# 論文の内容の要旨

## 論文題目

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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### 1. Research background

Currently, enhancing existing building operational efficiency via renovating building envelopes becomes an essential mission for reducing energy consumption and carbon emission and also for dealing with extreme climates. By applying energy-efficient retrofits when building envelope being renovated would bringing great benefits for living environments.

Through preliminary researches regarding current implement situations of energy-efficient retrofits on building envelopes in Japan and Taiwan, it is found although retrofitting methods of energy-efficient retrofits which have better improving effectiveness have been highly promoted by experts, the methods of energy-efficient retrofits are adopted differently in hundreds of retrofitted cases.

In order to find out the reasons and enhance quality of energy-efficient retrofits, practical decision-making processes of retrofitting designs are necessary to be studied. However, existing researches regarding actual decision-making processes of retrofitting designs are rare.

Furthermore, it is found that great amount of building envelope retrofits are implemented by a small-scale building construction system in Taiwan. The decision-making processes in a small-scale building construction system is still unclear and especially difficult to be predicted due to various types of decision makers.

Hence, decision-making processes of retrofitting designs in the small-scale building construction system are the main focus in this research to clarify the reasons resulting various choices of retrofitting methods for energy efficiency.

### 2. Research objective

The objective of this research is to clarify: (1) decision-makers' attributes in a small-scale building envelope retrofits for energy efficiency, (2) decision-making processes of retrofitting designs in small-scale building envelope retrofits for energy efficiency and (3) features of the decision-making processes of retrofitting designs executed by different combinations of decision makers. Moreover, suggestions are aiming to provide basing on the research results for decision makers in a small-scale building construction system to ensure the quality of energy-efficient retrofits.

### 3. Research subject and methodology

The 32 cases relating energy efficient retrofits of building envelopes and implemented by a small-scale building construction system in Taiwan are chose to be investigated and compared in this research. Furthermore, research methodologies are described according to the three research aims as below.

(1) To clarify decision-makers' attributes in a small-scale building construction system. The decision-makers' attributes are defined by decision-makers' professions in this research. The decision-makers' professions are investigated first by interviewing participants in 32 cases about their professions types and relevance. And then, categorize decision makers' professions according to the types and the relevance through comparative analyses.

(2) To clarify the decision-making processes of retrofitting designs in a small-scale building

construction system, the decision-making processes of retrofitting designs are investigated by interviewing decision makers in the 32 cases about following research questions.
(a) What decision makers think during decision-making processes?
(b) How decision makers do during decision-making processes?

(3) To clarify the features of the decision-making processes of retrofitting designs executed by different combinations of decision makers. Comparative analyses are utilized in this part. The contents of decision-making processes are compared and evaluated according to different combinations of decision makers.

**4. Research framework and content**

The dissertation is consisted of seven chapters. An overview of this research is introduced in Chapter 1. After showing the actual situations of building envelope retrofits for energy-efficiency and issues of implementations in Taiwan in Chapter 2. Attributes of decision makers in small-scale building envelope retrofits and decision-making processes of retrofitting designs are explained in Chapter 3 and Chapter 4. After that, the features and evaluating results of the decision-making processes of retrofitting designs executed by different combinations of decision makers are described in Chapter 5. Furthermore, suggestions for decision makers in a small-scale building construction system are also provided according to research results of Chapter 5. In Chapter 6, the verification results of the suggestions are narrated by two practical retrofitting cases. Finally, all the research results are concluded in Chapter 7.

**5. Research result**

The research results of each chapter are summarized as follows.

In Chapter 2, implementing situations and issues are defined according to theoretical and practical implement situations.

(1) Theoretical implement situations

The theoretical implement situations are found as follows: (A) building envelope retrofits for energy efficiency are implemented in a general building construction system, and (B) there are 18 types of improving methods are found suitable to apply in Taiwanese climate (hot and humid). Some of the methods are especially suggested by experts.

(2) Practical implement situations

However, the practical implement situations are found as follows: (A) there are great amount of building envelope retrofits are implemented in a small-scale building construction system, and (B) adopted improving methods in small-scale retrofitting projects of Taiwan are various and not always same as theoretical suggestions.

(3) Issue

According to above findings, varied decision-making results on improving methods are found as the issue to adopt building envelope retrofits for energy efficiency in a small-scale building construction system. Different decision-making results are assumed would affect qualities of building envelope retrofits for energy efficiency because of each of improving methods has very different improving effectiveness.

In Chapter 3, decision makers' attributes in small-scale building construction systems are defined through investigating "types of decision makers' professions" and "relevance of decision makers' professions".

Types of decision makers' professions

There are five common types of decision makers' professions are found in small-scale building envelope retrofits for energy efficiency: clients, consultants, designers, constructors and material suppliers. The combinations of decision makers are found can be categorized into 9 types according to the types of decision makers' professions. For example, Type 1 includes five types of professions (clients, consultants, designers, constructors and material suppliers), and Type 9 includes one type of profession (client).

Relevance of decision makers' professions

There are two kinds of relevance regarding decision makers' professions are found can be sorted: (1) independent-profession type and (2) multiple-profession type. The independent

type means a decision maker has single profession and is not related to other participated decision makers. The multiple-profession 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). There are five multiple types are found: (a) consultants + designers, (b) material suppliers + constructors, (c) clients + designers, (d) clients + consultants + designers and (e) designers + constructors (turn-key).
The combinations of decision makers are found can be can be further sorted as 15 patterns according to "relevance of decision makers' professions". For example, Pattern 1 includes five independent types (clients, consultants, designers, constructors and material suppliers) and "Pattern 2" includes one independent type (clients) and two multiple types ("consultants + designers" and "material suppliers + constructors").
According to above research results, it is clarified that the attributes of decision makers in small-scale retrofitting projects are having various specialties and also varied combinations.

In Chapter 4, decision-making processes of retrofitting designs in a small-scale building envelope retrofits for energy efficiency are clarified by investigating "what decision makers think" and "how decision makers do" during decision-making processes in studied cases.
(1) What decision makers think?
The research results regarding "what decision makers think" are clarified as following contents:
(A) Decision makers' considerations for retrofitting designs
The contents of decision makers' considerations could be sorted and categorized into six categories: (a) capability of improving thermal environment, (b) functionality, (c) affordability, (d) legality, (e) constructability and (f) durability.
(B) Priority orders of decision makers' considerations
The priority orders of the considerations in six categories are found various in studied cases.
(C) Development processes of decision makers' considerations
The development processes can be divided into two situations: (a) the considerations were developed by clients from the beginning, and (b) the considerations were developed after clients discussing with other decision makers.
(2) How decision makers do?
The research results regarding "what decision makers do" are clarified as following contents:
(A) Decision makers' interactive relationships
The interactions between decision makers are varied and not the same in 15 combination patterns.
(B) Activities between decision makers
There are four kinds of the activities between decision makers are distinguished: (a) requests, (b) suggestions, (c) discussions and (d) confirmations.
(C) Decision makers' working contents for assessments
Working contents for assessing the considerations in six categories are discovered.
(D) Assessment approaches for improving effectiveness.
Approaches for estimating "capability of improving thermal environment" can be sorted as three methods: (a) according to simulation and calculation, (b) according to theories of energy-saving design and data report, and (c) according to past experience, personal thought and feedback from users.
According to above research results, it is clarified that decision-making processes of retrofitting methods in small-scale building envelope retrofits for energy efficiency do varied and being affected by decision makers. Moreover, differences of what decision makers think and how decision makers do are found in the 15 patterns and are clarified as the factors resulting various choices on energy-efficient retrofitting designs of building envelopes and different from theoretical suggestions.

In Chapter 5, features of decision-making processes executed by 9 combination types of decision makers are defined and described according to participating situations of consultants.
(1) Group 1: Has consultant (Type 1, Type 2, Type 3, Type 4)
(a) Most of the considerations in six categories are concerned in these types except the

consideration regarding “functionality” and “legality”.

(b) Decision makers in these types are more emphasizing on the consideration “capability of improving thermal environment”.

(c) Clients in these types may have or may not have initial needs of improving thermal environment

(d) There are more interactive relationships between decision makers from different professions

(e) Activities between decision makers in these types are having more discussions and confirmations between decision makers from different professions.

(f) The consideration “capability of improving thermal environment” is all assessed by consultants.

(g) The common approaches utilized in these types are according to “simulation and calculation”, and “theories of energy-saving design and data reports”.

(2) Group 2: Has no consultants (Type 5, Type 6, Type 7, Type 8, Type 9)

(a) Most of the considerations in six categories are concerned in the types which having designers as one of decision makers. However, the consideration regarding “legality” are not concerned in Type 6, Type 8 and Type 9, and the consideration regarding “durability” is not concerned in Type 9.

(b) Decision makers in these types are less emphasizing on the consideration “capability of improving thermal environment”.

(c) The clients in these types have initial needs of improving thermal environment.

(d) Decision makers’ interactive relationships in these types are having less interactive relationships between decision makers from different professions.

(e) Activities between decision makers in these types are having less discussions and confirmations between decision makers from different professions.

(f) The research results show the consideration “capability of improving thermal environment” is all assessed by non-consultants (designers, clients, material suppliers and constructors).

(g) The common approaches utilized in these types are according to “past experience, personal thought and feedback from users”.

According to above research results, strategies and a checklist for decision makers in a small-scale building construction system to ensure the qualities of energy-efficient retrofits are also proposed in this chapter.

In Chapter 6, the suggested strategies and a checklist for decision makers in a small-scale building construction system to ensure quality of energy-efficient retrofits are verified by two practical retrofitting cases. The verification results show that by utilizing the strategies and checklist to confirm essential assessing works and communicate with other participated decision makers especially clients as a common communicating platform, “external shading devices on openings” (which is one of the retrofitting methods considered having great improving effects for energy efficiency in Taiwanese climates) are able to be applied successfully in both of two cases.

In conclusion, variability of decision-making processes are found the feature happening in a small-scale building construction system. The features would increase the difficulties of predicting retrofitting results and controlling qualities of improving effectiveness. The research results could be a reference for the following people: (1) for decision makers in a small-scale building construction system to ensure qualities of energy-efficient retrofits for building envelopes, (2) for researchers to understand the differences of decision-making processes between theoretical and practical situations, and (3) for the government to set up efficient promotion strategies for popularizing energy efficient retrofits being applied on existing building envelopes.