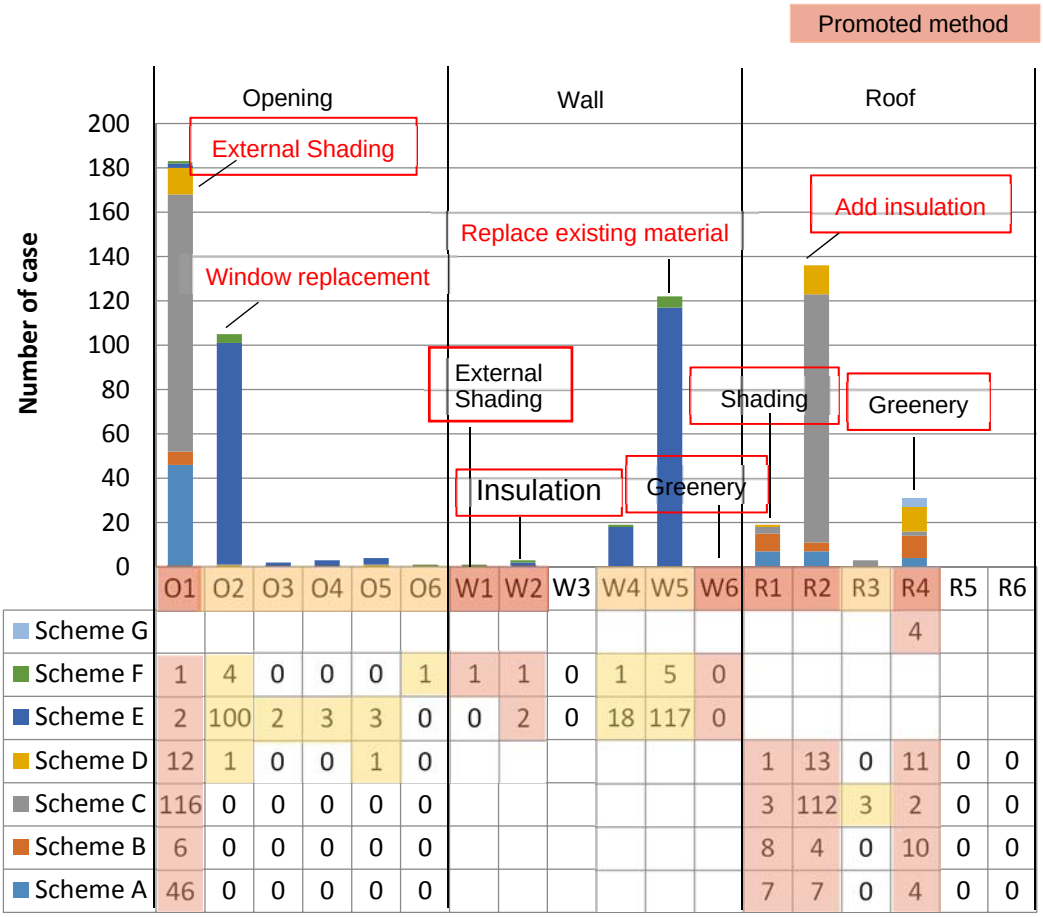
(8) Adding greenery on roof (R4)

Adding greenery on roof is the strategy seen applied popularly in the cases belonging to Scheme B, Scheme D and Scheme G. However, this strategy is rarely applied Scheme A and Scheme C.

Summary

(1) Within these popularly adopted methods, only O1 and R2 are the promoted methods.

(2) Other promoted methods, W1, W2, W6, R1 and R4, are found rarely adopted or not adopted in cases.



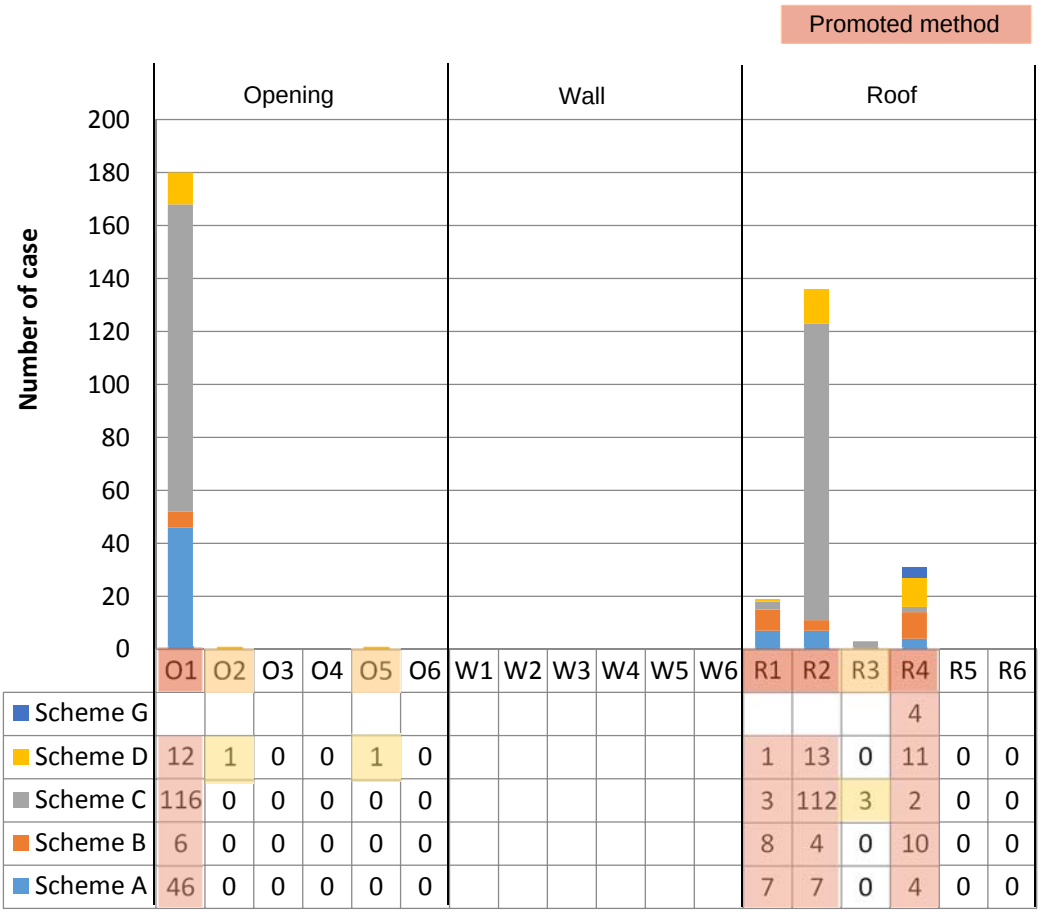
	O1	O2	O3	O4	O5	O6	W1	W2	W3	W4	W5	W6	R1	R2	R3	R4	R5	R6
Scheme G																4		
Scheme F	1	4	0	0	0	1	1	1	0	1	5	0						
Scheme E	2	100	2	3	3	0	0	2	0	18	117	0						
Scheme D	12	1	0	0	1	0							1	13	0	11	0	0
Scheme C	116	0	0	0	0	0							3	112	3	2	0	0
Scheme B	6	0	0	0	0	0							8	4	0	10	0	0
Scheme A	46	0	0	0	0	0							7	7	0	4	0	0

Figure 2-14 Application of promoted retrofitting methods

2.4.2.2 Application of promoted retrofitting methods in the cases of energy-efficiency retrofit

By looking at the cases which retrofitting purpose is only for energy efficiency in Scheme A, Scheme B, Scheme C, Scheme D and Scheme G, it is found the method O1 is adopted the most in the opening part; the methods R1, R2 and R4 are adopted commonly in the roof part. Furthermore, the methods, O1, R1, R2 and R4, are all belonging to promoted retrofitting methods.

Hence, it is clarified the promoted retrofitting methods are popularly adopted in the cases which retrofitting purpose is only for energy efficiency.



	O1	O2	O3	O4	O5	O6	W1	W2	W3	W4	W5	W6	R1	R2	R3	R4	R5	R6
Scheme G																4		
Scheme D	12	1	0	0	1	0							1	13	0	11	0	0
Scheme C	116	0	0	0	0	0							3	112	3	2	0	0
Scheme B	6	0	0	0	0	0							8	4	0	10	0	0
Scheme A	46	0	0	0	0	0							7	7	0	4	0	0

Figure 2-15 Application of promoted retrofitting methods in the cases of energy-efficiency retrofit

2.4.2.3 Application of promoted retrofitting methods in the cases of energy-efficiency retrofit and general retrofit

By looking at the cases which retrofitting purpose are for improving building appearance and energy efficiency in Scheme E and Scheme F, it is found: (1) the method O2 is adopted the most in the opening part, and (2) the methods W4 and W5 are commonly adopted in the wall part. Moreover, it is found these popularly adopted methods are not promoted.

Hence, it is clarified that the promoted retrofitting methods are not commonly adopted in the cases which retrofitting purpose are for improving building appearance and energy efficiency.

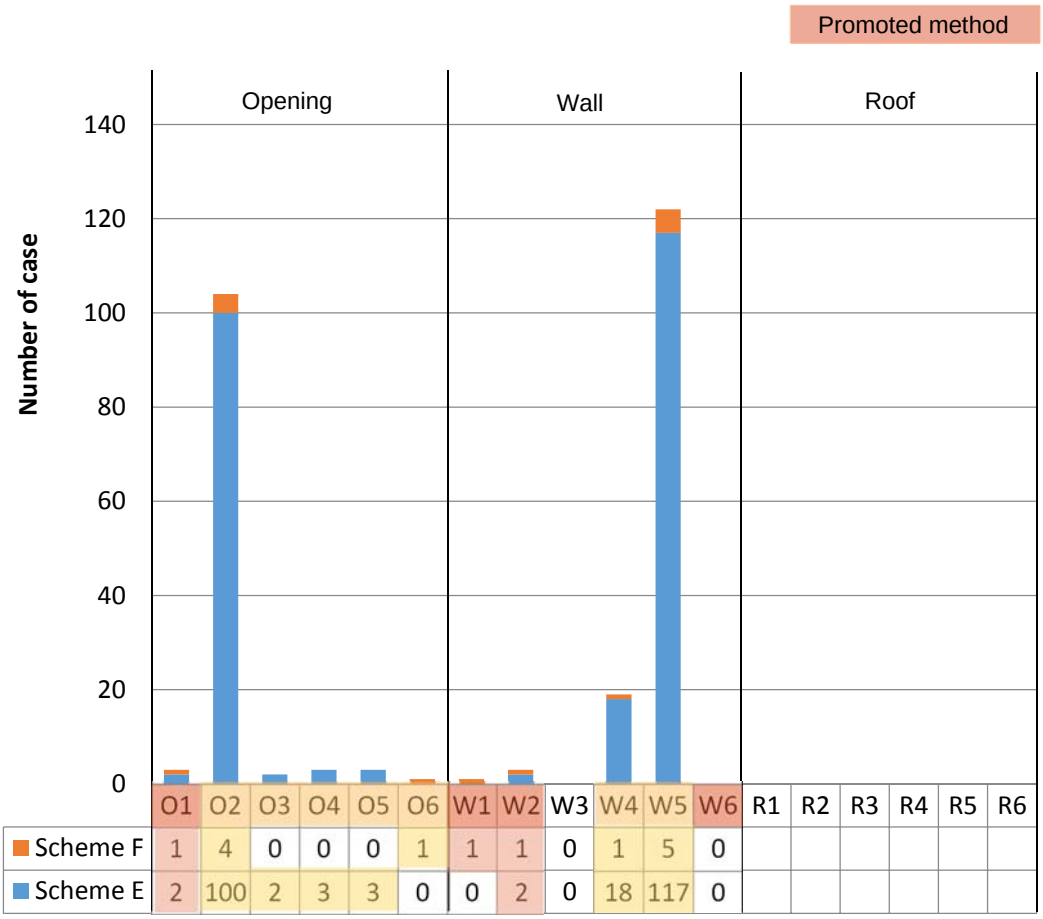


Figure 2-16 Application of promoted retrofitting methods in the cases of energy-efficiency retrofit and general retrofit

2.5 Conclusion of Chapter 2

In Chapter 2, research results regarding theoretical and practical context of building envelope retrofit for energy efficiency were clarified. According to research results, findings regarding issues of adopting energy-efficient building envelope retrofits in a small-scale building construction system were defined are as follows.

2.5.1 Summary

(1) Theoretical suggestions of energy-efficient building envelope retrofit

The research regarding theoretical suggestions of energy-efficient building envelope retrofits includes (a) ideal planning process, (b) ideal decision maker types, and (c) theoretical retrofitting methods of energy-efficient building envelopes.

The research regarding ideal decision makers' types, it is clarified that the decision makers are expected to have professional and technical abilities. Moreover, a design team including consultants and experts from several fields is expected

The research regarding theoretical planning process, it is clarified that the consideration "improving effects of energy efficiency" is decision makers' main focus to decide effective retrofitting methods in theoretical suggestions of energy-efficient building envelope retrofit.

The research regarding promoted retrofitting methods, it is clarified that the retrofitting methods suggested by experts according to their "improving effects of energy efficiency" in Taiwanese climate type, energy consumption type and building type.

In this study, it was found that the promoted retrofitting methods of energy-efficient building envelopes suggested by professionals are expected to be adopted popularly in retrofitting projects to achieve the best energy-saving effects.

(2) Practical application of energy-efficient building envelope retrofits

The research regarding practical application of energy-efficient building envelope retrofits was found following results.

(a) Multiple building-envelope retrofits had to be executed in some cases due to ineffective retrofitting results for improving indoor thermal environment.
(b) Various retrofitting methods were adopted, including both general and promoted methods, in each part of the building envelope.
(c) Promoted retrofitting methods were only popularly adopted in the cases where the retrofitting purpose was only energy efficiency and were less applied to the cases where the retrofitting purpose was both improving building appearance and energy efficiency.

(d) Popularly adopted retrofitting methods where retrofitting purpose was to improve building appearance and energy efficiency were not the promoted ones.

2.5.2 Issues of adopting energy-efficient building envelope retrofits in a small-scale building construction system

By comparing theoretical suggestions and practical applications of retrofitting methods, it was found that (1) various adopted retrofitting methods exist and (2) some of them are different from theoretical suggestions and have ineffective improving results.

According to above research results, it is assumed that actual compositions of decision makers and planning processes of energy-efficiency retrofitting designs in a small-scale building construction system might not be as professional as theoretical suggestions.

Next, actual compositions of decision makers and decision-making processes of retrofitting designs in the small-scale building construction system are going to be discovered and discussed for understanding what causes above issues.

Chapter 3
Composition of decision makers in a small-scale building construction system

3.1 Overview
3.2 Introduction of studied cases
  3.2.1 Basic information of studied cases
  3.2.2 Features of studied cases
3.3 Professions of decision makers
  3.3.1 Types of decision makers' professions
  3.3.2 Categorization according to types of decision makers' professions
  3.3.3 Features of decision makers' professions in nine combination types
3.4 Relevance of decision makers' professions
  3.4.1 Types of relevance regarding decision makers' professions
  3.4.2 Categorization according to relevance of decision makers' professions
  3.4.3 Features regarding profession relevance of decision makers in 15 combination patterns
3.5 How decision makers' compositions were decided
  3.5.1 Relationship between compositions of decision makers' professions and types of building envelope retrofitting projects
  3.5.2 Reasons of decision makers' compositions were decided
3.6 Relationship between decision makers' compositions and adopted retrofitting methods
3.7 Conclusion of Chapter 3
  3.7.1 Summary
  3.7.2 Attributes of decision makers in a small-scale building construction system

3.1 Overview

The aim of Chapter 3 is to clarify attributes of decision-makers in a small-scale building construction system by focusing on their compositions and how decision makers' compositions were decided. The contents regarding compositions include decision makers' profession types, relevance of profession types. The data were collected through case studies and interview surveys. Thirty-two retrofitting projects were selected from incentive and non-incentive programs as cases to be studied. Regarding interview surveys, decision makers from the 32 cases were interviewed to collect data on the profession types and relevance.

Subsequently, based on these data, decision makers' combinations were categorized.

The research contents and frameworks are presented as diagram below. (Figure 3-1)
Part 1 is to analyses basic information's and features of 32 cases. (3.2)
Part 2 is to clarify decision makers' profession types, combinations according to these profession types and features of decision makers' profession types in the combinations. (3.3)
Part 3 is to further clarify relevance of decision makers' professions, combinations according to the relevance and features of decision makers' profession relevance in the combinations. (3.4)
Part 4 is to understand how decision makers' combinations being decided and analyzed the reasons. (3.5)
Part 5 is to summarized the research results in this chapter and define attributes of decision-makers in a small-scale building construction system according to the research results of Part 2, Part 3 and Part 4. (3.6)

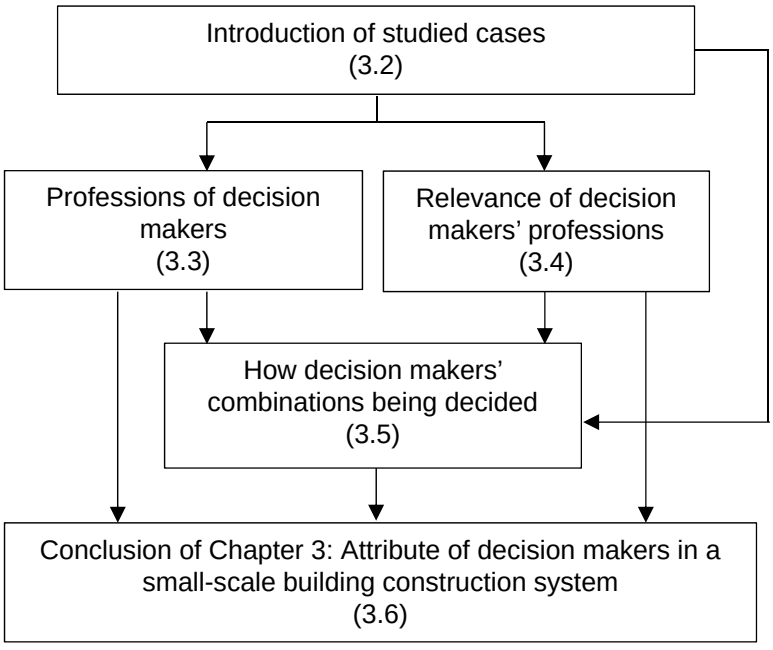


Figure 3-1 Framework of Chapter 3

3.2 Introduction of studied cases

3.2.1 Basic information of studied cases

Basic information of 32 studied cases are introduced in this part and including retrofitting program, location, building use, built year, retrofit year, building height, building material, status of usage during retrofit, adopted retrofitting strategy and decision makers.

(1) Case R1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme C		
Location	Yilan City		
Building Use	Residential		
Built Year	1987		
Retrofit Year	2007		
Building Height	3		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening, Roof		
Adopted retrofitting method	O1, R2		
Decision Maker	Client, Consultant, Designer		

Figure 3-2 Basic information of Case R1

(2) Case R2

Basic information		Image
Program	Scheme E	 Before
Location	Kaohsiung	
Building Use	Residential	
Built Year	1975	
Retrofit Year	2012	
Building Height	3	 After
Building Material	RB	
Ownership	Private	
Retrofitting Part	Opening, Wall	
Adopted retrofitting method	O2, W5	
Decision Maker	Client, Designer, Constructor	

Figure 3-3 Basic information of Case R2

(3) Case R3

Basic information		Image
Program	Scheme F	 Before
Location	Kaohsiung	
Building Use	Residential	
Built Year	1975	
Retrofit Year	2014	
Building Height	4	
Building Material	RC	
Ownership	Private	 After
Retrofitting Part	Opening, Wall	
Adopted retrofitting method	O2, W2+W5	
Decision Maker	Client, Consultant, Designer, Constructor, Material supplier	

Figure 3-4 Basic information of Case R3

(4) Case R4

Basic information		Image
Program	Scheme F	 Before
Location	Kaohsiung	
Building Use	Residential	
Built Year	1978	
Retrofit Year	2014	
Building Height	4	
Building number	20	
Building Material	RC	 After
Ownership	Private	
Retrofitting Part	Opening, Wall	
Adopted retrofitting method	O1, W1+W4	
Decision Maker	Client, Consultant, Designer, Constructor, Material supplier	

Figure 3-5 Basic information of Case R4

(5) Case R5

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme E		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1977		
Retrofit Year	2014		
Building Height	4		
Building Material	RB		
Ownership	Private		
Retrofitting Part	Opening, Wall		
Adopted retrofitting method	O2+O4, W5		
Decision Maker	Client, Consultant, Designer, Constructor		

Figure 3-6 Basic information of Case R5

(6) Case R6

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Taipei		
Building Use	Residential		
Built Year	1995		
Retrofit Year	2015		
Building Height	6		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening, Wall, Roof		
Adopted retrofitting method	O2, O3, W1+W2+W5, R2		
Decision Maker	Client, Consultant, Designer, Constructor, Material supplier		

Figure 3-7 Basic information of Case R6

(7) Case R7-1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1992		
Retrofit Year	1997		
Building Height	15/16		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening		
Adopted retrofitting method	O5		
Decision Maker	Client, Designer,		

Figure 3-8 Basic information of Case R7-1

(8) Case R7-2

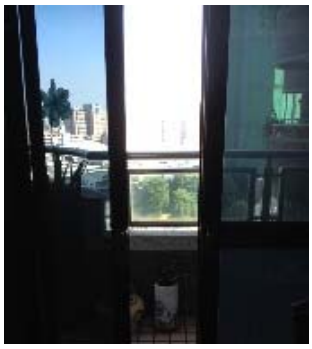
Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1992		
Retrofit Year	2012		
Building Height	15/16		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening		
Adopted retrofitting method	O1, O4		
Decision Maker	Client, Designer, Constructor		

Figure 3-9 Basic information of Case R7-2

(9) Case R8-1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1974		
Retrofit Year	1988		
Building Height	3		
Building Material	RB		
Ownership	Private		
Retrofitting Part	Opening, Wall		
Adopted retrofitting method	O2, W4, W5		
Decision Maker	Client Constructor, Material supplier		

Figure 3-10 Basic information of Case R8-1

(10) Case R8-2

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1974		
Retrofit Year	2014		
Building Height	3		
Building Material	RB		
Ownership	Private		
Retrofitting Part	Opening, Wall		
Adopted retrofitting method	O1, W1+W2,		
Decision Maker	Client, Constructor, Material supplier		

Figure 3-11 Basic information of Case R8-2

(11) Case R9

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme E		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1972		
Retrofit Year	2013		
Building Height	4		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening, Wall		
Adopted retrofitting method	O1+O2, W5		
Decision Maker	Client, Consultant, Designer, Constructor		

Figure 3-12 Basic information of Case R9

(12) Case R10

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme E		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1973		
Retrofit Year	2013		
Building Height	5		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening, Wall		
Adopted retrofitting method	O2, W5		
Decision Maker	Client, Consultant, Designer		

Figure 3-13 Basic information of Case R10

(13) Case R12

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Pingtung County		
Building Use	Residential		
Built Year	2009		
Retrofit Year	2013		
Building Height	3		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening		
Adopted retrofitting method	O1		
Decision Maker	Client, Constructor		

Figure 3-14 Basic information of Case R12

(14) Case R13

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme F		
Location	Kaohsiung		
Building Use	Residential		
Built Year	-		
Retrofit Year	2015		
Building Height	3		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening, Wall		
Adopted retrofitting method	O6, W5		
Decision Maker	Client, Designer, Constructor		

Figure 3-15 Basic information of Case R13

(15) Case R14

Basic information	
Program	Scheme F
Location	Kaohsiung
Building Use	Residential
Built Year	1975
Retrofit Year	2014
Building Height	4
Building Material	RC
Ownership	Private
Retrofitting Part	Opening, Wall
Adopted retrofitting method	O2, W5
Decision Maker	Client, Designer, Constructor,

Image

Before

After

Figure 3-16 Basic information of Case R14

(16) Case R16

Basic information	
Program	Scheme E
Location	Kaohsiung
Building Use	Residential
Built Year	1982
Retrofit Year	2014
Building Height	11
Building Material	RC
Ownership	Private
Retrofitting Part	Wall
Adopted retrofitting method	W4
Decision Maker	Client, Consultant, Designer, Constructor

Image (Before retrofit)

Image (After retrofit)

Figure 3-17 Basic information of Case R16

(17) Case R17

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme E		
Location	Kaohsiung		
Building Use	Residential		
Built Year	1957		
Retrofit Year	2009		
Building Height	3		
Building Material	RB		
Ownership	Private		
Retrofitting Part	Opening		
Adopted retrofitting method	O2		
Decision Maker	Client, Constructor		

Figure 3-18 Basic information of Case R17

(18) Case R18

Basic information		Image (After retrofit)
Program	None	 
Location	Taichung	
Building Use	Residential	
Built Year	-	
Retrofit Year	2012	
Building Height	-	
Building Material	RC	
Ownership	Private	
Retrofitting Part	Roof	
Adopted retrofitting method	R2	
Decision Maker	Client, Consultant, Constructor, Material supplier	

Figure 3-19 Basic information of Case R18

(19) Case G1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme B, Green remodeling project		
Location	Kaohsiung		
Building Use	Government office		
Built Year	1983		
Retrofit Year	2003, 2007		
Building Height	10		
Building Material	RC		
Ownership	Public		
Retrofitting Part	Opening		
Adopted retrofitting method	O1, O2		
Decision Maker	Client, Consultant, , Designer		

Figure 3-20 Basic information of Case G1

(20) Case G2

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme A		
Location	Kaohsiung		
Building Use	Government office		
Built Year	1981		
Retrofit Year	2002		
Building Height	8		
Building Material	RC		
Ownership	Public		
Retrofitting Part	Opening		
Adopted retrofitting method	O1		
Decision Maker	Client, Consultant, , Designer		

Figure 3-21 Basic information of Case G2

(21) Case G3-1

Basic information	
Program	None
Location	Kaohsiung
Building Use	Government office
Built Year	1960
Retrofit Year	2002, 2003,
Building Height	2
Building Material	RB
Ownership	Public
Retrofitting Part	Roof
Adopted retrofitting method	R3
Decision Maker	Client, Constructor

Image (After retrofit)

Figure 3-22 Basic information of Case G3-1

(22) Case G3-2

Basic information	
Program	None
Location	Kaohsiung
Building Use	Government office
Built Year	1960
Retrofit Year	2004,2005
Building Height	2
Building Material	RB
Ownership	Public
Retrofitting Part	Opening, Roof
Adopted retrofitting method	O4, R5
Decision Maker	Client

Image (After retrofit)

Figure 3-23 Basic information of Case G3-2

(23) Case S1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	None		
Location	Taipei		
Building Use	School		
Built Year	1967		
Retrofit Year	2010		
Building Height	2		
Building Material	RC		
Ownership	Public		
Retrofitting Part	Opening		
Adopted retrofitting method	O1		
Decision Maker	Client, Consultant, Designer, Constructor, Material supplier		

Figure 3-24 Basic information of Case S1

(24) Case S2

Basic information		Image
Program	Scheme C	 Before
Location	Kaohsiung	
Building Use	School	
Built Year	2000	
Retrofit Year	2007	
Building Height	3	
Building Material	S	 After
Ownership	Public	
Retrofitting Part	Opening	
Adopted retrofitting method	O1	
Decision Maker	Client, Consultant, , Designer	

Figure 3-25 Basic information of Case S2

(25) Case S3

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme D		 
Location	Taipei		
Building Use	School		
Built Year	1968		
Retrofit Year	2005		
Building Height	5		
Building Material	RC		
Ownership	Public		
Retrofitting Part	Opening		
Adopted retrofitting method	O1		
Decision Maker	Client, Consultant, Designer, Constructor, Material supplier		

Figure 3-26 Basic information of Case S3

(26) Case S4

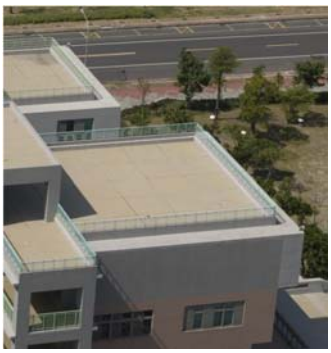
Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme G		
Location	Kaohsiung		
Building Use	School		
Built Year	2009		
Retrofit Year	2011		
Building Height	4		
Building Material	RC		
Ownership	Public		
Retrofitting Part	Roof		
Adopted retrofitting method	R4		
Decision Maker	Client, Consultant, , Designer		

Figure 3-27 Basic information of Case S4

(27) Case C1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme D		
Location	Kaohsiung		
Building Use	Car display & sales center		
Built Year	-		
Retrofit Year	2007		
Building Height	3		
Building Material	-		
Ownership	Private		
Retrofitting Part	Opening		
Adopted retrofitting method	O2		
Decision Maker	Client, Consultant, , Designer		

Figure 3-28 Basic information of Case C1

(28) Case C2

Basic information		Image (After retrofit)
Program	Scheme D	  
Location	Taichung	
Building Use	Office	
Built Year	2002	
Retrofit Year	2007	
Building Height	2	
Building Material	RC	
Ownership	Private	
Retrofitting Part	Opening	
Adopted retrofitting method	O1	
Decision Maker	Client, Consultant, , Designer	

Figure 3-29 Basic information of Case C2

(29) Case C3

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme E		
Location	Kaohsiung		
Building Use	Church		
Built Year	1979		
Retrofit Year	2013		
Building Height	4		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Wall		
Adopted retrofitting method	W4		
Decision Maker	Client, Designer, Constructor		

Figure 3-30 Basic information of Case C3

(30) Case C4

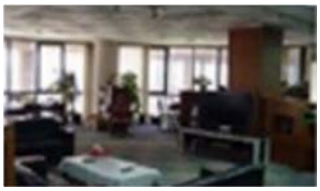
Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme D		
Location	Kaohsiung		
Building Use	Office		
Built Year	1992		
Retrofit Year	2006		
Building Height	23		
Building Material	RC		
Ownership	Private		
Retrofitting Part	Opening		
Adopted retrofitting method	O5		
Decision Maker	Client, Consultant, Designer		

Figure 3-31 Basic information of Case C4

(31) Case C5

Basic information		Image (After retrofit)
Program	None	
Location	Taipei	
Building Use	Office	
Built Year	-	
Retrofit Year	2006	
Building Height	14 / 15	
Building Material	RC	
Ownership	Private	
Retrofitting Part	Opening, Wall	
Adopted retrofitting method	O2, W3	
Decision Maker	Client, Consultant, Designer	

Figure 3-32 Basic information of Case C5

(32) Case M1

Basic information		Image (Before retrofit)	Image (After retrofit)
Program	Scheme A (Opening), Scheme B (Roof)		
Location	Kaohsiung		
Building Use	Museum		
Built Year	1997		
Retrofit Year	2007, 2008		
Building Height	2		
Building Material	RC		
Ownership	Public		
Retrofitting Part	Opening, Roof		
Adopted retrofitting method	O1, R4		
Decision Maker	Client, Consultant, , Designer		

Figure 3-33 E Case M1

3.2.2 Features of studied cases

Features of 32 studied cases are analyzed according to incentive programs, locations, building uses, built years, retrofit years, building height, building materials, Status of usage during retrofit, retrofitting parts, adopted retrofitting methods and decision makers. (Table 3-1)

(1) Incentive program

There are 21 cases are belong to incentive projects and 11 cases are belong to non-incentive projects.

Regarding incentive projects, research results show that two cases (Case G2, Case M1) are belonging to Scheme A, two case (Case G1, Case M1) are belonging to Scheme B, two cases (Case R1, Case S2) are belonging to Scheme C, four cases (Case S3, Case C1, Case C2, Case C4) are belonging to Scheme D, seven cases (Case R2, Case R5, Case R9, Case R10, Case R16, Case R17, Case C3) are belonging to Scheme E, four cases (Case R3, Case R4, Case R13, Case R14) are belonging to Scheme F, one case (Case S4) is belonging to Scheme G.

The non-incentive projects are including Case R6, Case R7-1, Case R7-2, Case R8-1, Case R8-2, Case R12, Case R18, Case G3-1, Case G3-2, Case S1 and Case C5.

(2) Location

The studied cases are located in several cities of Taiwan: Taipei city, Yilan city, Taichung city, Kaohsiung city and Pingtung city.

(3) Building use

The building uses of studied cases include residential uses, office uses, educational uses (ex: schools and museum), commercial uses (ex: car center) and religion use (ex: church)

The cases classified as the residential use are Case R1 to Case R18. The cases classified as the office use are Case G1, Case G2, Case G3, Case C2, Case C4 and Case C5. The cases classified as the educational use are Case S1 to Case S4 and Case M1. The case classified as the religion use is Case C3.

(4) Built year

The built years of studied cases show from 1957 to 2009. The buildings are built for 30~40 years show the most in cases and the oldest one is Case R17.

(5) Retrofit year

The retrofit year of studied cases show from 1988 to 2015.

(6) Building height

There are two kinds of buildings in studied cases according to their floor height: low-rise buildings and mid-rise buildings. Most of cases are belonging to low-rise buildings which are having two to six floors height, and other cases are belonging to mid-rise buildings which are having eight to 23 floors height.

(7) Building material

Regarding building materials of studied cases, the results show that reinforce concrete (RC) is the most common material, and reinforce brick (RB) and steel (S) are also found in the cases.

(8) Building ownership

The building ownership of studied cases are found having two situations: private and public. The studied cases belonging to private buildings are Case R1 ~ Case R18 and Case C1 ~ Case C5; the studied cases belonging to public buildings are Case G1 ~ Case G3 and Case M1.

(9) Retrofitting purpose

(a) For energy efficiency

The building envelopes are improved for only an energy-efficient purpose, such as Case R1, Case R7-2, Case R8-2, Case R12, Case R18, Case G1~Case G3, Case S1~Case S4, Case C1, Case C2, Case C4, and Case M1.

(b) For renewing (redesigning or repairing) building + energy efficiency

The building envelopes are improved for not only an energy-efficient purpose, but also a renewing or repairing purpose, such as Case R2~Case R6, Case R7-1, Case R8-1, Case R9, Case R10, Case R14~Case R17, Case C3 and Case C5.

(10) Retrofitting Part

The retrofitting parts of studied cases are found having three situations: partial (including single components of building envelopes), entire building façades (including multiple components of building envelopes) and entire buildings (including building envelope and indoor space).

(11) Adopted retrofitting method

The adopted retrofitting methods of studied cases are found various and having single method and multiple methods adopted situations.

(12) Decision Maker

Different types of decision makers show in studied cases. To be clarify decision-making processes, the decision makers of studied cases are going to be analyzed in detail from the following section 3.3.

Table 3-1 List of studied cases

	Incentive program	Location	Building use	Built year	Retrofit year	Building height	Building material	Building Ownership	Retrofitting purpose	Retrofitting Part	Adopted retrofitting method	Decision Maker
Case R1	Scheme C	Yilan	Residential	1987	2007	3	RC	Private	Energy efficiency	Opening, Roof	O1, R2	Client, Consultant, Designer
Case R2	Scheme E	Kaohsiung	Residential	1975	2012	3	RB	Private	Renew + Energy efficiency	Opening, Wall	O2, W5	Client, Designer, Constructor
Case R3	Scheme F	Kaohsiung	Residential	1975	2014	4	RC	Private	Renew + Energy efficiency	Opening, Wall	O2, W2+W5	Client, Consultant, Designer, Constructor, Material supplier
Case R4	Scheme F	Kaohsiung	Residential	1978	2014	4	RC	Private	Renew + Energy efficiency	Opening, Wall	O1, W1+W4	Client, Consultant, Designer, Constructor, Material supplier
Case R5	Scheme E	Kaohsiung	Residential	1977	2014	4	RB	Private	Renew + Energy efficiency	Opening, Wall	O2+O4, W5	Client, Consultant, Designer, Constructor
Case R6	None	Taipei	Residential	1995	2015	6	RC	Private	Renew + Energy efficiency	Opening, Wall, Roof, Indoor	O2, O3, W1+W2+W5, R2	Client, Consultant, Designer, Constructor, Material supplier
Case R7-1	None	Kaohsiung	Residential	1992	1997	15/16	RC	Private	Renew + Energy efficiency	Opening	O5	Client, Designer,
Case R7-2	None	Kaohsiung	Residential	1992	2012	15/16	RC	Private	Energy efficiency	Opening	O1, O4	Client, Designer, Constructor
Case R8-1	None	Kaohsiung	Residential	1974	1988	3	RB	Private	Renew + Energy efficiency	Opening, Wall	O2, W4, W5	Client, Constructor, Material supplier
Case R8-2	None	Kaohsiung	Residential	1974	2014	3	RB	Private	Energy efficiency	Opening, Wall	O1, W1+W2	Client, Constructor, Material supplier
Case R9	Scheme E	Kaohsiung	Residential	1972	2013	4	RC	Private	Renew + Energy efficiency	Opening, Wall	O1+O2, W5	Client, Consultant, Designer, Constructor
Case R10	Scheme E	Kaohsiung	Residential	1973	2013	5	RC	Private	Renew + Energy efficiency	Opening, Wall, Indoor	O2, W5	Client, Consultant, Designer
Case R12	None	Pingtung	Residential	2009	2013	3	RC	Private	Energy efficiency	Opening	O1	Client, Constructor
Case R13	Scheme F	Kaohsiung	Residential	-	2015	3	RC	Private	Renew + Energy efficiency	Opening, Wall	O6, W5	Client, Designer, Constructor
Case R14	Scheme F	Kaohsiung	Residential	1975	2014	4	RC	Private	Renew + Energy efficiency	Opening, Wall	O2, W2+W5	Client, Designer, Constructor
Case R16	Scheme E	Kaohsiung	Residential	1982	2014	11	RC	Private	Renew + Energy efficiency	Wall	W4	Client, Consultant, Designer, Constructor
Case R17	Scheme E	Kaohsiung	Residential	1957	2009	3	RB	Private	Renew + Energy efficiency	Opening	O2	Client, Constructor
Case R18	None	Taichung	Residential	-	2012	-	RC	Private	Energy efficiency	Roof	R2	Client, Consultant, Constructor, Material supplier
Case G1	Scheme B, Green remodeling project	Kaohsiung	Government office	1983	2003, 2007	10	RC	Public	Energy efficiency	Opening	O1, O2	Client, Consultant , Designer
Case G2	Scheme A	Kaohsiung	Government office	1981	2002	8	RC	Public	Energy efficiency	Opening	O1	Client, Consultant, Designer
Case G3-1	None	Kaohsiung	Government office	1960	2002, 2003,	2	RB	Public	Energy efficiency	Roof	R3	Client, Constructor
Case G3-2	None	Kaohsiung	Government office	1960	2004,2005	2	RB	Public	Energy efficiency	Opening, Roof	O4, R5	Client
Case S1	None	Taipei	School	1967	2010	2	RC	Public	Energy efficiency	Opening	O1	Client, Consultant, Designer, Constructor, Material supplier
Case S2	Scheme C	Kaohsiung	School		2007	3	S	Public	Energy efficiency	Opening	O1	Client, Consultant, Designer
Case S3	Scheme D	Taipei	School	1968	2005	5	RC	Public	Energy efficiency	Opening	O1	Client, Consultant, Designer, Constructor, Material supplier
Case S4	Scheme G	Kaohsiung	School	2009	2011	4	RC	Public	Energy efficiency	Roof	R4	Client, Consultant, Designer
Case C1	Scheme D	Kaohsiung	Commercial use (Car display & sales center)		2007	3	-	Private	Energy efficiency	Opening	O2	Client, Consultant, Designer
Case C2	Scheme D	Taichung	Office	2002	2007	2	RC	Private	Energy efficiency	Opening	O1	Client, Consultant, Designer
Case C3	Scheme E	Kaohsiung	Church	1979	2013	4	RC	Private	Renew + Energy efficiency	Wall	W4	Client, Designer, Constructor
Case C4	Scheme D	Kaohsiung	Office	1992	2006	23	RC	Private	Energy efficiency	Opening	O5	Client, Consultant, Designer
Case C5	None	Taipei	Office		2006	14 / 15	RC	Private	Renew + Energy efficiency	Opening, Wall	O2, W3	Client, Consultant, Designer
Case M1	Scheme A (Opening), Scheme B (Roof)	Kaohsiung	Museum	1997	2007, 2008	2	RC	Public	Energy efficiency	Opening, Roof	O1, R4	Client, Consultant, Designer

3.3 Professions of decision makers

3.3.1 Types of decision makers' professions

Decision makers' professions in studied cases are found include following five types.

(1) Client

The definition of clients in this research is who request and pay for building retrofits and including building owners, building users and the Taiwanese government. Moreover, the clients are found participating in all studied cases.

(2) Consultant

The definition of consultants in this research is who specialize in sustainable building designs and able to simulate or calculate building operating performance. Moreover, the consultants include academic researchers and specialists and found participating in Case R3, S1, S3, R6, R4, R5, R9, R16, R18, R10, C4, C5, R1, G1, G2, M1, S2, C1, C2 and S4.

(3) Designer

The definition of designers in this research is who in charge of building designs and including architects, building designers and interior designers. The designers are found participating in Case R3, S1, S3, R6, R4, R5, R9, R16, R10, C4, C5, R2, C3, R13, R14, R7-1 and R7-2.

(4) Constructor

The definition of constructors in this research is who in charge of constructing works and including different scale of construction companies. The constructors are found participating in Case R3, S1, S3, R6, R4, R5, R9, R16, R18, R2, C3, R13, R14, R7-2, R8-1, R8-2, R17, R12 and RG3-1.

(5) Material supplier

The definition of material suppliers in this research is who manufacture and sell materials for building uses. Their services might include planning, producing and installing. The material suppliers are found participating in Case R3, S1, S3, R6, R4, R18, R8-1 and R8-2.

3.3.2 Categorization according to types of decision makers' professions

Through observing combinations of decision makers' professions in studied cases, it is found that there are 9 types of combinations regarding decision makers' professions can be categorized. (Figure 3-34)

The decision makers' professions in combination Type 1 includes clients, consultants, designers, constructors and material suppliers. The studied cases belonging to this type are Case R3, Case S1, Case S3, Case R6 and Case R4)

The decision makers' professions in combination Type 2 includes clients, consultants, designers and constructors. The studied cases belonging to this type are Case R5 Case R9 and Case R16.

The decision makers' professions in combination Type 3 include clients, consultants, material suppliers and constructors. The studied case belonging to this type is Case R18.

The decision makers' professions in combination Type 4 include clients, consultants, and designers. The studied cases belonging to this type are Case R10, Case C4, Case C5, Case R1, Case G1, Case G2, Case M1, Case S2, Case C1, Case C2, and Case S4.

The decision makers' professions in combination Type 5 include clients, designers and constructors. The studied cases belonging to this type are Case R2, Case C3, Case R13, Case R14, and Case R7-2.

The decision makers' professions in combination Type 6 include clients, material suppliers and constructors. The studied cases belonging to this type are Case R8-1 and Case R8-2.

The decision makers' professions in combination Type 7 include clients and designers. The studied cases belonging to this type are Case R7-1.

The decision makers' professions in combination Type 8 include clients and constructors. The studied cases belonging to this type are Case R17, Case R12, and Case G3-1.

The decision makers' professions in combination Type 9 include clients. The studied cases belonging to this type are Case G3-2 and Case R8-1.

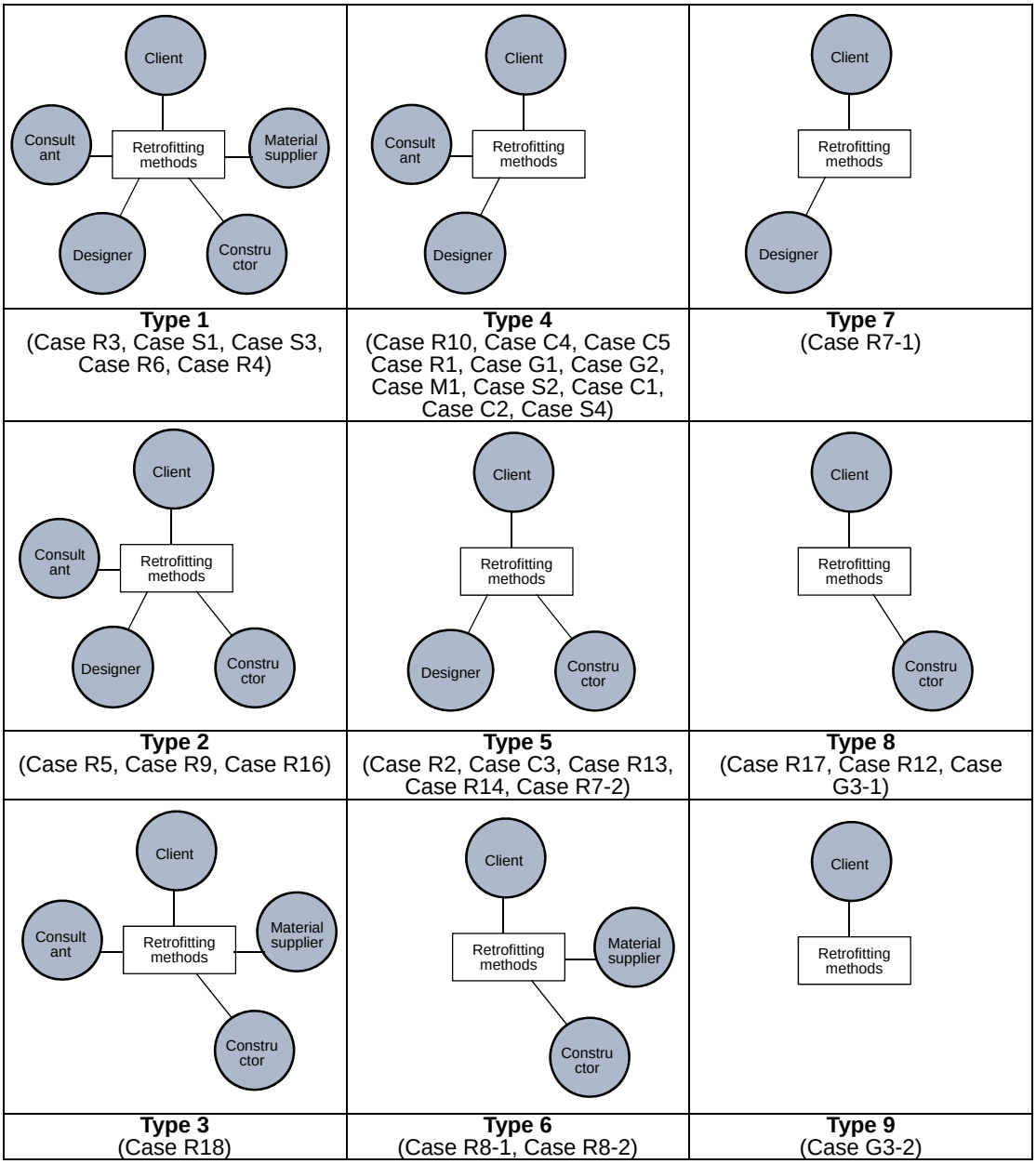


Figure 3-34 Combination types of decision makers' professions

3.3.3 Features of decision makers' professions in nine combination types

Features of decision makers' professions in 9 combination types are analyzed according to the participating situations of the five profession types. (Table 3-2)

[Client]
Clients are found participating in all 10 combination types of decision makers.

[Consultants]
Consultants are found participating in Type 1, Type 2, Type 3, and Type 4.

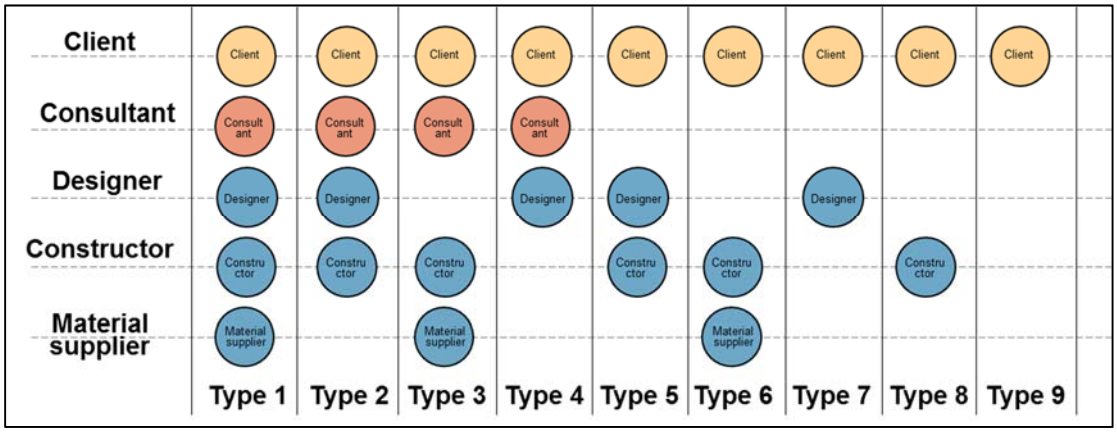
[Designer]
Designers are found participating in Type 1, Type 2, Type 4, Type 5 and Type 7.

[Constructor]
Constructors are found participating in Type 1, Type 2, Type 3, Type 5, Type 6 and Type 8.

[Material supplier]
Material supplier are found participating in Type 1, Type 3 and Type 6.

The research results regarding features of decision makers' professions in 9 combination types show that decision makers' profession numbers and types are composed differently in the 9 combination types. For examples, there are five types of decision makers in Type 1, but there is only one client in Type 9.

Table 3-2 Decision makers' professions in 9 combination types



3.4 Relevance of decision makers' professions

3.4.1 Types of relevance regarding decision makers' professions

The research results regarding "relevance of decision makers' professions" show there are two kinds of relevance regarding decision makers' professions: (1) independent-profession type and (2) multiple-profession type.

(A) Independent-profession type

The independent type means a decision maker has single profession and is not related to other participated decision makers.

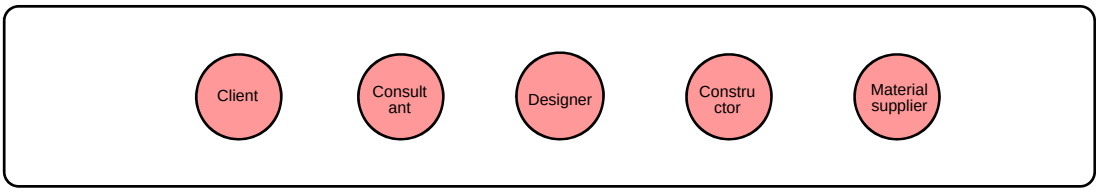


Figure 3-35 Independent*-profession *type

(B) Multiple-profession type

Multiple types of decision makers mean (a) a decision maker has more than one profession, or (b) decision makers who have different professions work together as a team (turnkey). There are five multiple types are found: (1) consultants + designers, (2) material suppliers + constructors, (3) clients + designers, (4) clients + consultants + designers and (5) designers + constructors (turn-key).

The five multiple types of decision makers' specialties are describe as below.

(1) Consultant + Designer

The first type is a decision maker who has two professions regarding consultants and designers.

(2) Material supplier + Constructor

The Type 2-1 is a decision maker who has two professions regarding material suppliers and constructors. The Type 2-2 is a material supplier and a constructor working together and are considered as a team.

(3) Client + Designer

The third type is a client who also has another profession regarding designer.

(4) Client + Consultant + Designer

The fourth type is a client who also has other two professions regarding consultants and designers.

(5) Designer + Constructor

The fifth type is a designer and a constructor working together and are considered as a team.

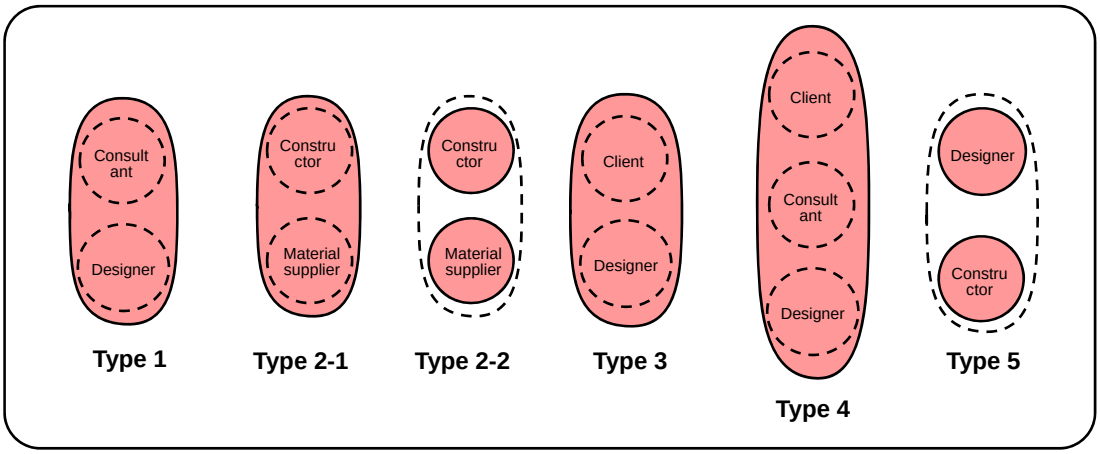


Figure 3-36 Multiple-profession type

3.4.2 Categorization according to relevance of decision makers' professions

Through observing combinations of relevance of decision makers' professions in studied cases, it is found that there are 15 patterns can be categorized. (Figure 3-37)

The relevance of decision makers' professions in Pattern 1 shows including five independent-profession types (clients, consultants, designers, constructors and material suppliers). The studied case belonging to this pattern is Case R3.

The relevance of decision makers' professions in Pattern 2 shows including one independent-profession type (clients) and two multiple-profession types (consultants + designers, material suppliers + constructors). The studied cases belonging to this pattern are Case S1 and Case S3.

The relevance of decision makers' professions in Pattern 3 shows including two independent-profession types (material suppliers, constructors) and one multiple-profession type (clients + consultants + designers). The studied case belonging to this pattern is Case R6.

The relevance of decision makers' professions in Pattern 4 shows including three independent-profession types (clients, material suppliers, constructors) and one multiple-profession type (consultants + designers). The studied case belonging to this pattern is Case R4.

The relevance of decision makers' professions in Pattern 5 shows including four independent-profession types (clients, consultants, designers and constructors). The studied cases belonging to this patterns are Case R5, Case R9 and Case R16.

The relevance of decision makers' professions in Pattern 6 shows including two independent-profession types (clients, consultants) and one multiple-profession type (material suppliers + constructors). The studied case belonging to this pattern is Case R18.

The relevance of decision makers' professions in Pattern 7 shows including three independent-profession types (clients, consultants, designers). The studied cases belonging to this patterns are Case R10, Case C4, Case R1, Case G1, Case G2, Case M1, Case S2, Case C1, Case C2, and Case S4.

The relevance of decision makers' professions in Pattern 8 shows including one multiple-profession type (clients + consultants + designers). The studied case belonging to this

pattern is Case C5.

The relevance of decision makers' professions in Pattern 9 shows including three independent-profession types (clients, designers, constructors). The studied cases belonging to this patterns are Case R2 and Case C3.

The relevance of decision makers' professions in Pattern 10 shows including one independent-profession type (clients) and one multiple-profession type (designers + constructors). The studied cases belonging to this patterns are Case R13 and Case R14.

The relevance of decision makers' professions in Pattern 11 shows including one independent-profession type (constructor) and one multiple-profession type (clients + designers). The studied case belonging to this patterns is Case R7-2.

The relevance of decision makers' professions in Pattern 12 shows including one independent-profession type (clients) and one multiple-profession type (material suppliers + constructors). The studied cases belonging to this patterns are Case R8-1 and Case R8-2.

The relevance of decision makers' professions in Pattern 13 shows including two independent-profession types (clients, designers). The studied case belonging to this patterns is Case R7-1.

The relevance of decision makers' professions in Pattern 14 shows including two independent-profession types (clients, constructors). The studied cases belonging to this patterns are Case R17, R12 and G3-1.

The relevance of decision makers' professions in Pattern 15 shows including one independent-profession type (clients). The studied cases belonging to this patterns is Case G3-2.

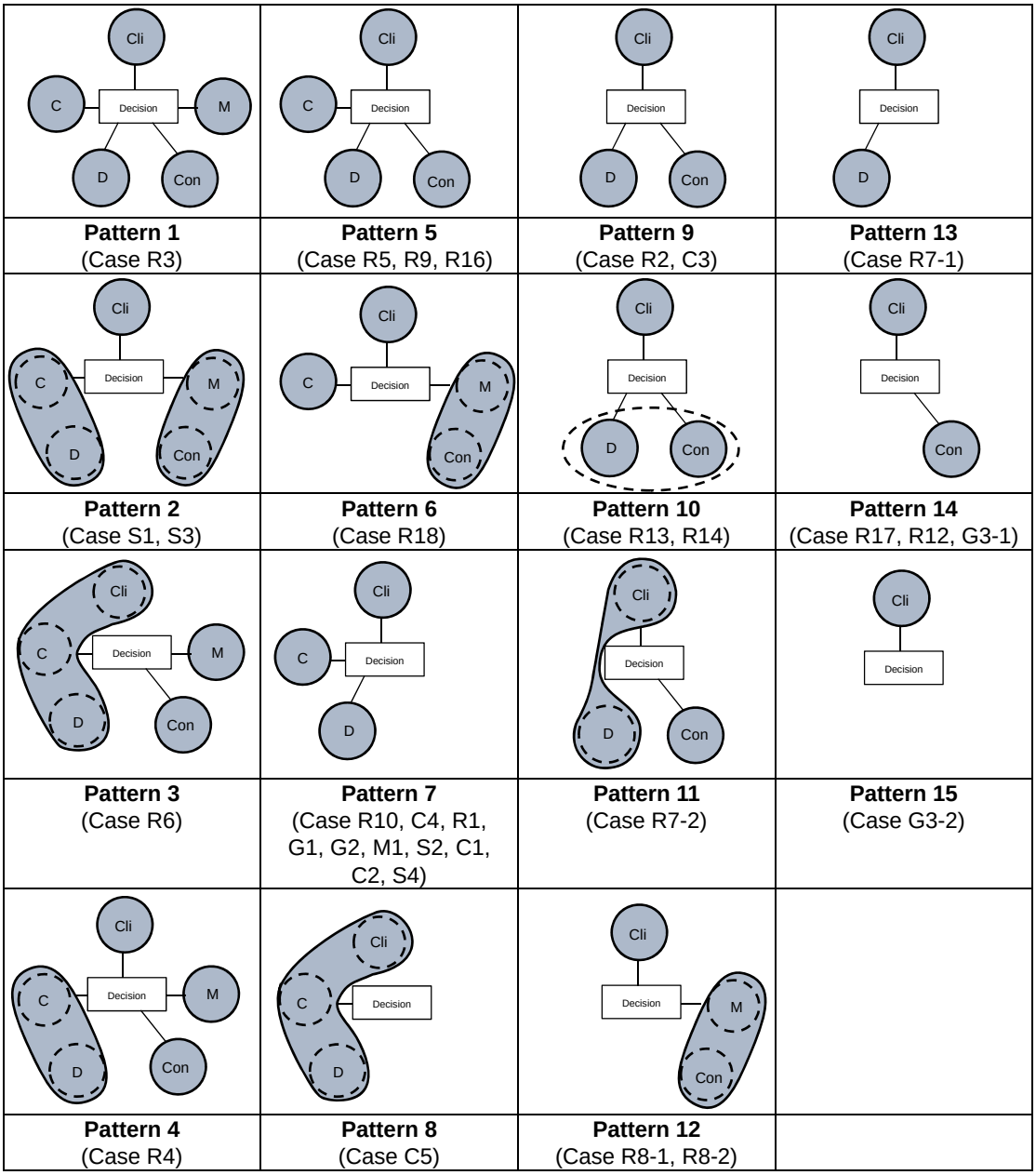


Figure 3-37 Combination patterns of decision makers' professions

3.4.3 Features regarding profession relevance of decision makers in 15 combination patterns

Research results show features of decision makers' profession relevance are different in 15 combination patterns. It is found that although the decision makers have same professions, but their professions relevance are different. For example, clients are found can be sorted into three types: clients, clients who are also designers and clients who are also consultants and designers.

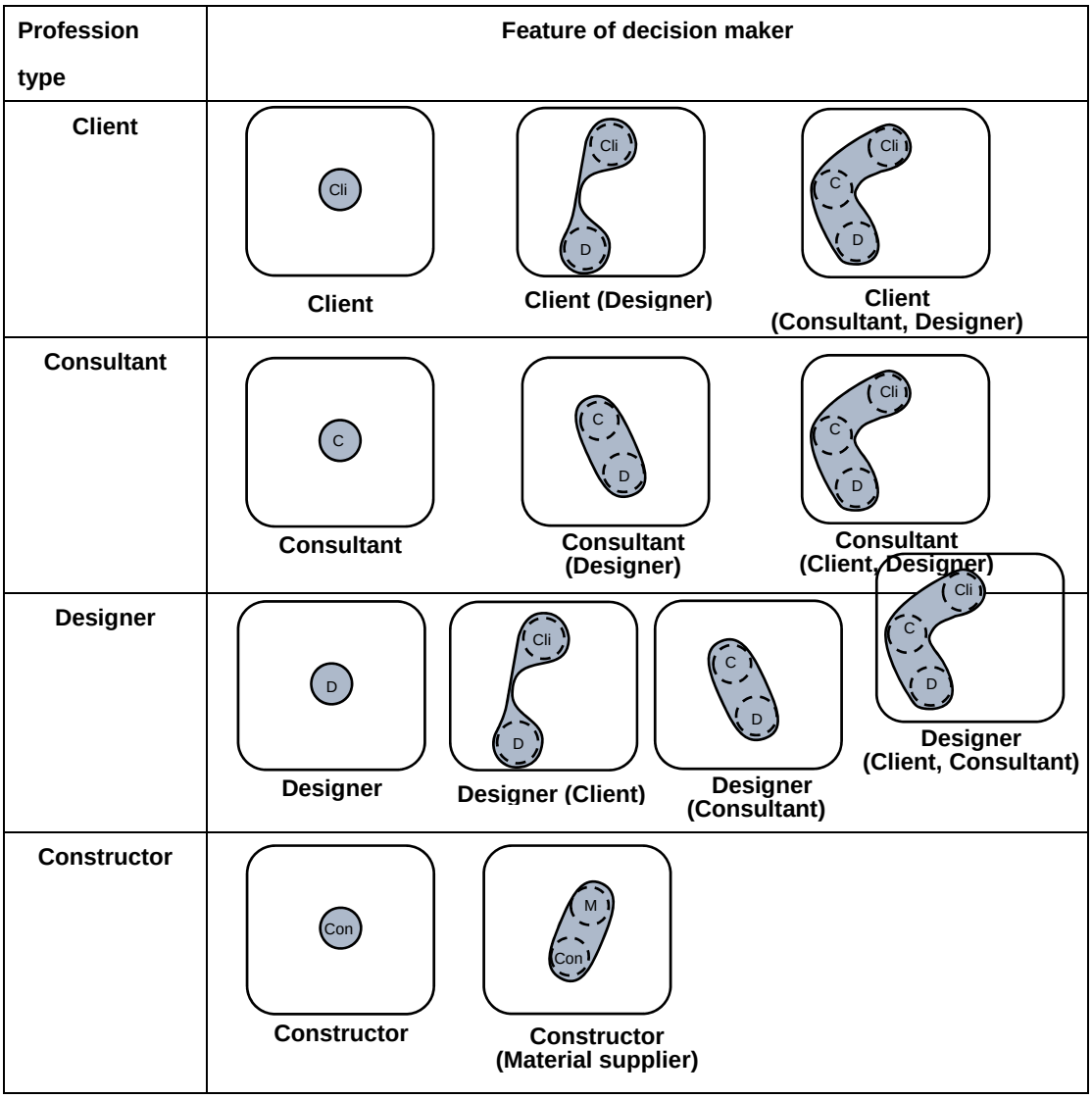


Figure 3-38 Feature of decision maker

3.5 How decision makers' combinations being decided

3.5.1 Relationship between combinations of decision makers' professions and types of building envelope retrofitting projects

Types of building retrofitting projects are analyzed through three categories which are found affecting combinations of decision makers. The three categories are retrofitting parts, ownership of buildings and Governmental incentive status.

(1) Retrofitting part

The retrofitting parts can be sorted as three categories: partial, entire building façade and entire building. (Table 3-3)

The retrofitting parts considered as partial are found being implemented in most of combination types except Type 6.

The retrofitting parts considered as an entire building façade are found being implemented in Type 1, Type 2, Type 5, Type 6 and Type 8. Features of these types are all having constructors as decision makers.

The retrofitting parts considered as an entire building are found being implemented in Type 1 and Type 4. Features of these types are all having designers and constructors as decision makers.

Table 3-3 Relationship between combinations of decision makers' professions and retrofitting parts

	Partial	**Entire building facade**	**Entire building**
Type 1	Case S1, Case S3	Case R3, Case R4	Case R6
Type 2	Case R16	Case R5, Case R9	-
Type 3	Case R18	-	-
Type 4	Case C4, Case C5, R1, G1, G2, M1, S2, C1, C2, S4	-	Case R10
Type 5	Case C3, R7-2	Case R2, R13, R14	-
Type 6	-	Case R8-1, R8-2	-
Type 7	Case R7-1	-	-
Type 8	Case R17, R12, G3-1	-	-
Type 9	Case G3-2	-	-

(2) Ownership of building

Ownership of buildings are analyzed according to two categories: public and private. (Table 3-4)

The research results show that Type 1, Type 4, Type 8, and Type 9 are found in retrofitting projects of public buildings. Features of combination types of decision makers in public retrofitting projects are all having designers and constructors as decision makers except the decision makers in Case G3.

The research results show that most of combination types of decision makers are found in private retrofitting projects except Type 9. The combination types of decision makers in private retrofitting projects are found more various than public retrofitting projects.

Table 3-4 Relationship between combinations of decision makers' professions and ownership of buildings

	Public	**Private**
Type 1	Case S1, Case S3	Case R3, Case R4, Case R6
Type 2	-	Case R5, Case R9, Case R16
Type 3	-	Case R18
Type 4	Case G1, Case G2, Case M1, Case S2, Case S4	Case R10, Case C4, Case C5, Case R1, Case C1, Case C2
Type 5	-	Case R2, Case C3, Case R13, Case R14, Case R7-2
Type 6	-	Case R8-1, R8-2
Type 7	-	Case R7-1
Type 8	Case G3-1	Case R17, Case R12
Type 9	Case G3-2	-

(3) Governmental incentive status

Governmental incentive status are analyzed according to two categories: incentive and non-incentive. (Table 3-5)

The research results show that combination types of decision makers found in incentive projects are Type 1, Type 2, Type 4, Type 5, and Type 8. Features of these combination types almost all having consultants as decision makers except Type 5 and Type 8.

The research results show that combination types of decision makers found in non-incentive projects are Type 1, Type 3, Type 5, Type 6, Type 7, Type 8 and Type 9. Features of these combination types are all lack of consults as decision makers except Type 3.

Table 3-5 Relationship between combinations of decision makers' professions and governmental incentive status

	Incentive project	Non-incentive project
Type 1	Case S1, Case S3, Case R3, Case R4	Case R6
Type 2	Case R5, Case R9, Case R16	-
Type 3	-	Case R18
Type 4	Case R10, Case C4, Case C5, Case G1, Case G2, Case M1, Case S2, Case S4, Case R1, Case C1, Case C2	-
Type 5	Case R2, Case C3, Case R13, Case R14	Case R7-2
Type 6	-	Case R8-1, R8-2
Type 7	-	Case R7-1
Type 8	Case R17	Case G3-1, Case R12
Type 9	-	Case G3-2-

(4) Retrofitting purpose

(a) <u>For energy efficiency</u>

The research results show that the combination types of decision makers in the cases retrofitted for energy efficiency only have Type 1, Type 3, Type 4, Type 5, Type 6, Type 8 and Type 9.

(b) <u>For energy efficiency + renew / Repair</u>

The research results show that the combination types of decision makers in the cases retrofitted for both energy efficiency and renew (or repair) building envelopes have Type 1, Type 2, Type 4, Type 5, Type 6, Type 7 and Type 8.

It is found the common retrofitting purpose of the cases which decision makers have designers are renewing building appearance or indoor decorations. (Type 1, Type 2, Type 4, Type 5, and Type 7)

The common retrofitting purpose of cases which decision makers have constructors are replacing existing window and existing material of walls. (Type 6 and Type 8)

Table 3-6 Relationship between combinations of decision makers and retrofitting purposes

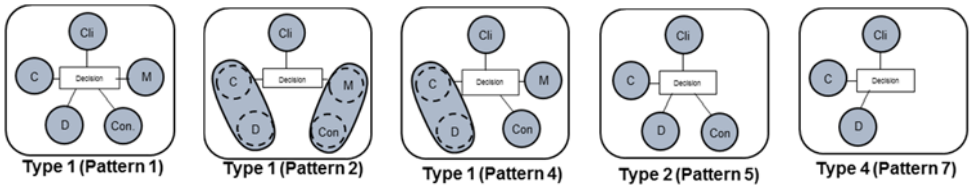
	For energy efficiency	For energy efficiency + renew / Repair
Type 1	Case S1, Case S3	Case R3, Case R4, Case R6
Type 2	-	Case R5, Case R9, Case R16
Type 3	Case R18	-
Type 4	Case R1, Case C4, Case G1, Case G2, Case M1, Case S2, Case C1, Case C2, Case S4	Case R10, Case C5
Type 5	Case R7-2	Case R2, Case C3, Case R13, Case R14
Type 6	Case R8-2	Case R8-1
Type 7	-	Case R7-1
Type 8	Case R12, Case G3-1	Case R17
Type 9	Case G3-2	-

3.5.2 Reasons of decision makers' compositions were decided

According to interview results regarding the reasons of decision makers were requested, it is found that the reasons of decision makers' compositions being decided are relating to following four categories:

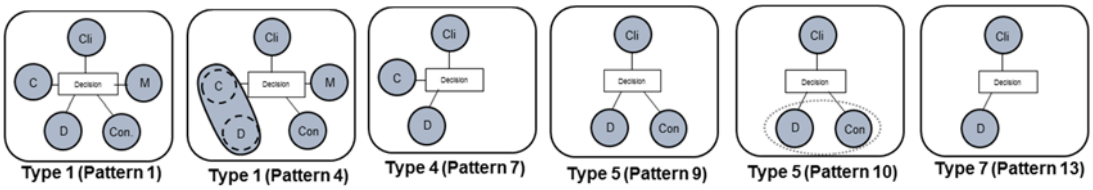
(a) Reasons relating to "attribute of retrofitting projects"

Consultants are usually participating in the projects which are belonging to governmental incentive programs or school buildings, such as Pattern 1, Pattern 2, Pattern 4, Pattern 5, and Pattern 7.



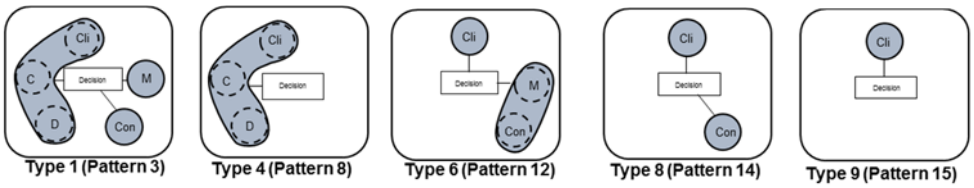
(b) Reasons relating to "attribute of retrofitting purposes"

Designers are usually participating in the projects which building appearance designs or interior designs are considered, such as Pattern1, Pattern 4, Pattern 7, Pattern 9, Pattern 10 and Pattern 13.



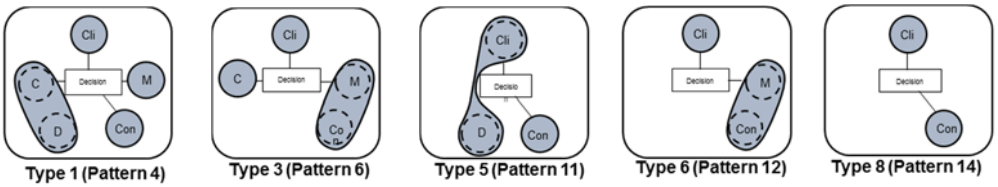
(c) Reasons relating to "budget control"

Only a minimum number of decision makers are requested when a budget control are concerned, such as Pattern 3, Pattern 8, Pattern 12, Pattern 14 and Pattern 15.



(d) Reasons relating to "familiarity"

Certain types of decision makers are requested because they are friends of clients, such as Pattern 4, Pattern 6, Pattern 11, Pattern 12 and Pattern 14.



3.6 Relationship between decision makers' compositions and adopted retrofitting methods

By analyzing retrofitting methods in each combination type of decision makers, the following results are clarified:

(1) Promoted retrofitting methods are adopted in the cases belonging to Combination Type 1, Type 2, Type 3, Type 4, Type 5, Type 6 and Type 8.

(2) The promoted methods are adopted in all cases belonging to in Combination Type 1.

(3) The promoted retrofitting methods are not adopted in the cases belonging to Combination Type 2, Type 4, Type 5, Type 6, Type 7, Type 8, and Type 9.

It was found that more promoted retrofitting methods are adopted in the combination types which have consultants (Type 1~Type 4). However, the promoted methods were also found in the combination types which have no consultant (Type 5 ~ Type 9). It is assumed that decision makers including consults might increase the possibilities of adopting promoted methods, but the decisions might still depend on clients' requirements.

Table 3-7 Adopted retrofitting methods in nine combination types

Type	Composition of decision maker	Case	Retrofitting method
Type 1	Client, Consultant, Designer, Constructor, Material supplier	Case R3	O2, W2+W5
		Case R4	O1, W1+W4
		Case R6	O2, O3, W1+W2+W5, R2
		Case S1	O1
		Case S3	O1
Type 2	Client, Consultant, Designer, Constructor	Case R5	O2+O4, W5
		Case R9	O1+O2, W5
		Case R16	W4
Type 3	Client, Consultant, Constructor, Material supplier	Case R18	R2
Type 4	Client, Consultant, Designer	Case R1	O1, R2
		Case R10	O2, W5
		Case C1	O2
		Case C2	O1
		Case C4	O5
		Case C5	O2, W3
		Case S2	O1
		Case S4	R4
		Case G1	O1, O2
		Case G2	O1
		Case M1	O1, R4
Type 5	Client, Designer, Constructor	Case R2	O2, W5
		Case C3	W4
		Case R13	O6, W5
		Case R14	O2, W2+W5
		Case R7-2	O1, O4
Type 6	Client, Constructor, Material supplier	Case R8-1	O2, W4, W5
		Case R8-2	O1, W1+W2
Type 7	Client, Designer	Case R7-1	O5
Type 8	Client, Constructor	Case R17	O2
		Case R12	O1
		Case G3-1	R3
Type 9	Client	Case G3-2	O4, R5

3.7 Conclusion of Chapter 3

3.7.1 Summary

In summary, attributes of decision makers were defined by understanding and investigating decision makers' profession types, relevance of profession types, and how decision makers' combinations were decided. The research results and findings are described as follows.

(1) Types of decision makers' professions

The research results regarding "types of decision makers' professions" show that five common kinds of decision makers' professions are found in this scenario. These five kinds of professions include clients, consultants, designers, constructors, and material suppliers. Furthermore, nine combination types are found which can be sorted according to the "types of decision makers' professions". (Table 3-8)

(2) Relevance of decision makers' professions

The research results regarding "relevance of decision makers' professions" show that the decision makers' professions are relevant in two ways: (A) independent-profession type and (B) multiple-profession type. (Figure 3-39) Furthermore, 15 combination patterns were found which were further sorted according to the "relevance of decision makers' professions". (Table 3-8)

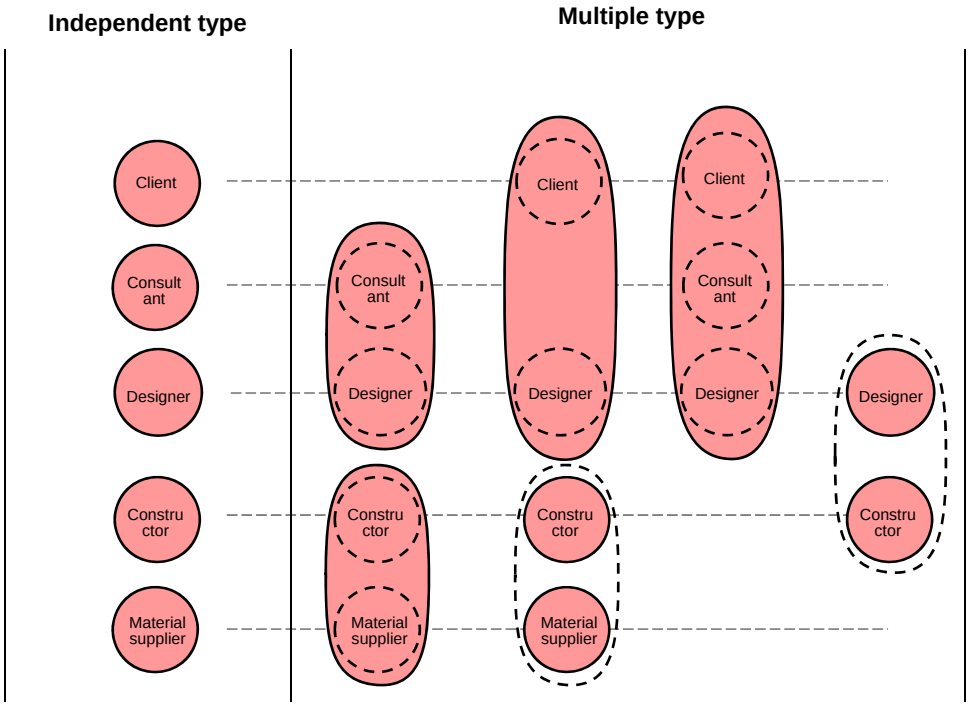


Figure 3-39 Relevance of decision makers' professions

(3) Research result regarding "feature of decision makers' compositions according to types and relevant"

The research results show types of decision makers' compositions in the cases which have multiple building-envelope retrofits are Type 7 (Case R7-1), Type 6 (Case R8-1), Type 8 (Case G3-1) and Type 9 (Case G3-2). The feature of these decision makers' compositions is only including few people from one or two fields, especially type 9 is only including a client.

(4) Research result regarding "how decision makers' combinations were decided"

It was found that the combinations of decision makers were influenced by the following four categories: (a) attributes of retrofitting projects, (b) attributes of retrofitting purposes, (c) budget control, and (d) familiarity.

3.7.2 Attributes of the decision makers in a small-scale building construction system

[Ideal decision maker types]

Theoretically, the decision makers planning energy-efficiency retrofits are expected to have professional and technical abilities. Moreover, a design team including consultants and experts from several fields is also expected. (mentioned in Chapter 2)

[Decision makers' attribute in a small-scale building construction system]

According to above-mentioned results, the findings regarding the attributes of decision makers in a small-scale building construction system are described as follows:

(a) A client is the basic profession type showing in all nine combinations of decision makers

(b) Numbers and specialties of decision makers in each of combination are different. Mostly, the decision is decided by only a few or one decision maker.

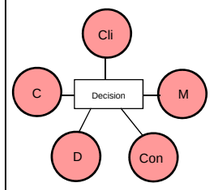
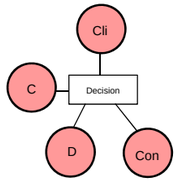
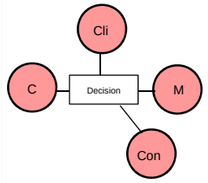
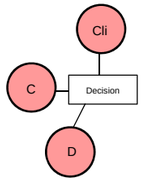
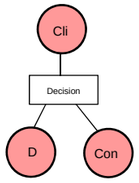
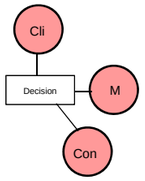
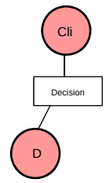
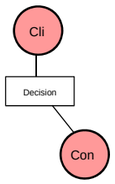
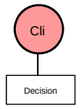
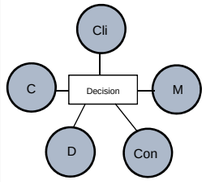
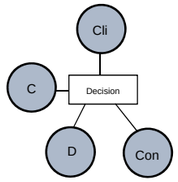
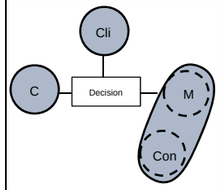
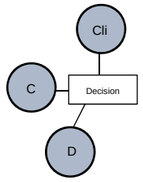
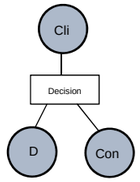
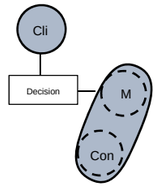
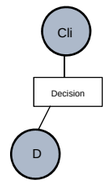
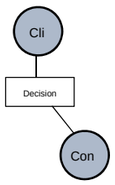
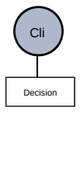
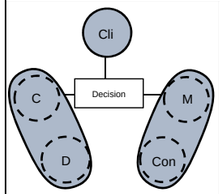
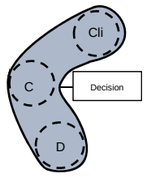
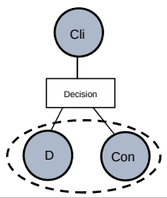
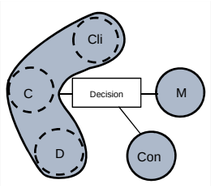
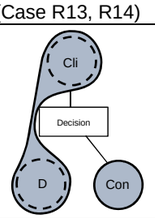
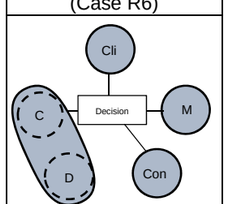
(c) Consultants participated only in four of the nine combination types; they are not always participating in the decision-making processes of retrofitting methods.

(d) The decision makers were requested not only based on their specialties but also depending on the resources provided from institutions, retrofitting purposes, clients' budgets, and preferences.

According to above research results, it was found that energy-efficiency retrofitting designs planned in the small-scale building construction system might be decided by non-consultants with different specialties. These results are different from the theoretical expectations for the types of decision makers. Moreover, the decision might be strongly affected by clients in the small-scale building construction system.

Attributes of the decision makers in a small-scale building construction system are understood in Chapter 3. Next, practical decision making processes of retrofitting designs in the small-scale building construction are going to be clarified and discussed in Chapter 4.

Table 3-8 Combinations of decision makers' professions regarding types and relevant

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9
Combination type									
	clients, consultants, designers, constructors and material suppliers	clients, consultants, designers and constructors	clients, consultants, constructors and material suppliers	clients, consultants, and designers	clients, designers and constructors	clients, constructors and material suppliers	clients and designers	clients and constructors	clients
Combination pattern	 **Pattern 1** (Case R3)	 **Pattern 5** (Case R5, R9, R16)	 **Pattern 6** (Case R18)	 **Pattern 7** (Case R10, C4, R1, G1, G2, M1, S2, C1, C2, S4)	 **Pattern 9** (Case R2, C3)	 **Pattern 12** (Case R8-1, R8-2)	 **Pattern 13** (Case R7-1)	 **Pattern 14** (Case R17, R12, G3-1)	 **Pattern 15** (Case G3-2)
	 **Pattern 2** (Case S1, S3)			 **Pattern 8** (Case C5)	 **Pattern 10** (Case R13, R14)				
	 **Pattern 3** (Case R6)				 **Pattern 11** (Case R7-2)				
	 **Pattern 4** (Case R4)								

Chapter 4
Practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system

4.1 Overview
4.2 Research result: practical decision-making processes of energy-efficiency retrofitting designs in 32 cases
4.3 What decision makers think
  4.3.1 Contents of decision makers' considerations for deciding retrofitting designs
  4.3.2 Priority orders of decision makers' considerations
  4.3.3 Development processes of decision makers' considerations
4.4 How decision makers arrive at the decisions
  4.4.1 Interactions between decision makers
  4.4.2 Decision makers' working contents for assessments
  4.4.3 Assessment approaches for improving effectiveness of energy efficiency
4.5 Conclusion of Chapter 4
  4.5.1 Summary
  4.5.2 Features of practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system
  4.5.3 Challenges of planning "energy-efficient building envelope retrofits" in a small-scale building construction system

4.1 Overview

The research objective of Chapter 4 is to clarify practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system. The research scope is focusing on decision-making processes of following steps: deciding retrofit strategies, deciding retrofitting plan and designs and estimating retrofitting effects. (Fig. 4-1)

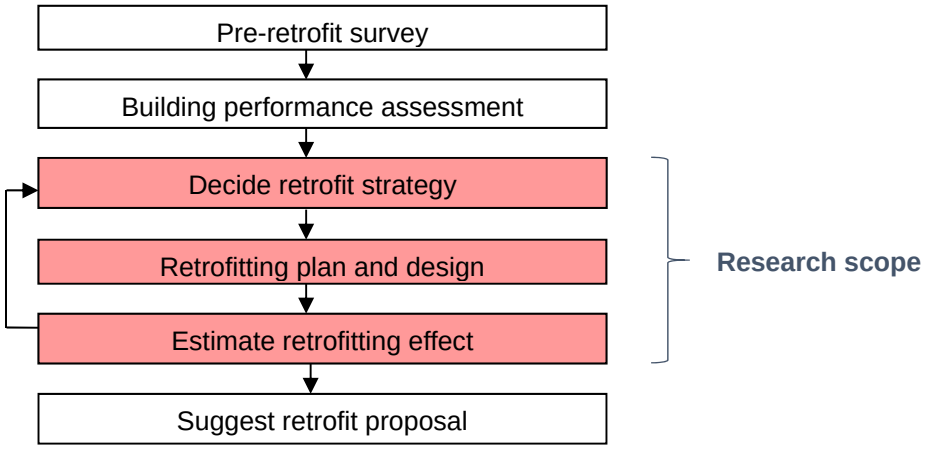


Figure 4-1 Research scope of Chapter 4

[Research methodology]

The decision-making processes of retrofitting designs in small-scale building construction system were clarified by understanding what decision makers think and how decision makers arrive at the decisions during decision-making processes.

What decision makers think and how decision makers arrive at the decisions were clarified by interviewing decision makers in the 32 cases about the following research questions:

(a) What decision makers think during decision-making processes?

The questions regarding the decision makers' thought process included decision-making considerations, priority orders of final decision-making considerations, and development processes of decision-making considerations.

(b) How decision makers arrive at the decisions during decision-making processes?

The questions regarding the decision makers' actions included interactions between decision makers, decision makers' working content for assessments, and assessment approaches for improving effectiveness of energy-efficiency.

Furthermore, research results were categorized to define features of practical decision-making processes of retrofitting designs in the small-scale building construction system.

[Research framework]

The research contents and frameworks are presented as diagram below. (Figure 4-2)
The contents in Section 4.2shows research result regarding overall decision-making processes of retrofitting designs in 32 cases.

The contents in Section 4.3 is the research results regarding what decision makers think during decision making processes. The contents include (A) decision makers' considerations for deciding retrofitting methods, (B) priority orders of final decision-making considerations and (C) development processes of decision makers' considerations.

The contents in Section 4.4 is the research results regarding how decision makers arrive at the decisions during decision-making processes. The contents include (A) interactions between decision makers, (B) decision makers' working contents for assessments, and (D) assessment approaches for improving effectiveness of energy-efficiency.

Finally, features of practical decision-making processes of retrofitting designs in the small-scale building construction system are categorized in Section 4.5.

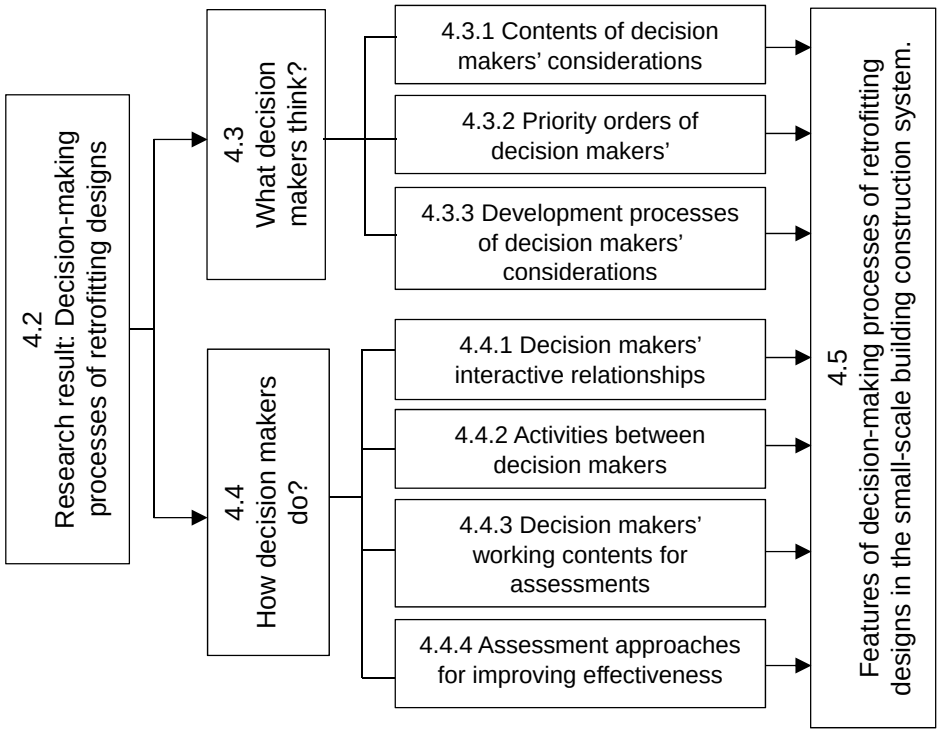


Figure 4-2 Research contents and frameworks of Chapter 4

4.2 Research result: practical decision-making processes of energy-efficiency retrofitting designs in 32 cases

4.2.0 Introduction

The decision-making process of retrofitting designs in 32 cases are described according 15 combination patterns of decision makers.

The research results of decision-making processes in each case are presented by two parts:
(1) The first part is regarding “what decision makers think”.
(2) The second part is regarding “decision makers arrive at the decisions”.

Moreover, the following contents are illustrated in diagrams: “decision makers’ considerations for deciding retrofitting methods”, “priority orders of decision makers’ considerations”, “development processes of decision makers’ considerations”, and “interactions between decision makers”.

The example of diagram is presented as Figure 4-3.

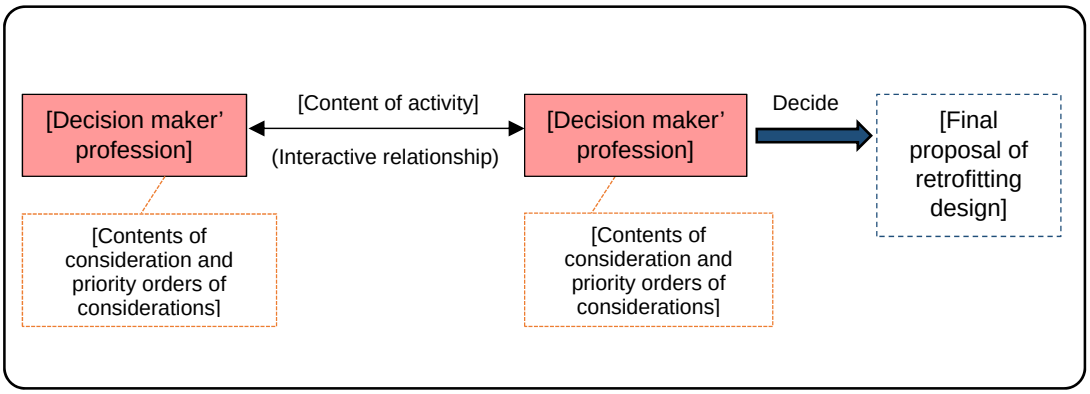
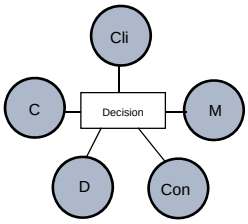


Figure 4-3 Decision-making process of case (Example)

4.2.1 **Pattern 1** (Case R3)



The studied case, Case R3, is included in Pattern 1. The types of decision makers in this case is including clients, consultants, designers, constructors and material suppliers; the relevance of decision makers are including five independent-profession types. The decision-making process of retrofitting designs in Case R3 is presented as Fig. 4-4.

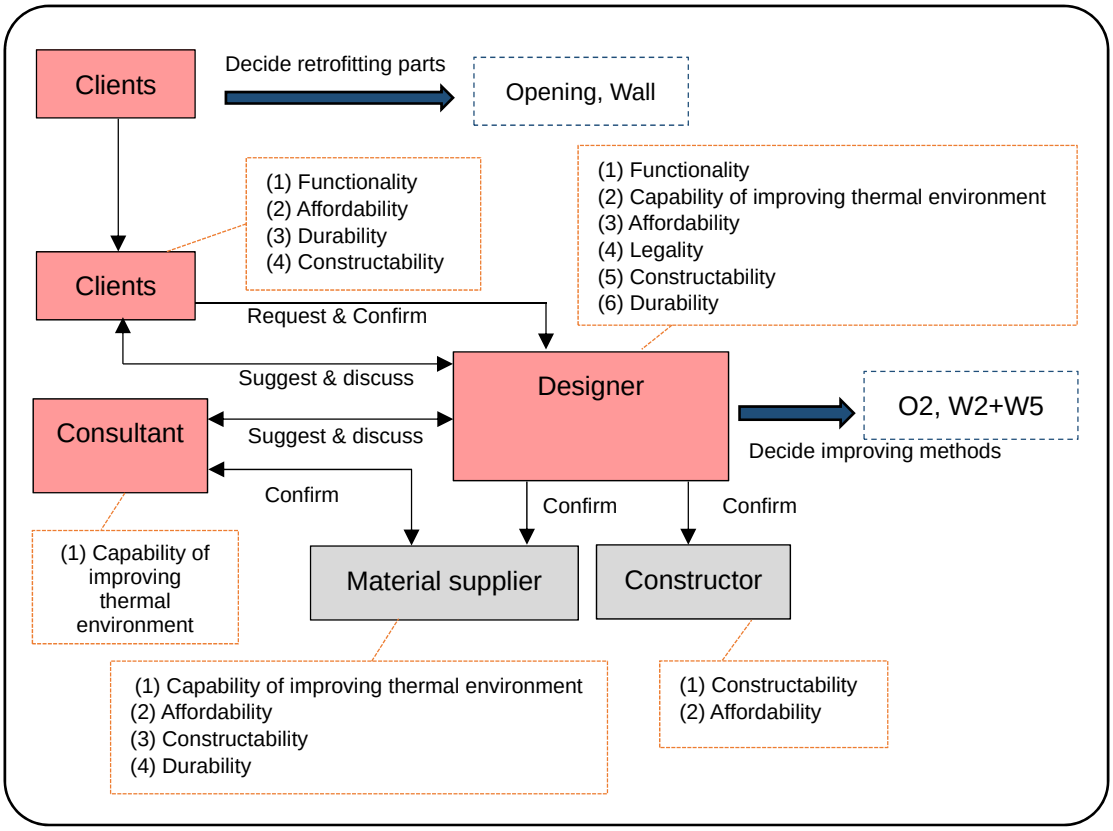


Figure 4-4 Decision-making process of retrofitting designs in Case R3

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Contents of decision makers' considerations for deciding retrofitting methods in Case R3 are showing as follows.

Clients' considerations relate to "functionality", "affordability", "durability" and "constructability".
Consultants' considerations relate to "capability of improving thermal environment".
Designers' considerations include the thought of clients, consultants and himself which are relating to "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability", and "durability".
Material suppliers' considerations relate to "capability of improving thermal environment", "affordability", "constructability", and "durability".
Constructors' considerations relate to "affordability" and "constructability".

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R3 are showing as Table 4-1.

Table 4-1 Priority orders of decision makers' considerations in Case R3

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Capability of improving thermal environment
(3)	Affordability
(4)	Legality
(5)	Constructability
(6)	Durability

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "functionality", "affordability", "constructability" and "durability" are concerned by clients from the beginning. The consideration "capability of improving thermal environment", is concerned after consultants suggesting. (Fig. 4-5)

Client	Consultant	Designer
-	Capability of improving thermal environment	Capability of improving thermal environment
Functionality		Functionality
Affordability		Affordability
-	-	Legality
Constructability		Constructability
Durability		Durability

Figure 4-5 Development processes of decision makers' considerations in Case R3

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research result shows that retrofitting methods are decided after a designer communicate with a consultant, clients, constructors and material suppliers, and also after a consultant communicate with material suppliers. The interactive relationships of decision makers in Case R3 are showing as following diagram.

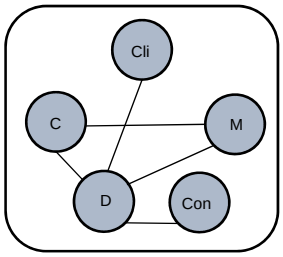


Figure 4-6 Interactive relationships of decision makers in Case R3

(5) Interaction between decision makers

During the decision-making process, clients expressed his requirements to designers and then discussed the retrofitting designs with the designers. Moreover, consultants suggested to focus "capability of improving thermal environment" to the designers, and also confirm material performance with material suppliers. After that, the designers confirmed retrofitting designs with material suppliers and constructors. Finally, the retrofitting designs are decided according to the considerations of clients, consultants and designers.

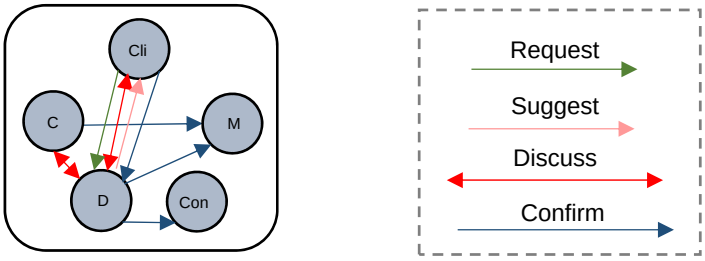


Figure 4-7 Activity between decision makers in Case R3

(6) Decision makers' working contents for assessments

In Case R3, the working contents of decision makers are found as follows: the clients confirmed expected functions, budget, expected construction duration and maintenance needs. The consultants estimated improving performance. The designers estimated if retrofitting method can achieve clients' expected functions, budget, constructing duration and useable period and meet building regulations. The constructors estimated constructing and material cost, construction duration and feasibility. The material suppliers estimate material performance,

material cost, constructing feasibility and useable period.

Table 4-2 Decision makers' working contents for assessments in Case R3

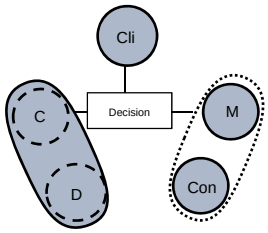
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budget	-	Confirm expected construction duration	Confirm maintenance needs
Consultant	Estimate improving performance by calculation and knowledge	-	-	-	-	-
Designer	-	Estimate if retrofitting methods can achieve client's required function	Confirm if retrofitting cost meet client's budget	Check if retrofitting methods meet building regulations	Confirm if construction duration meet clients' expectation	Confirm if maintenance needs and useable period meet clients' expectations
Constructor	-	-	Estimate material cost and constructing cost	-	Estimate construction duration and feasibility	-
Material supplier	Estimate material performance according to material performance data	-	Estimate material cost	-	Assess constructing feasibility	Estimate useable period

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

In Case R3, improving performance of retrofitting methods is estimated by consultants and material suppliers. The consultants estimated improving performance of retrofitting methods according to his knowledge and by calculation; the material suppliers estimated improving performance of retrofitting methods according to material performance data.

4.2.2 Pattern 2 (Case S1, Case S3)



Case S1 and Case S3 are the studied case included in Pattern 2. Profession types of decision makers are including clients, consultants, designers, constructors and material suppliers. Moreover, the relevance of decision makers' professions are including one independent-profession type and two multiple-profession types. Decision-making processes of retrofitting designs in Case S1 and Case S3 are presented as Figure 4-8

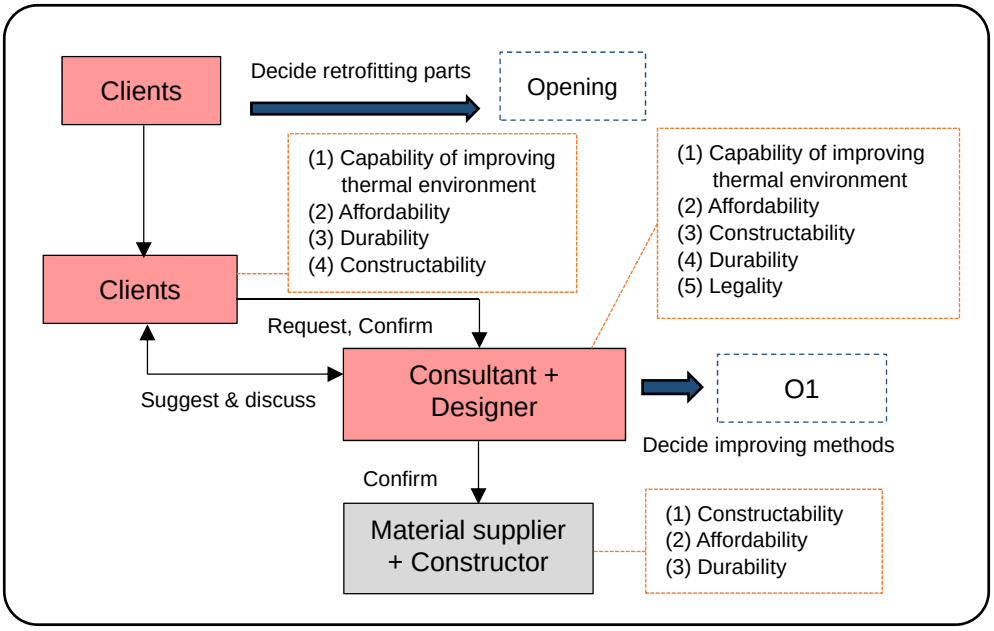


Figure 4-8 Decision-making process in Case S1 and Case S3

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Contents of decision makers' considerations for deciding retrofitting methods in Case R3 are showing as follows.

Clients' considerations relate to "capability of improving thermal environment", "affordability", "durability" and "constructability".

Consultants' (+ designers) considerations relate to "capability of improving thermal environment", "affordability", "durability", "constructability" and "legality".

Material suppliers' (+ constructor) considerations relate to "affordability", "constructability" and "legality".

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case S1 and S3 are showing as Table 4-3.

Table 4-3 Priority orders of decision makers' considerations in Case S1 & Case S3

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Affordability
(3)	Constructability
(4)	Durability
(5)	Legality
(6)	-

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "capability of improving thermal environment", "affordability" and "durability" are concerned by clients from the beginning. The considerations regarding "legality" and "constructability" are thought after consultant (designer) suggesting.

Client	Consultant + Designer
Capability of improving thermal environment	Capability of improving thermal environment
-	-
Affordability	Affordability
-	Legality
Constructability	Constructability
Durability	Durability

Figure 4-9 Development processes of decision makers' considerations in Case S1 & Case S3

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research result shows that retrofitting methods are decided after a consultant (who is also a designer) communicates with a client and a material supplier (who is also a constructor). Their interactive relationships are showing as following diagram.

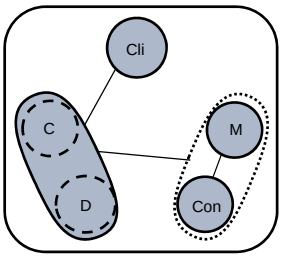


Figure 4-10 Interactive relationships of decision makers in Case S1 and Case S3

(5) Interaction between decision makers

During the decision-making process, clients expressed his requirements to consultants (also designers), discussed the retrofitting designs and confirm retrofitting cost and duration with consultants (also designers). Moreover, consultants (also designers) confirmed material performance with material suppliers (also constructors). Finally, the retrofitting designs are decided according to the considerations of clients, consultants (also designers).

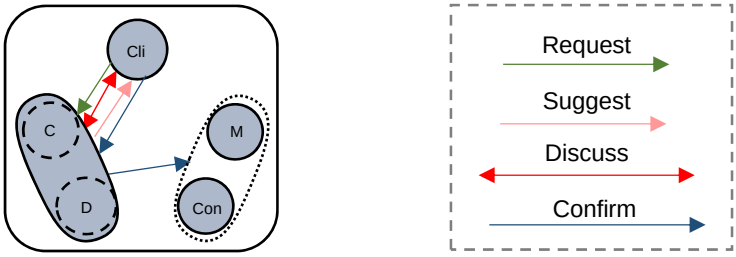


Figure 4-11 Activity between decision makers in Case S1 & Case S3

(6) Decision makers' working contents for assessments

By looking at Case S1 and S3, the working contents of decision makers in Pattern 2 are found as follows: the consultant (who is also a designer) estimated the considerations regarding "capability of improving thermal environment", and "legality". The constructor (who is also a material supplier) in this pattern estimated "affordability", "constructability" and "durability". The client confirmed expected improving performance, budget and expected useable period.

Table 4-4 Decision makers' working contents for assessments in Case S1 & Case S3

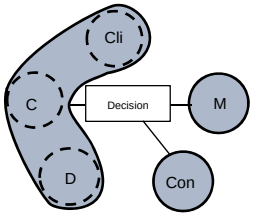
	A	B	C	D	E	F
Client	-	-	Confirm budget	-	-	Confirm expected useable period
Consultant	Estimate improving performance by calculation and knowledge	-	Confirm if retrofitting cost meet client's budget	Check if retrofitting methods meet building regulations	Check if the retrofitting methods are able to be constructed	Confirm if maintenance needs and useable period meet clients' expectations
Designer						
Constructor	-	-	Estimate material cost and constructing cost	-	Estimate material property , construction duration and feasibility	Estimate material property
Material supplier						

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The consultant (who is also a designer) estimated improving performance of retrofitting methods according to his knowledge and calculation.

4.2.3 Pattern 3 (Case R6)



The studied case, Case R6, is belong to Pattern 3. The types of decision makers in this case is including clients, consultants, designers, constructors and material suppliers; the relevance of decision makers are including one multiple-profession types and two independent-profession types. The decision-making process of retrofitting designs in Case R6 is presented as Fig. 4-12.

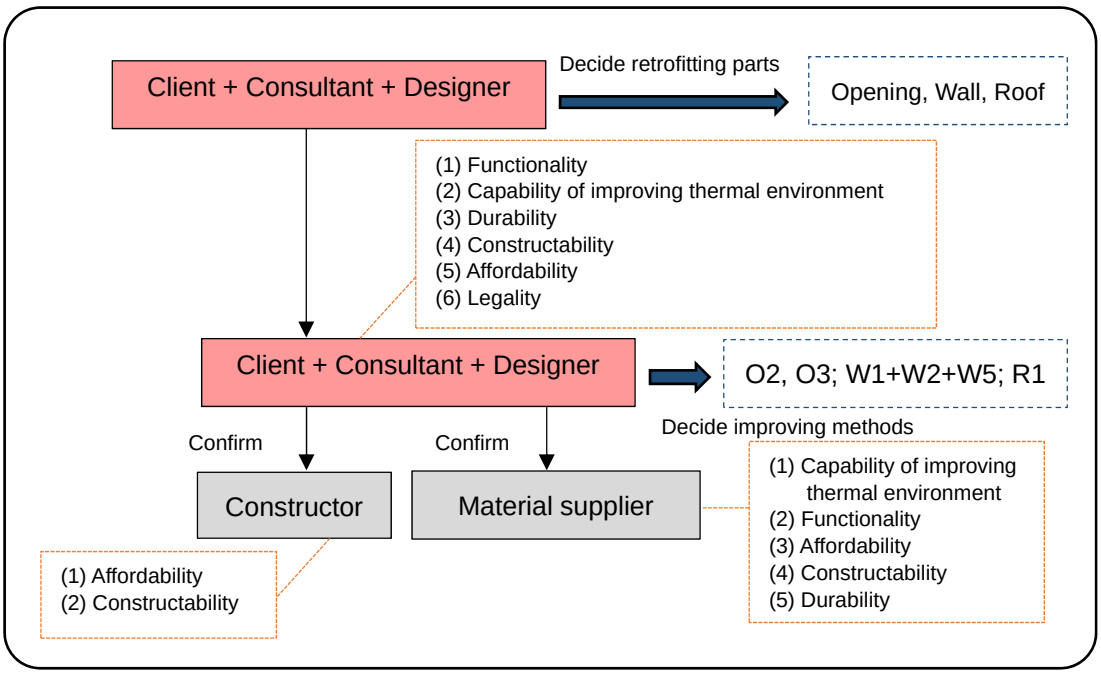


Figure 4-12 Decision-making process in Case R6

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

The considerations of clients (also consultants and designers) relate to "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability", and "durability".

The considerations of constructors relate to "affordability" and "constructability".

The considerations of material suppliers relate to "capability of improving thermal environment", "functionality", "affordability", "constructability", and "durability".

The considerations of constructors relate to "affordability" and "constructability".

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R3 are showing as Table 4-1.

Table 4-5 Priority orders of decision makers' considerations in Case R6

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Capability of improving thermal environment
(3)	Durability
(4)	Constructability
(5)	Affordability
(6)	Legality

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability" are cared by clients from the beginning.

Client + Consultant + Designer
Capability of improving thermal environment
Functionality
Affordability
Legality
Constructability
Durability

Figure 4-13 Development processes of decision makers' considerations in Case R6

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

In Pattern 3, the research result shows that retrofitting methods are decided after a client (who is also a consultant and designer) communicates with a material supplier and a constructor. Their interactive relationships are showing as following diagram.

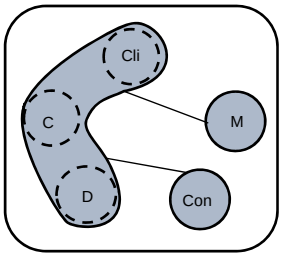


Figure 4-14 Interactive relationships of decision makers in Case R6

(5) Interaction between decision makers

During the decision-making process, clients (also consultants and designers) decide retrofitting designs by himself and only have actives regarding confirmation between material suppliers and constructors.

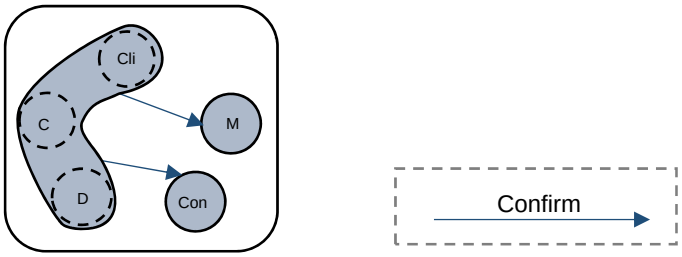


Figure 4-15 Activity between decision makers in Case R6

(6) Decision makers' working contents for assessments

By looking at Case R6, it was found the working contents of decision makers are as follows: the client (who is also a consultant and a designer) estimated the considerations regarding "capability of improving thermal environment", "functionality" and "legality". The constructor in this pattern estimated "affordability" and "constructability". The material supplier estimated "capability of improving thermal environment ", "functionality", "affordability", "constructability" and "durability".

Table 4-6 Decision makers' working contents for assessments in Case R6

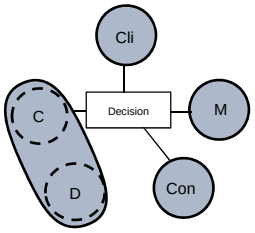
	A	B	C	D	E	F
Client	Estimate improving performance according to his knowledge	Confirm expected function and estimate if retrofitting methods can achieve the goal	Confirm budget and estimate if retrofitting cost meet client's budget	Check if retrofitting methods meet building regulations	Confirm if the design is able to be constructed	Confirm if useable period meet expectation
Consultant						
Designer						
Constructor	-	-	Estimate constructing cost	-	Estimate construction duration and feasibility	-
Material supplier	Estimate improving performance according to material performance data	Estimate material function	Estimate material cost	-	Estimate feasibility	Estimate useable period

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

Moreover, improving performance of retrofitting methods is estimated by client and material supplier. The client (who is also a consultant and a designer) estimates improving performance of retrofitting methods according to his knowledge; the material supplier estimate the improving performance according to material performance data.

4.2.4 **Pattern 4** (Case R4)



The studied case, Case R4, is included in Pattern 4. The types of decision makers in this case is including clients, consultants, designers, constructors and material suppliers; the relevance of decision makers in this case is including one multiple-profession type and three independent-profession types. The decision-making process of retrofitting designs in Case R4 is presented as Fig. 4-16.

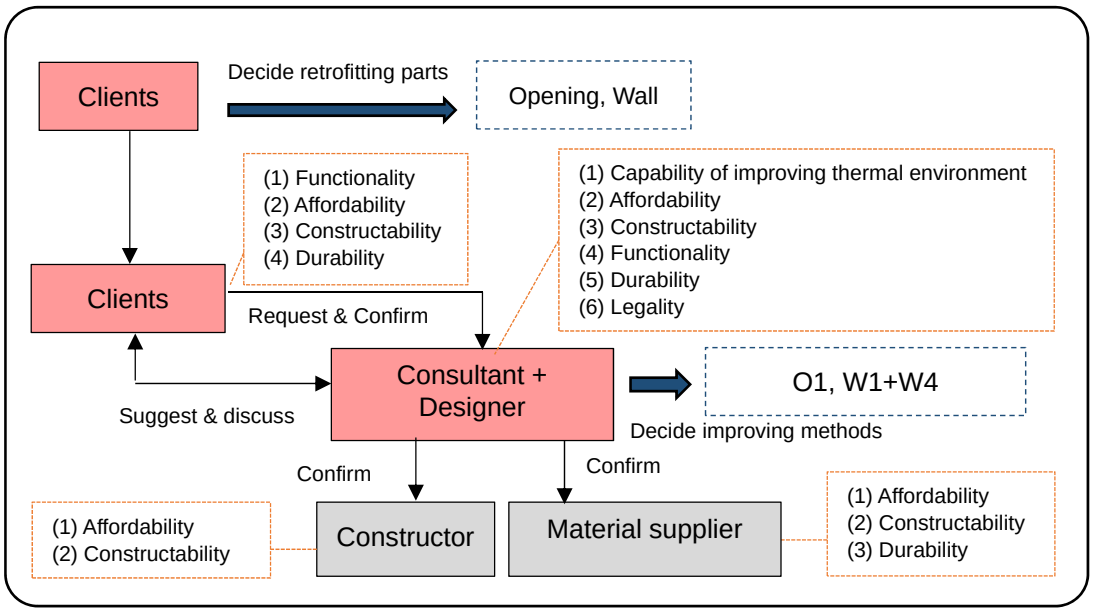


Figure 4-16 Decision-making process of retrofitting designs in Case R4

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Contents of decision makers' considerations for deciding retrofitting methods in Case R4 are showing as follows.

The considerations of clients relate to "functionality", "affordability", "constructability", and "durability".

The considerations of consultants (also designers) relate to "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability".

The considerations of material suppliers relate to “affordability”, “constructability”, and “durability”.

The considerations of constructors relate to “affordability” and “constructability”.

(2) Priority orders of decision makers’ considerations

Priority orders of decision makers’ considerations in Case R4 are showing as Table 4-7.

Table 4-7 Priority orders of decision makers’ considerations in Case R4

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Affordability
(3)	Constructability
(4)	Functionality
(5)	Durability
(6)	Legality

(3) Development processes of decision makers’ considerations

The research results show that the considerations regarding “functionality”, “affordability”, “constructability” and “durability” are concerned by clients from the beginning. The consideration regarding “capability of improving thermal environment” and “legality” are concerned after consultants suggesting.

Client		Consultant + Designer
-	◀----	Capability of improving thermal environment
Functionality	----------▶	Functionality
Affordability	----------▶	Affordability
-	◀----	Legality
Constructability	----------▶	Constructability
Durability	----------▶	Durability

Figure 4-17 Development processes of decision makers’ considerations in Case R4

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

In Pattern 4, the research result shows that retrofitting methods are decided after a consultant (who is also a designer) communicates with a client and a constructor. Their interactive relationships are showing as following diagram.

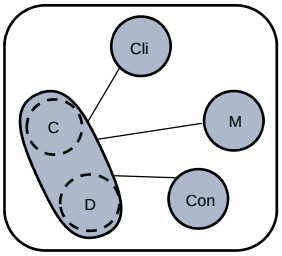


Figure 4-18 Interactive relationships of decision makers in Case R4

(5) Interaction between decision makers

During the decision-making process, the interactions between clients and consultants (also designers) are requests, suggestions, discussions and confirmations. Moreover, the interactions between consultants (also designers) and material suppliers is confirmations; the interactions between consultants (also designers) and constructors are also confirmations.

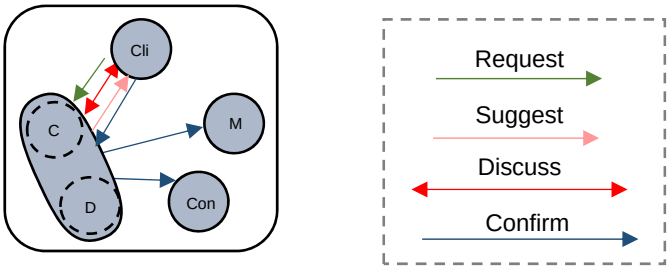


Figure 4-19 Activity between decision makers in Case R4

(6) Decision makers' working contents for assessments

In Pattern 4, a client, a consultant (who is also a designer), a constructor and a material supplier are the decision makers participated in the decision making process. By looking at Case R4, it was found the working contents of decision makers are as follows: the consultant (who is also a designer) estimated the consideration regarding "capability of improving thermal environment", "functionality" and "legality". The constructor in this pattern estimated "affordability" and "constructability". The material supplier estimated ""affordability", "constructability" and "durability".

Table 4-8 Decision makers' working contents for assessments in Case R4

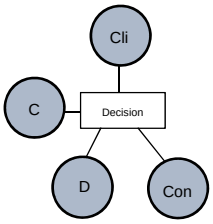
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budget	-	Confirm expected retrofitting period	Confirm expected useable period
Consultant / **Designer**	Estimate improving performance according to computer simulation and knowledge	Estimate if retrofitting methods can achieve clients' expected functions	Confirm if retrofitting cost meet client's budget	Check if retrofitting methods meet building regulations	Confirm if retrofitting period can meet clients' requirements	Confirm if useable period meet clients' expectation
Constructor	-	-	Estimate constructing cost	-	Estimate Constructing period and feasibility	-
Material supplier	-	-	Estimate material cost	-	Estimate manufacturing period	Estimate useable period

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

Moreover, the consultant (who is also a designer) estimates improving performance of retrofitting methods according to his knowledge and computer simulation.

4.2.5 Pattern 5 (Case R5, Case R9, Case R16)



The studied case, Case R5, Case R9 and Case R16, are included in Pattern 5. The types of decision makers in this case is including clients, consultants, designers, and constructors; the relevance of decision makers are including four independent-profession types. The decision-making process of retrofitting designs in these cases are presented as Fig. 4-20~Fig.22.

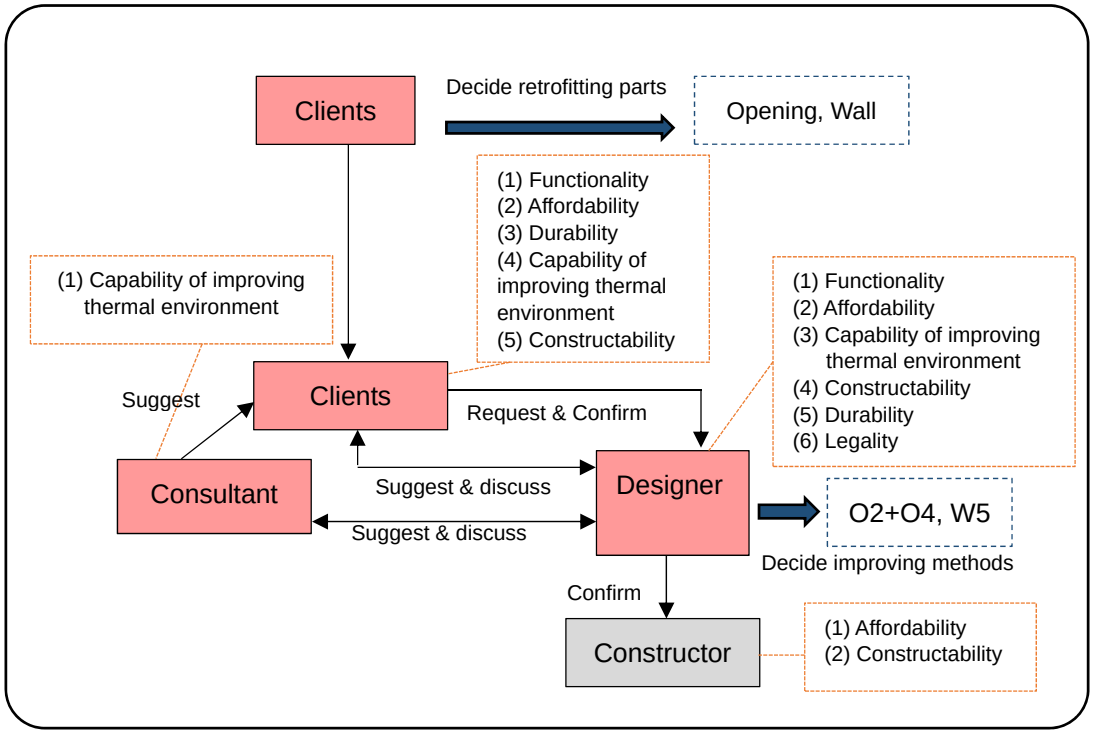


Figure 4-20 Decision-making process of retrofitting designs in Case R5

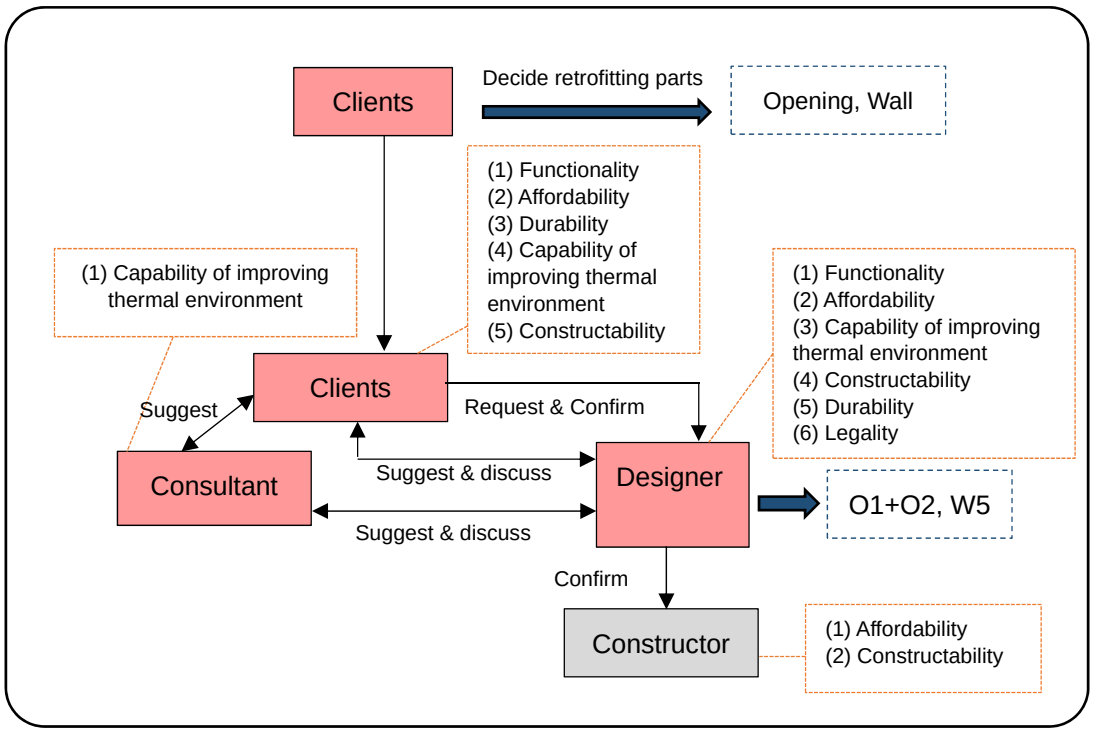


Figure 4-21 Decision-making process of retrofitting designs in Case R9

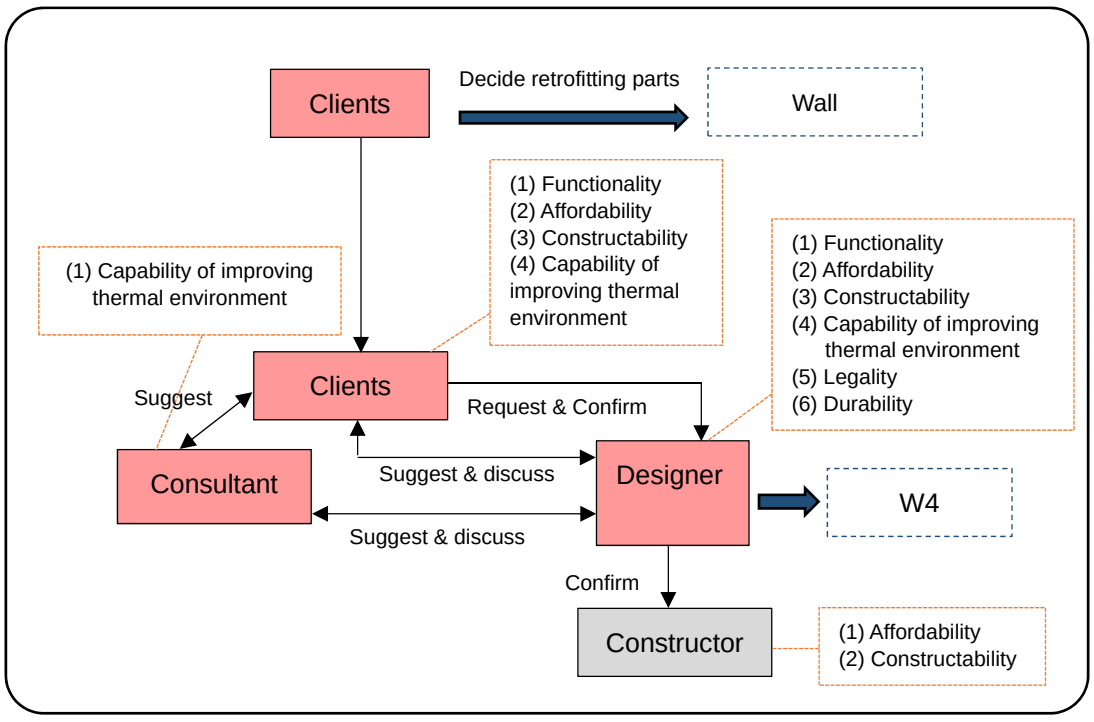


Figure 4-22 Decision-making process of retrofitting designs in Case R16

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

[Case R5 and Case R9]

Client: "capability of improving thermal environment", "functionality", "affordability", "constructability" and "durability"

Consultant: "capability of improving thermal environment"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

Constructor: "affordability" and "constructability"

[Case R16]

Client: "capability of improving thermal environment", "functionality", "affordability", and "constructability"

Consultant: "capability of improving thermal environment"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

Constructor: "affordability" and "constructability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R5, Case R9 and Case R16 are showing as Table 4-9, Table 10 and Table 4-11.

Table 4-9 Priority orders of decision makers' considerations in Case R5

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Affordability
(3)	Capability of improving thermal environment
(4)	Constructability
(5)	Durability
(6)	Legality

Table 4-10 Priority orders of decision makers' considerations in Case R9

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Affordability
(3)	Capability of improving thermal environment
(4)	Constructability
(5)	Durability
(6)	Legality

Table 4-11 Priority orders of decision makers' considerations in Case R16

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Affordability
(3)	Constructability
(4)	Capability of improving thermal environment
(5)	Legality
(6)	Durability

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "functionality", "affordability" and "constructability" are cared by clients from the beginning in all cases. However, the consideration regarding "capability of improving thermal environment" is thought after consultants suggesting to clients and designers in all cases. The considerations regarding "legality" are concerned after designers suggesting to clients in all cases. The consideration regarding "durability" is concerned after designers suggesting to clients in Case R16.

Client	Consultant	Designer
Capability of improving thermal environment	Capability of improving thermal environment	Capability of improving thermal environment
Functionality		Functionality
Affordability		Affordability
-		Legality
Constructability		Constructability
Durability		Durability

Figure 4-23 Development processes of decision makers' considerations in Case R5 & Case R9

Client	Consultant	Designer
Capability of improving thermal environment	Capability of improving thermal environment	Capability of improving thermal environment
Functionality		Functionality
Affordability		Affordability
-		Legality
Constructability		Constructability
-		-

Figure 4-24 Development processes of decision makers' considerations in Case R16

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research result shows that retrofitting methods are decided after a consultant communicates with a client and a designer; also a designer communicates with a consultant, a client and a constructor. Their interactive relationships are showing as following diagram.

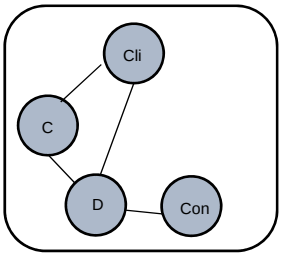


Figure 4-25 Interactive relationships of decision makers in Case R4, Case R9, and Case R16

(5) Interaction between decision makers

Interaction between decision makers in Case R4, Case R9, and Case R16 are showing as the diagram below.

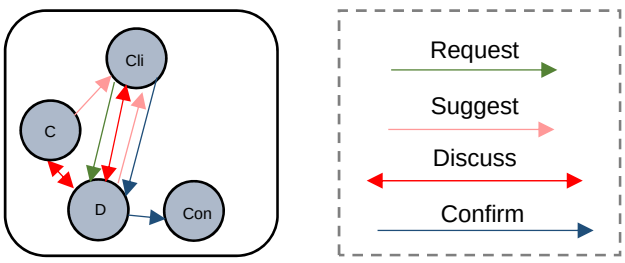


Figure 4-26 Activity between decision makers in Case R4, Case R9, and Case R16

(6) Decision makers' working contents for assessments

In Pattern 5, a client, a consultant, a designer and a constructor are the decision makers in the decision making process. By looking at Case R5, R9 and R16, it was found that the consultant estimated the consideration regarding "capability of improving thermal environment", the constructor in this pattern estimated "affordability", "constructability" and "durability", and the designer assessed "functionality" and "legality".

Table 4-12 Decision makers' working contents for assessments in Case R5, Case R9 and Case R16

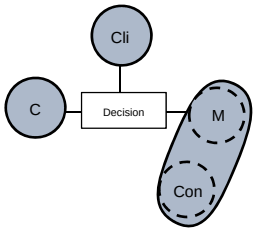
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budget	-	Confirm expected retrofit period	Confirm expected useable period
Consultant	Estimate improving performance according to his knowledge	-	-	-	-	-
Designer	-	Assess if retrofitting methods can achieve clients' expected function	Confirm if retrofitting cost meet client's budget	Assess if retrofitting methods meet building regulations	Confirm if retrofitting period can meet clients' requirements	Confirm if retrofitting methods meet clients' expected useable period
Constructor	-	-	Estimate constructing and material cost	-	Estimate manufacturing period , constructing period and feasibility	Estimate useable period
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The consultant estimates improving performance of retrofitting methods according to his knowledge.

4.2.6 **Pattern 6** (Case R18)



The studied case, Case R18, is included in Pattern 6. The types of decision makers in this case is including clients, consultants, designers, constructors and material suppliers; the relevance of decision makers in this case is including one multiple-profession type and two independent-profession types. The decision-making process of retrofitting designs in Case R18 is presented as diagram below.

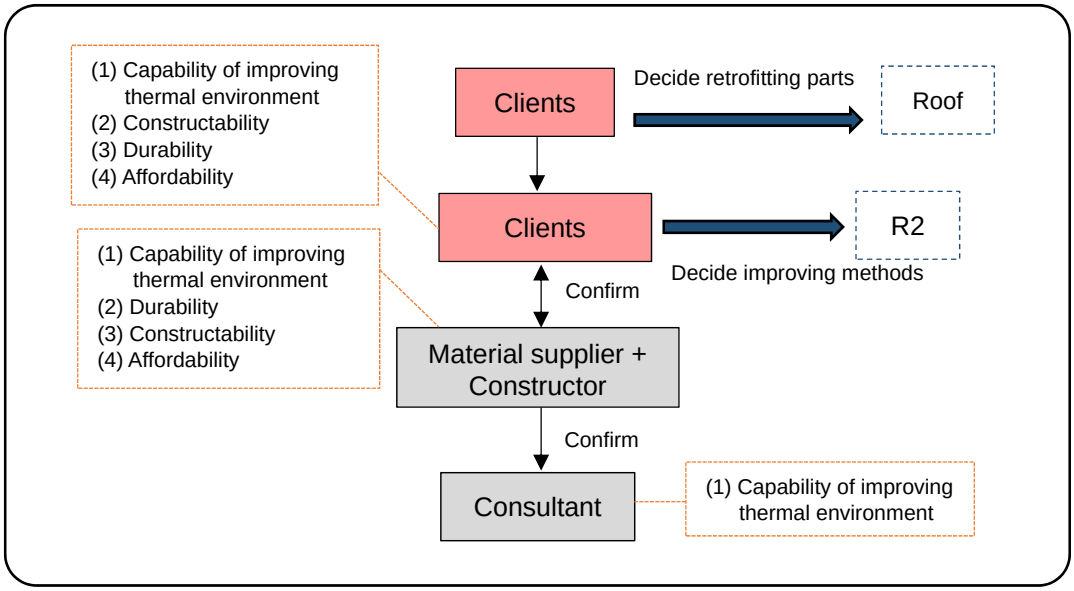


Figure 4-27 Decision-making process of retrofitting designs in Case R18

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Client: "capability of improving thermal environment", "affordability", "constructability" and "durability".

Material supplier (+ Constructor): "capability of improving thermal environment", "affordability", "constructability" and "durability".

Consultant: "capability of improving thermal environment"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R18 are showing as table below.

Table 4-13 Priority orders of decision makers' considerations in Case R18

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Constructability
(3)	Durability
(4)	Affordability
(5)	-
(6)	-

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "capability of improving thermal environment", "affordability", "constructability" and "durability" are cared by clients from the beginning.

Client
Capability of improving thermal environment
-
Affordability
-
Constructability
Durability

Figure 4-28 Development processes of decision makers' considerations in Case R18

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research result shows that retrofitting methods are decided after a client confirms with a material supplier (who is also a constructor), and the material supplier confirms with a consultant. Their interactive relationships are showing as following diagram.

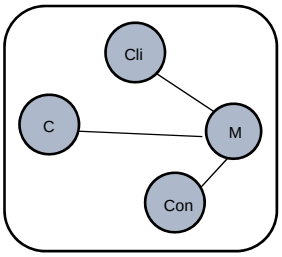


Figure 4-29 Interactive relationships of decision makers in Case R18

(5) Interaction between decision makers

Interaction between decision makers in Case R18 are showing as the diagram below.

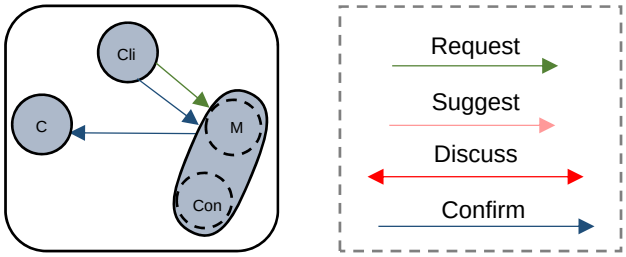


Figure 4-30 Activity between decision makers in Case R18

(6) Decision makers' working contents for assessments

In Pattern 6, a client, a consultant and a material supplier (who is also a constructor) are the decision makers in the decision making process. By looking at Case R18, it was found that the client decide retrofitting methods in this pattern by concerning the considerations regarding "capability of improving thermal environment", "durability", "constructability" and "affordability". However, he need the material supplier to estimate "durability", "constructability" and "affordability", and the consultant estimate "capability of improving thermal environment" for him.

Table 4-14 Decision makers' working contents for assessments in Case R18

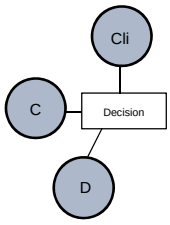
	A	B	C	D	E	F
Client	-	-	Confirm budget and check if retrofitting cost meet his budget	-	Confirm expected retrofit period	Confirm expected useable period
Consultant	Estimate improving performance by calculating	-	-	-	-	-
Designer	-	-	-	-	-	-
Constructor	-	-	Estimate constructing and material cost	-	Estimate manufacturing period , constructing period and feasibility	Estimate useable period
Material supplier						

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The consultant estimates improving performance of retrofitting methods by calculation.

4.2.7 Pattern 7 (Case R10, Case C4, Case R1, Case G1, Case G2, Case M1, Case S2, Case C1, Case C2, Case S4)



The studied cases, Case R10, Case C4, Case R1, Case G1, Case G2, Case M1, Case S2, Case C1, Case C2, and Case S4, are included in Pattern 7. The types of decision makers in this case is including clients, consultants and designers; the relevance of decision makers in this case is including three independent-profession types. The decision-making processes of retrofitting designs in these cases are presented as diagrams below.

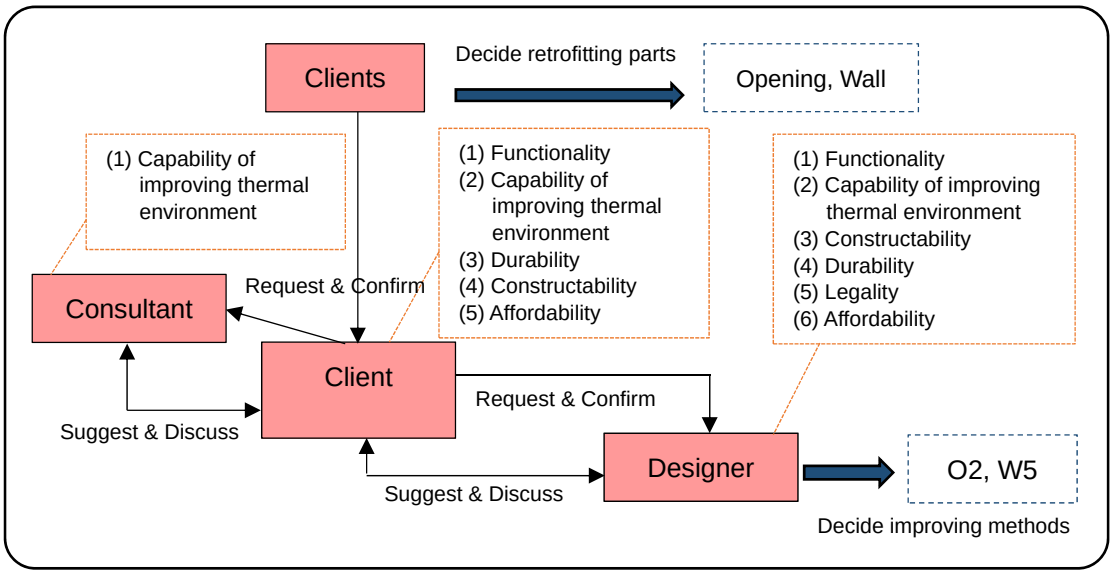


Figure 4-31 Decision-making process of retrofitting designs in Case R10

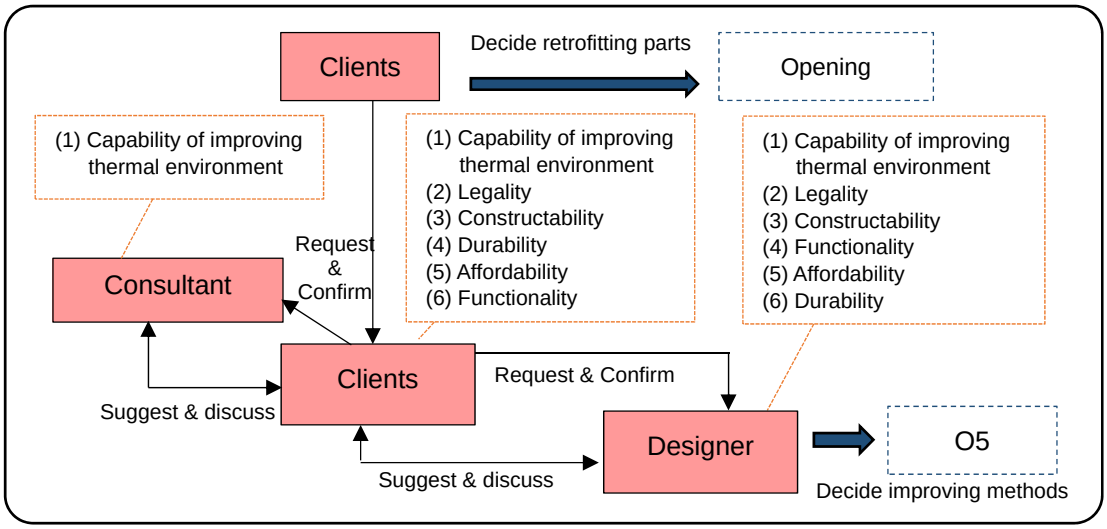


Figure 4-32 Decision-making process of retrofitting designs in Case C4

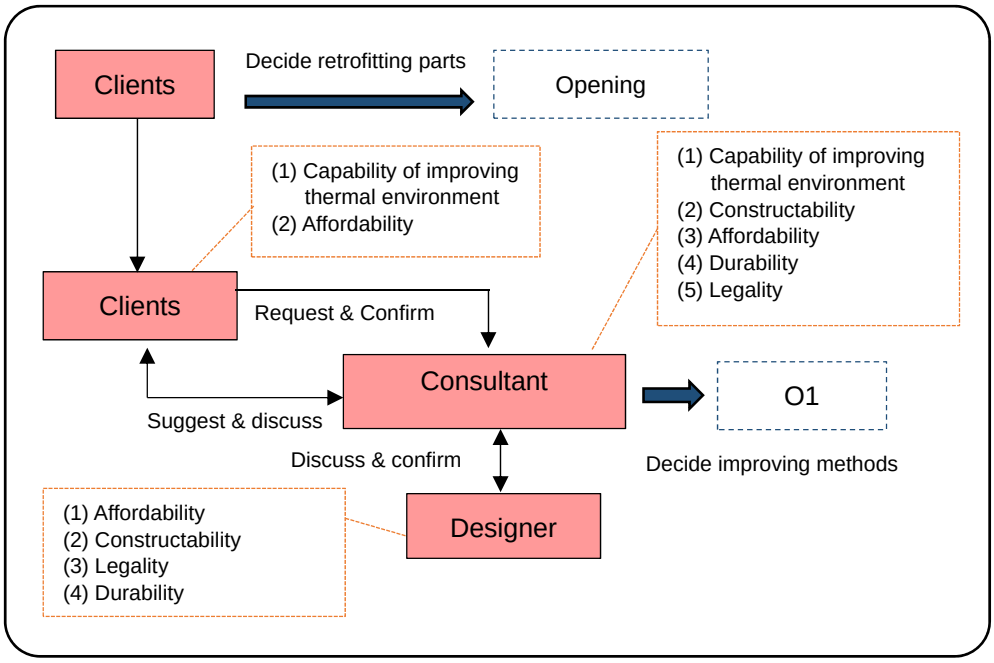


Figure 4-33 Decision-making process of retrofitting designs in Case R1, G1, G2, M1, S2, C2

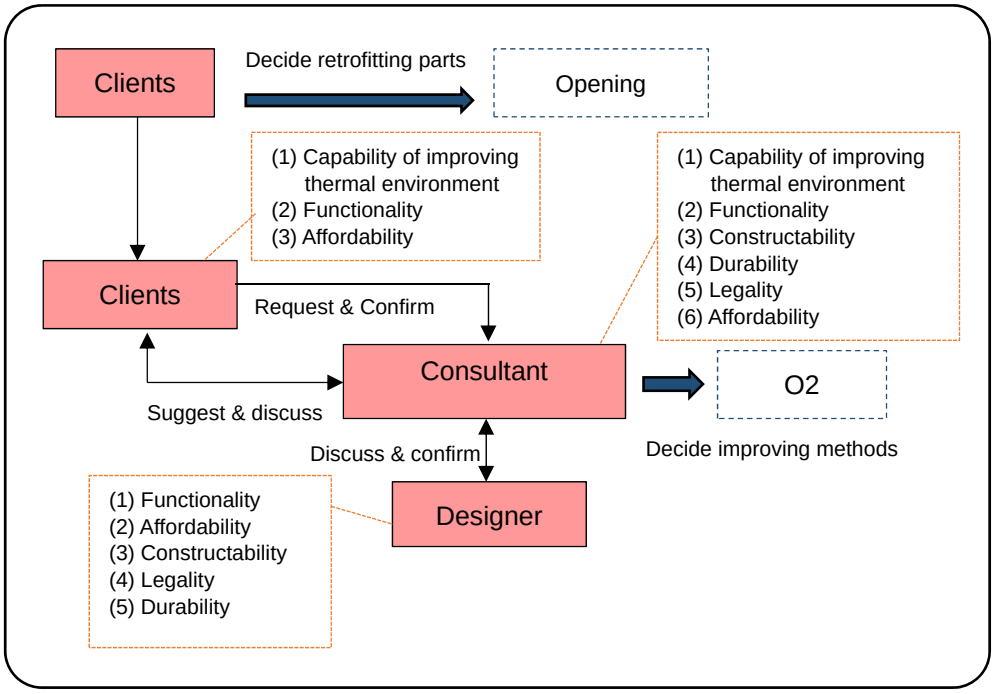


Figure 4-34 Decision-making process of retrofitting designs in Case C1

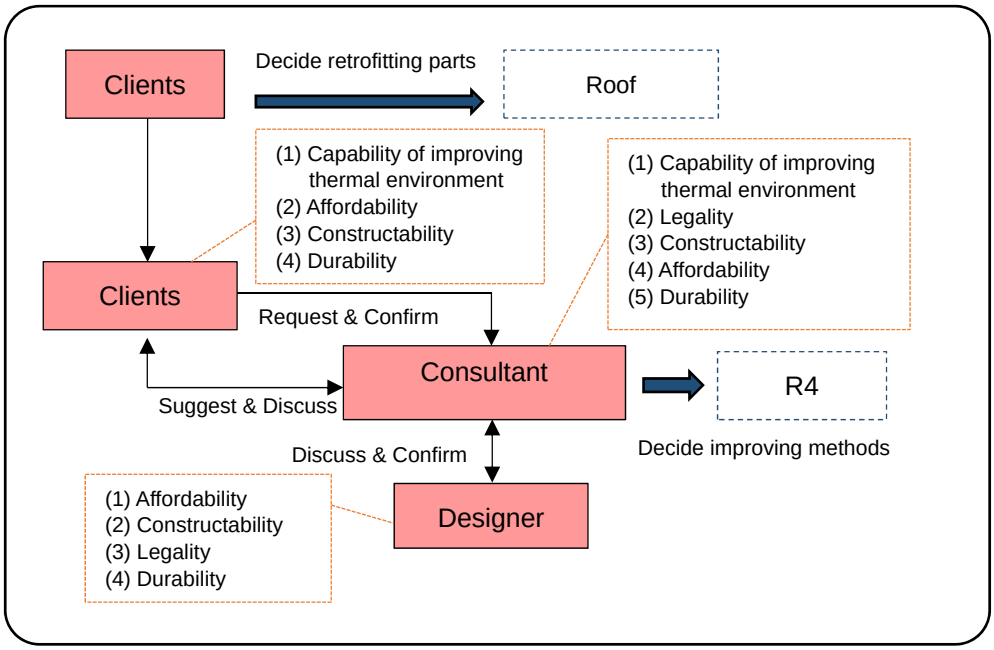


Figure 4-35 Decision-making process of retrofitting designs in Case S4

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

[Case R10]

Client: "capability of improving thermal environment", "functionality", "affordability", "constructability" and "durability"

Consultant: "capability of improving thermal environment"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

[Case C4]

Client: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

Consultant: "capability of improving thermal environment"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

[Case R1, Case G1, Case G2, Case M1, Case S2, Case C2]

Client: "capability of improving thermal environment" and "affordability"

Consultant: "capability of improving thermal environment", "affordability", "legality", "constructability" and "durability"

Designer: "affordability", "legality", "constructability" and "durability"

[Case C1]

Client: “capability of improving thermal environment”, “functionality”, “affordability”

Consultant: “capability of improving thermal environment”, “functionality”, “affordability”, “legality”, “constructability” and “durability”

Designer: “functionality”, “affordability”, “legality”, “constructability” and “durability”

[Case S4]

Client: “capability of improving thermal environment”, “affordability”, “constructability” and “durability”

Consultant: “capability of improving thermal environment”, “affordability”, “legality”, “constructability” and “durability”

Designer: “affordability”, “legality”, “constructability” and “durability”

(2) Priority orders of decision makers’ considerations

Priority orders of decision makers’ considerations in all cases of Pattern 7 are showing as tables below.

Table 4-15 Priority orders of decision makers’ considerations in Case R10

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Capability of improving thermal environment
(3)	Constructability
(4)	Durability
(5)	Legality
(6)	Affordability

Table 4-16 Priority orders of decision makers’ considerations in Case C4

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Legality
(3)	Constructability
(4)	Functionality
(5)	Affordability
(6)	Durability

Table 4-17 Priority orders of decision makers' considerations in Case R1, G1, G2, M1, S2, C2

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Constructability
(3)	Affordability
(4)	Durability
(5)	Legality
(6)	-

Table 4-18 Priority orders of decision makers' considerations in Case C1

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Functionality
(3)	Constructability
(4)	Durability
(5)	Legality
(6)	Affordability

Table 4-19 Priority orders of decision makers' considerations in Case S4

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Legality
(3)	Constructability
(4)	Affordability
(5)	Durability
(6)	-

(3) Development processes of decision makers' considerations

[Case R10]

The research results show that the considerations regarding "functionality", "affordability", "constructability" and "durability" are cared by clients from the beginning. However, the consideration regarding "capability of improving thermal environment" is thought after consultants suggesting to clients; the consideration regarding "legality" is developed after designer suggesting.

Consultant	Client	Designer
Capability of improving thermal environment	Capability of improving thermal environment	Capability of improving thermal environment
-	Functionality	Functionality
-	Affordability	Affordability
-	-	Legality
-	Constructability	Constructability
-	Durability	Durability

Figure 4-36 Development processes of decision makers' considerations in Case R10

[Case C4]

The research results show that the considerations regarding "functionality", "affordability", "legality", "constructability" and "durability" are cared by clients from the beginning. However, the consideration regarding "capability of improving thermal environment" is thought after consultants suggesting to clients.

Consultant	Client	Designer
Capability of improving thermal environment	Capability of improving thermal environment	Capability of improving thermal environment
-	Functionality	Functionality
-	Affordability	Affordability
-	Legality	Legality
-	Constructability	Constructability
-	Durability	Durability

Figure 4-37 Development processes of decision makers' considerations in Case C4

[Case R1, Case G1, Case G2, Case M1, Case S2, Case C2]

The research results show that the considerations regarding "capability of improving thermal environment", and "affordability" are cared by clients from the beginning. However, the consideration regarding "legality", "constructability" and "durability" are developed after consultants suggesting to clients.

Client	Consultant
Capability of improving thermal environment	Capability of improving thermal environment
-	-
Affordability	Affordability
-	Legality
-	Constructability
-	Durability

Figure 4-38 Development processes of decision makers' considerations in Case R1, G1, G2, M1, S2, C2

[Case C1]

The research results show that the considerations regarding “capability of improving thermal environment”, “functionality” and “affordability” are cared by clients from the beginning. However, the consideration regarding “legality”, “constructability” and “durability” are developed after consultants suggesting to clients.

Client	Consultant
Capability of improving thermal environment	Capability of improving thermal environment
Functionality	Functionality
Affordability	Affordability
-	Legality
-	Constructability
-	Durability

Figure 4-39 Development processes of decision makers’ considerations in Case C1

[Case S4]

The research results show that the considerations regarding “capability of improving thermal environment”, “affordability”, “constructability” and “durability” are cared by clients from the beginning. However, the consideration regarding “legality” is developed after consultants suggesting to clients.

Client	Consultant
Capability of improving thermal environment	Capability of improving thermal environment
-	-
Affordability	Affordability
-	Legality
Constructability	Constructability
Durability	Durability

Figure 4-40 Development processes of decision makers’ considerations in Case S4

Part 2: How decision makers arrive at the decisions

(4) Decision makers’ interactive relationships

The research results regarding decision makers’ interactive relationships in several studied cases show that retrofitting methods are decided after a client communicates with a consultant and a designer. Their interactive relationships are showing as following diagrams.

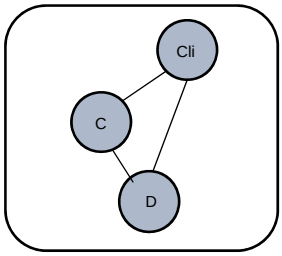


Figure 4-41 Interactive relationships of decision makers in Pattern 7

(5) Interaction between decision makers

Interactions between decision makers in Case R10, Case C4, Case R1, Case G1, Case G2, Case M1, Case S2, Case C2, Case C1 and Case S4 are showing as the diagram below.

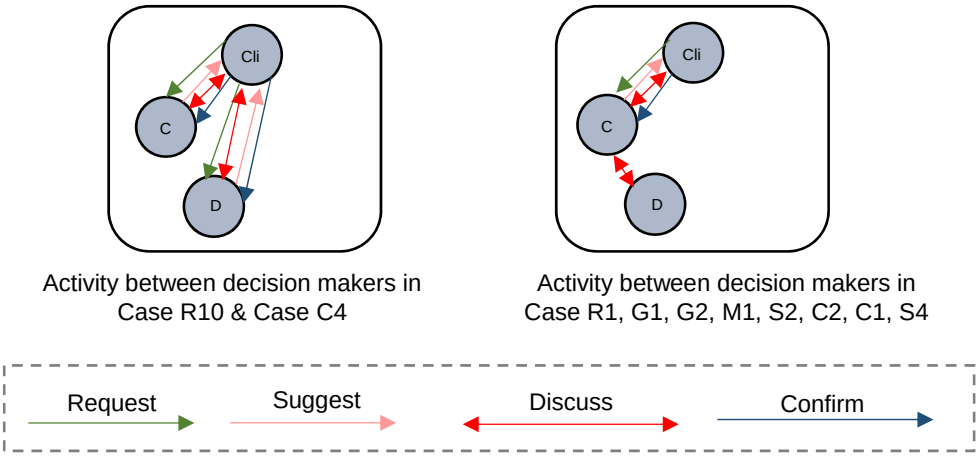


Figure 4-42 Activity between decision makers in Pattern 7

(6) Decision makers' working contents for assessments

In Pattern 7, a client, a consultant and a designer are the decision makers in the decision making process. By looking at cases belong to Pattern 7, it was found that the designers in this pattern estimate all considerations except the consideration regarding "capability of improving thermal environment". The consultant estimates improving performance of retrofitting methods.

Table 4-20 Decision makers' working contents for assessments in Pattern 7

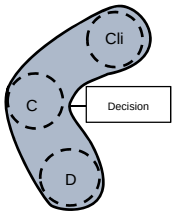
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budget	-	Confirm constructing feasibility and expected retrofitting period	Confirm expected useable period
Consultant	Suggest improving methods and estimate improving performance by his knowledge	-	-	-	-	-
Designer	-	Estimate if retrofitting methods can achieve clients' goal	Estimate if retrofitting cost meet client's budget	Assess if retrofitting methods meet building regulations	Estimate constructing feasibility	Estimate useable period and need of maintenance
Constructor	-	-	-	-	-	-
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The consultants estimates improving performance of retrofitting methods commonly by calculating and their professional knowledge.

4.2.8 Pattern 8 (Case C5)



The studied case, Case C5, is included in Pattern 8. The types of decision makers in this case is including clients, consultants and designers; the relevance of decision makers in this case is including one multiple-profession type. The decision-making process of retrofitting designs in Case C5 is presented as diagram below.

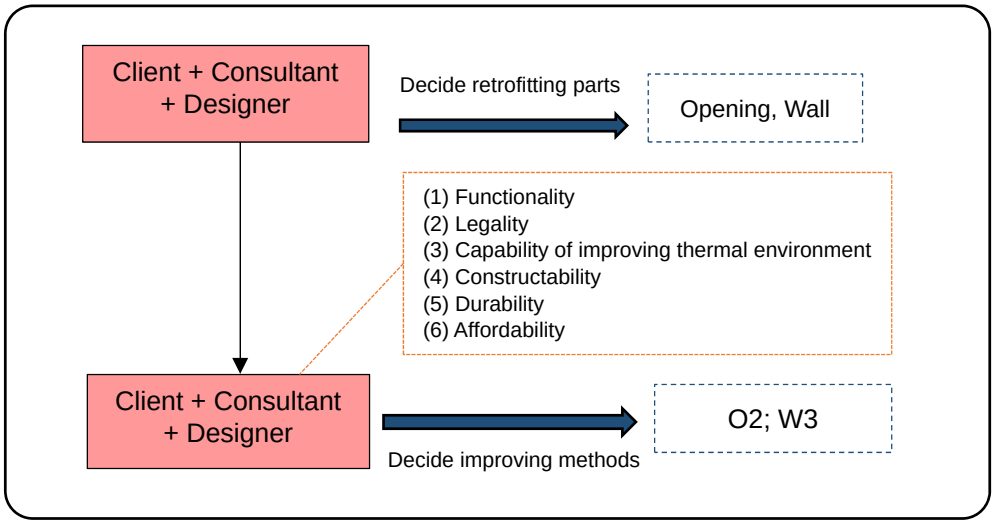


Figure 4-43 Decision-making process of retrofitting designs in Case C5

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

The clients (also consultants and designers) are caring about the consideration "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability".

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in all cases in Case C5 is showing as table below.

Table 4-21 Priority orders of decision makers' considerations in Case C5

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Legality
(3)	Capability of improving thermal environment
(4)	Constructability
(5)	Durability
(6)	Affordability

(3) Development processes of decision makers' considerations

In Case C5, the research results show that the considerations regarding "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability" are cared by clients from the beginning.

Client + Consultant + Designer
Capability of improving thermal environment
Functionality
Affordability
Legality
Constructability
Durability

Figure 4-44 Development processes of decision makers' considerations in Case C5

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research result shows that retrofitting methods are decided by a client (who is also a consultant and a designer) himself without having any interactive relationship with other decision makers.

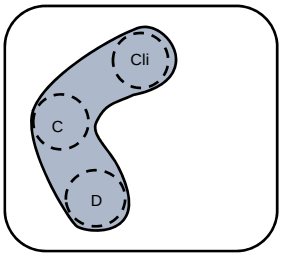


Figure 4-45 Interactive relationships of decision makers in Case C5

(5) Interaction between decision makers

Interactions between decision makers in Case C5 are showing as the diagram below.

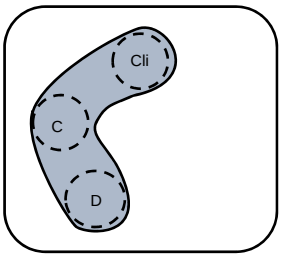


Figure 4-46 Activity between decision makers in Case C5

(6) Decision makers' working contents for assessments

In Pattern 8, a client (who is also a consultant and a designer) are the decision makers in the decision making process. By looking at Case C5, it was found that the client in this pattern estimate all considerations by himself. Moreover, the client estimates improving performance of retrofitting methods according to his knowledge and past working experience.

Table 4-22 Decision makers' working contents for assessments in Case C5

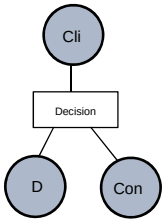
	A	B	C	D	E	F
Client / **Consultant** / **Designer**	Estimate improving performance according to his past working experience and knowledge	Assess if retrofitting methods can achieve his expected function	Estimate if retrofitting cost meet his budget	Check building regulations	Estimate constructing feasibility	Estimate useable period
Constructor	-	-	-	-	-	-
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The client (also consultant and designer) estimates improving performance of retrofitting methods is according to theories of energy-saving design and reports of material performance.

4.2.9 **Pattern 9** (Case R2, Case C3)



The studied case, Case R2 and Case C3, are included in Pattern 9. The types of decision makers in this case is including clients, designers and constructors; the relevance of decision makers in this case is including three independent-profession types. The decision-making processes of retrofitting designs in Pattern 9 are presented as diagrams below.

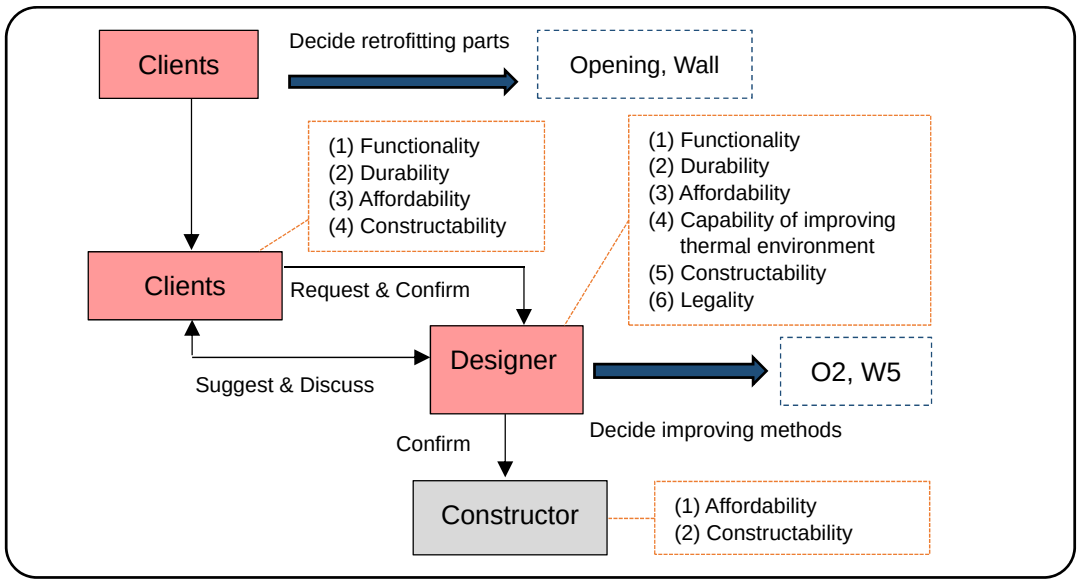


Figure 4-47 Decision-making process of retrofitting designs in Case R2

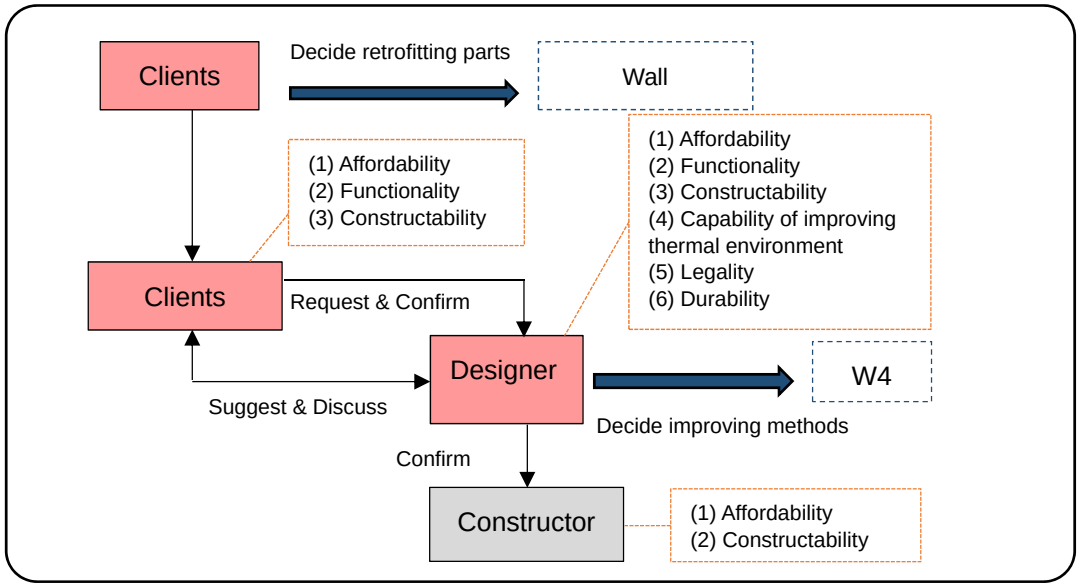


Figure 4-48 Decision-making process of retrofitting designs in Case C3

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

[Case R2]

Clients: "functionality", "affordability", "durability" and "constructability"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

[Case C3]

Clients: "functionality", "affordability" and "constructability"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R2 and Case C3 are showing as tables below.

Table 4-23 Priority orders of decision makers' considerations in Case R2

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Durability
(3)	Affordability
(4)	Capability of improving thermal environment
(5)	Constructability
(6)	Legality

Table 4-24 Priority orders of decision makers' considerations in Case C3

Priority order	Final decision-making considerations
(1)	Affordability
(2)	Functionality
(3)	Constructability
(4)	Capability of improving thermal environment
(5)	Legality
(6)	Durability

(3) Development processes of decision makers' considerations

[Case R2]

The research results show that the considerations regarding "functionality", "affordability", "constructability" and "durability" are concerned by clients from the beginning. The consideration regarding "capability of improving thermal environment" and "legality" are concerned after designers suggesting.

Client		Designer
-	◀----	Capability of improving thermal environment
Functionality	----------▶	Functionality
Affordability	----------▶	Affordability
-	◀----	Legality
Constructability	----------▶	Constructability
Durability	----------▶	Durability

Figure 4-49 Development processes of decision makers' considerations in Case R2

[Case C3]

The research results show that the considerations regarding "functionality", "affordability" and "constructability" are concerned by clients from the beginning. The consideration regarding "capability of improving thermal environment", "legality" and "durability" are concerned after designers suggesting.

Client		Designer
-	◀----	Capability of improving thermal environment
Functionality	----------▶	Functionality
Affordability	----------▶	Affordability
-	◀----	Legality
Constructability	----------▶	Constructability
	◀----	Durability

Figure 4-50 Development processes of decision makers' considerations in Case C3

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research results show clients have interactive relationship with designers; the designers have integrative relationship with clients and constructors. Their interactive relationships are showing as following diagram.

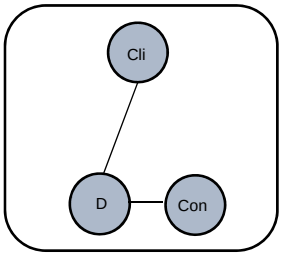


Figure 4-51 Interactive relationships of decision makers in Pattern 9

(5) Interaction between decision makers

In Pattern 9, the research result shows that retrofitting methods are decided after a designer communicates with a client and a constructor. Interaction between decision makers in Pattern 9 are showing as the diagram below.

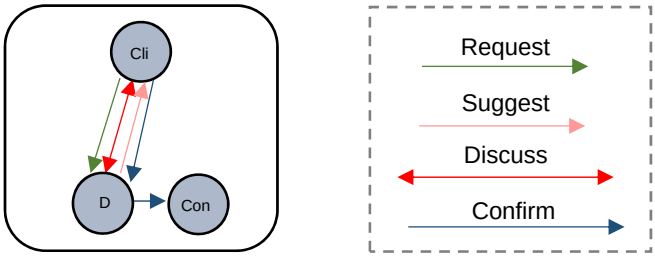


Figure 4-52 Activity between decision makers in Pattern 9

(6) Decision makers' working contents for assessments

In Pattern 9, a client, a designer and a constructors are the decision makers in the decision making process. By looking at Case R2 and Case C3, it was found that the designer in this pattern estimate all considerations and confirm "affordability", and "constructability" with the constructor.

Table 4-25 Decision makers' working contents for assessments in Pattern 9

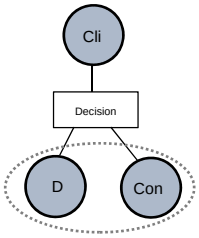
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budge	-	Confirm expected retrofit period	Confirm expected useable period
Consultant	-	-	-	-	-	-
Designer	Estimate improving performance according to his knowledge and past working experience	Assess if retrofitting methods can achieve client's expected functions	Confirm if retrofitting cost meet client's budget	Check if retrofitting methods meet building regulations	Confirm if retrofitting methods meet client's expected retrofit period	Estimate useable period and need of maintenance
Constructor	-	-	Estimate constructing and material cost	-	Estimate constructing period and feasibility	-
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

In this patterns, the designers estimate improving performance of retrofitting methods commonly according to his knowledge and past working experience.

4.2.10 **Pattern 10** (Case R13, Case R14)



The studied cases, Case R13 and Case R14, are included in Pattern 10. The types of decision makers in this case is including clients, designers and constructors; the relevance of decision makers in this case is including one multiple-professions types and one independent-profession type. The decision-making processes of retrofitting designs in Case R13 and Case R14 are presented as diagrams below.

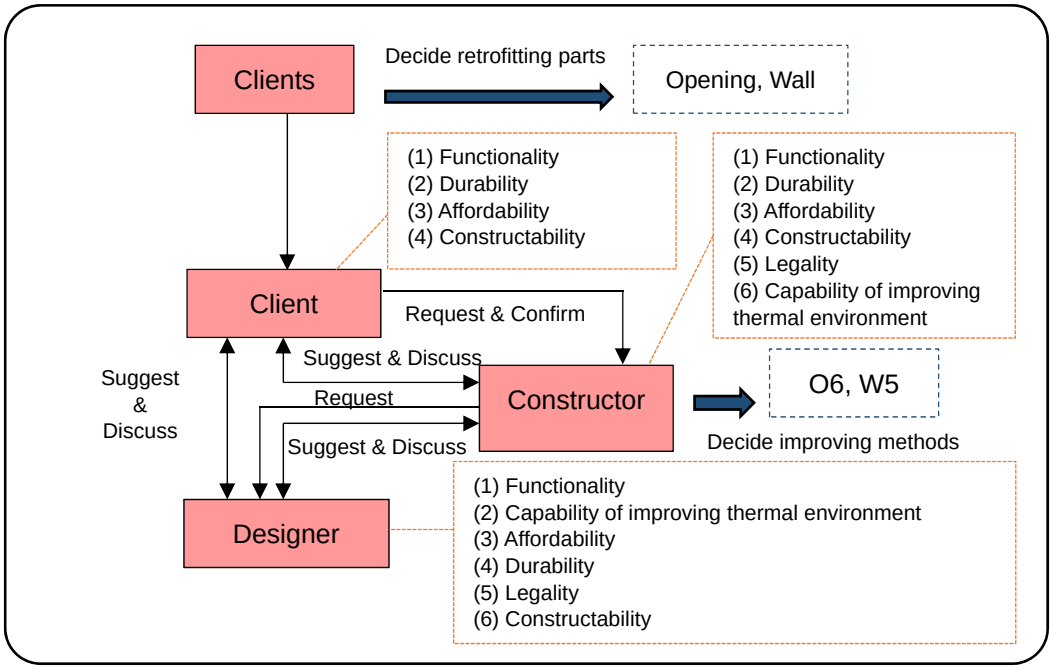


Figure 4-53 Decision-making process of retrofitting designs in Case R13

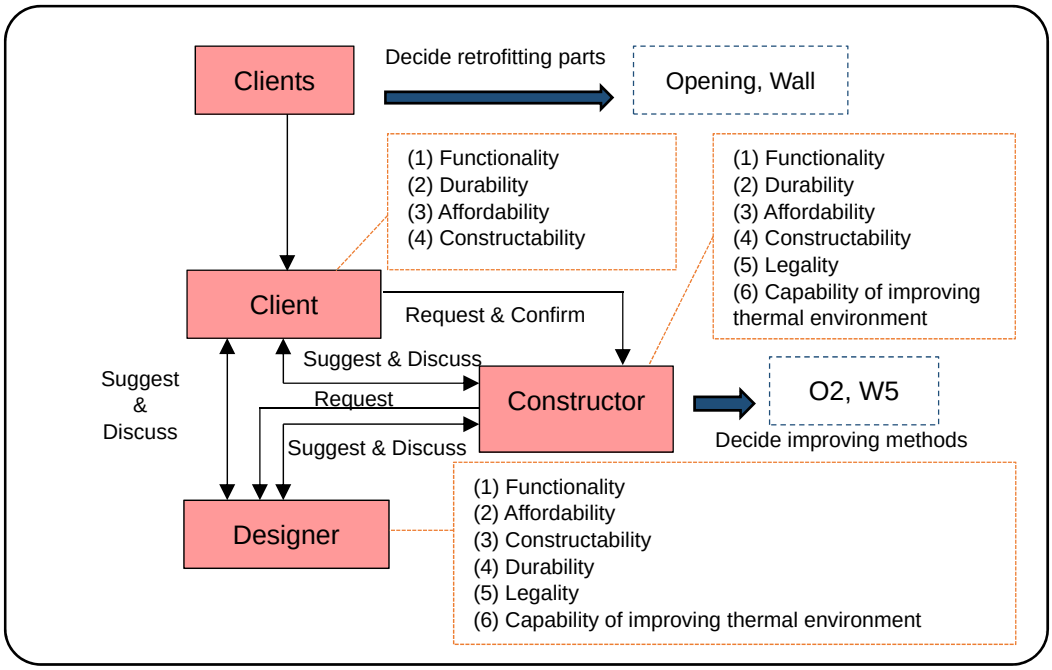


Figure 4-54 Decision-making process of retrofitting designs in Case R14

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

[Case R13]

Client: "functionality", "affordability", "constructability" and "durability"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

Constructor: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

[Case R14]

Client: "functionality", "affordability", "constructability" and "durability"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

Constructor: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R7-1 are showing as tables below.

Table 4-26 Priority orders of decision makers' considerations in Case R13

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Durability
(3)	Affordability
(4)	Constructability
(5)	Legality
(6)	Capability of improving thermal environment

Table 4-27 Priority orders of decision makers' considerations in Case R14

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Durability
(3)	Affordability
(4)	Constructability
(5)	Legality
(6)	Capability of improving thermal environment

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "functionality", "affordability", "constructability" and "durability" are concerned by clients from the beginning. Moreover, the considerations regarding "capability of improving thermal environment" and "legality" are concerned after designers suggesting.

Client	Designer	Constructor
-	Capability of improving thermal environment	Capability of improving thermal environment
Functionality	Functionality	Functionality
Affordability	Affordability	Affordability
-	Legality	Legality
Constructability	Constructability	Constructability
Durability	Durability	Durability

Figure 4-55 Development processes of decision makers' considerations in Pattern 10

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research results show clients, designers and constructors have interactive relationship with each other. Their interactive relationships are showing as following diagram.

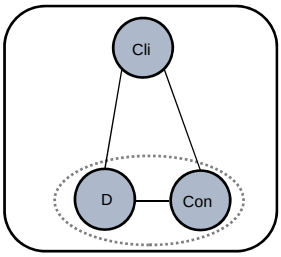


Figure 4-56 Interactive relationships of decision makers in Pattern 10

(5) Interaction between decision makers

The research result shows that retrofitting methods in Pattern 10 are decided after both a designer and constructor communicate with a client, and also the designer and the constructor discuss with each other. Interactions between decision makers in Pattern 10 are showing as the diagram below.

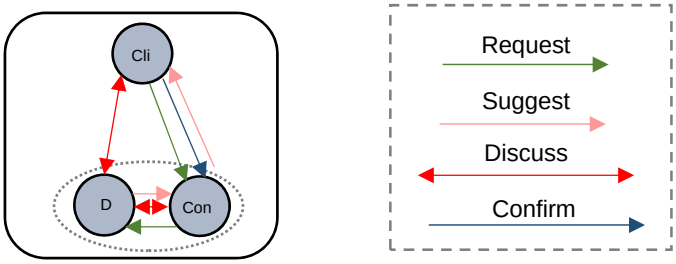


Figure 4-57 Activity between decision makers in Pattern 10

(6) Decision makers' working contents for assessments

In Pattern 10, a client, a designer and a constructors are the decision makers in the decision making process. Although a constructor leads decision0making process in this pattern, however he need a designer to do building designer and suggest retrofitting methods. By looking at Case R13 and Case R14, it was found that the designer can almost estimate all considerations and confirm "affordability", "constructability" and "durability" with the constructor.

Table 4-28 Decision makers' working contents for assessments in Pattern 10

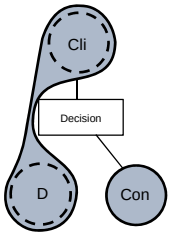
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budge	-	Confirm expected retrofit period	Confirm expected useable period
Consultant	-	-	-	-	-	-
Designer	Suggest improving methods and estimate improving performance according to his knowledge	Assess if retrofitting methods can achieve client's expected function	Confirm if retrofitting cost meet client's budget	Check if retrofitting methods meet building regulations	Confirm if retrofitting methods meet clients' expected period	Confirm if retrofitting methods meet clients' expected useable period and need of maintenance
Constructor	-	-	Estimate constructing and material cost	-	Estimate manufacturing period, constructing period and check constructing feasibility	Estimate useable period and need of maintenance
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The designer estimate improving performance of retrofitting methods according to his knowledge and design theories.

4.2.11 **Pattern 11** (Case R7-2)



The studied case, Case R7-2, is included in Pattern 11. The types of decision makers in this case is including clients, designers and constructors; the relevance of decision makers in this case is including one multiple-profession type and one independent-profession type. The decision-making process of retrofitting designs in Case R7-2 is presented as diagram below.

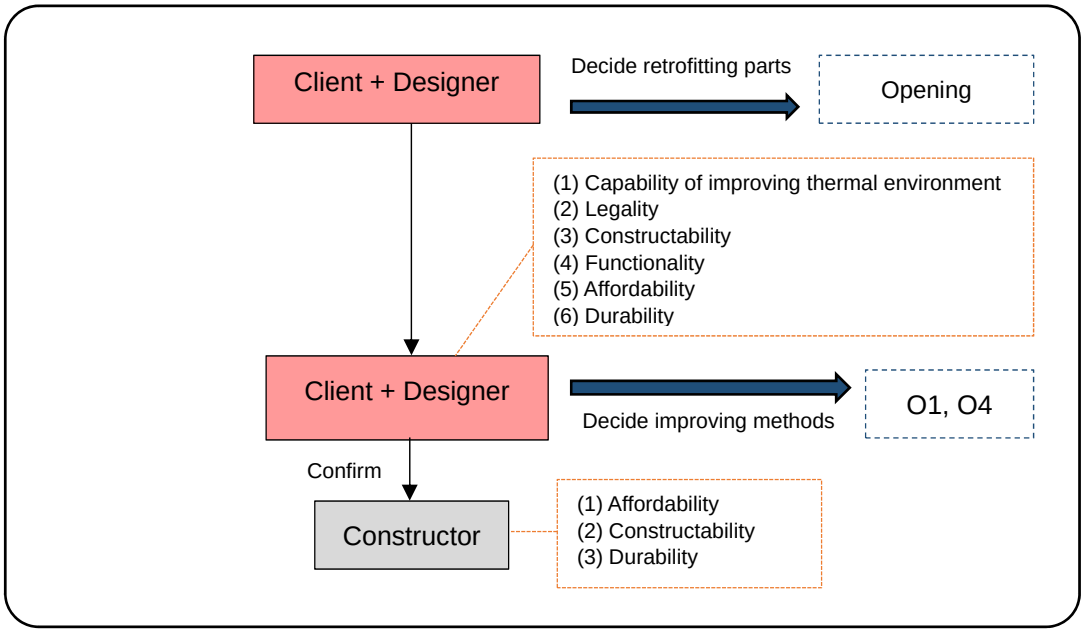


Figure 4-58 Decision-making process of retrofitting designs in Case R7-2

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Clients (also designers): "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

Constructor: "affordability", constructability" and "durability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R7-2 are showing as table below.

Table 4-29 Priority orders of decision makers' considerations in Case R7-2

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Legality
(3)	Constructability
(4)	Functionality
(5)	Affordability
(6)	Durability

(3) Development processes of decision makers' considerations

In Case R7-2, the research results show that the considerations regarding "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability" are cared by clients from the beginning.

Client + Designer
Capability of improving thermal environment
functionality"
Affordability
Legality
Constructability
Durability

Figure 4-59 Development processes of decision makers' considerations in Case R7-2

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

In Case R7-2, the client (also a designer) has an interactive relationship with a constructor. The interactive relationships are showing as following diagram.

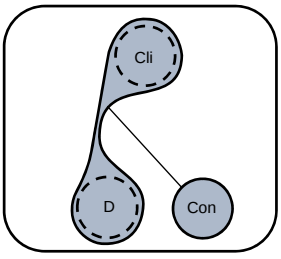


Figure 4-60 Interactive relationships of decision makers in Case R7-2

(5) Interactions between decision makers

The research result shows that retrofitting methods are decided after a client (who is also a designer) confirming with a constructor.

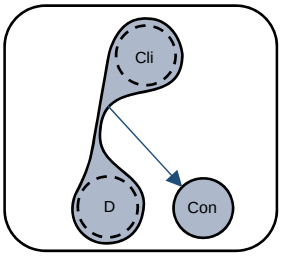


Figure 4-61 Activity between decision makers in Case R7-2

(6) Decision makers' working contents for assessments

In Case R7-2, a client (who is also a designer) and a constructors are the decision makers in the decision making process. By looking at Case R7-2, it was found that the clients can almost estimate all considerations by himself, but still need to confirm "affordability", "constructability" and "durability" with the constructor.

Table 4-30 Decision makers' working contents for assessments in Case R7-2

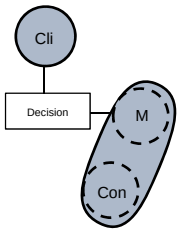
	A	B	C	D	E	F
Client	Estimate improving performance according to his knowledge and other people's feedback	Estimate if retrofitting methods meet his expected functions	Confirm if the retrofitting cost can meet his budget	Check if retrofitting methods meet building regulations	Confirm expected retrofit period	Confirm expected useable period
Consultant	-	-	-	-	-	-
Designer	(Same as client)	(Same as client)	(Same as client)	(Same as client)	(Same as client)	(Same as client)
Constructor	-	-	Estimate constructing cost and material cost	-	Estimate constructing period and feasibility	Estimate useable period
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The clients estimate improving performance of retrofitting methods according to according to his knowledge and other people's feedback.

4.2.12 **Pattern 12** (Case R8-1, Case R8-2)



The studied case, Case R8-1 and Case R8-2, are included in Pattern 12. The types of decision makers in this case is including clients, constructors and material suppliers; the relevance of decision makers in this case is including one multiple-profession type and one independent-profession type. The decision-making processes of retrofitting designs in Case R8-1 and Case R8-2 are presented as diagram below.

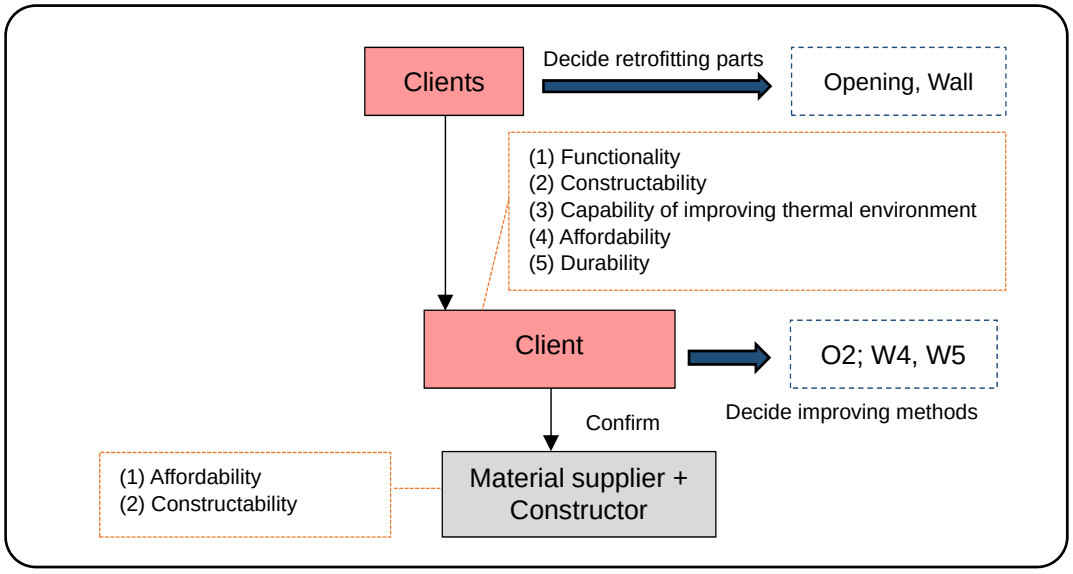


Figure 4-62 Decision-making process of retrofitting designs in Case R8-1

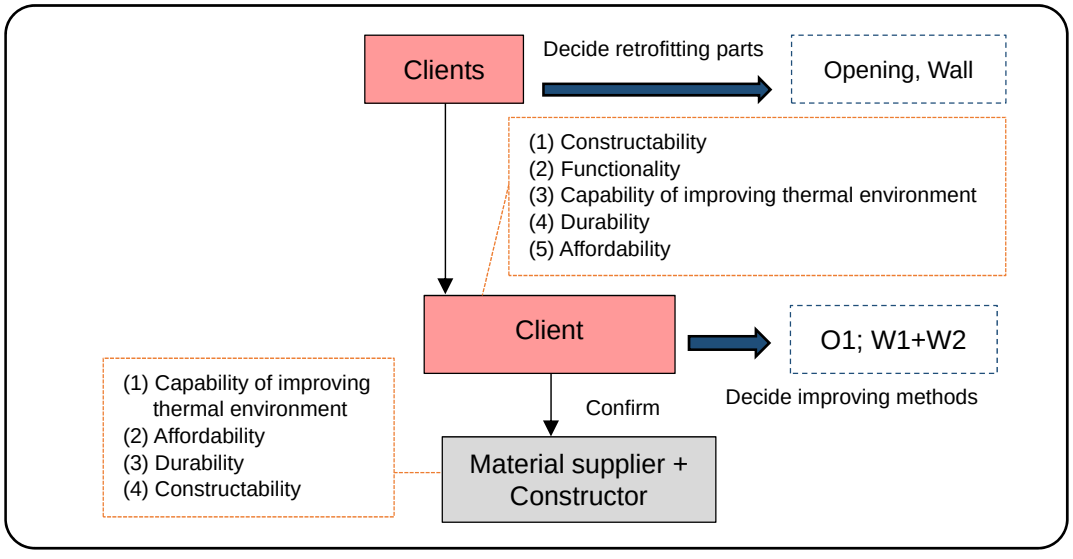


Figure 4-63 Decision-making process of retrofitting designs in Case R8-2

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

[Case R8-1]

Client: "capability of improving thermal environment", "functionality", "affordability", "constructability" and "durability"

Material supplier (+ Constructor): "affordability" and "constructability"

[Case R8-2]

Client: "capability of improving thermal environment", "functionality", "affordability", "constructability" and "durability"

Material supplier (+ Constructor): "capability of improving thermal environment", "affordability", "constructability" and "durability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R8-1 and Case 8-2 are showing as table below.

Table 4-31 Priority orders of decision makers' considerations in Case R8-1

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Constructability
(3)	Capability of improving thermal environment
(4)	Affordability
(5)	Durability
(6)	-

Table 4-32 Priority orders of decision makers' considerations in Case R8-2

Priority order	Final decision-making considerations
(1)	Constructability
(2)	Functionality
(3)	Capability of improving thermal environment
(4)	Durability
(5)	Affordability
(6)	-

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "capability of improving thermal environment", "functionality", "affordability", "constructability" and "durability" are cared by clients from the beginning.

Client
Capability of improving thermal environment
Functionality
Affordability
-
Constructability
Durability

Figure 4-64 Development processes of decision makers' considerations in Case R8-1 & Case R8-2

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

In Pattern 12, the research result shows that retrofitting methods are decided after a client confirms with a material supplier (who is also a constructor). Their interactive relationships are showing as following diagram.

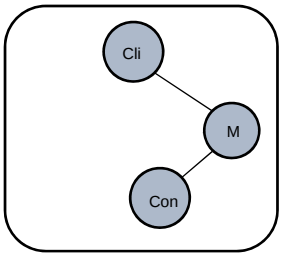


Figure 4-65 Interactive relationships of decision makers in Case R8-1 & R8-2

(5) Interactions between decision makers

Interactions between decision makers in Pattern 12 are showing as the diagram below.

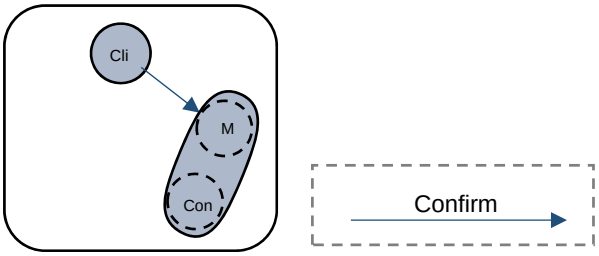


Figure 4-66 Activity between decision makers in Case R8-1 & R8-2

(6) Decision makers' working contents for assessments

In Pattern 12, a client and material suppliers (who are also constructors) are the decision makers in the decision making process. By looking at Case R8, it was found that the material suppliers can only check the considerations regarding "capability of improving thermal environment", "affordability", "constructability" and "durability" for clients. The client confirm if selected retrofitting methods meet his expected functions by himself.

Table 4-33 Decision makers' working contents for assessments in Case R8-1 & R8-2

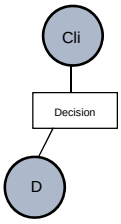
	A	B	C	D	E	F
Client	Estimate improving performance according to past experience and other people's feedback	Confirm if retrofitting methods meet his expected functions	Confirm budge	-	Confirm expected retrofit period	Confirm expected useable period
Consultant	-	-	-	-	-	-
Designer	-	-	-	-	-	-
Constructor	Estimate improving performance according to previous clients' feedbacks	-	Estimate constructing and material cost	-	Estimate manufacturing period and constructing period.	Estimate useable period
Material supplier						

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

In this pattern, improving performance of retrofitting methods estimated by clients is according to clients' past retrofitting experience and feedback from other users, and by material suppliers is according to other clients' feedbacks and reports of material performance.

4.2.13 **Pattern 13** (Case R7-1)



The studied case, Case R7-1, is included in Pattern 13. The types of decision makers in this case is including clients and designers; the relevance of decision makers in this case is including two independent-profession types. The decision-making processes of retrofitting designs in the case are presented as diagram below.

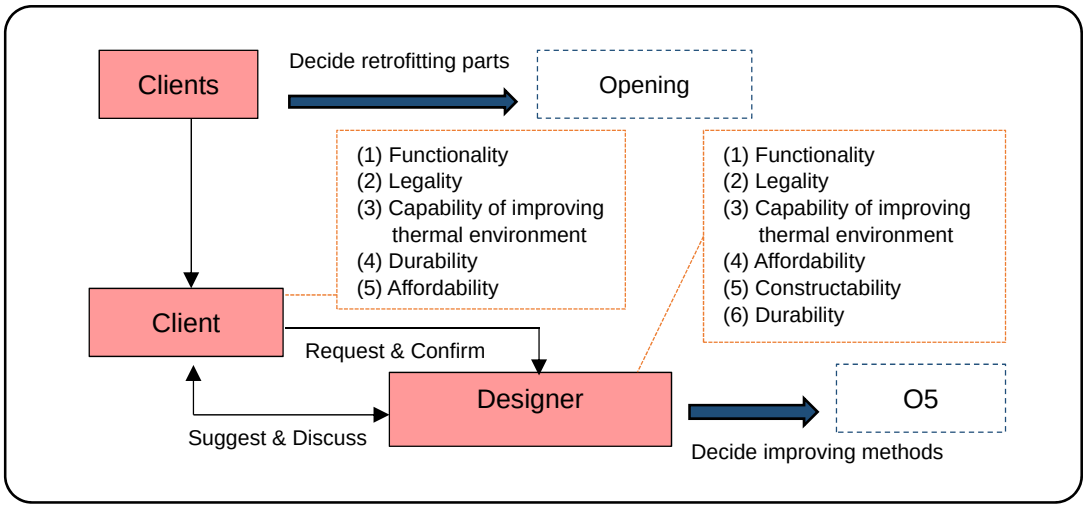


Figure 4-67 Decision-making process of retrofitting designs in Case R7-1

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Client: "capability of improving thermal environment", "functionality", "affordability", "legality" and "durability"

Designer: "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case R7-1 are showing as tables below.

Table 4-34 Priority orders of decision makers' considerations in Case R7-1

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Legality
(3)	Capability of improving thermal environment
(4)	Affordability
(5)	Constructability
(6)	Durability

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "capability of improving thermal environment", "functionality", "affordability", "legality", "constructability" and "durability" are all cared by clients from the beginning.

Client	Designer
Capability of improving thermal environment	Capability of improving thermal environment
Functionality	Functionality
Affordability	Affordability
Legality	Legality
Constructability	Constructability
Durability	Durability

Figure 4-68 Development processes of decision makers' considerations in Case R7-1

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

In Pattern 13, the research result shows that retrofitting methods are decided after a client communicate with a designer. Their interactive relationships are showing as following diagram.

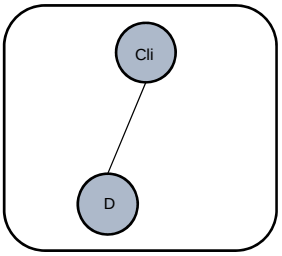


Figure 4-69 Interactive relationships of decision makers in Case R7-1

(5) Interactions between decision makers

Interactions between decision makers in Case R7-1 are showing as the diagram below.

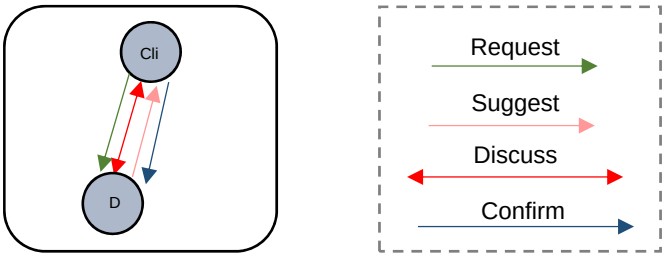


Figure 4-70 Activity between decision makers in Case R7-1

(6) Decision makers' working contents for assessments

In Pattern 13, a client and a designer are the decision makers in the decision making process. By looking at Case R7-1, it was found that the designer can check all considerations for clients.

Table 4-35 Decision makers' working contents for assessments in Case R7-1

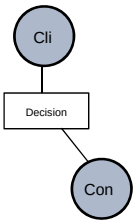
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budge	-	Confirm expected constructing methods	Confirm expected useable period
Consultant	-	-	-	-	-	-
Designer	Estimate improving performance according to his personal knowledge	Estimate if retrofitting methods can achieve client's goal	Estimate if retrofitting cost meet client's budget	Check if retrofitting methods meet building management regulations	Estimate constructing feasibility	Estimate useable period and need of maintenance
Constructor	-	-	-	-	-	-
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The designer estimate improving performance of retrofitting methods according to his personal knowledge.

4.2.14 **Pattern 14** (Case R17, Case R12, Case G3-1)



The studied case, Case R17, Case R12, Case G3-1, are included in Pattern 14. The types of decision makers in this case is including clients and constructors; the relevance of decision makers in this case is including two independent-profession types. The decision-making processes of retrofitting designs in Pattern 14 are presented as diagrams below.

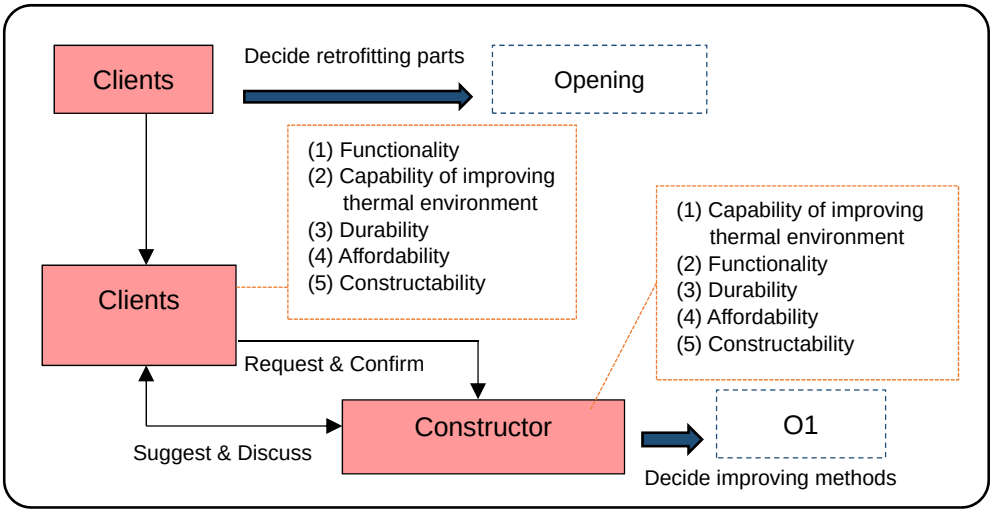


Figure 4-71 Decision-making process of retrofitting designs in Case R12

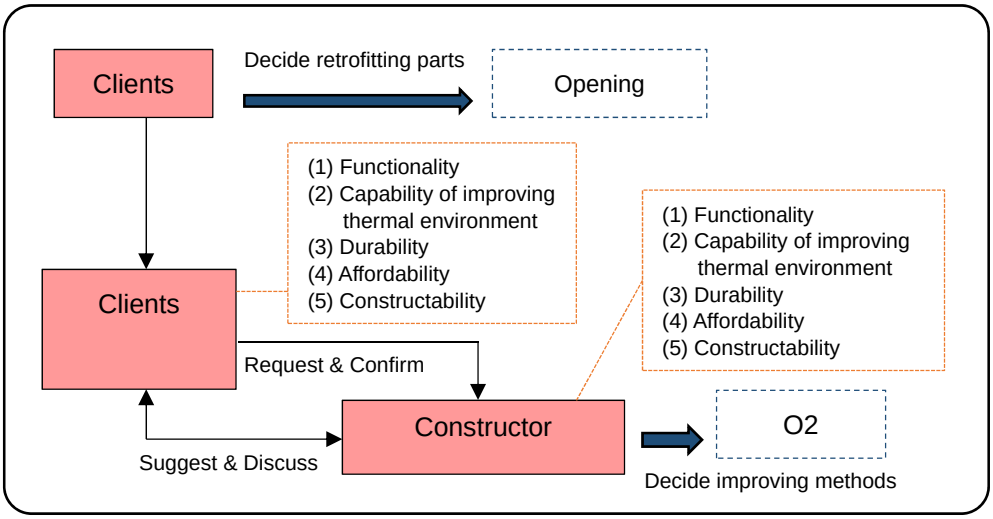


Figure 4-72 Decision-making process of retrofitting designs in Case R17

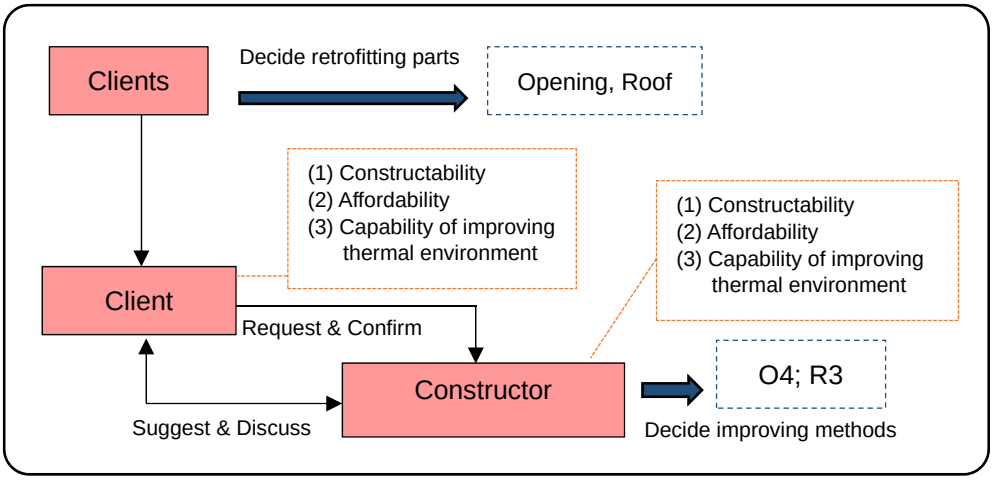


Figure 4-73 Decision-making process of retrofitting designs in Case G3-1

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

[Case R12 & Case R17]

Client: "capability of improving thermal environment", "affordability", "constructability" and "durability"

Constructor: "capability of improving thermal environment", "affordability", "constructability" and "durability"

[Case G3-1]

Client: "capability of improving thermal environment", "affordability" and "constructability"

Constructor: "capability of improving thermal environment", "affordability" and "constructability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in all cases of Pattern 14 are showing as tables below.

Table 4-36 Priority orders of decision makers' considerations in Case R12

Priority order	Final decision-making considerations
(1)	Functionality
(2)	Capability of improving thermal environment
(3)	Durability
(4)	Affordability
(5)	Constructability
(6)	-

Table 4-37 Priority orders of decision makers' considerations in Case R17

Priority order	Final decision-making considerations
(1)	Capability of improving thermal environment
(2)	Functionality
(3)	Durability
(4)	Affordability
(5)	Constructability
(6)	-

Table 4-38 Priority orders of decision makers' considerations in Case G3-1

Priority order	Final decision-making considerations
(1)	Constructability
(2)	Affordability
(3)	Capability of improving thermal environment
(4)	-
(5)	-
(6)	-

(3) Development processes of decision makers' considerations

[Case R17 & Case R12]

The research results show that the considerations regarding "capability of improving thermal environment", "functionality", "affordability", "constructability" and "durability" are cared by clients from the beginning. And then, constructors just follow client's considerations without developing other considerations.

Client	Constructor
Capability of improving thermal environment	Capability of improving thermal environment
Functionality	Functionality
Affordability	Affordability
-	-
Constructability	Constructability
Durability	Durability

Figure 4-74 Development processes of decision makers' considerations in Case R17 & Case R12

[Case G3-1]

The research results show that the considerations regarding "capability of improving thermal environment", "affordability" and "constructability" are cared by clients from the beginning. And then, constructors just follow client's considerations without developing other considerations.

Client	Constructor
Capability of improving thermal environment	Capability of improving thermal environment
-	-
Affordability	Affordability
-	-
Constructability	Constructability
-	-

Figure 4-75 Development processes of decision makers' considerations in Case G3-1

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research results show clients have interactive relationship with constructors in Pattern 14. Their interactive relationships are showing as following diagram.

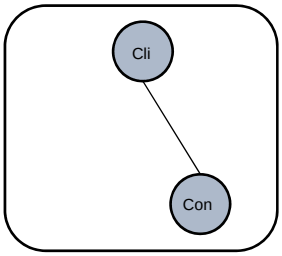


Figure 4-76 Interactive relationships of decision makers in Pattern 14

(5) Interactions between decision makers

The research result shows that retrofitting methods in Pattern 14 are decided after a client communicate with a constructor. Interactions between decision makers in Pattern 14 are showing as the diagram below.

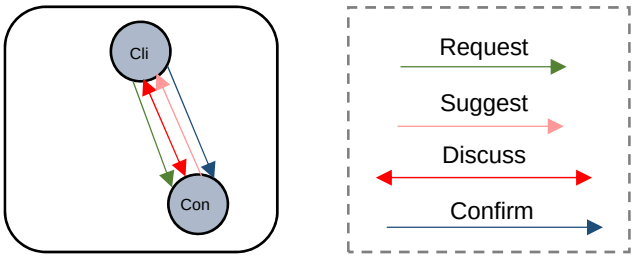


Figure 4-77 Activity between decision makers in Pattern 14

(6) Decision makers' working contents for assessments

In Pattern 14, a client and a constructor are the decision makers in the decision making process. By looking at Case R17, R12 and G3, it was found that the constructor can check all considerations except the consideration regarding "legality" for clients.

Table 4-39 Decision makers' working contents for assessments in Pattern 14

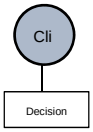
	A	B	C	D	E	F
Client	-	Confirm expected function	Confirm budge	-	Confirm expected retrofit period	Confirm expected useable period
Consultant	-	-	-	-	-	-
Designer	-	-	-	-	-	-
Constructor	Estimate improving performance according to previous clients' feedback	Estimate if retrofitting methods can achieve client's goal	Estimate if retrofitting cost meet client's budget	-	Estimate constructing feasibility and period	Estimate useable period and need of maintenance
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The constructors estimate improving performance of retrofitting methods commonly according to previous clients' feedback, past experiences and personal thoughts.

4.2.15 **Pattern 15** (Case G3-2)



The studied cases, Case G3-2, are included in Pattern 15. The types of decision makers in this case is only including clients. The relevance of decision makers are including one independent-profession type. The decision-making process of retrofitting designs in Case G3-2 is presented as the diagram below.

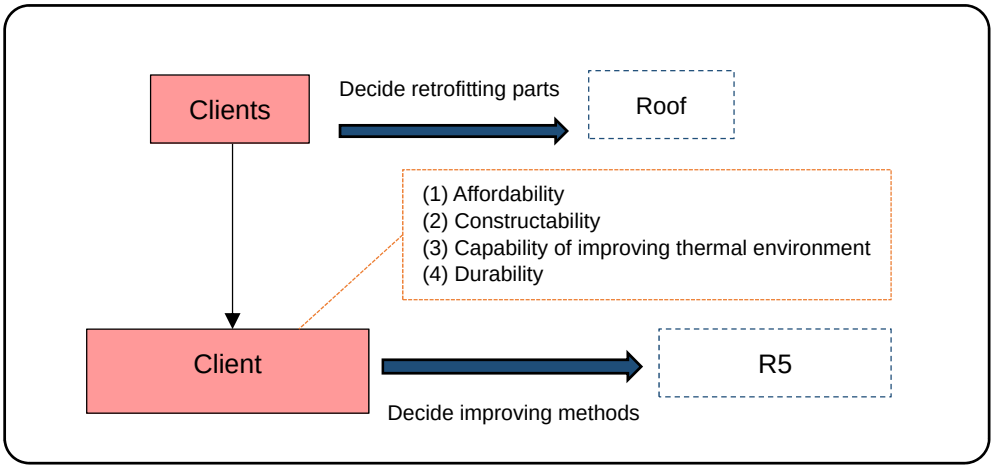


Figure 4-78 Decision-making process in Case G3-2

Part 1: What decision makers think

(1) Contents of decision makers' considerations for deciding retrofitting methods

Client: "capability of improving thermal environment", "affordability", "constructability" and "durability"

(2) Priority orders of decision makers' considerations

Priority orders of decision makers' considerations in Case G3-2 are showing as table below.

Table 4-40 Priority orders of decision makers' considerations in Case G3-2

Priority order	Final decision-making considerations
(1)	Affordability
(2)	Constructability
(3)	Capability of improving thermal environment
(4)	Durability
(5)	-
(6)	-

(3) Development processes of decision makers' considerations

The research results show that the considerations regarding "capability of improving thermal environment", "affordability", and "constructability" are cared by clients from the beginning.

Client
Capability of improving thermal environment
-
Affordability
-
Constructability
-

Figure 4-79 Development processes of decision makers' considerations in Case G3-2

Part 2: How decision makers arrive at the decisions

(4) Decision makers' interactive relationships

The research result shows that retrofitting methods are decided by a client himself without communicating with other decision makers.

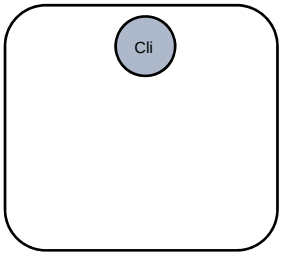


Figure 4-80 Interactive relationships of decision makers in Case G3-2

(5) Interactions between decision makers

During the decision-making process, there is no interactions between clients and other decision makers.

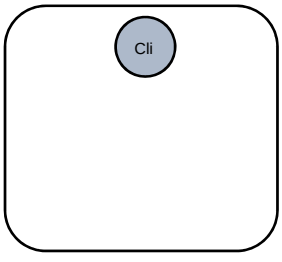


Figure 4-81 Activity between decision makers in Case G3-2

(6) Decision makers' working contents for assessments

In Pattern 16, a client is the only decision maker in the decision making process. By looking at Case G3-2, it was found that the client estimated improving performance, retrofitting cost and constructing feasibility and useable feasibility of retrofitting methods by himself.

Table 4-41 Decision makers' working contents for assessments in Case G3-2

	A	B	C	D	E	F
Client	Estimate the improving performance of retrofitting method according to personal knowledge	-	Estimate if retrofitting cost meet his budget	-	Check constructing feasibility	Estimate useable duration
Consultant	-	-	-	-	-	-
Designer	-	-	-	-	-	-
Constructor	-	-	-	-	-	-
Material supplier	-	-	-	-	-	-

A. Capability of improving thermal environment
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

(7) Assessment approaches for improving effectiveness

The research results show that when a client is the only decision makers in a decision making process, he is in charge of all evaluating works. Moreover, the constructor estimate improving performance of retrofitting methods according to his personal knowledge.

4.3 What decision makers think

Through investigating “what decision makers think”, the following constants are clarified: (A) contents of decision makers’ considerations for deciding retrofitting methods, (B) priority orders of decision makers’ considerations and (C) development processes of decision makers’ considerations. The detail contents are introduced as follows.

4.3.1 Contents of decision makers’ considerations for deciding retrofitting designs

4.3.1.1 Research result

According to research results regarding considerations of decision makers for deciding retrofitting designs in 32 cases, it was found that there are 17 common considerations can be sorted. The 17 considerations are presenting as follows.

(1) Improvement of indoor thermal environment

The selected improving methods are expected able to improve indoor thermal environment, such as reducing sunlight exposure and solar heat and increasing ventilation.

(2) Reduction of urban heat island effect

The selected improving methods are expected to cool down temperature of building surface and then to reduce urban heat island effects.

(3) Repair of building damage part

The selected improving methods are expected able to repair and fix existing building damage parts, such as broken windows, damaged finishing layers of walls and damaged waterproof layers.

(4) Renew of building appearance

The selected improving methods are expected can renew and change building appearances, such as redesign building appearance, replacing existing materials and building components.

(5) Function of building envelope

The selected improving methods are expected can keep or increase functions of building envelopes, such as soundproof, aesthetic, Window display, weather resistance, security, natural light control, view, receiving natural light…etc.

(6) Integration with other components

The selected improving methods are considered if it can integrate with other building components, such as indoor shading devices can integrate with interior decoration designs.

(7) Material cost

The selected improving methods are concerned about material costs.

(8) Constructing cost

The selected improving methods are concerned about constructing costs.

(9) Client's budget & Amount of governmental subsidy

The selected improving methods are considered if it can meet clients' budget or amount of governmental subsidy.

(10) Building management regulation

The selected improving methods are considered if it can meet building management regulation, such as existing building appearances (designs, shapes and colors) are not allowed to be changed.

(11) Need of license application

The selected improving methods are considered if it needs to apply any related license.

(12) Constructing period

The selected improving methods are concerned about constructing periods.

(13) Feasibility of construction

The selected improving methods are concerned about their feasibility of constructions.

(14) Impacts during constructions

The selected improving methods are concerned their impacts during constructions, such as the impacts of constructing pollutions on existing environment, the impact on safety of building structures and the impacts of noise and security on habitants.

(15) Need of maintenance

The selected improving methods are considered if it needs to be maintained frequently.

(16) Period of use

The selected improving methods are concerned their periods of uses.

(17) Capability of weather resistance

The selected improving methods are concerned their capability of weather resistance.

4.3.1.2 Features of decision makers' considerations

Furthermore, the decision-making considerations are found can be sorted into six categories according to their features. The six categories are: (A) capability of improving thermal environment, (B) functionality, (C) affordability, (D) legality, (E) constructability and (F) durability. (Fig. 4-82)

(A) Capability of improving thermal environment

The first category is about "capability of improving thermal environment". This category includes the considerations regarding (1) improvement of indoor thermal environment and (2) reduction of urban heat island effect.

(B) Functionality

The second category is about "functionality". This category includes the considerations regarding (1) repair of building damage part, (2) renew of building appearance, (3) function of building envelope and (4) integration with other component.

(C) Affordability

The third category is about "affordability". This category includes the considerations regarding (1) material cost, (2) constructing cost and (3) client's budget / amount of governmental subsidy.

(D) Legality

The forth category is about "legality". This category includes the considerations regarding (1) building management regulation and (2) need of license application.

(E) Constructability

The fifth category is about "constructability". This category includes the considerations regarding (1) constructing period, (2) feasibility of construction and (3) impacts during constructions.

(F) Durability

The sixth category is about "durability". This category includes the considerations regarding (1) need of maintenance, (2) period of use and (3) capability of weather resistance.

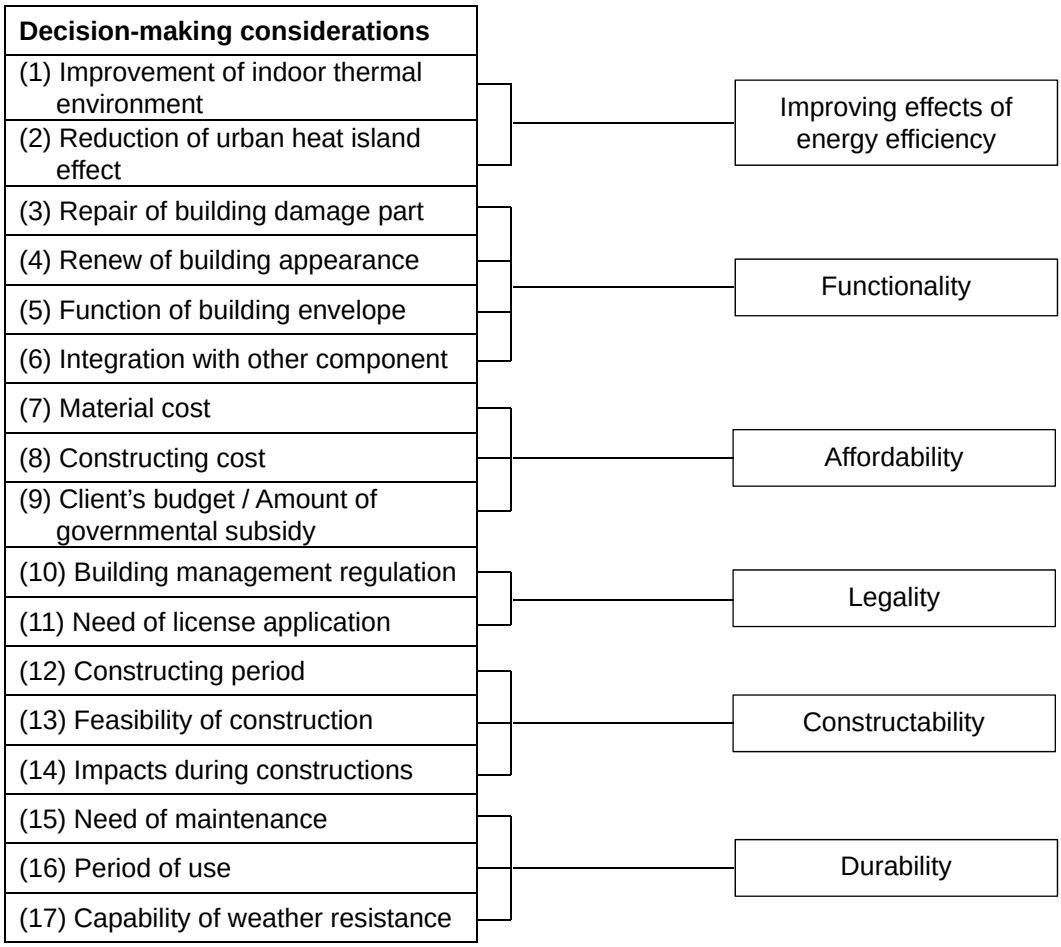


Figure 4-82 Content and features of decision makers' considerations

4.3.1.3 Summery and finding

Contents of decision makers' considerations for deciding retrofitting designs are clarified in this part. The research results show that common decision makers' considerations can be concluded as 17 items and then can be further categorized into six categories ("improving effects of energy efficiency", "functionality", "affordability", "legality", "constructability" and "durability") according to their common features.

Moreover, it is clarified that "improving effects of energy efficiency" is not the only consideration, other considerations "functionality", "affordability", "legality", "constructability" and "durability" are also concerned when decide energy-efficiency retrofitting designs.

4.3.2 Priority orders of decision makers' considerations

4.3.2.1 Research result

The priority orders of decision makers' considerations according to the six categories are observed and describe as below. (Table 4-42)

(1) Capability of improving thermal environment

The priority orders of the consideration "capability of improving thermal environment" are found various in studied cases as first priority, second priority, third priority and sixth priority.

(2) Functionality

The priority orders of the consideration "functionality" are found various in studied cases as first priority, second priority and fourth priority.

(3) Affordability

The priority orders of the consideration "affordability" are found various in studied cases as first priority, second priority, third priority, fourth priority, fifth priority and sixth priority.

(4) Legality

The priority orders of the consideration "legality" are found various in studied cases as second priority, fourth priority, fifth priority and sixth priority.

(5) Constructability

The priority orders of the consideration "constructability" are found various in studied cases as first priority, second priority, third priority, fourth priority and fifth priority.

(6) Durability

The priority orders of the consideration "durability" are found various in studied cases as second priority, third priority, fourth priority, fifth priority and sixth priority.

Table 4-42 Priority order of final decision-making considerations in 32 cases

	Improving effect	Functionality	Affordability	Legality	Constructability	Durability
1st priority	S1, S3, R4, R18, C4, R7-2, R12, , R1, G1, G2, M1, S2, C2, C1, S4	R3, R6, R5, R9, R16, R10, C5, R2, R13, R14, R7-1, R17, R8-1	C3, G3-2	-	R8-2, G3-1	-
2nd priority	R3, R6, R10, R17,	C3, R8-2, R12, C1	S1, S3, R4, R5, R9, R16, G3-1	C4, C5, R7-2, R7-1, S4	R18, R1, G1, G2, M1, S2, C2, G3-2, R8-1	R2, R13, R14
3rd priority	R5, R9, C5, R8-2, R7-1, G3-1, G3-2, R8-1	-	R3, R2, R13, R14, R1, G1, G2, M1, S2, C2,	-	S1, S3, R4, R16, R10, C4, C3, R7-2, C1, S4	R6, R18, R12, R17
4th priority	R16, R2, C3	R4, C4, R7-2	R18, R7-1, R12, R17, S4, R8-1	R3	R6, R5, R9, , C5, R13, R14,	S1, S3, R10, R8-2, R1, G1, G2, M1, S2, C2, C1, G3-2
5th priority	-	-	R6, C4, R7-2, R8-2	S1, S3, R16, R10, C3, R13, R14, R1, G1, G2, M1, S2, C2, C1	R3, R2, R7-1, R12, R17	R4, R5, R9, C5, S4, R8-1
6th priority	R13, R14	-	R10, C5, C1	R6, R4, R5, R9, R2	-	R3, R16, C4, C3, R7-2, R7-1

4.3.2.2 Relationship between "Priority orders of decision makers' considerations" and selected energy-efficiency retrofitting methods

After analyzing the first priority of decision makers' considerations in the retrofitting methods, relationship between "Priority orders of decision makers' considerations" and elected energy-efficiency retrofitting methods are clarified.

It was found that different retrofitting methods might be selected when priority orders of decision makers' considerations are different.

When the consideration regarding "improving effects of energy efficiency" is concerned the most, the retrofitting method O1 (adding external shading device) is commonly selected.

When the consideration regarding "functionality" is concerned the most, the retrofitting methods O2 (window replacement), O3 (moving position) and O6 (adding second window) are commonly selected.

When the consideration regarding "affordability" is concerned the most, the retrofitting method O4 (adding window film) is often chose.

When the consideration regarding "legality" is focused the most, the retrofitting methods O4

(adding window film) and O5 (adding internal shading) are commonly selected.

When the consideration regarding “constructability” is focused the most, the retrofitting methods O4 (adding window film), O5 (adding internal shading) and O6 (adding second window) are greatly selected.

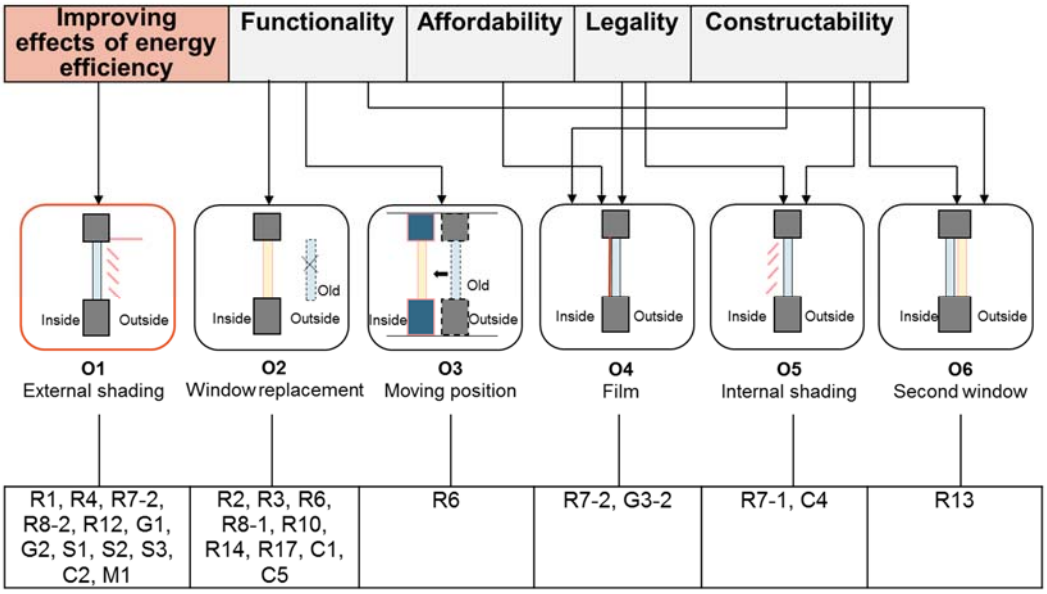


Figure 4-83 Priority orders of decision makers’ considerations and selected energy-efficiency retrofitting methods

4.3.2.3 Summery and finding

In summary, priority orders of decision makers’ considerations in the decision-making processes of retrofitting designs for energy-efficiency are clarified in this part. The research results show that priority orders of decision makers’ considerations in six categories are various in studied cases depending on clients’ requirements and other decision makers’ thoughts. For example, “capability of improving thermal environment” is considered as first priority in Case S1, S3, R4, R18, R7-2, R12, R1, G1, G2, M1, S2, C2, C1, C4 and S4; however, it is considered as second, third, fourth and sixth places in other cases.

According to research results, it was found:

(1) The consideration “improving effects of energy efficiency” is not always considered as first priority

(2) Other considerations might be thought more important than the consideration “improving effects of energy efficiency”

4.3.3 Development processes of decision makers' considerations

4.3.3.1 Research result

The situations of decision-making considerations being concerned in 15 patterns are compared according to six categories. The research results are showing as below.

[Improving effects of energy efficiency]

The research results regarding situations of the consideration "improving effects of energy efficiency" being concerned in the 15 patterns show in Table 4-43. Through comparing the situations in the 15 patterns, it was found that the development processes of the consideration can be categorized into two situations: (1) being considered by the clients from the beginning in nine patterns, and (2) not being considered until consultants suggest in six pattern

Table 4-43 Situation of the consideration "improving effects of energy efficiency" being concerned in 15 patterns

Pattern	Situation of the consideration "improving effects of energy efficiency" being concerned
Pattern 1	Not being considered until consultants suggest
Pattern 2	Being considered by clients from the beginning
Pattern 3	Being considered by clients from the beginning
Pattern 4	Not being considered until consultants (+designer) suggest
Pattern 5	Not being considered until consultants suggest
Pattern 6	Being considered by clients from the beginning
Pattern 7	Not being considered until consultants suggest
Pattern 8	Being considered by clients from the beginning
Pattern 9	Not being considered until designers suggest
Pattern 10	Not being considered until consultants suggest
Pattern 11	Being considered by clients from the beginning
Pattern 12	Being considered by clients from the beginning
Pattern 13	Being considered by clients from the beginning
Pattern 14	Being considered by clients from the beginning
Pattern 15	Being considered by clients from the beginning

[Functionality]

The research results regarding situations of the consideration “functionality” being concerned in the 15 patterns show in Table 4-44. Through comparing the situations in the 15 patterns, it was found that the development processes of the consideration “functionality” can be categorized into two situations: (1) being considered by the clients from the beginning in 11 patterns, and (2) not being considered from the beginning in six patterns.

Table 4-44 Situation of the consideration “functionality” being concerned in 15 patterns

Pattern	Situation of the consideration “functionality” being concerned
Pattern 1	Being considered by clients from the beginning
Pattern 2	Not being considered
Pattern 3	Being considered by clients from the beginning
Pattern 4	Being considered by clients from the beginning
Pattern 5	Being considered by clients from the beginning
Pattern 6	Not being considered
Pattern 7	Being considered by clients from the beginning or not being considered
Pattern 8	Being considered by clients from the beginning
Pattern 9	Being considered by clients from the beginning
Pattern 10	Being considered by clients from the beginning
Pattern 11	Not being considered
Pattern 12	Being considered by clients from the beginning
Pattern 13	Being considered by clients from the beginning
Pattern 14	Being considered by clients from the beginning or not being considered
Pattern 15	Not being considered

[Affordability]

The research results regarding situations of the consideration “affordability” being concerned in the 16 patterns show in Table 4-45. Through comparing the situations in the 15 patterns, it was found that the development processes of the consideration “affordability” has only one situation which is being considered by clients from the beginning in all patterns.

Table 4-45 Situation of the consideration “affordability” being concerned in 15 patterns

Pattern	Situation of the consideration “affordability” being concerned
Pattern 1	Being considered by clients from the beginning
Pattern 2	Being considered by clients from the beginning
Pattern 3	Being considered by clients (consultant + designer) from the beginning
Pattern 4	Being considered by clients from the beginning
Pattern 5	Being considered by clients from the beginning
Pattern 6	Being considered by clients from the beginning
Pattern 7	Being considered by clients from the beginning
Pattern 8	Being considered by clients (consultant + designer) from the beginning
Pattern 9	Being considered by clients from the beginning
Pattern 10	Being considered by clients from the beginning
Pattern 11	Being considered by clients (designers) from the beginning
Pattern 12	Being considered by clients from the beginning
Pattern 13	Being considered by clients from the beginning
Pattern 14	Being considered by clients from the beginning
Pattern 15	Being considered by clients from the beginning

[Legality]

The research results regarding situations of the consideration “legality” being concerned in the 15 patterns show in Table 4-46. Through comparing the situations in the 15 patterns, it was found that the development processes of the consideration “legality” have three situations: (1) being considered by the clients from the beginning in four patterns, (2) not being considered until consultants suggest in eight pattern, and (3) not being considered from the beginning in four patterns.

Table 4-46 Situation of the consideration “legality” being concerned in 15 patterns

Pattern	Situation of the consideration “legality” being concerned
Pattern 1	Not being considered until designers suggest
Pattern 2	Not being considered until designers (consultant) suggest
Pattern 3	Being considered by clients (consultant + designer) from the beginning
Pattern 4	Not being considered until designers (consultant) suggest
Pattern 5	Not being considered until designers suggest
Pattern 6	Not being considered from the beginning
Pattern 7	Not being considered until designers suggest
Pattern 8	Being considered by clients (consultant + designer) from the beginning
Pattern 9	Not being considered until designers suggest
Pattern 10	Not being considered until designers suggest
Pattern 11	Being considered by clients (designer) from the beginning
Pattern 12	Not being considered from the beginning
Pattern 13	Being considered by clients from the beginning
Pattern 14	Not being considered from the beginning
Pattern 15	Not being considered from the beginning

[Constructability]

The research results regarding situations of the consideration “constructability” being concerned in the 15 patterns show in Table 4-47. Through comparing the situations in the 15 patterns, it was found that the development processes of the consideration “constructability” have two situations: (1) being considered by the clients from the beginning in all 15 patterns, (2) not being considered until consultants suggest in one pattern.

Table 4-47 Situation of the consideration “constructability” being concerned in 15 patterns

Pattern	Situation of the consideration “constructability” being concerned
Pattern 1	Being considered by clients from the beginning
Pattern 2	Being considered by clients from the beginning
Pattern 3	Being considered by clients(consultant + designer) from the beginning
Pattern 4	Being considered by clients from the beginning
Pattern 5	Being considered by clients from the beginning
Pattern 6	Being considered by clients from the beginning
Pattern 7	Being considered by clients from the beginning or not being considered until consultants suggest
Pattern 8	Being considered by clients (consultant + designer) from the beginning
Pattern 9	Being considered by clients from the beginning
Pattern 10	Being considered by clients from the beginning
Pattern 11	Being considered by clients (designers) from the beginning
Pattern 12	Being considered by clients from the beginning
Pattern 13	Being considered by clients from the beginning
Pattern 14	Being considered by clients from the beginning
Pattern 15	Being considered by clients from the beginning

[Durability]

The research results regarding situations of the consideration “durability” being concerned in the 15 patterns show in Table 4-48. Through comparing the situations in the 15 patterns, it was found that the development processes of consideration “durability” has three situations: (1) being considered by the clients from the beginning in 14 patterns, (2) not being considered until consultants suggest in one pattern, and (3) not being considered from the beginning in four patterns.

Table 4-48 Situation of the consideration “durability” being concerned in 15 patterns

Pattern	Situation of the consideration “durability” being concerned
Pattern 1	Being considered by clients from the beginning
Pattern 2	Being considered by clients from the beginning
Pattern 3	Being considered by clients (consultant + designer) from the beginning
Pattern 4	Being considered by clients from the beginning
Pattern 5	Being considered by clients from the beginning, Not being considered from the beginning
Pattern 6	Being considered by clients from the beginning
Pattern 7	Being considered by clients from the beginning, Not being considered until consultants suggest
Pattern 8	Being considered by clients (consultant + designer) from the beginning
Pattern 9	Being considered by clients from the beginning, Not being considered from the beginning
Pattern 10	Being considered by clients from the beginning
Pattern 11	Being considered by clients (designers) from the beginning
Pattern 12	Being considered by clients from the beginning
Pattern 13	Being considered by clients from the beginning
Pattern 14	Being considered by clients from the beginning , Not being considered from the beginning
Pattern 15	Not being considered from the beginning

4.3.3.2 Summary and finding

In summary, development processes of decision makers' considerations are clarified in this part. The research results show that the development processes of decision makers' considerations can be categorized into three situations: (1) the considerations were considered by clients from the beginning, (2) the considerations were considered after other decision makers suggesting, and (3) the considerations were not considered from the beginning.

Moreover, the research results regarding situations of development processes in the six categories show that: (1) the considerations which development processes are affected by clients and other participated decision makers include "improving effects of energy efficiency", "legality", "constructability" and "durability", (2) the considerations which development processes are mainly decided by clients from the beginnings are "functionality" and "affordability". (Table 4-49)

According to above research results, it is clarified that the development processes of decision-making considerations are not only influenced by clients from the beginning of decision-making processes but also affected by participated decision makers during decision-making processes. Furthermore, it is clarified that clients' awareness on "improving effects of energy efficiency" are different in retrofitting projects

Table 4-49 Situation of development processes of decision makers' considerations in six categories

Decision makers' consideration	Situation of development process
Improving effects of energy efficiency	(1) being considered by the clients from the beginning (2) not being considered until other decision makers suggesting
Functionality	(1) being considered by the clients from the beginning (3) not being considered from the beginning
Affordability	(1) being considered by the clients from the beginning
Legality	(1) being considered by the clients from the beginning (2) not being considered until other decision makers suggesting (3) not being considered from the beginning
Constructability	(1) being considered by the clients from the beginning (2) not being considered until other decision makers suggesting
Durability	(1) being considered by the clients from the beginning (2) not being considered until other decision makers suggesting (3) not being considered from the beginning

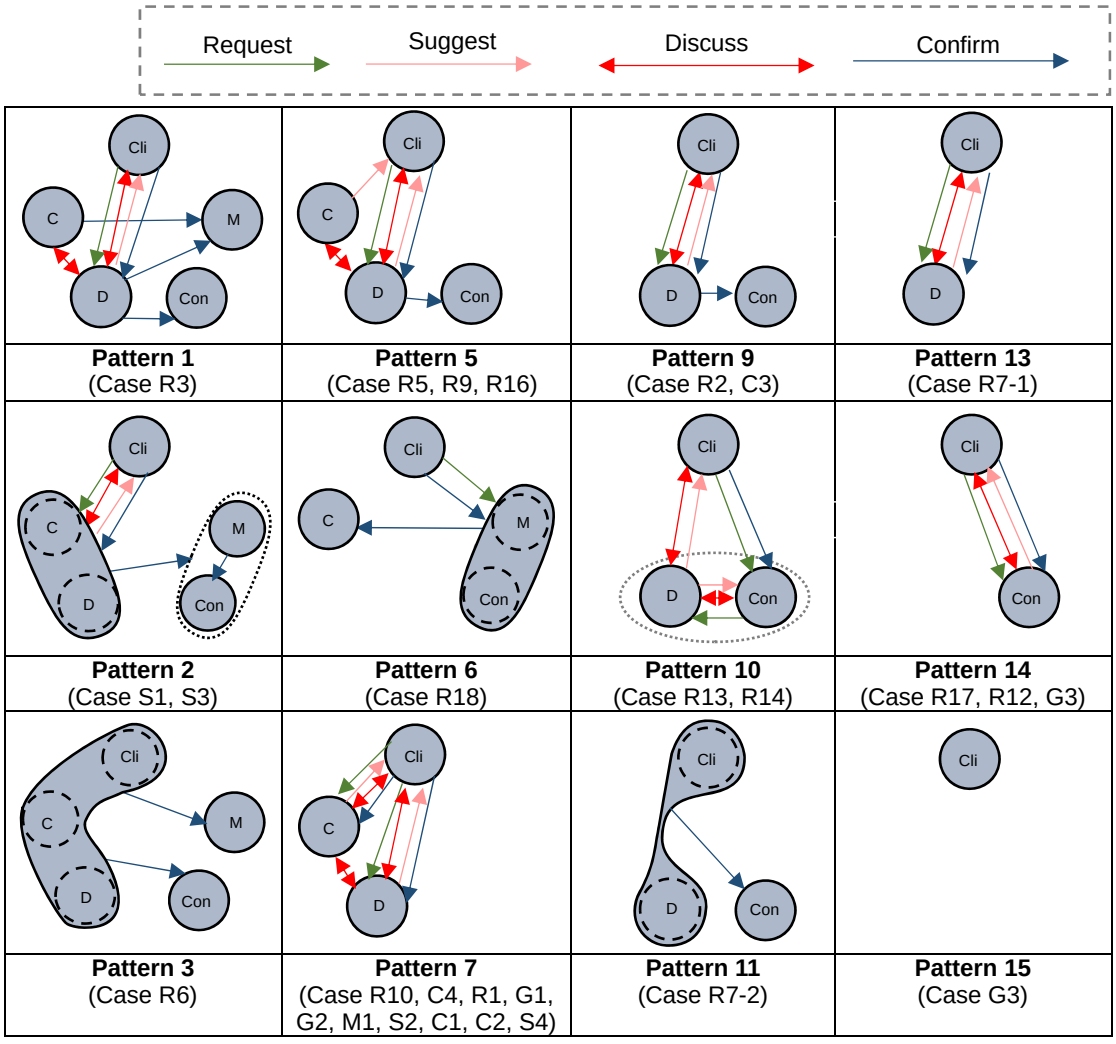
4.4 How decision makers arrive at the decisions

Through investigating “what decision makers do”, the following constants are clarified: (1) decision makers’ interactive relationships, (2) interactions between decision makers, (3) decision makers’ working contents for assessments, and (4) assessment approaches for improving effectiveness.

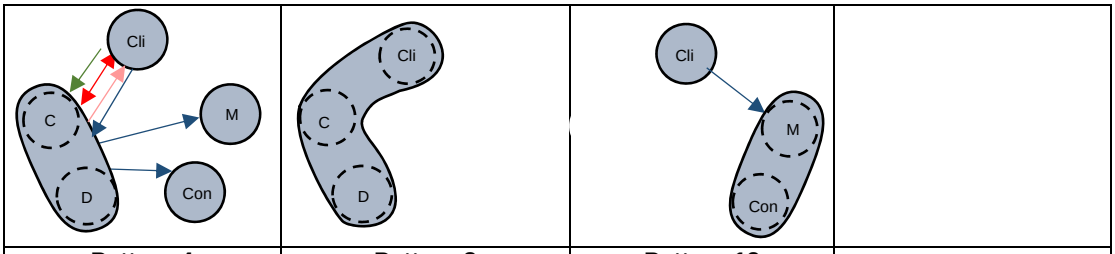
4.4.1 Interactions between decision makers

4.4.1.1 Research result

The purpose of this research part is to clarify interactions between decision makers in decision-making processes. The research results show there are four kinds of the interactions between decision makers are distinguished: (1) requests, (2) suggestions, (3) discussions and (4) confirmations.



Pattern 1 (Case R3)	**Pattern 5** (Case R5, R9, R16)	**Pattern 9** (Case R2, C3)	**Pattern 13** (Case R7-1)
Pattern 2 (Case S1, S3)	**Pattern 6** (Case R18)	**Pattern 10** (Case R13, R14)	**Pattern 14** (Case R17, R12, G3)
Pattern 3 (Case R6)	**Pattern 7** (Case R10, C4, R1, G1, G2, M1, S2, C1, C2, S4)	**Pattern 11** (Case R7-2)	**Pattern 15** (Case G3)



Pattern 4 (Case R4)	**Pattern 8** (Case C5)	**Pattern 12** (Case R8-1, R8-2)	

Figure 4-84 Interactions between decision makers in 15 patterns

Furthermore, the research results regarding executing situations of these four interactions in the 16 combination patterns are presenting as follows.

(1) Request

The interactions regarding "requesting someone to propose retrofitting designs" appears in following situations: (1) clients request designers in Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9 and Pattern 13, (2) clients request consultants in Pattern 2, Pattern 4 and Pattern 7, (3) clients request material suppliers in Pattern 6, (4) clients request constructors in Pattern 6, Pattern 10 and Pattern 14, and (5) constructors request designers in Pattern 10.

Table 4-51 Situation of interactions regarding "request" in 15 patterns

Interactions regarding "request"		Combination patterns of decision makers
(1) Client	→ Designer	Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9 and Pattern 13
(2) Client	→ Consultant	Pattern 2, Pattern 4 and Pattern 7
(3) Client	→ Material supplier	Pattern 6
(4) Client	→ Constructor	Pattern 6, Pattern 10 and Pattern 14
(5) Constructor	→ Designer	Pattern 10

(2) Suggest

The interactions regarding "suggesting someone about proposals of retrofitting designs" appears in following situations: (1) designers suggest to clients in Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9, Pattern 10 and Pattern 13, (2) consultants suggest to clients in Pattern 2, Pattern 4, Pattern 5, and Pattern 7, (3) designers suggest to constructors in Pattern 10, (4) constructors suggest to clients in Pattern 14.

Table 4-52 Situation of interactions regarding "suggest" in 15 patterns

Interactions regarding "suggest"		Combination patterns of decision makers
(1) Designer →	Client	Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9, Pattern 10 and Pattern 13
(2) Consultant →	Client	Pattern 2, Pattern 4, Pattern 5, Pattern 7
(3) Designer →	Constructor	Pattern 10
(4) Constructor →	Client	Pattern 14

(3) Discuss

The interactions regarding "discussing proposals of retrofitting designs" appears in following situations: (1) designers discuss with clients in Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9, Pattern 10 and Pattern 13, (2) designers discuss with consultants in Pattern 1, Pattern 5 and Pattern 7, (3) consultants discuss with clients in Pattern 2, Pattern 4 and Pattern 7, (4) designers discuss with constructors in Pattern 10, (5) constructor discuss with clients in Pattern 14, and (6) material suppliers with constructors in Pattern 2.

Table 4-53 Situation of interactions regarding "discuss" in 15 patterns

Interactions regarding "discuss"		Combination patterns of decision makers
(1) Designer ↔	Client	Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9, Pattern 10 and Pattern 13.
(2) Designer ↔	Consultant	Pattern 1, Pattern 5 and Pattern 7
(3) Consultant ↔	Client	Pattern 2, Pattern 4 and Pattern 7
(4) Designer ↔	constructor	Pattern 10
(5) Constructor ↔	Client	Pattern 14
(6) Material supplier ↔	Constructor	Pattern 2

(4) Confirm

The interactions regarding "confirming proposals of retrofitting designs" appears in following situations: (1) consultants confirm with material suppliers in Pattern 1, Pattern 2, pattern 3 and Pattern 4, (2) designers confirm with constructors in Pattern 1, Pattern 2, Pattern 3, Pattern 4, Pattern 5, Pattern 9 and Pattern 11, (3) designers confirm with material suppliers in Pattern 1, Pattern 2, Pattern 3 and Pattern 4, (4) clients confirm with material suppliers in Pattern 3, Pattern 6 and Pattern 12, (5) clients confirmed with constructors in Pattern 2, Pattern 3, Pattern 11 and Pattern 14, (6) clients confirm with consultants in Pattern 2, Pattern 4, and Pattern 7, (7) clients confirm with designers in Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9 and Pattern 13, (8) material suppliers confirm with consultants in Pattern 6.

Table 4-54 Situation of interactions regarding "confirm" in 15 patterns

Interactions regarding "confirm"		Combination patterns of decision makers
(1) Consultant	→ Material supplier	Pattern 1, Pattern 2, pattern 3 and Pattern 4
(2) Designer	→ Constructor	Pattern 1, Pattern 2, Pattern 3, Pattern 4, Pattern 5, Pattern 9 and Pattern 11
(3) Designer	→ Material supplier	Pattern 1, Pattern 2, Pattern 3 and Pattern 4
(4) Client	→ Material supplier	Pattern 3, Pattern 6 and Pattern 12
(5) Client	→ Constructor	Pattern 2, Pattern 3, Pattern 11 and Pattern 14
(6) Client	→ Consultant	Pattern 2, Pattern 4, Pattern 7
(7) Client	→ Designer	Pattern 1, Pattern 2, Pattern 4, Pattern 5, Pattern 7, Pattern 9 and Pattern 13
(8) Material supplier	→ Consultant	Pattern 6

4.4.1.2 Summary and finding

[Summary]

In summary, interactions between decision makers in decision-making processes of retrofitting designs are clarified in this part.

The research results show there are four kinds of the interactions between decision makers are distinguished: request, suggest, discuss and confirm. The four kinds of interactions are executed differently in the 15 combination patterns. For instance, the four interactions are carried out in 10 patterns; however, only the interactions confirmation found in Pattern 3, Pattern 11 and Pattern 12. Moreover, there is no interactions happening between decision makers in Pattern 8 and Pattern 15.

Furthermore, it was found that these four interactions are carried out by different decision makers in the 15 combination patterns. For example, the decision maker who suggested to clients about retrofitting designs in Pattern 1 is a designer, but the decision makers is a constructor in Pattern 14.

[Finding]

According to above research results, the findings are listed as bellow.

(1) Retrofitting designs are decided through different interactions between decision makers.

(2) By observing the interactions between decision makers, influential decision makers in each pattern are clarified and categorized into five groups.

(a) Clients, consultants and designers: Pattern 1~Pattern 4, Pattern 5, Pattern 7 and Pattern 8

(b) Clients, and designers: Pattern 9, Pattern 11, and Pattern 13

(c) Clients, designers and constructors: Pattern 10

(d) Clients and constructors: Pattern 14

(e) Clients: Pattern 6, Pattern 12 and Pattern 15

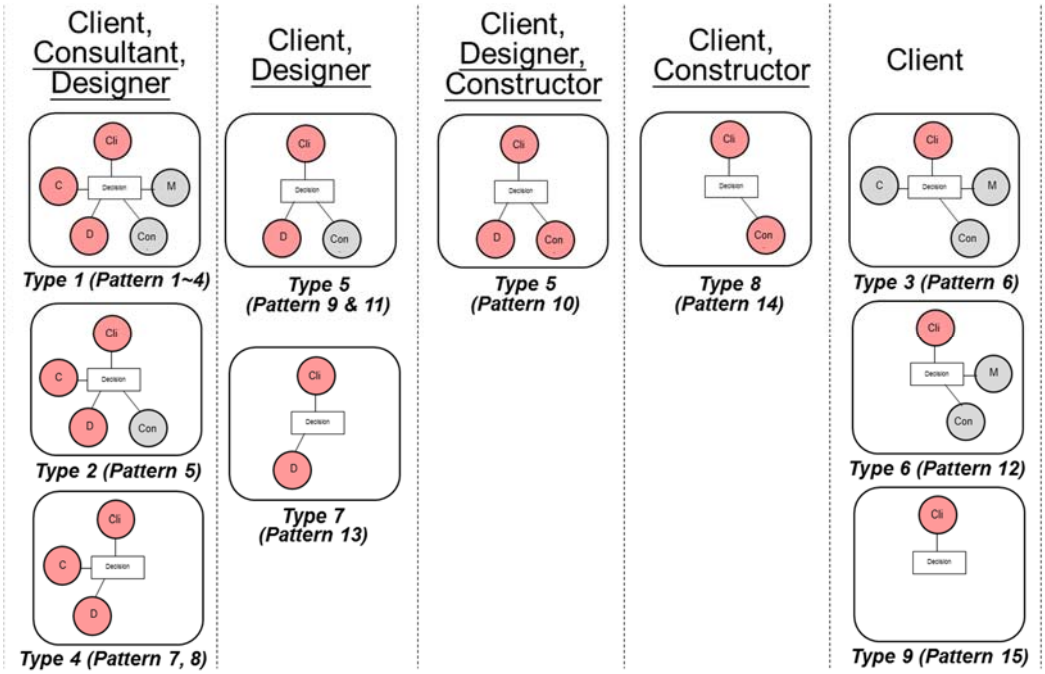


Figure 4-85 Five categories of influential decision makers

4.4.2 Decision makers' working contents for assessments

4.4.2.1 Research result

The working contents of decision makers for assessing six categories of decision-making considerations in the decision-making processes of retrofitting designs are observed in this part.

(1) Improving effects of energy efficiency

The research results regarding working contents for evaluating "improving effects of energy efficiency" of retrofitting methods are to check: (a) improving performance of applications, and (b) data of material performance.

The research results regarding types of decision makers assessing "improving effects of energy efficiency" show decision makers' professions including the following types: (a) consultants (also a designer), (b) designers, (c) constructors, (d) material suppliers, and (e) clients.

Furthermore, by comparing decision makers' professions of 15 patterns who evaluated the consideration regarding "improving effects of energy efficiency", the research results show that a consultant is usually the decision maker who is in charge of evaluating improving performance of thermal environment. However, when a consultant doesn't participate in decision making processes, a designer, a constructor or a client is in charge of the evaluating works.

It is clarified the consideration "improving effect of energy efficiency" is assessed by different number and specialties of decision makers.

	Specialties of assessed decision makers	Case
One person	Consultant	Pattern 5, Pattern 6, Pattern 7
	Designer (Consultant)	Pattern 2, Pattern 4
	Client (Consultant, Designer)	Pattern 8
	Client	Pattern 15
	Client (Designer)	Pattern 11
	Designer	Pattern 9, Pattern 10, Pattern 13
	Constructor	Pattern 14
	Client, Material supplier	Pattern 12
More than one person	Client (Consultant, Designer), Material supplier	Pattern3
	Consultant, Material supplier	Pattern 1

Figure 4-86 Specialties of assessed decision makers

(2) Functionality

The research results regarding working contents for evaluating “functionality” of retrofitting methods are to check: (a) clients’ expected functions, (b) additional functions of retrofitting methods and (c) properties of material.

The research results regarding types of decision makers assessing “functionality” show decision makers’ professions including the following types: (a) consultants (also a designer), (b) designers, (c) constructors, (d) material suppliers, and (e) clients., by comparing decision makers’ professions of 13 patterns who evaluated the consideration regarding “functionality”, the research results show that all the five types of professions might participate in the evaluating works of this consideration. The most common decision makers’ professions show in the patterns are clients and designers.

(3) Affordability

The research results regarding working contents for evaluating “affordability” of retrofitting methods are to check: (a) clients’ budget, (b) constructing cost, and (c) material cost.

The research results regarding types of decision makers assessing “affordability” show decision makers’ professions including the following types: (a) consultants (also a designer), (b) designers, (c) constructors, (d) material suppliers, and (e) clients.

Furthermore, by comparing decision makers’ professions of 15 patterns who evaluated the consideration regarding “affordability”, the research results show that a client, a consultant, a designer, a constructor and a material supplier are able to participate in evaluating works. The most common decision makers’ professions show in the patterns are clients, designers and constructors.

(4) Legality

The research results regarding working contents for evaluating “legality” are to check if the retrofitting methods meet (a) building management regulations of the buildings expected to be retrofitted and (b) general building regulations regarding safety of structure and escape, and property right.

The research results regarding types of decision makers assessing “legality” show decision makers’ professions including the following types: (a) consultants (some of them are also designers), (b) designers, and (c) clients (who usually also a designer).

Furthermore, by comparing decision makers’ professions of 11 patterns who evaluated the consideration regarding “legality”, the research results show that the designers are the main decision makers in charge of evaluating works. However, for the patterns without designers

participating, consultants are in charge of the evaluating works.

(5) Constructability

The research results regarding working contents for evaluating “constructability” of retrofitting methods are to check: (a) clients’ expected retrofitting period, (b) constructing period, and (c) feasibility of application.

The research results regarding types of decision makers assessing “constructability” show decision makers’ professions including the following types: (a) consultants (who usually are also designers), (b) designers, (c) constructors, (d) material suppliers and (e) clients.

Furthermore, by comparing decision makers’ professions of 15 patterns who evaluated the consideration regarding “constructability”, it was found participated situations of decision makers are various. Although a constructor is the main person to evaluate the “constructability” of retrofitting methods, the research result show that a client, a consultant, a designer and material supplier are also able to evaluate it when a constructor is absent in the decision-making processes.

(6) Durability

The research results regarding working contents for evaluating “durability” of retrofitting methods are to check: (a) clients’ expected useable duration and maintenance frequency, (b) useable duration of material, and (c) needs and frequency of maintenance.

The research results regarding types of decision makers assessing “constructability” show decision makers’ professions including the following types: (a) consultants (who usually are also designers), (b) designers, (c) constructors, (d) material suppliers and (e) clients.

Furthermore, by comparing decision makers’ professions of 14 patterns who are evaluating the consideration regarding “durability”, the research results show that a client, a consultant, a designer, a constructor and a material supplier might be all able to participate in evaluating works. The most common decision makers’ professions seen in the patterns are clients and designers.

Table 4-55 Assessing categories and types of decision makers in charge of assessments in 15 patterns

	Improving effects of energy efficiency	Functionality	Affordability	Legality	Constructability	Durability
Pattern 1	(1) Consultant (2) Material suppliers	(1) Clients (2) Designer	(1) Client (2) Designer: (3) Constructor (4) Material supplier	(1) Designer	(1) Client (2) Designer (3) Constructor (4) Material supplier	(1) Client (2) Designer (3) Material supplier
Pattern 2	(1) Consultant + Designer	-	(1) Client (2) Consultant + Designer (3) Material supplier (4) Constructor	(1) Consultant + Designer	(1) Clients (2) Consultant + Designer (3) Material supplier (4) Constructor	(1) Client (2) Consultant + Designer (3) Material supplier (4) Constructor
Pattern 3	(1) Client + Consultant + Designer (2) Material supplier	(1) Client + Consultant + Designer (2) Material supplier	(1) Client + Consultant + Designer (2) Material supplier (3) Constructor	(1) Client + Consultant + Designer	(1) Client + Consultant + Designer (2) Material supplier (3) Constructor	(1) Client + Consultant + Designer (2) Material supplier
Pattern 4	(1) Consultant + Designer	(1) Client (2) Consultant + Designer	(1) Client (2) Consultant + Designer (3) Constructor (4) Material supplier	(1) Consultant + Designer	(1) Client (2) Consultant + Designer (3) Constructor (4) Material supplier	(1) Client (2) Consultant + Designer (3) Material supplier
Pattern 5	(1) Consultant	(1) Client (2) Designer	(1) Client (2) Designer (3) Constructor	(1) Designer	(1) Client (2) Designer (3) Constructor	(1) Client (2) Designer (3) Constructor
Pattern 6	(1) Consultant	-	(1) Client (2) Material supplier	-	(1) Client (2) Material supplier	(1) Client (2) Material supplier
Pattern 7	(1) Consultant	(1) Client (2) Designer	(1) Client (2) Designer	(1) Designer	(1) Client (2) Designer	(1) Client (2) Designer
Pattern 8	(1) Client +Consultant +Designer	(1) Client +Consultant +Designer	(1) Client +Consultant +Designer	(1) Client +Consultant +Designer	(1) Client +Consultant +Designer	(1) Client +Consultant +Designer
Pattern 9	(1) Designer	(1) Client: (2) Designer	(1) Client (2) Designer (3) Constructor	(1) Designer	(1) Client (2) Designer (3) Constructor	(1) Client (2) Designer (3) Constructor
Pattern 10	(1) Designer	(1) Client (2) Designer	(1) Client (2) Designer (3) Constructor	(1) Designer	(1) Client (2) Designer (3) Constructor	(1) Client (2) Designer (3) Constructor
Pattern 11	(1) Client + Designer	(1) Client + Designer	(1) Client + Designer (2) Constructor	(1) Client + Designer	(1) Client + Designer (2) Constructor	(1) Client + Designer (2) Constructor
Pattern 12	(1) Client (2) Material supplier	(1) Client	(1) Client (2) Material supplier	-	(1) Client (2) Material supplier	(1) Client (2) Material supplier
Pattern 13	(1) Designer	(1) Client (2) Designer	(1) Client (2) Designer	(1) Designer	(1) Designer (2) Client	(1) Client (2) Designer
Pattern 14	(1) Constructor	(1) Client (2) Constructor	(1) Client (2) Constructor	-	(1) Client (2) Constructor	(1) Client (2) Constructor
Pattern 15	(1) Client	-	(1) Client	-	(1) Client	-

4.4.2.2 Summary and finding

(1) Research result regarding decision makers' working contents in decision-making processes of retrofitting designs

In summary, decision makers' working contents for assessments in decision-making processes of retrofitting designs are clarified in this part. According to the research results, the assessment works for the six categories of considerations are concluded as Table 4-56.

Table 4-56 Assessment works for six categories of considerations

Consideration	Assessment work
(1) Improving effects of energy efficiency	(a) Checking improving performance of applied retrofitting methods (b) Checking data of material performance
(2) Functionality	(a) Confirming clients' expected functions (b) Checking additional functions of retrofitting methods (c) Checking properties of material
(3) Affordability	(a) Confirming clients' budget (b) Checking constructing cost (c) Checking material cost
(4) Legality	(a) Checking building management regulations of the buildings expected to be retrofitted (b) Checking general building regulations regarding safety of escape route, property right and need of license application for building design changes and additions
(5) Constructability	(a) Confirming clients' expected retrofitting period (b) Checking constructing period (c) Checking feasibility of application (d) Checking strength of existing structure
(6) Durability	(a) Confirming clients' expected useable duration and maintenance frequency (b) Checking useable duration of material (c) Checking needs and frequency of maintenance

(2) Features of decision makers' types assessing in small-scale building envelope retrofits for energy efficiency

According to research results regarding types of decision makers assessing the six categories of considerations, it was found that the types of decision makers in charge of assessment works are different in each of considering categories. For example, the types of decision makers evaluating the consideration "capability of improving thermal environment" have: (a) clients in Pattern 3, Pattern 8, Pattern 11, Pattern 12, Pattern 15, (b) consultants in Pattern 1 ~ Pattern 8, (c) designer in Pattern 2 ~ Pattern 4, Pattern 8 ~ Pattern 11 and Pattern 13, (d) constructors in Pattern 14, and (e) material suppliers in Pattern 1, Pattern 3 and Pattern 12. (Table 4-57)

Table 4-57 Types of decision makers assessing in small-scale building envelope retrofits for energy efficiency in 15 patterns

	Improving effects	Functionality	Affordability	Legality	Constructability	Durability
Client	Pattern 3, Pattern 8, Pattern 11, Pattern 12, Pattern 15	Pattern 1, Pattern 3, ~ Pattern 5, Pattern 7~ Pattern 14	Pattern 1~ Pattern 15	Pattern 3, Pattern 8, Pattern 11	Pattern 1~ Pattern 15	Pattern 1~ Pattern 15
Consultant	Pattern 1 ~Pattern 8	Pattern 3, Pattern 4, Pattern 8,	Pattern 2 ~ Pattern 4, Pattern 8,	Pattern 2 ~Pattern 4, Pattern 8	Pattern 2~ Pattern4, Pattern 8,	Pattern 2 ~ Pattern 4, Pattern 8
Designer	Pattern 2 ~ Pattern 4, Pattern 8 ~ Pattern 11, Pattern 13	Pattern 1, Pattern 3 ~Pattern 5, Pattern 7 ~Pattern 11, Pattern 13	Pattern 1 ~Pattern 5, Pattern 7 ~ Pattern 11, Pattern 13	Pattern 1 ~Pattern 5, Pattern 7~Pattern 11, Pattern 13	Pattern 1~ Pattern 5, Pattern 7~Pattern 11, Pattern 13	Pattern 1~ Pattern 5, Pattern 7~Pattern 11, Pattern 13
Constructor	Pattern 14	Pattern 14	Pattern 1 ~Pattern 5, Pattern 9 ~ Pattern 11, Pattern 14	-	Pattern 1 ~Pattern 5, Pattern 9 ~Pattern 11, Pattern 14	Pattern 2, Pattern 5, Pattern 9~ Pattern 11, Pattern 14
Material supplier	Pattern 1, Pattern 3, Pattern 12	Pattern 3	Pattern 1 ~Pattern4, Pattern 6, Pattern 12	-	Pattern 1 ~Pattern 4, Pattern 6, Pattern 12	Pattern 1 ~Pattern 4, Pattern 6, Pattern 12

According to the findings, it is clarified that different types of decision makers participating assessment works in decision-making processes of retrofit designs.

4.4.3 Assessment approaches for improving effectiveness of energy efficiency

4.4.3.1 Research result

Research results regarding assessment approaches for estimating “improving effects of energy efficiency” are found can be sorted as following methods. (Table 4-58)

(1) According to simulation and calculation

The assessment approach which is according to simulation and calculation are saw in Pattern 1, Pattern 2, Pattern 4, Pattern 6 and Pattern 7.

(2) According to theories of energy-saving design & Data report

The assessment approach which is according to theories of energy-saving designs and data reports are applied in Pattern 3, Pattern 5, Pattern 7, Pattern 8, Pattern 10 and Pattern 11.

(3) According to past experience, Personal thought & Feedback from users

The assessment approach which is according to past experience, personal thought and feedback from other users are found in Pattern 9, Pattern 13, Pattern 11, Pattern 12, Pattern 14, Pattern 15.

Table 4-58 Assessment approaches for improving effectiveness of energy efficiency in 15 patterns

Assessment approaches for improving effects of energy efficiency	Combination pattern of decision makers
(1) According to simulation and calculation	Pattern 1, Pattern 2, Pattern 4, Pattern 6, Pattern 7
(2) According to theories of energy-saving design & Data report	Pattern 3, Pattern 5, Pattern 7, Pattern 8, Pattern 10, Pattern 11
(3) According to past experience, Personal thought & Feedback from users	Pattern 9, Pattern 13, Pattern 11, Pattern 12, Pattern 14, Pattern 15

4.4.3.2 Summary and finding

In summary, assessment approaches for improving effectiveness in decision-making processes of retrofitting designs are clarified in this part. The research results show that the methods to estimate “improving effects of energy efficiency” are different in studied cases.

It was found that the assessment approach, “simulations and calculations”, which is usually utilized in theoretical planning situation is only applied in some of retrofitting projects. Hence, it is clarified that “improving effects of energy efficiency” are assessed by various assessing approaches and might different from theoretical suggestions

4.5 Conclusion of Chapter 4

4.5.1 Summary

In summary, features of decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system are clarified in Chapter 4 through discovering “what decision makers think” and “how decision makers arrive at the decisions” in 32 cases.

4.5.1.1 Research result regarding “what decision makers think”

Through investigating “what decision makers think” for energy-efficient deciding retrofitting methods, the following constants are clarified: (A) contents of decision makers’ considerations, (B) priority orders of decision makers’ considerations and (C) development processes of decision makers’ considerations. Moreover, the differences of decision makers’ thoughts in a small-scale building construction system are discovered and categorized.

(A) Decision makers’ considerations

The research results regarding “decision makers’ considerations” show different contents of decision-making considerations are found in 32 cases and can be categorized into 17 subjects and six categories. The six categories are: (1) capability of improving thermal environment, (2) functionality, (3) affordability, (4) legality, (5) constructability and (6) durability.

(B) Priority orders of decision makers’ considerations

The research results regarding “priority orders of decision makers’ considerations” show the priority orders of considerations in the six categories are concerned differently by decision makers.

(C) Development processes of decision makers’ considerations

The research results regarding “development processes of decision makers’ considerations” show the considerations might be (1) concerned by clients from the beginning, (2) concerned and raised their priority order after decision makers’ discussions during the processes or (3) not concerned as all.

4.5.1.2 Research result regarding “how decision makers arrive at the decisions”

Through investigating “how decision makers arrive at the decisions”, the following constants are clarified: (A) interactions between decision makers, (B) decision makers’ working contents for assessments, and (C) assessment approaches for improving effectiveness. Moreover, the differences of decision makers’ ways of making decisions discovered and categorized.

(A) Interactions between decision makers

The research results regarding “interactions between decision makers” show that retrofitting

designs are decided through different interactions between decision makers. The interactions include: (1) requests, (2) suggestions, (3) discussions and (4) confirmations.
Moreover, influential decision makers in each pattern are clarified and categorized into five groups by observing the interactions between decision makers. The specialties of decision makers in the five groups are: (a) clients, consultants and designers, (b) clients, and designers, (c) clients, designers and constructors, (d) clients and constructors, and (e) clients.

(B) Decision makers' working contents for assessments
The research results regarding "decision makers' working contents for assessments" show different assessment contents and different specialties of assessed decision makers. For example, the consideration regarding "capability of improving thermal environment" are assessed by consultants and material suppliers in Pattern 1 but the consideration are assessed by clients in Pattern 15.

(C) Assessment approaches for improving effectiveness
The research results regarding "assessment approaches for improving effectiveness" show assessment approaches for improving effectiveness are utilized differently in studied cases and can be categorized into three kinds of approaches: (a) according to simulation and calculation, (b) according to theories of energy-saving design and data report of material, and (c) according to past experience, personal thought and feedback from users.

4.5.2 Features of practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system

In conclusion, different cases of decision-making processes of energy-efficiency retrofits are clarified. It was found that retrofitting methods are decided differently and relating to decision making considerations, priority orders of decision makers' considerations, types of influential decision makers, types of interactions and assessed approaches..

Moreover, according to research results regarding "how decision makers arrive at the decisions", it is also found the retrofitting designs might be decided by only few people or clients themselves in the small-scale building construction system.

4.5.3 Challenges with respect to planning "energy-efficient building envelope retrofits" in a small-scale building construction system

Furthermore, the following contents: (A) challenges of planning "energy-efficient building envelope retrofits" in a small-scale building construction system, and (B) reasons result the issues mentioned in Chapter 2 are also clarified in this chapter according to above research results.

(1) Differences between theoretical decision-making processes and practical decision-making processes

In a theoretical decision-making process, the consideration "improving effects of energy efficiency" is always concerned as the first priority and retrofitting designs are decided after confirming the "improving effects of energy efficiency" by objective assessing approaches - calculations and simulations.

However, in practical decision-making processes, it was found the decision making processes of retrofitting designs are relating to influential decision makers' expectations and approaches of making decisions. Hence, it was also clarified that the consideration "improving effects of energy efficiency" is not always considered as first priority and concerned by clients from the beginnings. Furthermore, the consideration "improving effects of energy efficiency" might be assessed by non-consultants according to subjective assessing approaches – decision makers' experiences and feedback from other users.

Hence, it was found that decision makers' thoughts and ways of making decisions in a "small-scale building construction system" are various and different from theoretical expectations. The consideration regarding "improving effects of energy efficient" is (a) not the only consideration, (b) not always considered as first priority, (c) not always concerned by clients from the beginning,

and (d) not assessed carefully and accurately by consultants and experts from several fields.

(2) Variety of decision-making processes

Moreover, according to research results regarding “relationship between decision-making considerations and selected energy-efficiency retrofitting methods”, it was found that the differences in decision-making processes might be the reason causing the adopted retrofitting methods became various and different from theoretical expectations.

(3) Decisions of energy-efficiency retrofitting designs are made by non-experts

It was found the issue - multiple building-envelope retrofits have been executed due to ineffective retrofitting results for improving indoor thermal environment is affected by attributes of decision makers.

Retrofitting designs decided by non-experts and who have less experiences on energy-efficiency retrofits are mainly according to clients’ requirements. This might be the reason resulting less effective improving performance of energy efficiency.

Practical decision-making processes of retrofitting designs in a small-scale building construction system are clarified in Chapter 4. According to research results in Chapter 2, Chapter 3 and Chapter 4, practical situation of retrofitting designs in a small-scale building construction system were discovered.

Next, quality of these decision-making processes executed by decision makers in different compositions are going to be evaluated. And then, provide suggestions for decision makers in the small-scale building construction system to enhance the quality of adopting energy-efficiency retrofits according to different cases of decision-making processes in Chapter 5.

Chapter 5
Evaluation and suggestion for the decision-making processes executed by decision makers in different compositions

5.1 Overview
5.2 Comparisons of “what decision makers think” in nine combination types of decision makers
5.2.1 Decision makers’ considerations for deciding retrofitting methods
5.2.2 Priority orders of decision makers’ considerations
5.2.3 Development processes of decision makers’ considerations regarding improving effect of energy-efficiency
5.2.4 Finding: Evaluating result regarding “level of awareness on energy efficiency”
5.3 Comparisons of “how decision makers arrive at decisions” in nine combination types of decision makers
5.3.1 Interactions between decision makers
5.3.2 Decision makers’ working contents for assessing improving effect
5.3.3 Assessment approaches for improving effectiveness
5.3.4 Finding: Evaluating result regarding “level of rigor in discussion and assessment”
5.4 Conclusion of Chapter 5
5.4.1 Summary
5.4.2 Quality of decision-making processes executed by different compositions of decision makers in a small-scale building construction system
5.4.3 Suggestions for decision makers in a small-scale building construction system to ensure quality of decision-making processes

5.1 Overview

After clarifying practical situation of retrofitting designs in a small-scale building construction system. In Chapter 5, the decision-making processes are going to be evaluated, and suggestions are going to provide for ensuring qualities of adopting energy-efficiency retrofits in a small-scale building construction system.

[Research method]
To find out the solutions, the research methods are: (1) to compare decision-making processes executed by different compositions of decision makers, and (2) to evaluate these decision-making processes by concerning: (a) level of awareness regarding energy efficiency and (b) level of rigor in discussions and assessments.

The methods to compare decision-making processes executed by decision makers in different compositions are to categorize “what decision makers think” and “how decision makers arrive at decisions” in the nine combination types of decision makers.

The methods to evaluate decision-making processes executed by decision makers in different compositions are comparing “what decision makers think” and “how decision makers arrive at decisions” in the nine combination types of decision makers. (Figure 5-1)

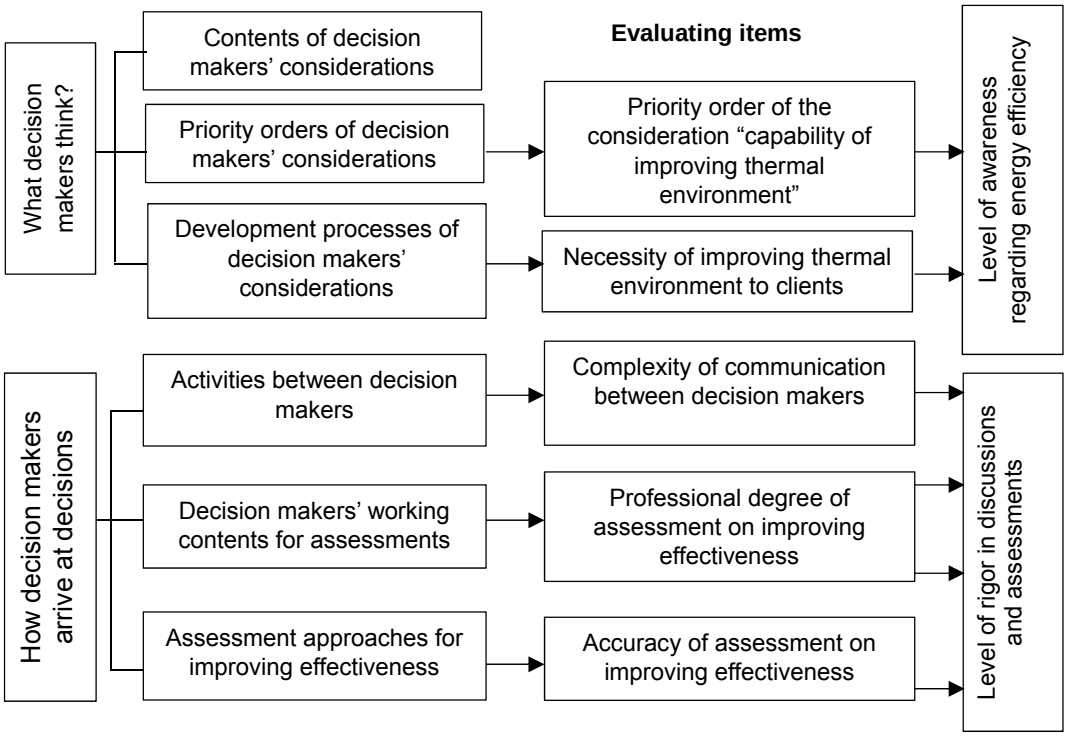


Figure 5-1 Analysis process of evaluate decision-making processes

[Research framework]
The research contents and frameworks are showing as Figure 5-2.

Section 5.2 show research results regarding comparisons of decision-making processes regarding “what decision makers think” and the finding of the evaluation regarding “level of awareness regarding energy efficiency”.

Section 5.3 is the research results regarding comparisons of decision-making processes regarding “how decision makers arrive at decisions” and the finding of the evaluation regarding “level of rigor in discussions and assessments”

Section 5.4 is the conclusions includes: (1) summary of the research in Chapter 5, (2) the finding regarding quality of decision-making processes executed by decision makers in different combinations, and (3) suggestions for decision makers in a small-scale building construction system to ensure quality of decision-making processes.

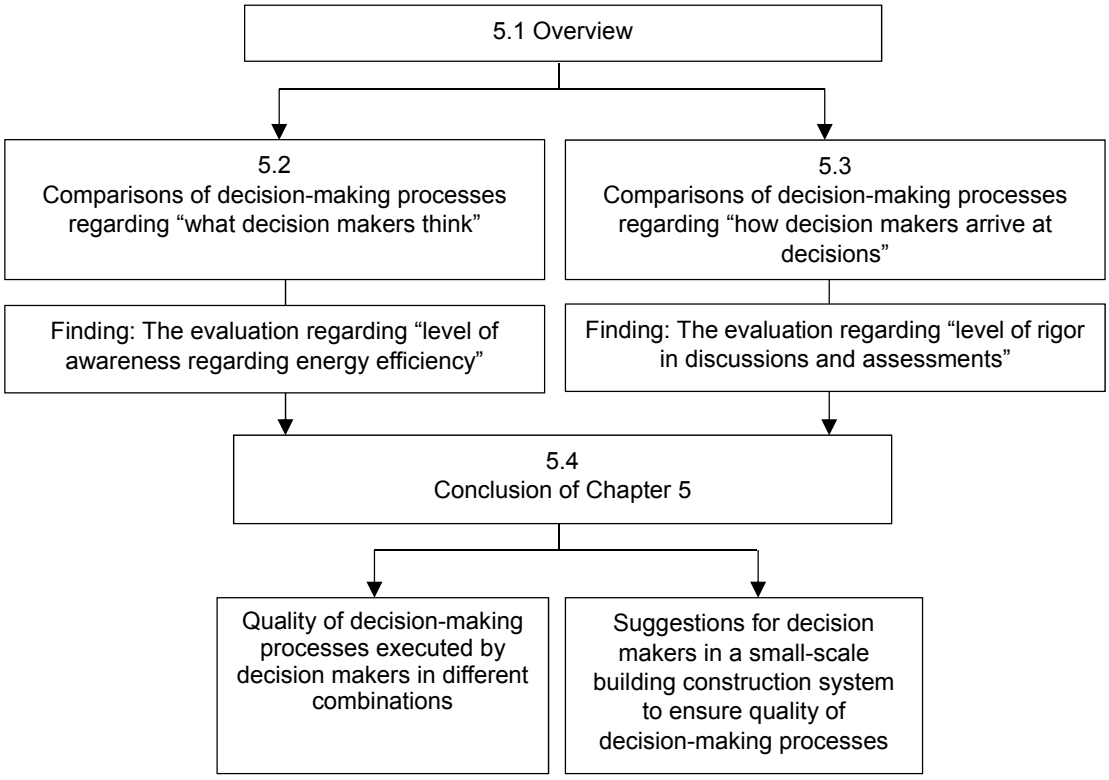


Figure 5-2 Research framework of Chapter 5

5.2 Comparisons of “what decision makers think” in nine combination types of decision makers

5.2.1 Decision makers’ considerations for deciding retrofitting methods

Research results regarding decision makers’ considerations for deciding retrofitting designs in 10 combination types of decision makers show as follows. (Table 5-1)

(1) Considerations in six categories are all concerned in Type 2, Type 4, Type 5, Type 7 and some patterns in Type 1.

(2) The consideration regarding “functionality” is not concerned in Type 3 and some patterns in Type 1 and Type 4.

(3) The consideration regarding “legality” is not concerned in Type 3, Type 6, Type 8 and Type 9

(4) The consideration regarding “durability” is not concerned in Type 9.

According to comparative analyses of final decision-making considerations in 10 combination types of decision makers, it is found that: (1) the consideration regarding “functionality” is not concerned when clients have no needs improving other building functions, (2) the consideration regarding “legality” is not concerned when there is no designer participated in the decision-making processes, and (3) the consideration regarding “durability” is not concerned when a client is the only decision maker and it is not required by the clients.

It is clarified that although the contents of decision-making considerations are influenced by clients’ needs greatly, but when decision-making processes which have no designers participated might not pay attention on the consideration regarding “legality”.

Table 5-1 Decision makers’ considerations for deciding retrofitting designs in 9 types

	Capability	Functionality	Affordability	Legality	Constructability	Durability
Type 1	○	△	○	○	○	○
Type 2	○	○	○	○	○	○
Type 3	○	×	○	×	○	○
Type 4	○	△	○	○	○	○
Type 5	○	○	○	○	○	○
Type 6	○	○	○	×	○	○
Type 7	○	○	○	○	○	○
Type 8	○	○	○	×	○	○
Type 9	○	○	○	×	○	×

5.2.2 Priority orders of decision makers' considerations

Research results regarding priority orders of decision makers' considerations in 9 combination types of decision makers show as follows. (Table 5-2)

5.2.2.1 Overview of considerations in six categories

In Type 1, the considerations in first priority order are "improving effect of energy-efficiency" and "functionality". The considerations in second priority are "improving effect of energy-efficiency" and "affordability". The considerations in third priority are "affordability" and "constructability". The considerations in forth priority are "legality", "durability", "constructability" and "functionality". The considerations in fifth priority are "constructability", "legality", "affordability" and "durability". The considerations in sixth priority are "durability" and "legality".

In Type 2, the considerations in first priority order are "functionality". The consideration in second priority is "affordability". The considerations in third priority are "improving effect of energy-efficiency" and "constructability". The considerations in forth priority are "improving effect of energy-efficiency" and "constructability". The considerations in fifth priority are "durability" and "legality". The considerations in sixth priority are "durability" and "legality".

In Type 3, the considerations in first priority order is "improving effect of energy-efficiency". The consideration in second priority is "constructability". The consideration in third priority is "durability". The consideration in forth priority is "affordability".

In Type 4, the considerations in first priority order are "improving effect of energy-efficiency" and "functionality". The considerations in second priority are "improving effect of energy-efficiency", "functionality", "legality" and "constructability". The considerations in third priority are "affordability", "constructability" and "improving effect of energy-efficiency". The considerations in forth priority are "functionality", "affordability", "constructability" and "durability". The considerations in fifth priority are "affordability", "legality" and "durability". The considerations in sixth priority are "affordability" and "durability".

In Type 5, the considerations in first priority order are "improving effect of energy-efficiency", "functionality" and "affordability". The considerations in second priority are "functionality", "legality" and "durability". The considerations in third priority are "affordability" and "constructability". The considerations in forth priority are "improving effect of energy-efficiency", "functionality" and "constructability". The considerations in fifth priority are "affordability", "legality" and "constructability". The considerations in sixth priority are "improving effect of energy-efficiency", "legality" and "durability".

In Type 6, the considerations in first priority order is “constructability”. The consideration in second priority is “functionality”. The consideration in third priority is “improving effect of energy-efficiency”. The consideration in forth priority is “durability”. The consideration in fifth priority is “affordability”.

In Type 7, the considerations in first priority order is “functionality”. The consideration in second priority is “legality”. The consideration in third priority is “improving effect of energy-efficiency”. The consideration in forth priority is “affordability”. The consideration in fifth priority is “constructability”. The consideration in sixth priority is “durability”.

In Type 8, the considerations in first priority order are “improving effect of energy-efficiency”, “functionality” and “constructability”. The considerations in second priority are “improving effect of energy-efficiency”, “functionality” and “affordability”. The considerations in third priority are “improving effect of energy-efficiency” and “durability”. The considerations in forth priority are “affordability”. The considerations in fifth priority are “constructability”.

In Type 9, the considerations in first priority order are “functionality” and “affordability”. The considerations in second priority are “improving effect of energy-efficiency” and “constructability”. The considerations in third priority are “improving effect of energy-efficiency” and “affordability”. The considerations in forth priority are “constructability” and “durability”.

The research results show different priority orders of considerations in the decision-making processes of 9 combination types of decision makers. The consideration regarding “improving effect of energy-efficiency” is considered as first priority in Type 1, Type 3, Type 4, Type 5, and Type 8. The consideration regarding “functionality” is considered as first priority in Type 1, Type 2, Type 4, Type 5, Type 7, Type 8 and Type 9. The consideration regarding “affordability” is considered as first priority in “Type 5 and Type 9. The consideration regarding “constructability” is considered as first priority in Type 6 and Type 8.

According to above research results, it is found that the consideration regarding “improving effect of energy-efficiency” is paid more attentions when there are consultants and designers participating in decision-making processes. The consideration regarding “legality” is paid more attention when the buildings have management committees and required by building management regulations. The rest of consideration regarding “functionality”, “affordability”, “constructability” and “durability” are paid more attentions when they are especially required by clients.

5.2.2.2 The priority order of the consideration regarding “improving effect of energy-efficiency” in the nine types.

Moreover, by focusing on the priority order of the consideration regarding “improving effect of energy-efficiency” in the nine types.

In Type 1, the consideration regarding “improving effect of energy-efficiency” is considered as first priority and second priority.

In Type 2, the consideration regarding “improving effect of energy-efficiency” is considered as third priority and fourth priority.

In Type 3, the consideration regarding “improving effect of energy-efficiency” is considered as first priority

In Type 4, the consideration regarding “improving effect of energy-efficiency” is considered as first priority, second priority and third priority.

In Type 5, the consideration regarding “improving effect of energy-efficiency” is considered as first priority, fourth priority and sixth priority.

In Type 6, the consideration regarding “improving effect of energy-efficiency” is considered as third priority.

In Type 7, the consideration regarding “improving effect of energy-efficiency” is considered as third priority.

In Type 8, the consideration regarding “improving effect of energy-efficiency” is considered as first priority, second priority and third priority.

In Type 9, the consideration regarding “improving effect of energy-efficiency” is considered as second priority and third priority.

It is clarified the consideration regarding ”improving effect of energy-efficiency” has higher priority when consultants participate in decision-making processes.

Table 5-2 Priority order of final decision-making considerations in 9 types

Type	Pattern		A	B	C	D	E	F
Type 1	Pattern 1	Case R3	(2)	(1)	(3)	(4)	(5)	(6)
	Pattern 2	Case S1, S3	(1)	-	(2)	(5)	(3)	(4)
	Pattern 3	Case R6	(2)	(1)	(5)	(6)	(4)	(3)
	Pattern 4	Case R4	(1)	(4)	(2)	(6)	(3)	(5)
Type 2	Pattern 5	Case R5, R9	(3)	(1)	(2)	(6)	(4)	(5)
		Case R16	(4)	(1)	(2)	(5)	(3)	(6)
Type 3	Pattern 6	Case R18	(1)	-	(4)	-	(2)	(3)
Type 4	Pattern 7	Case R10	(2)	(1)	(6)	(5)	(3)	(4)
		Case C4	(1)	(4)	(5)	(2)	(3)	(6)
		Case R1, G1, G2, M1, S2, C2	(1)	-	(3)	(5)	(2)	(4)
		Case C1	(1)	(2)	(6)	(5)	(3)	(4)
		Case S4	(1)	-	(4)	(2)	(3)	(5)
	Pattern 8	Case C5	(3)	(1)	(6)	(2)	(4)	(5)
Type 5	Pattern 9	Case R2	(4)	(1)	(3)	(6)	(5)	(2)
		Case C3	(4)	(2)	(1)	(5)	(3)	(6)
	Pattern 10	Case R13, R14	(6)	(1)	(3)	(5)	(4)	(2)
	Pattern 11	Case R7-2	(1)	(4)	(5)	(2)	(3)	(6)
Type 6	Pattern 12	Case R8-2	(3)	(2)	(5)	-	(1)	(4)
Type 7	Pattern 13	Case R7-1	(3)	(1)	(4)	(2)	(5)	(6)
Type 8	Pattern 14	Case R12	(1)	(2)	(4)	-	(5)	(3)
		Case R17	(2)	(1)	(4)	-	(5)	(3)
		Case G3-1	(3)	-	(2)	-	(1)	-
Type 9	Pattern 15	Case G3-2	(3)	-	(1)	-	(2)	(4)
		Case R8-1	(2)	(1)	(3)	-	(4)	-

A. Improving effect of energy-efficiency
B. Functionality
C. Affordability
D. Legality
E. Constructability
F. Durability

5.2.3 Development processes of decision makers' considerations regarding energy-efficiency

Research results regarding development processes of "improving effect of energy-efficiency" in 9 combination types of decision makers show as follows. (Table 5-3)

The development processes of the consideration "improving effect of energy-efficiency" in Type 1 show the consideration is considered by clients from the beginning and not considered until consultant suggesting.

The development processes of the consideration "improving effect of energy-efficiency" in Type 2 show the consideration is not considered until consultant suggesting.

The development processes of the consideration "improving effect of energy-efficiency" in Type 3 show the consideration is considered by clients from the beginning.

The development processes of the consideration "improving effect of energy-efficiency" in Type 4 show the consideration is considered by clients from the beginning and not considered until consultant suggesting.

The development processes of the consideration "improving effect of energy-efficiency" in Type 5 show the consideration is considered by clients from the beginning and not considered until consultant suggesting.

The development processes of the consideration "improving effect of energy-efficiency" in Type 6 is considered by clients from the beginning.

The development processes of the consideration "improving effect of energy-efficiency" in Type 7 is considered by clients from the beginning.

The development processes of the consideration "improving effect of energy-efficiency" in Type 8 is considered by clients from the beginning.

The development processes of the consideration "improving effect of energy-efficiency" in Type 9 is considered by clients from the beginning.

Moreover, the research results of comparisons show: (1) the consideration "improving effect of energy-efficiency" is both considered by clients from the beginning and not considered until consultant suggesting in Type 1, Type 4 and Type 5, (2) the consideration is considered by clients from the beginning in Type 3, Type 6, Type 7, Type 8 and Type 9, and (3) the consideration is not considered until consultant suggesting in Type 2.

According to above research results, it is found that the clients in Type 3, Type 6, Type 7, Type 8, and Type 9 are especially focusing on the consideration " improving effect of energy-efficiency" due to their originally retrofitting purpose aims to improve thermal environment. Hence, it is clarified that improving thermal environment is more necessary to clients in Type 3, Type 6, Type 7, Type 8, and Type 9.

Table 5-3 Development processes of decision makers' considerations regarding "improving effect of energy-efficiency" in 9 types

Type	Pattern	Situation of the consideration "improving effect of energy-efficiency" being concerned
Type 1	Pattern 1	Not being considered until consultants suggest
	Pattern 2	Being considered by clients from the beginning
	Pattern 3	Being considered by clients from the beginning
	Pattern 4	Not being considered until consultants (+designer) suggest
Type 2	Pattern 5	Not being considered until consultants suggest
Type 3	Pattern 6	Being considered by clients from the beginning
Type 4	Pattern 7	Not being considered until consultants suggest
	Pattern 8	Being considered by clients from the beginning
Type 5	Pattern 9	Not being considered until designers suggest
	Pattern 10	Not being considered until consultants suggest
	Pattern 11	Being considered by clients from the beginning
Type 6	Pattern 12	Being considered by clients from the beginning
Type 7	Pattern 13	Being considered by clients from the beginning
Type 8	Pattern 14	Being considered by clients from the beginning
Type 9	Pattern 15	Being considered by clients from the beginning

5.2.4 Finding: Evaluating result regarding “level of awareness on energy efficiency”

Level of awareness on energy efficiency in the 9 combination types of decision makers is evaluated by (1) priority order of the consideration “improving effect of energy-efficiency” and (2) necessity of improving thermal environment to clients. The result is illustrated as diagram below. (Fig.5-3)

[Priority order of the consideration “improving effect of energy-efficiency”]
According to the research results regarding “priority order of final decision-making consideration”, priority order of the consideration “improving effect of energy-efficiency” in the 9 combination types of decision makers are clarified as vertical axis. The vertical axis is divided into three parts: (A) the priority order of the consideration is in the first and second places, (B) the priority order of the consideration is in the third and fourth places, and (C) the priority order of the consideration is in the fifth and sixth places. The priority order of the consideration is in the first and second places has higher priority to decision makers, and the consideration is in the fifth and sixth places has lower priority to decision makers.

[Necessity of improving thermal environment to clients]
According to the research results regarding “development process of the consideration “improving effect of energy-efficiency”, necessity of improving thermal environment to clients are clarified as horizontal axis. The horizontal axis is divided into two parts: (A) the consideration is developed from the beginning by clients, and (B) the consideration is developed after decision makers suggesting. The clients has higher necessity in the types of decision-making processes which the consideration is developed from the beginning by clients (A); the clients has lower necessity in the types of decision-making processes which the consideration is developed after other decision makers suggesting (B).

[Summary]
According to above research results, the evaluation regarding “level of awareness on improving effect of energy-efficiency” is clarified and can be conclude. It was found “level of awareness on improving effect of energy-efficiency” is different in the decision-making processes executed by different compositions of decision makers.

The diagram shows the “level of awareness on improving effect of energy-efficiency” in Type 3 (Pattern 6), Type 5 (Pattern 11) and Type 1 (Pattern 2) is relatively higher than other combination types. The features of these combination types are: (1) clients’ retrofitting purpose is mainly to improve indoor thermal environment, and (2) other influential decision makers are consultants (Pattern 2 and Pattern 6) or designers having knowledge about green building

designs (Pattern 11).

On the other hand, the diagram shows the “level of awareness on improving effect of energy-efficiency” in Type 5 (Pattern 10) is lowest. The features of this combination types are (1) clients’ retrofitting purpose is mainly to improve building appearance, (2) other influential decision makers include designers (having knowledge about green building designs) and constructors and (3) decision-making results have to be agreed by constructors.

Hence, it is clarified that the following situations might be able to achieve higher level of awareness on improving effect of energy-efficiency: (1) clients’ retrofitting purposes have better to include improving indoor thermal environment, (2) influential decision makers have better to have knowledge about green building designs, and (3) main influential decision makers should be designers or consultants.

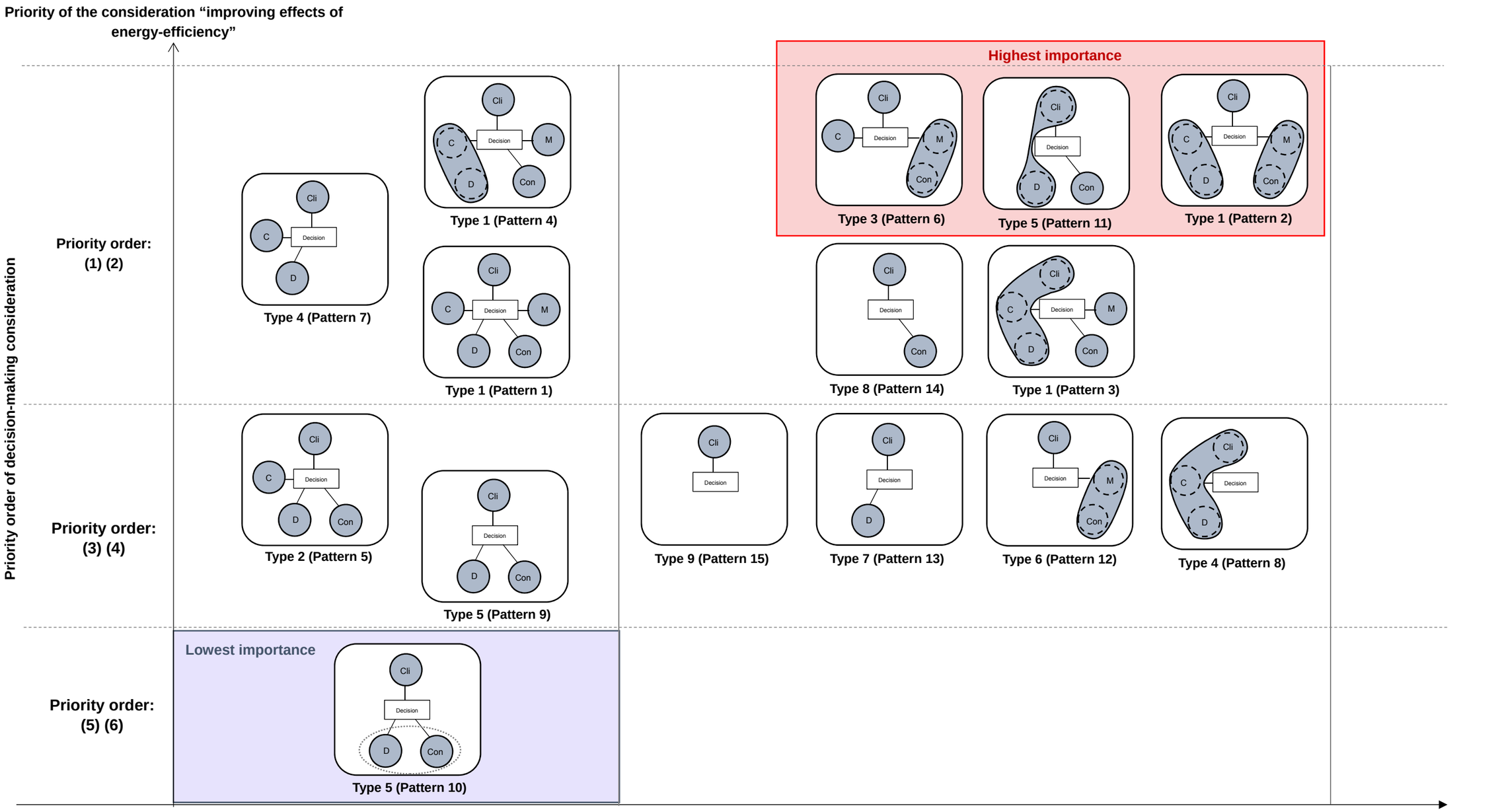


Figure 5-3 Evaluation chart regarding importance of the consideration “improving effects of energy-efficiency” being concerned

5.3 Comparisons of “how decision makers arrive at decisions” in nine combination types of decision makers

5.3.1 Interactions between decision makers

In this part, activities between decision makers in 9 types are concluded. Moreover, the decision makers who have activities regarding requests, suggestions and discussion with other decision makers are considered as influential decision makers. The results are presenting as follow.

In Type 1, activities between decision makers are concluded by viewing the activities in Pattern 1~ Pattern 4, and the activities regarding requests, suggestions and discussion show between clients, designers and consultants. (Fig. 5-13) Hence, it is clarified that clients, consultants and designers are influential decision makers in decision-making processes of Type 1, and the roles of material suppliers and constructors are only confirming information of retrofitting designs. (Fig. 5-14)

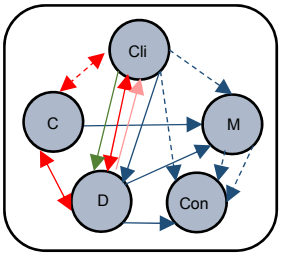


Figure 5-4
Activities between decision makers in Type 1

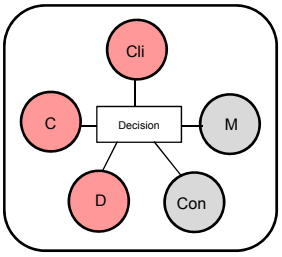


Figure 5-5
Influential decision makers in Type 1

In Type 2, activities between decision makers are concluded by viewing the activities in Pattern 5, and the activities regarding requests, suggestions and discussion show between clients, designers and consultants. (Fig.5-15) Hence, it is clarified that clients, consultants and designers are influential decision makers in decision-making processes of Type 2, and the roles of constructors are only confirming information of retrofitting designs. (Fig. 5-16)

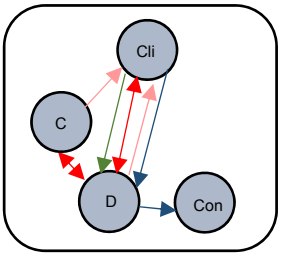


Figure 5-6
Activities between decision makers in Type 2

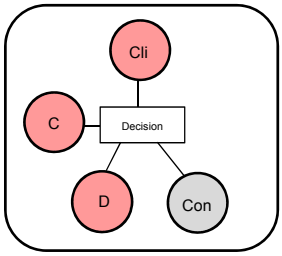


Figure 5-7
Influential decision makers in Type 2

In Type 3, activities between decision makers are concluded by viewing the activities in Pattern 6. The activities regarding requests show between clients and material suppliers, but there are no activities regarding suggestions and discussion show between decision makers. (Fig. 5-17) Hence, it is clarified that clients are the only influential decision makers in decision-making processes of Type 3, and the roles of material suppliers, constructors and consultants are only confirming information of retrofitting designs for clients. (Fig. 5-18)

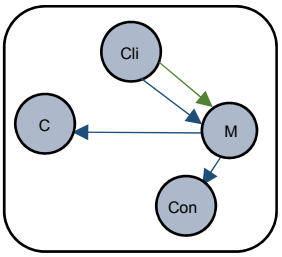


Figure 5-8
Activities between decision makers in Type 3

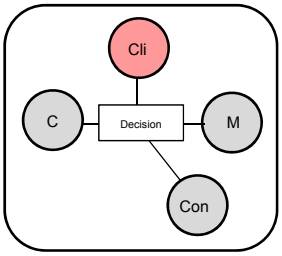


Figure 5-9
Influential decision makers in Type 3

In Type 4, activities between decision makers are concluded by viewing the activities in Pattern 7 and Pattern 8, and the activities regarding requests, suggestions and discussion show between clients, designers and consultants. (Fig. 5-19 ~ Fig. 5-21) Hence, it is clarified that clients, consultants and designers are influential decision makers of Type 4. (Fig. 5-22)

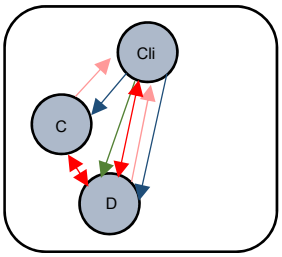


Figure 5-10
Activities between decision makers in Type 4 (Pattern 7)

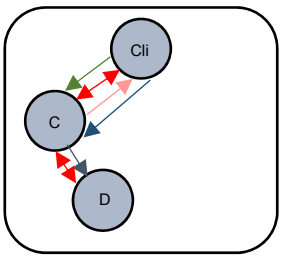


Figure 5-11
Activities between decision makers in Type 4 (Pattern 7)

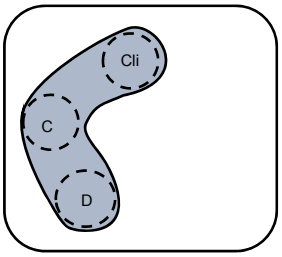


Figure 5-12
Activities between decision makers in Type 4 (Pattern 8)

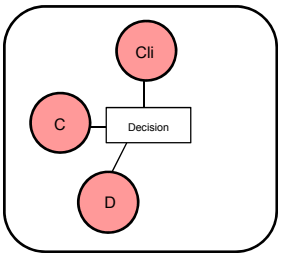


Figure 5-13
Influential decision makers in Type 4

In Type 5, activities between decision makers are concluded by viewing the activities in Pattern 9, Pattern 10 and Pattern 11, and the activities regarding requests, suggestions and discussions show between clients, designers and constructors. (Fig. 5-23) Hence, it is clarified that professions of influential decision makers have two types in decision-making processes of Type 5: (1) clients, designers and constructors are influential decision makers in Pattern 9 and Pattern 11 (Fig. 5-25), (2) clients and designers are influential decision makers in Pattern 10. (Fig. 5-24)

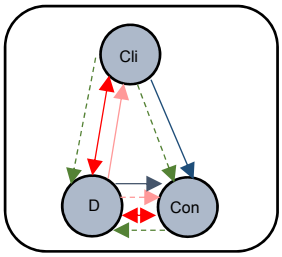


Figure 5-14
Activities between decision makers in Type 5

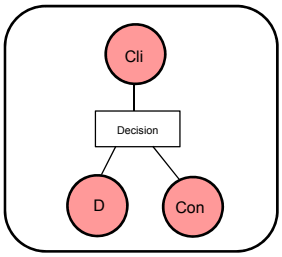


Figure 5-15
Influential decision makers in Type 5 (Pattern 10)

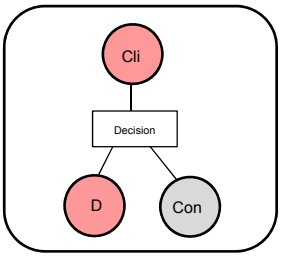


Figure 5-16
Influential decision makers in Type 5 (Pattern 9 & Pattern 11)

In Type 6, activities between decision makers are concluded by viewing the activities in Pattern 12. The activities regarding requests show between clients and material suppliers, but there are no activities regarding suggestions and discussion show between decision makers. (Fig.5-26) Hence, it is clarified that clients are the only influential decision makers in decision-making processes of Type 6, and the roles of material suppliers and constructors are only confirming information of retrofitting designs for clients. (Fig. 5-27)

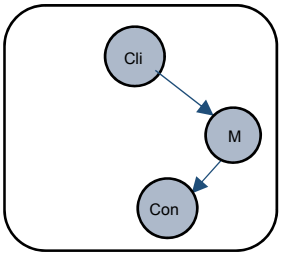


Figure 5-17
Activities between decision makers in Type 6

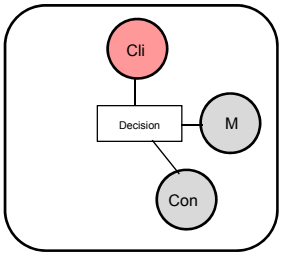


Figure 5-18
Influential decision makers in Type 6

In Type 7, activities between decision makers are concluded by viewing the activities in Pattern 13. The activities regarding requests, suggestions and discussions show between clients and designers. (Fig. 5-28) Hence, it is clarified that clients and designers are influential decision makers in decision-making processes of Type 7. (Fig. 5-29)

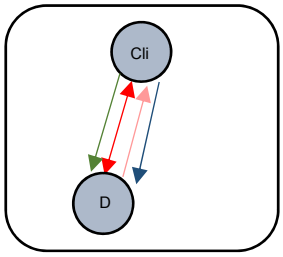


Figure 5-19
Activities between decision makers in Type 7

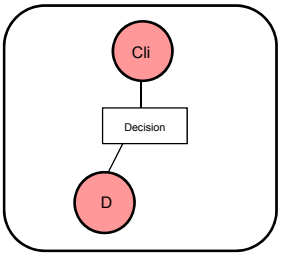


Figure 5-20
Influential decision makers in Type 7

In Type 8, activities between decision makers are concluded by viewing the activities in Pattern 14. The activities regarding requests, suggestions and discussions show between clients and constructors. (Fig. 5-30) Hence, it is clarified that clients and constructors are influential decision makers in decision-making processes of Type 8. (Fig. 5-31)

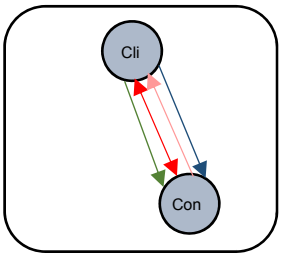


Figure 5-21
Activities between decision makers in Type 8

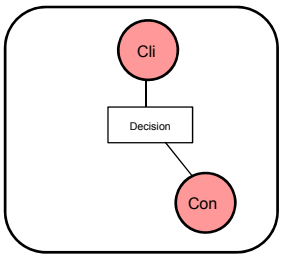


Figure 5-22
Influential decision makers in Type 8

In Type 9, activities between decision makers are concluded by viewing the activities in Pattern 15. (Fig. 5-32) There are no activities regarding requests, suggestions and discussion show between decision makers in Type 9. (Fig. 5-33)

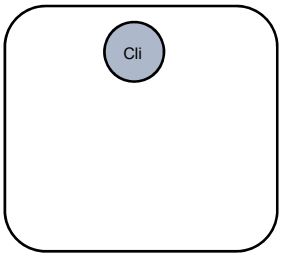


Figure 5-23
Activities between decision makers in Type 9

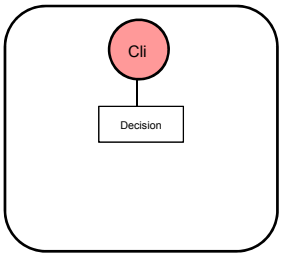


Figure 5-24
Influential decision makers in Type 9

5.3.2 Decision makers' working contents for assessing improving effect

In this part, the decision makers who assess improving effectiveness in the 9 types of decision making processes are presenting as below. (Table 5-4)

The decision makers who assess improving effectiveness in Type 1 are consultants and material suppliers.

The decision makers who assess improving effectiveness in Type 2, Type 3, and Type 4 are consultants.

The decision makers who assess improving effectiveness in Type 5 and Type 7 are designers.

The decision makers who assess improving effectiveness in Type 6 are clients and material suppliers.

The decision makers who assess improving effectiveness in Type 8 are constructors.

The decision makers who assess improving effectiveness in Type 9 are clients.

Table 5-4 Type of decision makers who assess improving effectiveness in 9 types

Type	Pattern	Improving effect of energy-efficiency	
Type 1	Pattern 1	(1) Consultant (2) Material suppliers	(1) Consultant (2) Material suppliers
	Pattern 2	(1) Consultant (Designer)	
	Pattern 3	(1) Client (Consultant & Designer), (2) Material supplier	
	Pattern 4	(1) Consultant (Designer)	
Type 2	Pattern 5	(1) Consultant	Consultant
Type 3	Pattern 6	(1) Consultant	Consultant
Type 4	Pattern 7	(1) Consultant	Consultant
	Pattern 8	(1) Client (Consultant & Designer)	
Type 5	Pattern 9	(1) Designer	Designer
	Pattern 10	(1) Designer	
	Pattern 11	(1) Client (Designer)	
Type 6	Pattern 12	(1) Client (2) Material supplier	(1) Client (2) Material supplier
Type 7	Pattern 13	(1) Designer	Designer
Type 8	Pattern 14	(1) Constructor	Constructor
Type 9	Pattern 15	(1) Client	Client

5.3.3 Assessment approaches for improving effectiveness

There are three assessment approaches for improving effectiveness are clarified in Chapter 4: (A) according to simulation and calculation, (B) according to theory of energy-saving design and data report, and (C) according to past experience, personal thought and feedback from users. The three assessment approaches for improving effectiveness utilized in decision-making processes of 9 combination types are presenting as follows. (Table 5-5)

In Type 1, Type 2 and Type 4, the approaches, according to simulation and calculation (A) and according to theory of energy-saving design and data report (B), are utilized for assessing improving effectiveness.

In Type 3, the approach, according to simulation and calculation (A), is utilized for assessing improving effectiveness.

In Type 5, both of the approaches, according to theory of energy-saving design and data report (B) and according to past experience, personal thought and feedback from users (C), are utilized for assessing improving effectiveness.

In Type 6, Type 7, Type 8 and Type 9, the approach, according to past experience, personal thought and feedback from users (C), is utilized for assessing improving effectiveness.

According to above research results, the findings are presenting as follows:

(1) The research results show that the approach according to simulation and calculation (A) is used in Type 1, Type 2, Type 3 and Type 4. It is found that the common feature of these combination types is having consultants participating in.

(2) The research results show that the approach according to theory of energy-saving design and data report (B) is used in Type 1, Type 2, Type 4, and Type 5. It is found that the common feature of these combination types is having designers participating in.

(3) The research results show that the approach according to past experience, personal thought and feedback from users (C) is used in Type 5, Type 6, Type 7, Type 8 and Type 9. It is found that the common feature of these combination types having no consultants participating in.

Table 5-5 Assessment approaches for improving effectiveness in 9 types

	Assessment approaches for improving effectiveness
Type 1	(A) Simulation and calculation, (B) Theory of energy-saving design & Data report
Type 2	(A) Simulation and calculation, (B) Theory of energy-saving design & Data report
Type 3	(A) Simulation and calculation
Type 4	(A) Simulation and calculation (B) Theory of energy-saving design & Data report
Type 5	(B) Theory of energy-saving design & Data report, (C) Past experience, Personal thought & Feedback from users
Type 6	(C) Past experience, Personal thought & Feedback from users
Type 7	(C) Past experience, Personal thought & Feedback from users
Type 8	(C) Past experience, Personal thought & Feedback from users
Type 9	(C) Past experience, Personal thought & Feedback from users

5.3.4 Finding: Evaluating result regarding “level of rigor in discussion and assessment”

“Level of rigor in discussion and assessment” in the nine combination types of decision makers is evaluated by (1) complexity of communication between decision makers, (2) professional degree of assessment on improving effectiveness, and (3) accuracy of assessment on improving effectiveness. The results are illustrated as diagrams below. (Fig. 5-34 & Fig.5-35)

[Complexity of communication between decision makers]
“The complexity of communication between decision makers” in the nine combination types of decision makers is clarified according to the research results regarding “decision makers’ interactive relationships” and “activities between decision makers”. The result is presented as horizontal axis in the diagram. The more decision makers participated in discussing and confirming activities, the higher complexity of communication are between decision makers. (Fig. 5-34)

[Professional degree of assessment on improving effectiveness]
“The professional degree of assessment on improving effectiveness” in the nine combination types of decision makers is clarified according to the research results regarding “decision makers’ working contents for assessments”. Decision makers’ working contents for assessment of improving effectiveness are divided into two parts on horizontal axis of diagram: (A) not consultant assessment, and (B) consultant assessments. The improving effectiveness of retrofitting designs assessed by consultants are considered having higher professional degree of assessment on improving effectiveness; the improving effectiveness of retrofitting designs assessed by non-consultants are considered having lower professional degree of assessment on improving effectiveness. (Fig.5-35)

[Accuracy of assessment on improving effectiveness]
“The accuracy of assessment on improving effectiveness” in the nine combination types of decision makers is clarified according to the research results regarding “assessment approaches for improving effectiveness”. The assessment approaches for improving effectiveness are showing on vertical axis of diagram and divided into three categories: (A) simulation and calculation, (B) theory of energy-saving design and data report, and (C) past experience, personal thought and feedback from users. The assessment approach “simulation and calculation” (A) is considered having higher accuracy of assessment on improving effectiveness; the assessment approach “past experience, personal thought and feedback from users” (C) is considered having lower accuracy of assessment on improving effectiveness. (Fig.5-35)

[Summary]

According to above research results, the evaluation regarding "level of rigor in discussion and assessment" is clarified and can be conclude. In summary, "level of rigor in discussion and assessment" is found different in the decision-making processes executed by different compositions of decision makers.

The diagram shows that the "level of rigor in discussion and assessment" is highest in Type 1 (Pattern 1, Pattern 4 and Pattern 2). The features of these combination types are: (1) all five profession types of decision makers are included, (2) designers have suggestions and discussions with clients and also confirmations with constructors and material suppliers, and (3) decision-making considerations are assessed by decision makers from different fields.

The diagram shows that the "level of rigor in discussion and assessment" is lowest in Type 9 (Pattern 15). The features of this type are: (1) clients are the only decision makers, (2) the clients have no interactions with other decision makers, and (3) decision-making considerations are all assessed by clients.

Hence, it is clarified that confirming decision-making considerations comprehensively and carefully by professionals from different fields might be able to achieve higher level of rigor in discussion and assessment.

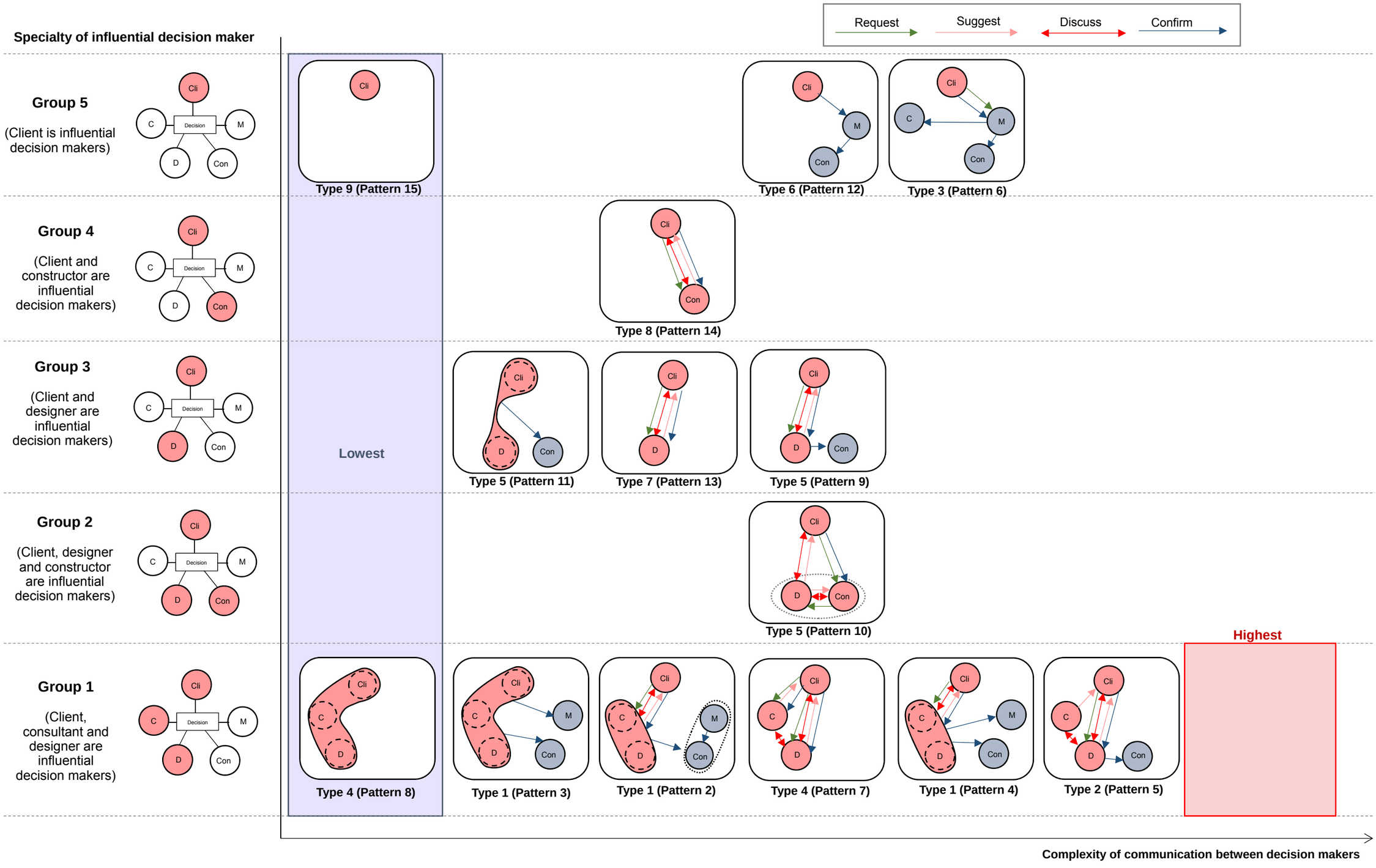


Figure 5-25 Evaluation chart regarding complexity of communication between decision makers

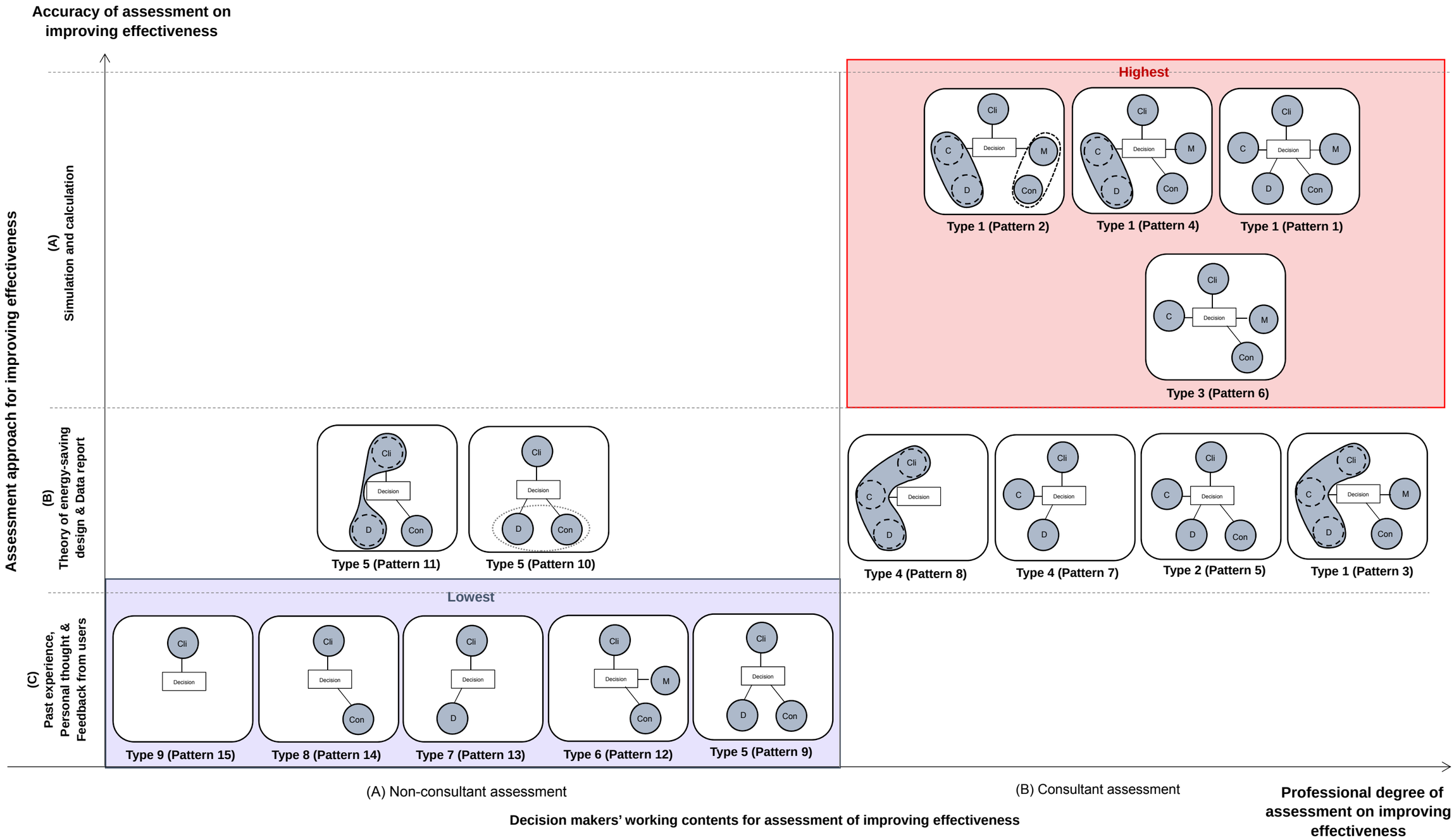


Figure 5-26 Evaluation chart regarding accuracy and professional degree of assessment on improving effectiveness

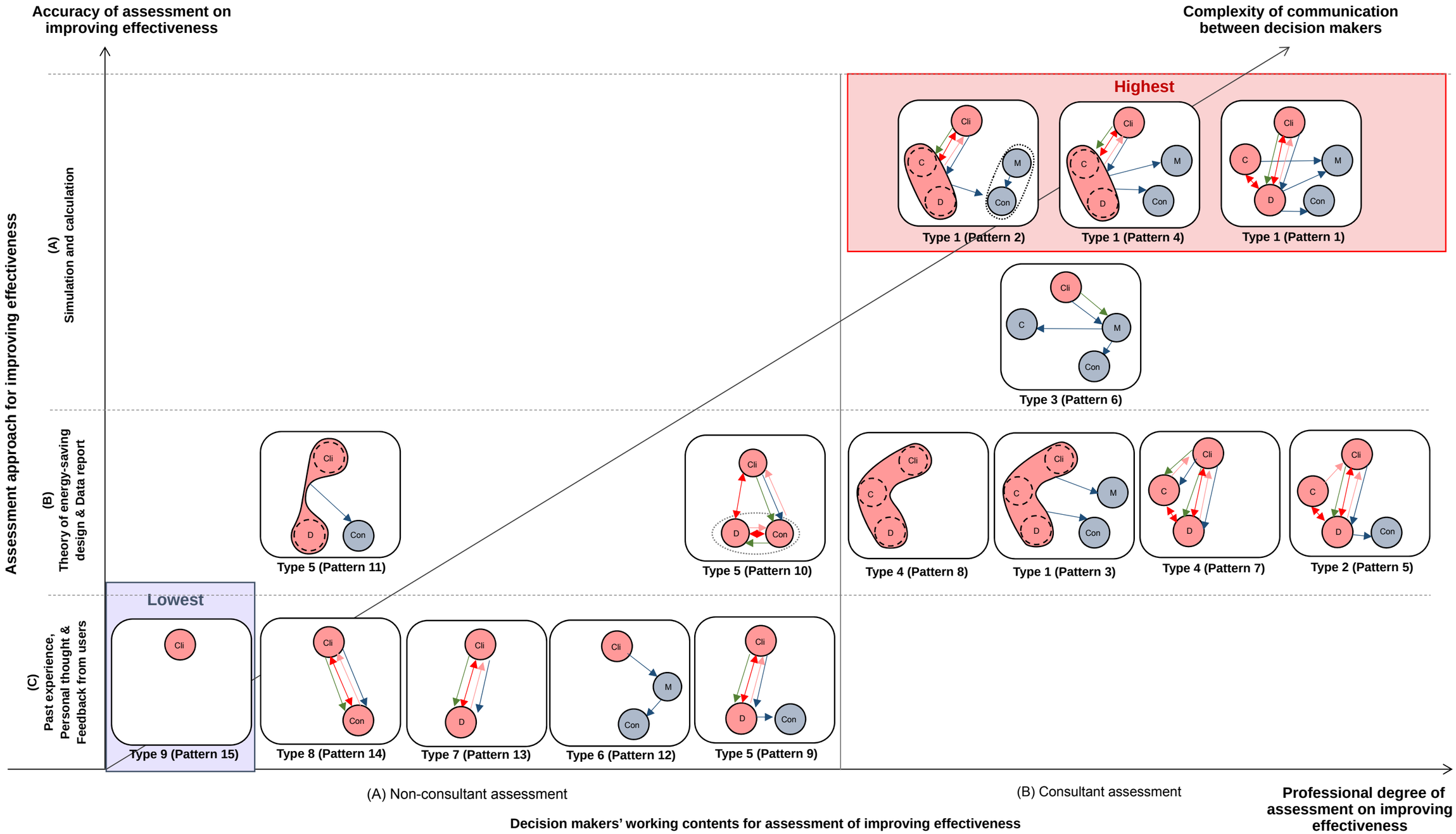


Figure 5-27 Evaluation chart regarding accuracy and professional degree of assessment on improving effectiveness

5.4 Conclusion of Chapter 5

5.4.1 Summary

In Chapter 5, different decision-making processes in nine combination types of decision makers are compared. (Table 5-6) Moreover, qualities of decision-making processes executed by decision makers in different compositions are evaluated. According to above research results, suggestions for decision makers in a small-scale building construction system to ensure quality of decision-making processes are also provided.

5.4.2 Quality of decision-making processes executed by different compositions of decision makers in a small-scale building construction system

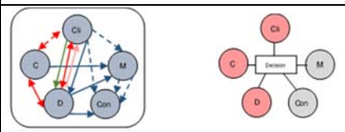
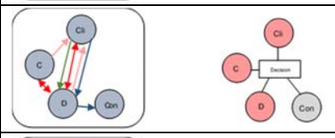
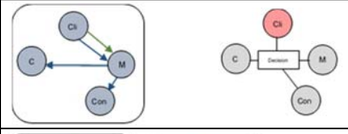
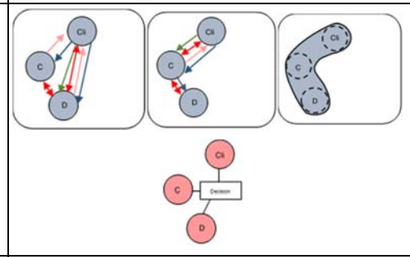
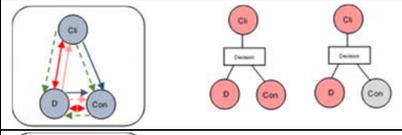
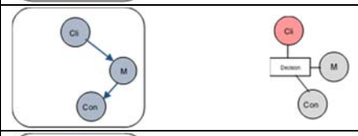
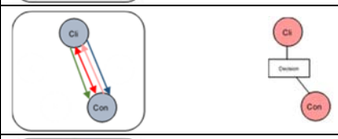
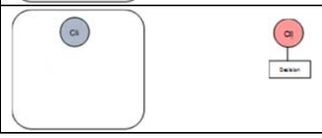
By understanding “what decision makers think,” their “level of awareness regarding energy efficiency” can be determined. By viewing “how decision makers arrive at decisions”, the “level of rigor in discussions and assessments” can be ascertained. Afterwards, the quality of the decision-making processes were evaluated by the “level of awareness for improving effects of energy efficiency” and “the level of rigor in discussions and assessments.” According to evaluation results, these two components were found to be different in the decision-making processes executed by different compositions of decision makers.

Regarding “level of awareness on improving effect of energy-efficiency”, the research results showed that the following situations might be able to achieve higher level of awareness on improving effect of energy-efficiency: (1) clients’ retrofitting purposes have better to include improving indoor thermal environment, (2) influential decision makers have better to have knowledge about green building designs, and (3) main influential decision makers should be designers or consultants.

Regarding “level of rigor in discussion and assessment”, the research results showed that confirming decision-making considerations comprehensively and carefully between professionals from different fields might be able to achieve higher level of rigor in discussion and assessment.

Moreover, it was found that retrofitting designs which have higher energy-efficient performance are usually adopted in the decision-making processes which have higher level of awareness regarding energy efficiency” and higher level of rigor in discussions and assessments.

Table 5-6 Features of decision-making processes relating to the consideration "improving effect of energy-efficiency" in 9 types

Type	What decision makers think			How decision makers arrive at decisions		
	Decision makers' consideration	**Priority orders of consideration**	**Development processes of consideration**	**Activities between decision makers**	**Working content for assessment**	**Assessment approaches for improving effectiveness**
Type 1	The considerations in six categories are almost concerned, except "functionality" is according to clients' needs.	The consideration is considered as first priority and second priority.	The development processes of the consideration Including two situations: the consideration is considered from the beginning and also during processes.		The consideration is assessed by consultants. The consultants might also confirm the performance with material suppliers.	(A) Simulation and calculation, (B) Theory of energy-saving design & Data report
Type 2	The considerations in six categories are all concerned	The consideration is considered as third priority and fourth priority.	The consideration is considered during processes		The consideration is assessed by consultants.	(A) Simulation and calculation (B) Theory of energy-saving design & Data report
Type 3	The considerations regarding "functionality" and "legality" are not concerned	The consideration is considered as first priority	The consideration is considered from the beginning		The consideration is assessed by consultants.	(A) Simulation and calculation
Type 4	The considerations in six categories are all concerned	The consideration is considered as first priority, second priority and third priority.	The development processes of the consideration Including two situations: the consideration is considered from the beginning and also during processes.		The consideration is assessed by consultants.	(A) Simulation and calculation (B) Theory of energy-saving design & Data report
Type 5	The considerations in six categories are all concerned	The consideration is considered as first priority, fourth priority and sixth priority.	The development processes of the consideration Including two situations: the consideration is considered from the beginning and also during processes.		The consideration is assessed by designers.	(B) Theory of energy-saving design & Data report, (C) Past experience, Personal thought & Feedback from users
Type 6	The consideration regarding "legality" is not concerned	The consideration is considered as third priority	The consideration is considered from the beginning		The consideration is assessed by clients and material suppliers.	(C) Past experience, Personal thought & Feedback from users
Type 7	The considerations in six categories are all concerned	The consideration is considered as third priority	The consideration is considered from the beginning		The consideration is assessed by designers	(C) Past experience, Personal thought & Feedback from users
Type 8	The consideration regarding "legality" is not concerned	The consideration is considered as first priority, second priority and third priority.	The consideration is considered from the beginning		The consideration is assessed by constructors	(C) Past experience, Personal thought & Feedback from users
Type 9	The considerations regarding "legality" and "durability" are not concerned	The consideration is considered as second priority and third priority.	The consideration is considered from the beginning		The consideration is assessed by clients	(C) Past experience, Personal thought & Feedback from users

5.4.3 Suggestions for decision makers in a small-scale building construction system to ensure quality of adopting energy-efficiency retrofits

According to above research results, the suggestions to ensure quality of decision-making processes in a small-scale building construction system are showed as follows and include strategies, checklists and evaluation guidelines.

(1) Strategies for raising level of awareness on improving effect of energy efficiency

First, it is found: (1) the design decisions in many cases are especially influenced by clients' opinions in a small-scale building construction system, and (2) higher level of awareness on improving effect of energy-efficiency shows in decision-making processes when clients are willing to improve thermal indoor environment. Therefore, educating and arising awareness of clients about benefit of energy-conservation is important.

The strategy for raising level of awareness on improving effect of energy efficiency refers increased communication between influential decision makers, especially with regard to paying attention to improving energy efficiency. (Figure 5-36)

For instance, the strategies for the specialties of influential decision makers who are clients, consultants and designers are: (a) consultants should persuade clients and designers about paying attentions on effects of energy efficiency, and (b) consultants should persuade designers and then the designers should persuade clients about paying attentions on effects of energy efficiency.

The strategy for the specialties of influential decision makers who are clients, designers and constructors is that designer should persuade clients and constructors about paying attentions on effects of energy efficiency.

The strategy for the specialties of influential decision makers who are clients and designers is that designers should persuade clients about paying attentions on effects of energy efficiency.

The strategy for the specialties of influential decision makers who are clients and constructors is that constructors should persuade clients about paying attentions on effects of energy efficiency.

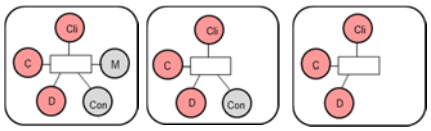
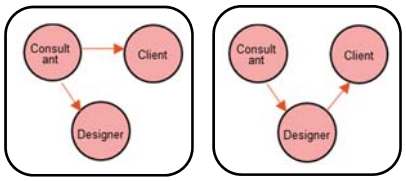
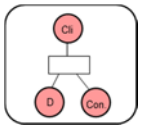
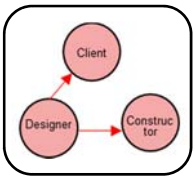
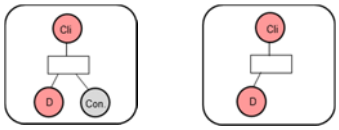
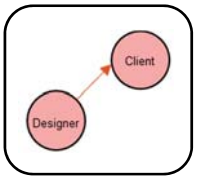
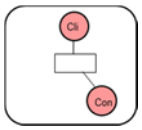
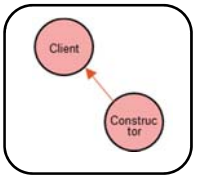
Specialty of influential decision makers		Suggestion
Client, Consultant, Designer		
Client, Designer, Constructor		
Client, Designer		
Client, Constructor		

Figure 5-28 Strategies for raising level of awareness on improving effect of energy efficiency

(2) Checklist for enhancing level of rigor in discussion and assessment

A checklist includes constants of decision-making consideration and assessment works regarding six categories of considerations is suggested for enhancing level of rigor in discussion and assessment. (Table 5-7)

For example, the considerations in the category regarding “improving effects of energy efficiency” might include (a) improvement of indoor thermal environment, and (b) reduction of urban heat island effect. Moreover, its assessment works include (a) checking performance of applied retrofitting methods, (b) checking data of material performance and (c) users’ experience.

Table 5-7 Checklist for planning energy-efficiency retrofit

Category of consideration	Contents of decision-making consideration	Assessment work
Improving effects of energy efficiency	□ Improvement of indoor thermal environment □ Reduction of urban heat island effect	□ Checking performance of applied retrofitting methods □ Checking data of material performance □ Checking users’ experience
Functionality	□ Repair of building damage part □ Renew of building appearance □ Function of building envelope □ Integration with other component	□ Confirming clients’ expected functions □ Checking additional functions of retrofitting methods □ Checking properties of material
Affordability	□ Material cost □ Constructing cost □ Client’s budget / Amount of governmental subsidy	□ Confirming clients’ budget □ Checking constructing cost □ Checking material cost □ Checking maintenance cost
Legality	□ Building management regulation □ Need of license application	□ Checking building management regulations of the buildings expected to be retrofitted □ Checking general building regulations regarding safety of escape route, property right and need of license application for building design changes and additions
Constructability	□ Constructing period □ Feasibility of construction □ Impacts during constructions	□ Confirming clients’ expected retrofitting period □ Checking constructing period □ Checking feasibility of application □ Checking strength of existing structure
Durability	□ Need of maintenance □ Period of use □ Capability of weather resistance	□ Confirming clients’ expected useable duration and maintenance frequency □ Checking useable duration of material □ Checking needs and frequency of maintenance

(3) Evaluation guideline of energy-efficiency retrofitting methods for confirming suitable retrofitting methods

An evaluation guideline of energy-efficiency retrofitting methods is suggested for decision makers confirming suitable retrofitting methods. The features of 18 retrofitting methods in six categories of considerations are listed in the table. (Table 5-8)

Take one retrofitting method as an example, the retrofitting method O1 (adding external shading device on opening) is considered having following features regarding six categories of considerations:

(A) Improving effect of energy-efficiency: The method has great improvement effect of energy-efficiency regarding shading performance.

(B) Functionality: The method is able to reduce rainwater and wind from outside, enhance privacy, security, control natural light, be a sound barrier, combine insulation layer of external wall (W2).

(C) Affordability: The cost of adopting the method is considered higher depending on material types, number and design. Moreover, the cost might increase when installing on high-rise buildings

(D) Legality: The method: (a) will change building appearance and won't meet building management regulations of condominium, (b) might need to apply miscellaneous license, and (c) installation might be over the property line.

(E) Constructability: The method is considered having shorter installation period, less affect impact on indoor space when installing, might increase load on existing building structures and might be difficult and not safe to install on high-rise buildings.

(F) Durability: Useable duration and need of maintenance are depending on applied material

Suggestions for quality enhancement of adopting energy-efficiency retrofits in a small-scale building construction system were provided in Chapter 5. Next, these suggestions are going to be verified by applying in two real design projects in Chapter 6.

Table 5-8 Suggested evaluation guideline

Retrofitting methods / Evaluating category			Improving effect of energy-efficiency	Functionality	Affordability	Legality	Constructability	Durability
Suggested improving methods	Opening	**O1: Adding external shading devices**	- Great improvement effect regarding shading performance	- Able to reduce rainwater and wind from outside - Able to enhance privacy - Able to enhance security - Able to control natural light - Able to be a sound barrier - Able to combine with insulation layers of external wall (W2)	- Cost is considered higher depending on material types, number and design -Cost might increase when installing on high-rise buildings	-This method will change building appearance and won't meet building management regulations of condominium - Might need to apply miscellaneous license - The installation might be over the property line	- Shorter installation period - Less impact on indoor space when installing - Can be installed from inside or outside of building - Might increase load on existing building structures - Might be difficult and not safe to install on high-rise buildings	- Useable duration and need of maintenance are depending on applied material
		O2: Replacing by high performance window	- Good improvement effect for insulating performance	- Good to be used when existing windows are damaged - Able to renewing building appearance - Able to improve water tightness and airtightness function of openings - Able to enhance soundproof function of openings - Have window display function and good for commercial space - Able to keep indoor space warmer as well	- Cost is depending on material types, number and design	- Good to be used when building management regulation is concerned	- Installation period is depending on construction methods - Can be installed from inside or outside of building - Will affect indoor space when installing - Might have security issue during installations - Might affect existing building structures depending on construction methods	- Has long useable duration and less need of maintenance
		O3: Moving position of window	- Great improvement effect for shading performance	- Able to change building appearance design - Able to create a balcony space - Able to reduce rainwater coming from outside	- More expensive than other methods	- Might need to apply license for changing building appearances	- Longer installation period than other methods - Will affect indoor decorations and usually is chose when indoor space also renewing - Will affect existing building structures	- Has longest useable duration - No maintenance needs
		O4: Adding window film	- Least improvement effect for shading and insulating performance	- Able to enhance security	- Cost is depending on types of films, but usually considered cheaper than other methods	- Good to be used in condominium when building management regulation is concerned	- Short installation period - Can be installed from inside or outside of building - Good to be used when load bearing of existing building structures is worried	- Shorter useable duration than other methods
		O5: Adding interior shading devices	- Less improvement effect for shading performance than the method "O1"	- Able to combine with indoor decorations	- Cost is depending on material types, number and design of shading devices	- Good to be used when building management regulation is concerned	- Short installation period - Can be installed from inside	- Useable duration and need of maintenance are depending on material
		O6: Adding second window	- Great improvement effect for insulating performance	- Able to improve water tightness and airtightness function of openings - Able to enhance soundproof function of openings - Able to keep indoor space warmer as well	- Cost is depending on material types, number and design	- Good to be used when building management regulation is concerned	- Can be installed on inside or outside of existing windows - Can be installed from inside or outside of building - Short installation period - Can reduce the influence on indoor space when installing outside - Might increase load on existing building structures	- Has long useable duration and less need of maintenance

Suggested improving methods	**Wall**	**W1: Adding external shading devices or second walls**	- Great improvement effect for shading performance	- Able to change building appearance design - Able to protect existing structure - Able to reduce rainwater coming from outside - Able to enhance soundproof function	- Cost is depending on material types, area and designs, and usually is considered more expensive than other methods	-This method will change building appearance	- Easy to be installed on low-rise buildings, but might be harder to be installed on high-rise buildings - Low impact on indoor space when installing, but might increase load on existing structure - Might affect existing structure	- Useable duration and need of maintenance are depending on types of material
		W2: Adding insulation material externally	- Great improvement effect for insulating performance	- Able to enhance soundproof function - Able to change building appearance design - Able to protect existing structure - Able to keep indoor space warmer as well	- Cost is depending on material types and area	-This method might change building appearance	- Short installation period - Should be installed from outside - Low impact on indoor space when installing - Might increase load on existing building structures - Low impact on existing structure	- Useable duration and need of maintenance are depending on types of materials and designs - Longer duration and less need of maintenance than Method W4
		W3: Adding insulation material internally	- Less improvement effect for insulating performance	- Able to enhance waterproof function - Able to cover existing walls - Able to integrate with indoor decorations	- Cost is depending on material types and area	- The method won't affect building appearances	- Short installation period - Should be installed from inside - Will affect indoor space when installing - Low impact on existing structure	- Useable duration and need of maintenance are depending on types of material. -Has longer durability than installing externally
		W4: Covering heat reflective or insulating paint externally	- Least improvement effect for insulating performance	- Able to enhance waterproof function - Able to change building appearance design	- Cost is depending on material types and area, and is usually considered cheaper than other methods	-This method will change building appearance	- Short installation period - Should work from outside - Low impact on indoor space when installing, can reduce the influence on indoor space when installing outside - Good to be used when load bearing of existing building structures is worried - Low impact on existing structure	- Shorter useable duration than other methods
		W5: Replacing by higher performance finishing material	- Good improvement effect for insulating performance	- Able to change building appearance design - Able to repair existing damages	- Cost is depending on material types and area	-This method might change building appearance	- Long installation period - Should work from outside - High impact on existing structures, environments and habitants	- Useable duration and need of maintenance are depending on types of material, but considered having longer useable duration and less need of maintenance
		W6: Adding greenery vertically	- Great improvement effect regarding shading performance	- Able to create natural landscape	- Cost is considered higher than other methods due to extra cost for installing watering system	-This method might change building appearance	- Might need to build a new extra structure - Might increase load on existing structure and impact existing structure	- Is considered shorter useable duration than other methods and high maintenance needs - Roots of plants might damage existing structure
	Roof	**R1: Adding second roof or canopy**	- Great effect for enhancing shading performance	- Able to enhance weather resistance (rainwater, sunburn)	- Cost is depending on material types, area and designs, and usually is considered more expensive than other methods	- The height, area and form of structure have to meet the building regulation	- Low impact when installations, but might increase load on existing structure	- Useable duration and need of maintenance are depending on types of materials and designs
		R2: Adding insulation material externally	- Great improvement effect for insulating performance	- Able to enhance waterproof and protect existing structures	- Cost is depending on material types and area	- The material should choose flame retardant	- Low impact when installations, but might increase load on existing structure	- Useable duration and need of maintenance are depending on types of materials
		R3: Adding heat reflective or insulating paint externally	- Least improvement effect for insulating performance	- Able to enhance waterproof performance	- Cost is depending on material types and area, and is usually considered cheaper than other methods	-The glare issue should be noticed	- Low impact when installation and on existing structure	- Is usually considered shorter useable duration than other methods
		R4: Adding greenery	- Able to enhancing shading and insulating performance - Able to reduce unban heat island effect	- Improving landscape on rooftop	- Cost should include material cost, construction cost and expense for waterproof, watering and drainage system	-	- Low impact when installations, but might increase load on existing structure	- Is considered shorter useable duration than other methods and high maintenance needs
		R5: Watering	- Good improvement effect for cooling down	Not considered	- Cost is considered low	-	- Low impact on existing structure	Not considered
		R6: Adding insulation material internally	- Less improvement effect by considering Taiwanese climate	- Might reduce water leakage problem	- Cost is depending on material types and area	- The material should choose flame retardant	- Low impact on existing structure - Able to work inside the space	- Useable duration and need of maintenance are depending on types of materials

Chapter 6
Verification

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6.1 Overview

(1) Research background

According to research results of Chapter 5, it is found decision making processes of retrofitting designs executed by different compositions of decision makers in a small-scale building construction system have different qualities. To enhance the quality of decision-making processes, the following suggestions are provided: (a) the strategy refers increased communication between influential decision makers, especially with regard to paying attention to improving energy efficiency, (b) the checklist for enhancing the level of rigor in discussion and assessment, and (c) the evaluation guideline for finding suitable energy-efficiency retrofitting methods listing retrofitting features of the methods in six categories.

(2) Research objective

In Chapter 6, the objective is to verify the suggestions regarding quality enhancement of adopting energy-efficiency retrofit in the small-scale building construction system.

(3) Research subject and methodology

In this chapter, two cases which the author participated as one of decision makers are utilized for verifying the usefulness of proposed suggestions. The verifying methods comprised applying the suggestions to increase the chances of adopting promoted energy-efficiency retrofitting methods in the two cases.

(4) Research contents and frameworks

The research contents and frameworks presented in Figure 6-1. The contents in Section 6.2 defined positions of cases and suggested strategies for two studied cases. The contents in Section 6.3 and Section 6.4 are the verification results of two cases. Finally, the above research results are summarized in Section 6.5.

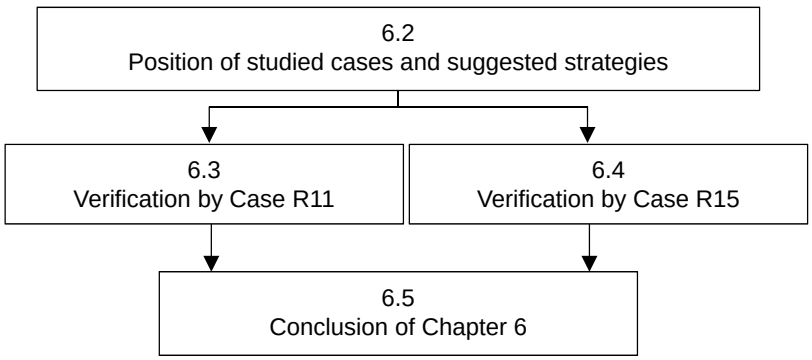

Figure 6-1 Research framework of Chapter 6

6.2 Position of studied cases and suggested strategies

6.2.1 Compositions of decision maker

According to research results of Chapter 3 regarding professions of decision makers, both of Case R11 and Case R15 are considered as “Combination type 5” which is including clients, designers and constructors. (Figure 6-2)

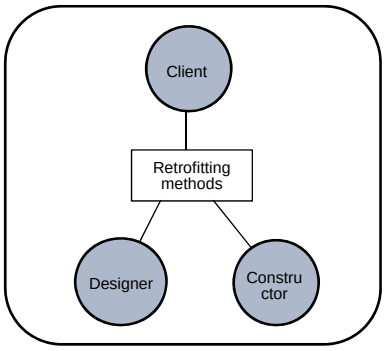

Figure 6-2
Profession of decision maker in Combination type 5

Furthermore, according to research results of Chapter 3 regarding relevance of decision makers’ professions, Case R11 and Case R15 are categorized into different patterns. Case R11 is categorized into Pattern 9 which includes three independent types of professions. Case R15 is a constructor-lead turn-key project (a designer and constructor are working as a group). It is categorized into Pattern 10 which includes one independent type and two multiple types. (Figure 6-3)

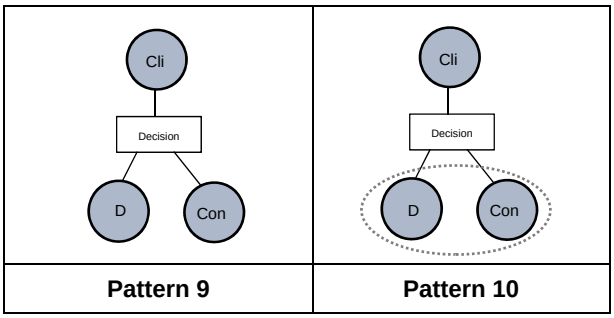

Figure 6-3
Relevance of decision makers’ professions in Pattern 9 and Pattern 10

6.2.2 Feature of decision making process

According to evaluating results of Chapter 5, the features of decision-making processes in Pattern 9 and Pattern 10 are showing as follows.

The decision-making processes of retrofitting designs in Type 5 are found (a) having comprehensively thinking in six categories of considerations but less focused on “improving effects of energy efficiency”, (instead, they are more focusing on other considerations such as functionality, affordability, legality and constructability depending on client’s requirements) and (b) less emphasizing on “accuracy of improvement effectiveness”. Moreover, designers are found as the decision makers who suggest clients to focus improving performance of energy efficiency.

Furthermore, the decision-making processes in Pattern 9 is that a designer is a main person who is in charge of retrofitting design. During a decision-making process, the designer mainly suggests and discusses with a client about ideas of retrofitting designs, and then confirms retrofitting cost and constructing period with a constructor. Hence, the decision makers whose considerations would influence results of retrofitting designs greatly are the client and the designer.

The decision-making processes in Pattern 10 is different from Pattern 9, a designer is not only suggests and discusses the ideas of retrofitting designs with clients but also a constructor. Hence, the decision makers whose considerations would influence results of retrofitting designs greatly are the clients, the designer and the constructor.

6.2.3 Suggested for studied cases

According to above features of decision making processes, suggested strategies to raise level of awareness on “improving effects of energy efficiency” are as follows.

(1) For Project A is a designer should increase communications with a client about paying attentions on improving effects of energy efficiency.
(2) For Project B is a designer should increase communications with clients and constructors about paying attentions on improving effects of energy efficiency.

Furthermore, a proposed checklist and a decision-making reference are suggested to utilize as a common communicating platform among decision makers and assessing tool in small-scale building construction systems to raise level of rigor in discussion and assessment.

6.3 Verification by Project A (Case # R11)

6.3.1 Introduction of case

[Feature of existing building]

The building is located in Kaohsiung city and was built in 1976. It is a six-story building and constructed by reinforced concretes and bricks. Existing windows are consisted by aluminum frames with single glazing; existing walls are covered by tiles.

The problems of existing building show that building façade is shabby, building components and structures are damaged, interior space is not suitable for current usage and indoor environment is uncomfortable for living.

[Client's retrofitting purpose]

A client aims to redesign building appearance, repairing damages, enhance building functions and improving indoor thermal environment.

[Feature of retrofitting scale]

The retrofitting project is implemented since 2014. Retrofitting part of this project include building envelope and its interior space.

[Features of decision makers]

(1) Client: The building owner is interested in sustainable design.

(2) Designer: The main designer is an architect who has about 40 years' experience on building designs and also has basic knowledge about sustainable building design. He is in charge of building and interior designs in this project.

(3) Constructor: The constructor is belonging to a small-scale construction company.

[Required constructing period]

The design period and constructing period are not specifically required by the client.

[Client's budget]

In this case, the client's budget is less than ten million new Taiwan dollar (equal to thirty-six million Japanese yen).

Figure 6-4 Image of existing building in Case R11 (Before the retrofit)

6.3.2 Observation of decision-making process

The decision-making process of Case R11 is described as follows.

Step 1:
A client described his requirements for a building renovation to a designer

Step 2:
The designer suggested client to focus on the consideration "improving effects of energy efficiency" in energy-efficiency retrofitting designs (adding external shading devices on openings (O1) + window replacements (O2), adding external shading devices (W1) + replacement of finishing material (W5) on walls and adding greenery on roofs (R4)). The client accepted the idea after discussing with the designer.

Step 3:
The designer used proposed checklist to confirm the feasibility of proposed retrofitting designs with a constructor regarding affordability and constructability. And then, the designer modified the retrofitting designs (adding external shading devices on openings (O1) + window replacements (O2), replacement of finishing material (W5) on walls and adding greenery on roofs (R4)).

Step 4:
The designer discussed proposed energy-efficiency retrofitting designs with the client and modified the proposed designs (adding external shading devices (O1) + window replacements (O2) on openings, replacement of finishing material on walls (W5) and adding insulation material externally on roofs (R2)) to meet the client's requirements by using the checklist

Step 5:
The designer confirmed a final proposal of retrofitting design with the client and constructor by using the checklist.

Step 2 and Step 4 are the decision-making processes utilizing suggested strategies (which is focusing on the communications between a designer and a client to enhance the priority order of the consideration "improving effects of energy efficiency" in retrofitting designs).

Design proposal 1

Design proposal 2

Final proposal

Figure 6-5 Design proposals of Case R11

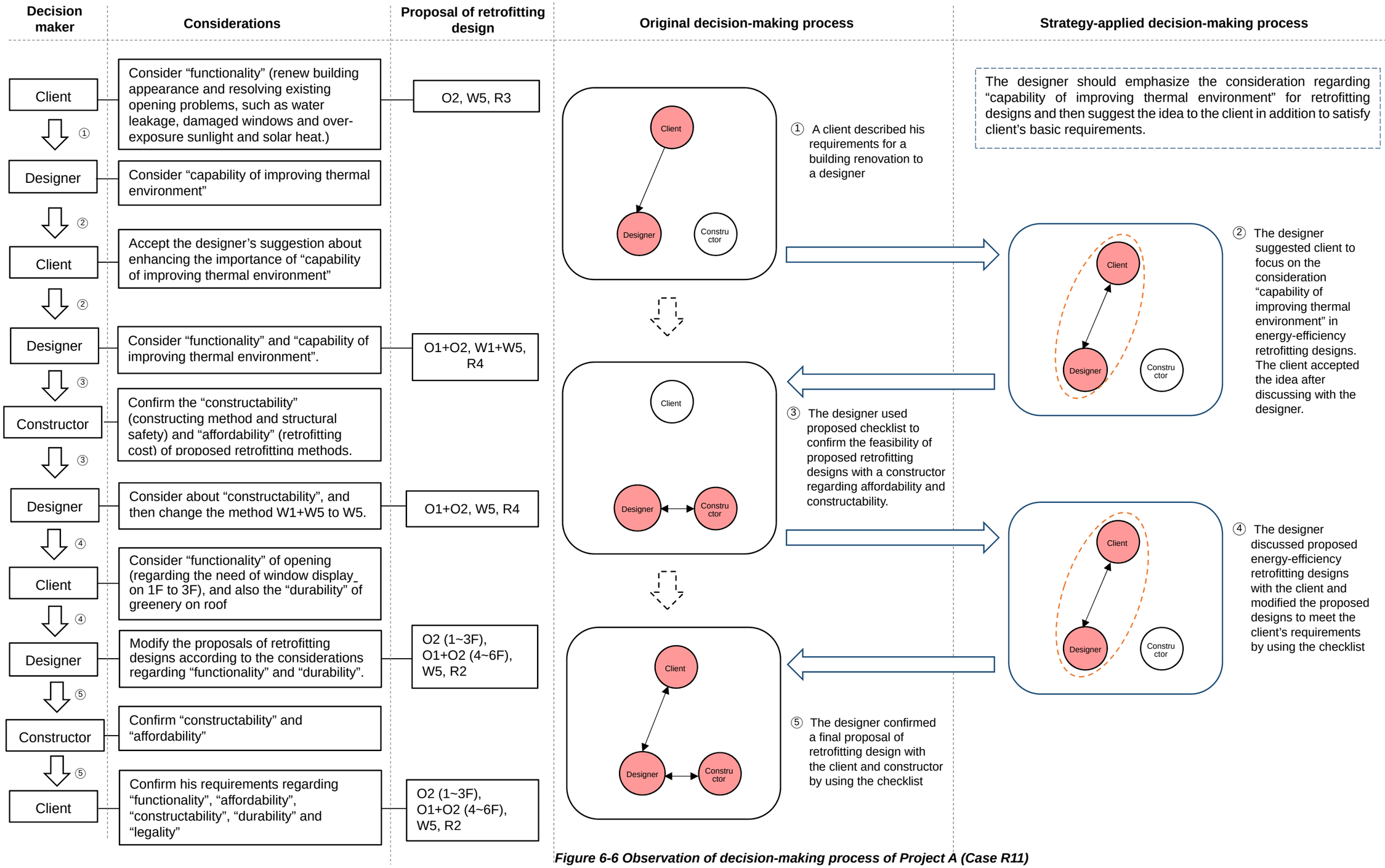

Figure 6-6 Observation of decision-making process of Project A (Case R11)

6.3.3 Result of verification in Project A (Case R11)

According to observing results, it is found:

(1) By using decision-making reference as a common communicating platform, decision makers are able to find out suitable retrofitting methods (O1+O2, W5, R2).

(2) The proposed checklist do assist decision makers to confirm their decision-making considerations and assessment works for design proposals.

(3) The promoted energy-efficient method O1 (adding external shading devices) and R2 (adding insulation on roof) are successfully applied in Case 11 by focusing on the communications with clients. The clients would accept the designer's suggestions regarding adoption of energy-efficiency retrofitting methods when the clients confirm the methods can meet their retrofitting purposes and requirements.

6.4 Verification by Project B (Case R15)

6.4.1 Introduction of case

[Feature of building]

Case R15 is the project includes 11 residential buildings. The 11 buildings are four-story height and constructed by reinforced concrete. Existing windows are consisted by aluminum frames with single glazing; existing walls are covered by tiles.

The problems of existing building show that building façade is shabby, building components are damaged due to gas explosion.

[Client's retrofitting purpose]

The retrofitting purposes of clients are redesign building appearance, replacing existing materials and repairing damages.

[Feature of retrofitting scale]

The retrofitting project is implemented in 2014. The retrofitting parts of this project include openings and external walls.

[Features of decision makers]

(1) Clients: There are 11 clients participate in this project.
(2) Designer: The designer is same as Case R11 and who is an architect who has 40 years building design experience.
(3) Constructor: The constructor is belonging to a big-scale construction company.

[Required constructing period]

The design is required to finish in one month, and the constructing period is required to complete in two months.

[Client's budget]

In this case, the clients' budget is about 400,000 NT (equal to 1,440,000 Yen) for each of buildings.

Figure 6-7 Image of existing building in Case R15 (Before the retrofit)

6.4.2 Observation of decision-making process

The decision-making process of Case R15 is described as follows.

Step 1:
A client described his requirements for a building renovation to a constructor

Step 2:
The constructor described clients' requirements and his retrofitting plans to a designer

Step 3:
The designer suggested the clients to focus on the consideration "improving effects of energy efficiency" in energy-efficiency retrofitting designs by using a checklist. The client accepted the idea after discussing with the designer.

Step 4:
The clients required the constructor about their expectations according to the designer's suggestions.

Step 5:
The constructor asked the designer to modify the retrofitting designs. And then the designer confirmed affordability and constructability by using proposed checklist with the constructor.

Step 6:
The constructor confirm a final proposal of retrofitting design with the clients.

Step 3 and Step 4 are the decision-making processes utilizing suggested strategies (which is focusing on the communications between a designer and a client to enhance the priority order of the consideration "improving effects of energy efficiency" in retrofitting designs).

Design proposal 1

Design proposal 2

Design proposal 3 (Final)

After construction

Figure 6-8 Design proposals of Case R15

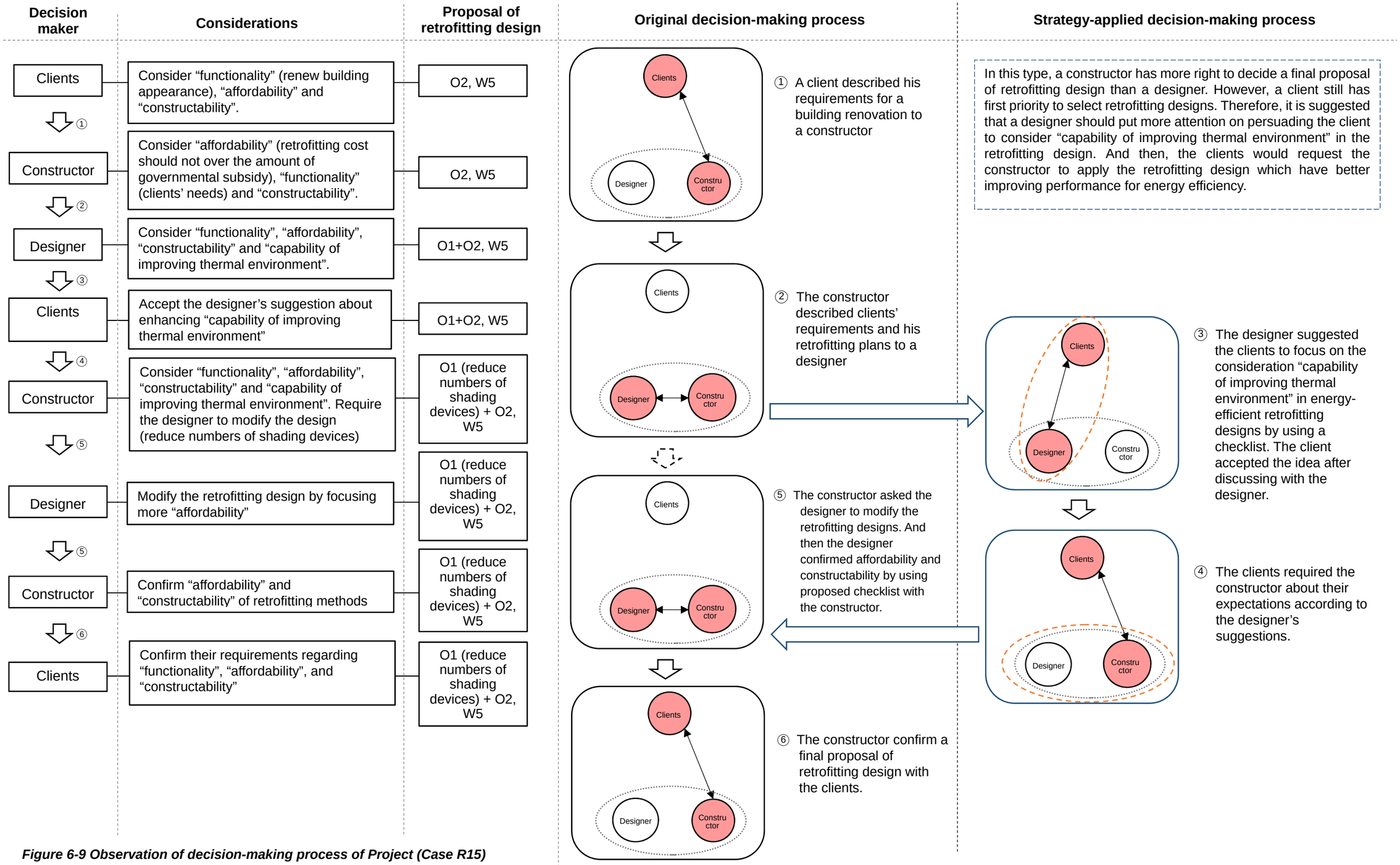

Figure 6-9 Observation of decision-making process of Project (Case R15)

6.4.3 Result of verification in Project B (Case R15)

According to observing results, it is found:

(1) By using decision-making reference as a common communicating platform is able to find out suitable retrofitting methods (O1+O2, W5).

(2) The proposed checklist do assist decision makers to confirm their decision-making considerations and assessment works for design proposals.

(3) The promoted energy-efficient method O1 (adding external shading devices) is successfully applied in Case 15 by focusing on the communications with clients and constructors. The clients would accept the designer's suggestions regarding adoption of energy-efficiency retrofitting methods when the clients confirm the methods can meet their retrofitting purposes and requirements. And then, the constructor would also accept adoption of energy-efficiency retrofitting methods due to clients' requirements.

6.5 Conclusion of Chapter 6

6.5.1 Summary

In Chapter 6, the possibility of improving the quality of decision-making processes associated with energy-efficiency retrofits in a small-scale building construction system were verified by application of suggestions to two practical retrofitting cases.

The retrofitting objectives of the two projects were mainly to renew existing building components and appearances; clients didn't consider to use any energy-efficiency retrofitting methods at the beginning. However, some of promoted energy-efficiency retrofitting methods (O1 and R2) are accepted by clients after the author: (1) communicating with clients about benefits of adoptions according to suggested strategies, (2) confirming assessment works with all decision makers for six categories of considerations by using suggested checklist, and (3) found suitable and applicable retrofitting methods from a checking suggested evaluation guideline.

6.5.2 Possibility of improving the quality of decision-making processes associated with energy-efficiency retrofits in a small-scale building construction system

According to above research results, it was verified that the quality of the decision-making processes could be improved by using (a) proposed strategies to raise "level of client's awareness on improving effect of energy efficiency" and (b) suggested checklists to raise "level of rigor in discussion and assessment" between decision makers in the decision-making processes. It was also concluded that suitable retrofitting methods were selected more readily by decision makers who did not specialize in energy-efficiency retrofits by using the suggested "evaluation guideline for energy-efficiency retrofitting methods"

It has known that the suggestions are useful for decision-makers in a small-scale building construction system to enhancing quality of adopting energy-efficiency retrofit.

Chapter 7:
Conclusion

7.1 Summary and achievement

- 7.1.1 Planning situations of energy-efficient building envelope retrofits and associated issues in a small-scale building construction system (Chapter 2)
- 7.1.2 Composition of decision makers in a small-scale building construction system (Chapter 3)
- 7.1.3 Practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system (Chapter 4)
- 7.1.4 Evaluation and suggestions for the decision-making processes executed by decision makers in different combinations (Chapter 5)
- 7.1.5 Verification (Chapter 6)

7.2 Conclusion

7.3 Research limitations

7.4 Future study

7.1 Summary and achievements

By exploring the decision makers and their decision-making processes in a small-scale building construction system, practical situation of retrofitting designs were clarified and suggestions for quality enhancement of adopting energy-efficiency retrofits in a small-scale building construction system are provided in this research. The research results and findings of this dissertation are summarized as follows.

7.1.1 Planning contexts of energy-efficient building envelope retrofits and associated issues in a small-scale building construction system (Chapter 2)

In Chapter 2, theoretical and practical context of building envelope retrofit for energy efficiency were clarified. The issues concerning planning energy-efficiency retrofits were also defined. The research results and findings are as follows.

(1) Theoretical suggestions of energy-efficient building envelope retrofit

The research regarding theoretical suggestions of energy-efficient building envelope retrofits includes (a) ideal planning process, (b) ideal decision maker types, and (c) theoretical promoted retrofitting methods of energy-efficient building envelopes. In this study, it was found that the promoted retrofitting methods of energy-efficient building envelopes suggested by professionals are expected to be adopted popularly in retrofitting projects to achieve the best energy-saving effects.

(2) Practical application of energy-efficient building envelope retrofits

The research regarding practical application of energy-efficient building envelope retrofits was found following results.

(a) Multiple building-envelope retrofits had to be executed in some cases due to ineffective retrofitting results for improving indoor thermal environment.

(b) Various retrofitting methods were adopted, including both general and promoted methods, in each part of the building envelope.

(c) Promoted retrofitting methods were only popularly adopted in the cases where the retrofitting purpose was only energy efficiency and were less applied to the cases where the retrofitting purpose was both improving building appearance and energy efficiency.

(d) Popularly adopted retrofitting methods where retrofitting purpose was to improve building appearance and energy efficiency were not the promoted ones.

(3) Issues with applied energy-efficient building envelope retrofits in a small-scale building construction system

By comparing theoretical suggestions and practical applications of retrofitting methods, it was found that (1) various adopted retrofitting methods exist and (2) some of them are different from theoretical suggestions and have ineffective improving results.

According to above research results, it is assumed that actual compositions of decision makers and planning processes of energy-efficiency retrofitting designs in a small-scale building construction system might not be as professional as theoretical suggestions.

7.1.2 Composition of decision makers in a small-scale building construction system (Chapter 3)

In Chapter 3, attributes of decision makers were defined by understanding and investigating decision makers' profession types, relevance of profession types, and how decision makers' combinations were decided. The research results and findings are described as follows.

(1) Types of decision makers' professions

The research results regarding "types of decision makers' professions" show that five common kinds of decision makers' professions are found in this scenario. These five kinds of professions include clients, consultants, designers, constructors, and material suppliers. Furthermore, nine combination types are found which can be sorted according to the "types of decision makers' professions". For example, "Type 1" consisted of all the five kinds of professions and "Type 9" consisted of only one kind of profession.

(2) Relevance of decision makers' professions

The research results regarding "relevance of decision makers' professions" show that the decision makers' professions are relevant in two ways: (A) independent-profession type and (B) multiple-profession type. The independent type means a decision maker has single profession and is not related to other participating decision makers. The multiple type means (a) a decision maker who has more than two professions, or (b) two decision maker who have different professions but are considered as the same unit (turn-key). Five multiple types were found: (a) consultants + designers, (b) material suppliers + constructors, (c) clients + designers, (d) clients + consultants + designers, and (e) designers + constructors (turn-key).

Furthermore, 15 combination patterns were found which were further sorted according to the "relevance of decision makers' professions". For example, "Pattern 1" included five independent-profession types (clients, consultants, designers, constructors, and material

suppliers) while “Pattern 2” included one independent-profession type (clients) and two multiple-profession types (“consultants + designers” and “material suppliers + constructors”).

(3) Research results regarding “how decision makers’ combinations were decided”

It was found that the combinations of decision makers were influenced by the following four categories: (a) attributes of retrofitting projects, (b) attributes of retrofitting purposes, (c) budget control, and (d) familiarity.

(4) Attributes of the decision makers in a small-scale building construction system

According to above-mentioned results, the findings regarding the attributes of decision makers in a small-scale building construction system are described as follows:

(a) A client is the basic profession type showing in all nine combinations of decision makers
(b) Numbers and specialties of decision makers in each of combination are different. In some combination types, only a few or one decision maker is included
(c) Consultants participated only in four of the nine combination types
(d) The decision makers were requested not only based on their specialties but also depending on the resources provided from institutions, retrofitting purposes, clients’ budgets, and preferences.

In summary, it was found that energy-efficiency retrofitting designs planned in the small-scale building construction system might be strongly affected by clients and decided by non-consultants with different specialties. These results are different from the theoretical expectations for the types of decision makers.

7.1.3 Practical decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system (Chapter 4)

In Chapter 4, practical decision-making processes of retrofitting designs in a small-scale building construction system were clarified. The decision-making processes were evaluated by understanding “what decision makers think” and “how decision makers arrive at the decisions” while deciding retrofitting designs. The research results and findings are described as follows.

(1) What decision makers think during the decision-making processes?

By investigating “what decision makers think,” following three elements were identified: (a) the content of decision makers’ considerations, (b) the priority orders of decision makers’ considerations, and (c) the development processes of decision makers’ considerations.

[Content of decision makers' considerations]

The results in this regard show that the decision makers' considerations can be sorted into 17 subjects and further categorized into six categories. The six categories are: (1) improving effects of energy efficiency, (2) functionality, (3) affordability, (4) legality, (5) constructability, and (6) durability.

[Priority orders of decision makers' considerations]

The results suggest that the priority orders of the considerations across the six categories varied across different decision makers.

[Development processes of decision makers' considerations]

The results indicate that the considerations might be (1) concerned according to clients' requirements from the beginning, (2) concerned and raised their priority order after discussions with the decision makers or (3) not concerned during decision-making processes.

(2) How decision makers arrive at the decisions in decision-making processes?

In this regard, the following three elements were identified: (1) interactions between decision makers, (2) decision makers' working contents for assessments, and (3) assessment approaches for improving effectiveness.

[Interactions between decision makers]

The results highlight that retrofitting designs are decided through different interactions between decision makers. The activities include: (1) requests, (2) suggestions, (3) discussions, and (4) confirmations.

Moreover, influential decision makers in each pattern were identified and categorized into five groups by observing the activities between decision makers. The specialties of decision makers in the five groups were: (a) clients, consultants and designers, (b) clients and designers, (c) clients, designers, and constructors, (d) clients and constructors, and (e) clients.

[Decision makers' working contents for assessments]

The results indicate that different assessment contents and different specialties of assessed decision makers. For example, the consideration regarding "improving effects of energy efficiency" are assessed by consultants and material suppliers in Pattern 1 but the consideration are assessed by clients in Pattern 15.

[Assessment approaches for improving effectiveness]

The results in this regard indicate that different assessment approaches for improving effects

were utilized across different case studies and can be categorized into three kinds: (a) according to simulation and calculation, (b) according to theories of energy-saving design and data utilized, and (c) according to past experiences, personal thoughts, and feedback from users.

According to the results, following are the findings: (a) features of decision-making processes of energy-efficiency retrofitting designs in a small-scale building construction system, and (b) challenges with respect to planning “energy-efficient building envelope retrofits” in a small-scale building construction system.

[Features of decision-making processes in a small-scale building construction system]

The findings are listed below:

(1) Decision-making processes are various and are influenced by the decision making considerations, priority orders of decision makers’ considerations, types of influential decision makers, types of interactions, and the assessed approaches.

(2) Retrofitting designs mostly were decided by only few people or by clients themselves.

[Challenges with respect to planning “energy-efficient building envelope retrofits” in a small-scale building construction system]

The findings in this part are as follows:

(1) Practical decision-making processes are various and different from theoretical decision-making processes affecting by what decision makers think and how decision makers arrive at the decisions.

(2) Differences in decision-making processes might be the reason causing the adopted retrofitting methods became various and different from theoretical expectations.

(3) Retrofitting designs decided by non-experts and who have less experiences on energy-efficiency retrofits are mainly according to clients’ requirements, personal experience and thought. This might be the reason resulting less effective improving performance of energy efficiency.

Practical decision-making processes of retrofitting designs in a small-scale building construction system are clarified in Chapter 4. According to research results in Chapter 2, Chapter 3 and Chapter 4, practical situation of retrofitting designs in a small-scale building construction system were discovered.

7.1.4 Evaluation of and suggestions for decision-making processes executed by decision makers in different compositions (Chapter 5)

The quality of decision-making processes executed by decision makers in different compositions was evaluated in Chapter 5. Furthermore, suggestions for decision makers to enhance the quality of adopting energy-efficiency retrofits in small-scale building construction systems were provided.

(1) Quality evaluation of decision-making processes executed by decision makers in different compositions

By understanding “what decision makers think,” their “level of awareness regarding energy efficiency” can be determined. By viewing “how decision makers arrive at decisions”, the “level of rigor in discussions and assessments” can be ascertained. The quality of the decision-making processes were evaluated by the “level of awareness for improving effects of energy efficiency” and “the level of rigor in discussions and assessments.” According to evaluation results, these two components were found to be different in the decision-making processes executed by different compositions of decision makers.

Regarding “level of awareness on improving effect of energy-efficiency”, the research results showed that the following situations might be able to achieve higher level of awareness on improving effect of energy-efficiency: (1) clients’ retrofitting purposes have better to include improving indoor thermal environment, (2) influential decision makers have better to have knowledge about green building designs, and (3) main influential decision makers have better to have designers or consultants.

Regarding “level of rigor in discussion and assessment”, the research results showed that confirming decision-making considerations comprehensively and carefully between professionals from different fields might be able to achieve higher level of rigor in discussion and assessment.

Moreover, it was found that retrofitting designs which have higher energy-efficient performance are usually adopted in the decision-making processes which have higher level of awareness regarding energy efficiency” and higher level of rigor in discussions and assessments.

(2) Suggestions for decision makers in small-scale building construction systems to enhance the quality of adopting energy-efficiency retrofits

The suggestions to enhance the quality of decision-making processes included strategies, a checklist, and an evaluation guideline.

The strategy refers increased communication between influential decision makers, especially

with regard to paying attention to improving energy efficiency. For example, one such strategy is where a designer could persuade clients and constructors to focus on improving energy efficiency.

The checklist for enhancing the level of rigor in discussion and assessment includes two parts: (a) suggested decision-making considerations, and (b) suggested assessment works.

The evaluation guideline for finding suitable energy-efficiency retrofitting methods listing retrofitting features of the 18 methods in six categories.

7.1.5 Verification (Chapter 6)

In Chapter 6, the possibility of improving the quality of decision-making processes associated with energy-efficiency retrofits in a small-scale building construction system were verified by application of suggestions to two practical retrofitting cases.

The verification results indicate the following:

(1) The retrofitting objectives of the two projects were mainly to renew existing building components and appearances; clients didn't consider energy-efficient designs at the beginning. However, energy-efficiency retrofitting methods are accepted after utilizing suggestions: (a) by checking suggested checklist, decision-making considerations are carefully discussed and assessed, (b) based on decision-making reference, the two promoted energy-efficiency retrofitting methods, O1 (adding external shading devices on openings) and R2 (adding insulation on roof), are decided, and (c) the decisions are successfully adopted in the two retrofitting projects by applying proposed strategies to persuade influential decision makers.

(2) In this study, it was verified that the quality of the decision-making processes could be improved by using (a) proposed strategies to raise the "level of awareness regarding energy efficiency" and (b) suggested checklists to raise "level of rigor in discussion and assessment" in the decision-making processes.

(3) It was also concluded that suitable retrofitting methods were selected more readily by decision makers who did not specialize in energy-efficiency retrofits by using the suggested "evaluation reference for energy-efficiency retrofitting methods"

7.2 Conclusion

In conclusion, the discussions in this research can be separated and concluded into two topics: (1) building envelope retrofits designed in a small-scale building construction system, and (2) quality of energy-efficiency retrofits implemented in a small-scale building construction system. The conclusions drawn from the research are discussed in details as follows:

[Building envelope retrofits designed in a small-scale building construction system]
Previously, it was assumed that a building design process is always executed by a professional team especially designers' qualifications are required as per regulations while planning new building constructions. For a retrofitting design project, however, the qualifications of the participants in design process are barely required by regulations. Thus, not always all types of decision makers defined in this research will participate in a project.

In the actual practice of retrofitting projects, few studies are available on the types of designers and their design processes. The combination of participants in the design process and the decision-making approaches under limitation, such as budget, time, manpower…etc, remains a black box in actual practice.

In Chapter 3 and Chapter 4, the author analyzed the 32 diverse cases of small-scale building construction systems and clarified the combinations of decision makers and the common practice of their decision-making processes. The author found that in practice a retrofitting project can be carried out by a number of team combinations of five different professional fields or even by clients themselves. Results from this study indicated that a variety of choices occurred in the common practice of decision-making process for energy-efficient building envelope retrofit in a small-scale building construction system. Under conditions of limitation, different team combinations will bring different benefits to the decision-making process. At the end of this research, the author developed a decision-making tool and a suggested process for better retrofitting design decision-making in small-scale building construction systems. The study also clarified two major factors that affect the results of decision in the studied cases: One major factor relates to the clients, i.e., decisions are largely affected by the retrofitting purposes of the clients and their willingness for energy-efficient retrofits. The other factor relates to the decision makers in the design process, i.e., the profession of the participants and their combinations affect their consideration and approach to arrive at an optimized decision.

[Quality of energy-efficiency retrofits implemented in a small-scale building construction system]
In general, the improvement of energy-saving performance is especially important and commonly required in a successful retrofitting project for energy-efficiency. The study shows

that: (1) it would be necessary to incorporate the role of a consultant, one of the five types of decision makers, specialized in energy-efficiency assessment in the decision-making process, and (2) it would help to make a better decision on selecting retrofitting methods by comprehensive discussions and careful assessments among different parties in the design process.

According to the analysis of cases discussed in Chapter 3 and Chapter 4, the author found that: (1) not always a consultant and all five types of decision makers participate and (2) those who do participate often lack of communications/interactions during the decision-making processes in the small-scale building construction systems. Further analysis on the characteristics of the decision-making processes in Chapter 5 indicates that the quality of the decision-making processes is closely associated with the combination of decision makers. The decision makers are more likely to make good decisions and adopt a better retrofitting methods with the combination types of 1 to 4. However, the clients' decision will still dominate the retrofitting-method decisions. In such cases, other participants in the projects will simply follow the basic improving requests from the clients. As a result, the decision-making in energy-efficiency retrofitting projects is usually considered as difficult to actually improve the projects' energy-efficiency.

The author points out in this study that the variability of decision-making processes make it challenging to accurately estimate the retrofitting results and the performance of energy-saving improvement. This study made it clear about the characteristics of the decision makers' thoughts and their approaches to making decisions in small-scale systems; the client's actual demands when implementing building envelope retrofitting projects were also clarified. The case studies in this research provide a great source of reference for researchers who are interested in comparing the theoretical and practical aspects of the decision-making processes.

Although the quality varied, most of the general public are believed to accept the construction cost and time of the energy-efficiency retrofits implemented by small-scale building construction systems due to its high flexibility and efficiency. In addition, the increasing amount of the retrofitting projects on the market makes the quality improvement of the decision-making process crucial. Suggestions provided in Chapter 5 were apply to 2 real design projects in Chapter 6, in both projects, the quality of decision-making processes and the performance improvement were verified. The two major suggestions include: (1) to properly convey the benefits of the energy-efficient retrofitting project to clients in order to increase their willingness of participation, and (2) to utilize tools for assisting influential decision makers to assess and confirm the suitability of design proposals. The research result could serve as a reference for: (1) decision makers associated with small-scale building construction systems and keen to

apply energy-efficiency retrofitting methods for improving indoor thermal environments, (2) researchers intended to develop tools for supporting decision-making processes and (3) governments intended to promote energy-efficient building designs through policy application.

7.3 Research limitations

[Limitation on case collection]

In this research, across the 32 case studies, 9 combination types and 15 combination patterns of decision makers were categorized with respect to their professions. It is likely that more combinations types of decision makers might emerge by reviewing more cases. However, information regarding decision-making processes of small-scale retrofitting projects is difficult to find and collect from published literatures or media. Additionally, it is challenging to contact their decision makers for interviewing. Hence, insufficient case studies is one of the limitations of this research.

[Limitation on the willingness to be interviewed]

One of the highlights of this research was to understand the execution of decision-making processes with respect to retrofitting projects by different experts. For a comprehensive understanding, ideally all participants involved in the decision-making process should be interviewed. However, constructors, material suppliers, and owners were usually less willing to be interviewed in comparison to designers and consultants. Hence, in most of the studied cases, research results are mainly indicative of perspectives of designers and consultants.

7.4 Future research

Suggested future research can be discussed in two aspects: theoretical and practical.

Advices regarding theoretical field are as follows:

(1) Clients' requirements, and decision-makers' backgrounds and compositions were considered important according to research results; therefore, these factors should also take into account while studying decision-making results of retrofitting designs.
(2) The roles of constructors, material suppliers in the decision-making processes might be investigated more to understand comprehensively.
(3) Further research is needed to suggest assessment approaches to ensure a thoughtful design guideline and checklist

Advices regarding practical field, clients' awareness were found important for adopting energy-efficient retrofits. Therefore, to educate clients about the benefits of adopting energy-efficient retrofitting methods is necessary. Moreover, retrofitting methods suggested by designers should achieve the clients' retrofitting goals in the first place and increasing the clients' willingness to adopt energy-efficient retrofitting methods comes next.