A Research on Knowledge Theory of Innovative Design for Adaptive Reuse of Old Buildings in Public Space

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Doctoral Dissertation

A Research on Knowledge Theory of Innovative Design for Adaptive Reuse of Old Buildings in Public Space

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ABSTRACT

The pursuit of sustainability in architecture and interior design has become central to mainstream discussion due to increasingly serious environmental problems. The development of the city is a dynamic process that requires constant change and renewal. The existence of old buildings with huge quantities and large areas in the city is an effective way for us to practice sustainable development. The renewal of old buildings not only improves energy consumption but also reduces the consumption of resources and energy to decrease adverse impacts on the environment.

Although some old buildings have been revitalized, most old building renewal projects in China have only focused on functional and aesthetic improvements. Additionally, most adaptive reuse of old buildings is focused on the building itself—that is, the objective dimension of aesthetics. Furthermore, some architecture looks the same in New York, Paris, New Delhi, and Tokyo, and such international architecture is equally inappropriate wherever it is built. Design needs innovative elements to result in an energetic building. Although innovation design has been explored in the field of architecture and interior design, most buildings are based solely on an individual's motivation to realize his or her own innovative design ideas.

Therefore, the design of old building renewal requires a combination of sustainability and innovation. The purpose of this study is to build a theoretical model of innovative design for the adaptive reuse of old buildings. The Major Research Question of this paper is to comprehensively classify the typology of the adaptive reuse of old buildings from the perspective of sustainable and innovative design and explore sustainable and creative directions in future design.

To address this issue, old building renewal must first be explored not only by conducting a literature review but also using an experimental comparison method. The result shows that old building renewal is more effective than constructing new buildings. Second, based on this premise, four types of innovative design for the adaptive reuse of old buildings are summarized through many cases by analysing their similarities and differences which including functional, aesthetic, technological, and locational innovation. Then, evaluation part combines the four innovative types and the adaptSTAR model to establish the criterions and verify the type with the most influence—that is, the technological innovation that is consistent with the previous result, above mentioned are basic research. The key criteria for each type of innovation are obtained as well. In the last case study, this part combines with the previous theoretical analysis using an art studio as a prototype to explore the application of the innovative design of adaptive reuse of old buildings in practice—this is the applied research. Through the basic research in Chapter 4-6 and applied research in Chapter 7 to get knowledge innovation. This study is founded upon the knowledge base of innovative design for adaptive reuse of old buildings.

The originality of this research lies in our use of a mixed methodology to examine various subjects, including architecture, interior design, ecology, innovation, psychology, Kansei engineering, Extenics, economic, and other theoretical bases to explore the knowledge theory of innovative design for adaptive reuse of old buildings in public space. Additionally, concerning the knowledge innovation model in management, this study tries to find an innovation model in architecture and interior design field among these four types: this can be called the TFAL model (technological, functional, aesthetic and locational innovation). The TFAL model is proposed as a knowledge innovation model.

The novelty of this paper is that old buildings renewal is classified comprehensively from the perspective of the typology of innovative design and form the TFAL model, which contribute to knowledge science. What's more, Extenic analysis method is used to tentatively analyze the objects of interior design innovation to find out the corresponding transformation strategy. Although it is a beginning step, this method of applying Extenics to practical engineering is a new exploration in interior design.

The possibilities of this paper will act as a useful reference for both environmental design academics and practitioners

that are interested in sustainable and innovative design field. Not only lies in the guiding designers to make critical design decisions that will contribute to the sustainable environment development and construct the new buildings with greater adaptive reuse potential, but also teach designers to replace short term thinking by an integrated view on people's quality of life on a long-term scale.

Keywords: Adaptive reuse; Innovative design; Old building typology; Sustainability; Creativity.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF FORMULA

LIST OF ABBREVIATIONS

A	Physical innovation
A1	Baltic Centre for Contemporary Art, UK
A2	An Old Breton Barn Converted into an Artist Studio, France
A3	Wall Cloud, Japan
A4	Allez UP Rock Climbing Gym; Montreal, Canada
B	Economic innovation
B1	PCH International Innovation Hub, USA
B2	Musée d'Orsay, France
B3	House of Vans London, UK
C	Functional innovation
C1	Town Folktales, China
C2	Impact Hub Belgrade, Serbia
C3	Library, Museum & Community Centre 'De Petrus', Netherland
C4	Wooden Structure at Launchlabs, Switzerland
D	Technological innovation
D1	Parliament building, German
D2	The Green Building, USA
D3	Rainbow, Vietnam
D4	Garvergården, Denmark
E	Social innovation
E1	Arquipélago Contemporary Arts Centre, Portugal
E2	Zeitz Museum of Contemporary Art Africa, South Africa
E3	MALHAArchitecture, Brazil
F	Legal innovation
F1	Centre for Individuals with Disabilities, Spain
F2	Professional Cooking School in Ancient Slaughterhouse, Spain
F3	Boxin the Box, Spain
G	Contextual innovation
G1	Guggenheim Museum, USA
G2	Glass Pyramid at the Louvre Museum, France
G3	O-office, China

PART ONE

Part One Contains…

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Research Methodology

CHAPTER 1 Introduction

In this chapter…

- Background of study
- Problem Statement
- Research Motivation and Objective
- Research Questions
- Structure of this Dissertation
- References

In the twentieth century, architects preferred the responsibility of designing new buildings, and only a few of pioneers had explored the allure of mingling historical and modern architecture, today the work of these trailblazers has borne achievement; working with existing old buildings has long since grown into an independent architectural type.

Frank Peter Jäger

1. Introduction

Chapter one describes the general content of the dissertation. It begins by establishing the background of the study, including how urbanization leads to old building renewal, the necessity of sustainability in the current period, and the need for update conceptual innovation. After that, the problems of the four phenomena are investigated in study. Subsequently, to tackle these phenomena, I present the motivation and purpose of this study. Thereafter, the research questions are explained. Finally, the chapter ends by briefly reviewing each chapter.

1.1 Background of This Study

1.1.1 Urbanization brings about old building renewal

The development of the city is a dynamic process that undergoes constant change and renewal. Due to city scale expansion, industrial structure regulation, and environmental pollution control, the existing urban areas no longer adapt to the development of the city (Li et al., 2017). In this way, the original buildings are left to be demolished or renovated. Rapid urbanization has not only led to an increasing use of non-renewable resources but has also contributed to the generation of renewal and demolition waste and its associated environmental concerns (Passarini et al., 2014). It is inevitable that old building renewal is begun.

From a fiscal perspective, the transformation of the original buildings is undoubtedly the most economical choice. The site often retains good infrastructure such as drainage and electricity, which not only saves a many costs such as demolition and cleaning but also shortens the construction period to achieve the intended goals as soon as possible. In fact, demolition and the new construction of energy-efficient buildings require decades to equal the energy savings of reusing existing buildings (TEC, 2008).

From the perspective of promoting the regional economy, abandoned old buildings generally have superior geographical locations, open space, and few building layers, which allow the space to exhibit potential and can be expanded. The most effective method to do this is to breathe life into these structures by providing them with a new use (WARD, 2013). The investors can invest in more extensive projects so that enhancing the quality and value of this location and revitalizing the surrounding economy.

It is not strange for us to see the demolition of old buildings and construction of new buildings. In America, it is reported that for every four commercial buildings constructed or every six houses built, one is demolished (Tobias & Vavaroutsos, 2012). In fact, from the

perspective of environmental protection, air pollution and noise are inevitable in the process of dismantling, and most demolition waste is not degradable and becomes a burden on the environment. With our increasingly polluted world, old building renewal is an effective way to reduce environmental pollution.

From the perspective of the inheritance of culture, old buildings record the history of urban development, and their environment and places can arouse people's memories. People have a sense of identity and belonging because of the common experiences of their places. Most old building renewal focuses on buildings that truly are irreplaceable—those that have a special, endangered status in the eyes of individuals (Bloszies, 2013). Meanwhile, old buildings record the historical development and cultural value orientation of the society in which they are situated in terms of spatial scale, material colour, and construction technology, which is an important clue for future generations to understand history. Therefore, the reuse of old buildings helps maintain the historical continuity of the urban environment and enhance its sense of history.

1.1.2 The current necessity of sustainability

Since the 1970s oil crisis, the demand to protect the environment has been increasing internationally. Research on sustainable development has rapidly increased in various countries around the world, and sustainable architecture development is flourishing under this context.

Like other fields, architects and interior designers have begun to deeply reflect on the impact of previous construction activities on the global environment and have conducted in-depth research on the relationship between construction activities and human sustainable development. By the early 1990s, green sustainability issues have received more attention at international conferences. Environmental designers—architects and interior designers—have begun to re-evaluate the relationship between architecture and natural environments and realize the environmental factors that contribute to architectural and interior design (Zhou, 2011).

In the 21st century, the pursuit of sustainability in architecture and interior design has become central to mainstream discourse. Sustainable development is an important theme of contemporary design. The core of sustainable design includes using existing resources effectively and rationally, reducing the load of human activities on the environment, thus improving healthy environments. Sustainability is defined not only according to qualities of the object was built (the building itself) but also by its position (location environment) and its development procedure (process quality). Efficiency in the use of energy and resources has become a vital quality indication for a building (Hegger et al., 2012)

Revitalizing many old buildings and large city areas is an effective way for us to practice sustainable development. The adaptive reuse of old buildings not only improves building energy performance but also reduces the consumption of resources and energy, which may further decrease adverse impacts on the environment.

1.1.3 The need to update our conceptual innovation

The earliest research on innovation began in 1912. The American Austrian scholar Schumpeter first proposed the Innovation concept in his book 'Economic Development Theory'. In this book, he indicated that innovation was a process and an economic activity. After that, innovative research was introduced into the field of management, and one of the most important theoretical works was that of American scholar James M. Utterback entitled 'Innovation', in which the intrinsic links between innovation, markets, and business are explained, which has been gradually introduced to other fields (Wang, 2007).

Innovation was adopted to design field as a crossed research which have been studied for recent years, like Taura & Nagai (2010) edited the research of design innovation, that promoting innovative theory, tool and methods, and incorporating creativity into the discipline etc.

Innovative design is defined as a practical process by which the designer uses his or her ability to generate some novel and valuable ideas, solutions, or products (Sarkar & Chakrabarti, 2011). The essence of innovative design in architecture is reconfiguring an established system that links existing elements in a new way (Henderson & Clark, 1990). We can see that the concept of innovative design in architecture needs to be updated.

In summary, old building renewal, sustainability, and innovation are generated under the background above mentioned， which have become central topics in the field of architectural design. Just like the First Session of the United Nations Habitat Assembly of the United Nations Human Settlements Programme is held on 27- 31, May 2019 at Nairobi, Kenya. The topic is "Innovation for Better Quality of Life in Cities and Communities". It aims to find innovative and sustainable solutions to the challenges of global urbanization (United Nations, 2019).

Combining sustainability and old building renewal, the main object of this study is the adaptive reuse of old buildings. Thinking about the innovation as well, this paper specifically focuses on the study of innovative design for adaptive reuse of old buildings (Figure 1-1).

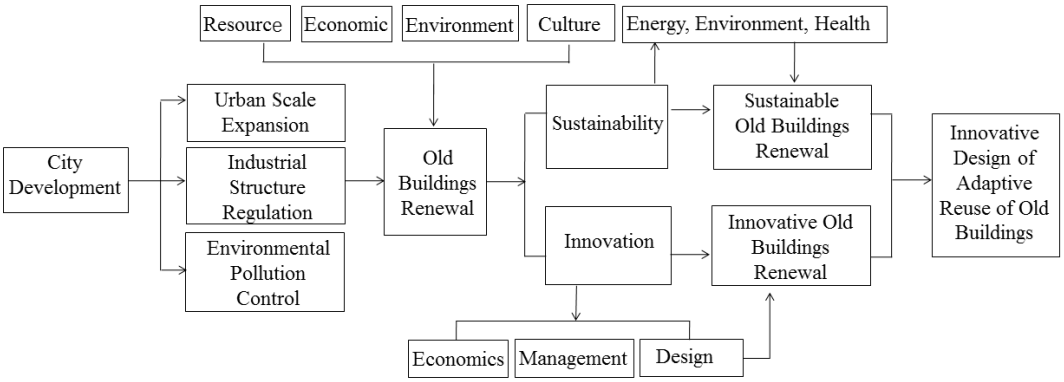

Figure 1-1: Origin of innovative design for adaptive reuse of old buildings

1.2 Problems Statement

In spite of the evidence that shows the significance of old building renewal, sustainability, and innovation, designers encounter many challenges in solving complex sets of issues that must be considered (Conejos et al., 2013). There are four existing problems.

Phenomenon 1:

Most new buildings consume a significant amount of resources and energy, and old building renewal is superior. Reuse (2004) states that environmental benefits combined with energy savings and the social advantage of recycling a valued place make the adaptive reuse of old buildings an essential component of sustainable development. Although some old buildings have been reborn, it is not difficult to find that old building renewal in China only focuses on functional and aesthetic requirements. They rarely pay attention to the application of sustainable concepts and cannot be under the premise of low energy consumption to providing people with a comfortable indoor environment, accompanied by serious waste of resources and environmental pollution during the reconstruction process.

Simultaneously, the phenomenon of building homogenization is serious; buildings presents the convergence of urban space and the unification of architectural culture—now, nearly every place looks the same. Contemporary architecture often looks the same in New York, Paris, New Delhi, and Tokyo, and such international architecture is equally inappropriate wherever it is built, as it is not sustainable for local climates (Lechner, 2014; Li & Guo, 2017). Design requires innovative elements.

Therefore, the design of old building renewal needs a combination of sustainability and innovation. The adaptive reuse old buildings present a true challenge to architects and designers to find innovative solutions under the sustainable development trend (Reuse, 2004).

Phenomenon 2：

It can be seen that there are many examples of abandoned buildings (such as factories and warehouses) being converted into useful alternative spaces such as commercial, recreational, and residential buildings in the worldwide. Many cases, however, are based solely on an individual's motivation to discover his or her own innovative design ideas. Most research on design innovation has focused on such individual innovation (Smith, 2003). Some studies have addressed innovative points of old building renewal based on their perspective. Extant research focuses on the adaptive reuse of old buildings only (Conejos et al., 2014). Few successful cases of old-building renewal have been comprehensively classified from the perspective of innovative design. The contribution of innovative design typology in old-building renewal has not yet been comprehensively explored, especially in the public space design.

Meanwhile, the definition of the innovation must be updated in the environmental design field. Actually, the cross study of innovation and environmental design is rare, not to mention innovative design in adaptive reuse of old buildings.

Phenomenon 3:

The current assessments of sustainability vary, using different criteria and examining different countries, such as BREEAM, LEED, CASBEE, and GB/T 50378-2014. Atkinson et al. (2009) demonstrates that there is a rapidly growing tendency for rating methodologies that can be used to define the environmental performance of our activities, ranging from personal carbon emission tools to complex sustainability assessments and standards for building. Few studies link specific criteria to innovative design in the adaptive reuse of old buildings.

Phenomenon 4:

Additionally, most adaptive reuse of old buildings are focusing on the building themselves—that is, the objective dimension of aesthetics, which are carried out for aesthetic reasons. They focus on reusing old buildings by transforming the texture, colour, and other aesthetic aspects (Guo, 2011). Few studies have examined the adaptive reuse of old buildings from the perspective of the users of the space—or, the subjective dimension of aesthetics. Thus far, scholars have failed to mention the effect of adaptive reuse of old buildings from the users' perspective.

Hence, this study attempts to address the phenomena mentioned above and shed light on the topic.

1.3 Research Motivation and Objectives

The overall purpose of this study is to develop a theoretical model of innovative design for the adaptive reuse of old buildings, focusing on the four objectives listed below:

1. Identify the adaptive reuse of old buildings has a richer meaning to new buildings, which could be integrated with sustainability and innovation in environmental design to response phenomenon 1.
2. Classify the typology of the adaptive reuse of old buildings from the perspective of innovative design to explore the creative direction of future design to response phenomenon 2.
3. Evaluate the criteria of the adaptive reuse of old buildings from the perspective of innovative typology design to facilitate sustainability to response phenomenon 3.
4. Illustrate a real case study to demonstrate a creative adaptive reuse practice from the perspective of users' needs and explore the feasibility of such a practice to response phenomenon 4.

As a result, this study will play a critical role in both identifying common research themes and sorting and summarizing the typology and evaluation of innovative design in the adaptive reuse of old buildings in public space, thus guiding future sustainability and innovative research trends.

1.4 Research Questions

To attain the above objective, the study answers one Major Research Question (MRQ) and three Subsidiary Research Questions (SRQs):

MRQ: What is the innovative design typology for the adaptive reuse of old buildings in public space?

SRQ1: Why is innovative design in old-building renewal more effective than new building development?

SRQ2: What evaluation criteria are used in innovative design for the adaptive reuse of old buildings?

SRQ3: How have innovative elements affected the adaptive reuse of old buildings through a case study?

1.5 Structure of this Dissertation

The structure of this dissertation is outlined as follows. This dissertation consists of 3 parts comprised of 8 chapters. The dissertation begins with an introduction in Chapter 1. Then, a literature review and related definitions are discussed in Chapter 2. The research methodology is outlined in Chapter 3. In the second part, the main findings of the dissertation are delineated. Chapters 4, 5, and 6 explain Study 1, 2, and 3, respectively. Chapter 7 includes the case study, respectively. The third part, which includes Chapter 8, outlines the discussion, implications, and recommendations. The specific details are outlined below.

Chapter 1 introduces an overview of this dissertation, including the background of this study, problem statement, research motivation and objectives, research questions, and structure. This chapter briefly explains the problems, goals, and structure of this dissertation.

Chapter 2 provides the study's theoretical background based on a literature review, including a review of previous literature, a synthesis of research findings, and definitions of terms. The main purpose of the literature review is to inform the research topic, both in terms of research findings and theory.

Chapter 3 explains the research methodology, including research design, research methods, and research procedures for each chapter. The chapter describes how the research question was answered. The step-by-step methods and procedure are used in this chapter.

Chapter 4 presents the findings of Study 1, 'A Comparison of old buildings renewal and new buildings'. This chapter outlines this study's introduction, research aim, methodology, results, and discussion as well as a project illustration and chapter summary. The aim of this chapter is to verify the renewal of old buildings' sustainability and innovation by comparing this process to the development of new buildings—or, comparing the old buildings renewal to new buildings by using an experimental way to prove the premise of this study.

Chapter 5 outlines the findings of Study 2, 'Innovative design typology for adaptive reuse of old buildings'. The chapter includes the study's introduction, examples of innovative design, analysis, discussion, and reflection as well as a summary. The aim of this chapter is intended to challenge traditional approaches to classifying innovative design by clarifying its typology through evidence from the adaptive reuse of old buildings, and use this innovative design type to guide the evaluation part.

Chapter 6 concentrates on the findings of Study 3, 'Evaluation criterion of innovative design for adaptive reuse of old buildings'. The chapter includes an introduction and literature review, outlines the study's research aim, motivation, method, results, and discussion as well as a summary. The main purpose of this chapter is to find the most influential type of the four and establish more effective criteria for each type of the adaptive reuse of old buildings.

Chapter 7 focuses on the findings of a case study of a 90-year-old dining hall that served as a prototype for exploring the feasibility of the practice outlined in this study. This chapter includes an introduction, outlines research methods, analysis, discussion, design process, construction process, and evaluation as well as a summary. This chapter is aimed at making a practical contribution that brings new life to an old building and establishes a creative space for users by employing a sustainable environmental design.

Chapter 8 discusses findings from all analyses and highlights original contributions to Knowledge Science, including both theoretical and practical implications. Limitations and recommendations for future studies and inspiration for new buildings are also considered.

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CHAPTER 2 Literature Review

In this chapter…

- Review of Literature
- Synthesis of Research Findings
- Definition of Terms
- References

2. Literature review

This chapter reviews relevant literature on important concepts and definitions involved in this dissertation. The main purpose of the literature review is to explain what is known about the research topic, both in terms of research findings and theory. Firstly, it introduces the review of literature of keys words in this paper; secondly, based on the above literature review, this paper is synthesized of research findings; finally, a clear definition of terms is given in this paper involved.

2.1 Review of Literature

2.1.1 Review of old building renewal, sustainability, and adaptive reuse

Old building renewal has been a central topic in the architectural design field. In international research, there are mainly three components to this topic: restoration, repair, and remodelling. Some people argue for restoration—which simply means rehabilitation—which refers to reverting a building to its original condition. It may also refer to removal or replacement, but never addition (Williams, 2013). According to some others, it involves repair, which is necessary when structural or weatherproofing elements require mending to ensure their on-going structural integrity (Collings, 2016). Still others insist that restoration implies remodelling and may call for modifications in shape, style, accommodations, or design (Williams, 2013).

Restoration, repairing, or remodelling old buildings could be said to reflect a certain degree of sustainability. The integration of existing structures in a renewed building and qualifying extension or renovation of an existing building equals practiced sustainability (Jäger, 2012).

Sustainable development first occurred in the report of our common future. The definition of it as paths of human progress, which meets the requirements and aspirations of the present generation without compromising the ability of future generations to meet their own needs (Brundtland et al., 1987). The idea of sustainable development in architecture and interior design refers to a need of sustainability, which designers adhere to with sustainable strategic thinking in all aspects of the design, construction, operation, and eventual demise of the building (Zhou, 2011).

Adaptive reuse is a main feature of sustainability; the predominant vision of a sustainably built future is of state-of-the-art buildings that utilise energy efficient design and materials (Reuse, 2004). For greater energy efficiency, savings in raw materials and energy that are ensured by adaptive reuse. The ecological significance depends on the fact that an existing building that still easily fulfils its aim continues to be used for as long as possible. This is essentially a perspective based in frugality (Jäger, 2012).

In addition to the environmental benefits achieved by the adaptive reuse of old buildings as opposed to the development of new ones, should be considerate. Adaptive reuse plays a vital role in reducing emissions from the built environment (Conejos et al., 2013). According to

Zushi (2005), successful adaptive reuse projects require both good design and consideration of the surrounding environment. Adaptive reuse of old buildings is often in advantageous locations in the city and close to transport, making reuse more viable. They are constantly appreciated as comfortable working environments by participants (Langston et al., 2008).

Hence, Snyder (2005) points out that adaptive reuse and sustainability have a significant role in the future of architectural practice. In the context of sustainable development and the effects of climate change caused by previous lack of considerations for our environment, adaptive reuse has significant implications (Langston, 2008).

2.1.2 Review of innovation

Innovation has been cited as one of the key factors that affects competitiveness. As a multidimensional knowledge base, every field has been exploring integration with innovation as summarized below.

From the perspective of economics, innovation establishes a new productive function. It changes the technological conditions or levels of enterprises, and ultimately, the result of these changes bring economic benefits. Neely & Hii (1998) assert that, in the emerging knowledge economy, the ability to innovate at the firm, regional, and national levels dictates an economy's capacity for wealth generation. While ecological economists seem to be aware of the need to redefine progress to meet the challenge of sustainable development, no comparable effort has yet been made to redefine the term innovation (Rennings, 2000).

From a management perspective, innovation is the process by which entrepreneurs see the potential profit opportunities of the market and recombine production conditions, factors, and organizations to create a more efficient operational system and more financially sound production. Birkinshaw et al. (2008) affirm that the invention and implementation of novel management practices, processes, structures, and techniques are intended to further organizational aims. Crossan & Apaydin (2010) report that this concept is reflected by production, adoption, assimilation, and exploitation of a value-adding novelty in economic and social field; the renewal and development of products, services, and markets; development of novel production methods; and establishment of new management systems.

From a philosophical point of view, the process of innovation is that in which the innovative object is changed by an innovative subject in a specific manner—it is an activation process in which the innovative object become the item that meets the purpose and need of a user. Zeng (2003) emphasizes the innovation subject in his master's thesis, using the system method to analyse the innovation subject and innovation activities, and clarifies the basic composition and activity law of the innovation subject.

From the viewpoint of design, the purpose of pursuing design innovation is to create better products in the future (Georgiev et al., 2012). For us, that means building a better environment in the future. The innovation of interior design mainly includes the initiative and value of the designer in the interior design as well as the active activities and processes that can generate new results. Research on interior design innovation generally includes a small number of

exploratory articles, and most focus on journals and online resources. One representative theoretical work is a doctoral dissertation about a study on interior design innovation based on the outcome of design research (Wang, 2007).

Meanwhile, some examples of innovative designs for sustainable buildings are visible in practice. Hauke & Werner (2012) present some innovative practice case studies from several countries in Europe. The recycling of old buildings means reducing the ecological footprint in a cost-effective and efficient way. To highlight aspects beyond 'sustainability', like water conservation, energy conservation, the use of recycled or sustainable materials, improved indoor air quality, and solar power utilization from photo-voltaic panels, a book edited by Marshall (2008)—which includes 21 developments from Shanghai that feature Western-style buildings and traditional Chinese structures as well as workshops and warehouses—focuses on buildings that been transformed into contemporary spaces with their own innovative character.

Some outstanding innovation cases exhibit outstanding performance regarding the use of specific technology or new materials. To achieve a significant decrease in energy consumption, innovative technologies should be adopted, including renewable energy (Chwieduk, 2003). Wu et al. (2016) outline data concerning innovative technological characteristics of sources of demolition waste that were collected using GIS techniques. Gann (2000) shows that material innovations have been widely recognized as an important role in the evolution of the industry. This material innovation does not refer to creating new materials but new applications of existing materials (Wang, 2007). Some waste materials that are recycled and reused in the old buildings are common in the design field.

2.1.3 Review on evaluation

2.1.3.1 Sustainability assessment

To assess sustainable buildings, different countries develop their own assessment criteria that suit their specific national conditions. BREEAM in the UK, LEED in the USA, CASBEE in Japan, and GB/T 50378-2014 in China are a few of these specific criteria. This topic is discussed in detail in Chapter 6. The adaptive reuse of old buildings evaluation is very rare, and the distinguished criteria are the ARP model and adaptSTAR model.

Langston (2008) proposes a new model for the early identification of adaptive reuse potential. The ARP model examines the following attributes: physical, economic, functional, technological, social, legal, and political. If the ARP ranking matches the evaluation ranking, then it can be concluded that the ARP model is robust.

The adaptSTAR model is an extension of the existing sustainability tools used to measure buildings' energy efficiency. Since adaptSTAR forecasts the optimal value of a building's adaptability, it is both logical and urgent that it is compared with the ARP model (Conejos et al., 2014). It may be possible to integrate sustainability and adaptability into a single decision tool, and it develops a new concept of 'future building adaptive reuse', which is now defined

as a strategy to prolong the useful life of buildings. Conejos et al. (2014) insist that the more successful the adaptive reuse project, the higher the adaptSTAR score.

2.1.3.2 Creativity assessment

One of the most important criteria for performance quality in both art and design seems to be the creativity of the work. Several notable arguments have been presented in creativity studies. Being original and innovative is, by definition, a feature of both areas (Christiaans, 2002). Creativity is one of the main terms. Five keywords form a seamless quintet: curiosity, imagination, creativity, innovation, and invention. Being curious, creative, imaginative, innovative, or talented are nearly synonymous (Landry, 2012).

It is generally acknowledged that there are two major components of creativity. The first is novelty, and the second is value or usefulness (Runco & Pritzker (Eds.), 1999). Two related terms are used in this paper to evaluate the design results is based on the method of Finke et al.—practicality (the idea for achievability and feasibility) and originality (the idea for innovation and novelty), which are examined on a five-point scale (1: low and 5: high) (Finke et al., 1992).

Creativity is the capability or act of conceiving something original, and innovation is the implementation of something new. The evaluation of 'innovation' should adopt an irrational standard evaluation method—that is, a qualitative evaluation method. The level of innovation is mainly judged by psychological satisfaction in interior design (Wang, 2007).

2.1.3.3 Experimental psychology evaluation on the semantic differential method in Kansei Engineering

The Semantic Differential Method was initiated by American psychologist C. E. Osgood in 1957, and it is an experimental psychology method. It has been gradually neglected in related fields, but it is favoured in fields such as architecture and interior design and commodity development investigation (Zhuang, 1996).

It is important that designers learn the human factors and develop a human-centred orientation (Nagamachi, (Ed.), 2016). The aim of the SD Method is to study the human experience in space, focusing on measuring the psychological response of the experience, selecting adjective pairs describing the space, and collecting a certain number of adjectives, which becomes a key step in the design experiment in Kansei Engineering (Luo & Hong, 2015).

In order to make the selected adjectives more representative and comprehensive, at the beginning of the collection work, various methods are used, including reviewing specialized literature, magazines, networks, expert opinions, participant's interviews, and comments. Meanwhile, adjectives are also added or removed. The basis is a series of adjectives and their antonyms. A pair of opposite adjectives is defined at the left and right ends of an attitude scale, generally divided into 5 to 7 point Likert scale. In its quantitative form, participants express their feelings about space on the attitude scale of this particular adjective vocabulary, and it

becomes part of the questionnaire to evaluate the user's thoughts. The object of this experience can comprise the whole of the space or become part of the space.

2.1.3.4 User experience evaluation on Extenic thinking

As mentioned in the first chapter, the aesthetic object is architecture itself, and the aesthetic subject is the person who is embodied and felt in the building—that is, the user. Modern architectural aesthetics emphasizes the experience and feelings of people in architecture, which is the process of aesthetic subject experience. Meanwhile, the behaviour of users in the interior environment is also an important factor affecting sustainability; sustainable research must involve the behaviour of users and the level of ecological awareness, which affects the ecological quality of the interior environment (Zhou, 2011). Hence, it is important to focus on aesthetic subject experience.

The term 'User Experience' was first proposed by American cognitive psychologist Donald Arthur Norman in the mid-1990s. A subjective feeling is produced in the process of use, which emphasizes design that meets the psychological needs of users (McDonagh et al., 2004).

Donald Arthur Norman insists user experience can be divided into five categories in his book *Design and Emotion*: aesthetic experience, emotional experience, social experience, cognitive experience, and functional experience, which can then be summarized into three levels—sensory, behaviour and reflection. Maslow's theory of the hierarchy of needs divides human needs into five levels: physiology, safety, socialization, respect, and self-realization. Physiology and safety belong to basic needs, society and respect are included in behavioural needs, self-realization is a psychological need.

Extenics is a wide-ranging and mixed-discipline founded by Chinese scholar Cai Wen, a researcher at Guangdong University of Technology in China. It uses formal models to study the possibilities of project expansion and the rules and methods of pioneering innovation to solve contradictions (Cai & Yang, 2010).

According to Yang & Cai (2007), Extenics theory establishes matter elements, affair elements, and relation elements as the basic elements of descriptions, things, and relationships. Matter element refers to the characteristics of objects, the basic elements of descriptions; the interaction between objects and things is the affair element. The relation element is a formal tool that describes the interaction and interaction between anything, item, and person.

It is easier to see that these kinds of theories exhibit similarities when compared; thus, a hierarchy of user experience design based on extension thinking is shown in Figure 2-1.

Figure 2-1: User experience design based on the Extenics thinking

2.2 Synthesis of Research Findings

Based on the above literature review, it can be seen that there is only a general description that old building renewal outweighs new building development, but the characteristics of the two types of buildings are not compared using experimental methods. Therefore, the fourth chapter uses the SD method to compare and analyse how old building renewal has a rich meaning new building development—the promise of this research. The planning of old building renewal is a very tough task compared to the planning of a new building (Hauke & Werner, 2012). For example, compared to new buildings, it is known that some wastes are dismantled during the reconstruction process, which produces a lot of trash and noise. How to handle garbage is also a hard task. It spends some time and labour force. If it could not be treated well, negative influences still increase the burden of the environment.

Sustainability is closely linked to innovation. Birkeland (2012) argues the prioritized thinking of eco-innovation, which addresses social and environmental needs while greatly reducing net resource and energy consumption. The responsible measure of old building renewal is far from being a well-established concept. While proof that the results are worth the effort is provided by this selection of projects, the majority of the work is small offices, many of which were developed with very limited budgets (Jäger, 2012).

Fewer categorization types of case innovations for sustainable designs could be summarized by a typology. Therefore, the fifth chapter of the study summarizes the typology of adaptive reuse of old buildings using a number of individual cases from the perspective of innovation design and explores which innovation types have higher effects, it is the focal point of this dissertation.

For the evaluation of the adaptive reuse of old buildings, the adaptSTAR model was developed based on the ARP mode. Chapter 6 follows the four innovative types of the adaptive reuse of old building—summarized in Chapter 5—combining each of the rules of the adaptSTAR model as evaluation criteria to find the key criterion in each innovative design type.

In the case study of the adaptive reuse of old buildings in Chapter 7, SD Method is used to develop a creative practice for old building renewal considering an art studio space designed

from the perspective of users' needs. Through this comparison, a practical contribution that brings new life to an old building can be made and a creative space for users can be built by employing a sustainable environmental design.

Concurrently, Extenic thinking and users' needs are combined in a case study, and the highest level of psychological experience is attempted to define. This is an exploration to revitalize and invigorate innovative design of the user experience and derive more innovative value. The user experience design method is also a beginning exploration of the formal application of Extenics.

In addition, it is also found that, in the process of the adaptive reuse of old buildings, the main transformation modes are mostly creative industrial areas—large and medium supermarkets, shops, museums, art exhibition centres, and concert halls; most places are public space (Li et al., 2017). Even if the original function of the building was a living space, more spaces are generally transformed into public spaces such as hotels and offices. Therefore, the research object is old building renewal in public space.

The adaptive reuse of old buildings in innovative design should be considered in this context as an encouragement and an inspiration for architects and interior designers.

2.3 Definition of Terms

2.3.1 Old building renewal and the adaptive reuse of old buildings

The definition of old building renewal is the renovation and reuse of structures existing previously for new usages, which is a process that transforms an obsolete or ineffective project into a new one that can be used for a different aim (Reuse, 2004), such as a neighbourhood revitalization strategy that employs a series of linked procedures to plan, inventory, acquire, manage, and reuse surplus or abandoned real estate (Zushi, 2005). Old buildings renewal is the process of refurbishing old structures to make them suitable for new purposes (Bullen, 2007).

The adaptive reuse of old buildings is revered as the 'holy grail of the sustainability movement' (Melaver and Mueller, 2009). If the building is properly renovated at its most basic situation, the retrofitting of old buildings reuses existing structural materials, reduces demolition waste, preserves the historical legacy of locally informed construction practices, conserves already expended energy, and reduces new carbon emissions (Preservation Green Lab 2011).

Conejos (2013) posits that future building adaptive reuse is a novel conception that pertains to design of new buildings, so that their adaptive reuse potential later in life is maximized to reduce the influence of building on the environment and alleviate the effects of climate change.

Therefore, repair and renovation belong to the old buildings renewal, while adding the environment element in old building renewal design with the sustainable development theory, then it can be called adaptive reuse of old buildings.

Another scholar noted that, due to the integral relationship between architecture and the interior environment, it is impossible to separate these two problems. This is because many elements of architecture and interior environment are directly linked together and have consistent attributes (Zhou, 2011). This study is also emphasizes the consistency of the two elements.

2.3.2 Innovative design

Narrowly defined innovation, represented by Joseph Alois Schumpeter, believes that the role of innovation is new combinations (Śledzik, 2013). In the broad definition of innovation in the American traditional dictionary, innovation is interpreted as 'the act of introducing something new'. In the Chinese dictionary, the meaning of innovation is very rich: it can also refer to a new idea, a new scientific discovery, or a new invention or creation.

According to Wang (2007), the meaning of interior design innovation involves several aspects:

- Creation of a new form in art that is rare, at least statistically;
- Technical expression of a new combination method—that is, the creation of technology under the guidance of universal technology or the creation of detailed methods; Landry (2012) emphasizes creativity is a method of exploiting resources and helping them grow.
- Advocation of a new aesthetic concept;
- Provision of new meaning to the environment of the space.

2.3.3 Innovative design of the adaptive reuse of old buildings

The above sections discuss novel design standards form the viewpoint of form and aesthetics, so it is difficult to express them comprehensively in terms of rational thinking such as concept, norm, decision, and reasoning.

In my opinion, the innovative design of the adaptive reuse of old buildings mainly refers to the adaptive reuse of old buildings that are furnished by distinguished performance on the background of sustainability and innovation. This is discussed further in Chapters 8.

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CHAPTER 3 Research Methodologies

In this chapter…

- Research Design
- Research Method
- Research Procedures
- References

3. Research Methodologies

This chapter describes the research methodology by which the research design and main research procedures of the dissertation are obtained. It begins with the research design by system methodologies. Then, it focuses on the crossed research method, including quantitative research and qualitative research, interdisciplinary research, and methods of combining theory with practice. Finally, this chapter presents the major research procedures, such as the target object, selection of adjectives and participants, and data collection instruments.

3.1 Research Design

The overall purpose of this study is to build a knowledge theoretical model of innovative design in the adaptive reuse of old buildings in public spaces. To achieve this goal, system methodology was used to design the whole dissertation.

First, 'Why' was asked. *Why* did it need this study? Facing Phenomenon 1 in Chapter 1, it was mentioned that this study attempted to verify the fact that old building renewal was more effectively to the new building by using both literature review and objective experimentation. Hence, Experiment 1was designed by comparing old building renewal and new building.

Conventional old buildings renewal design considers the characteristics of function, cost, and aesthetics. If the environmental factor was considered, it can be sustainable architecture and interior design. However, regardless of whether old or new buildings were renewed, if they were designed by innovative elements, then it should be thought about the characteristic of innovation with originality and practicality.

Second, it continued with 'What'. *What* is it? Zhou (2011) states that renewal and reuse are the two basic contents of 5R principles in sustainable design. The adaptive reuse of old buildings belongs to the sustainable design category; sustainability with innovation were combined to explore the adaptive reuse of old buildings from the viewpoint of creativity.

Third, this research explored by asking 'How.' *How* could it attain these goals? The typology of adaptive reuse of old buildings was attempted to combine with inductive analysis to respond to Phenomenon 2, and found the higher effect type from the perspective of creativity.

Based on the type of innovation of the adaptive reuse of old buildings, it further sought the evaluation criterions of these four types which is outlined by Finding 3 and discovered the higher scores of influence criterions with deductive analysis to respond to Phenomenon 3.

In the last step, this study applied theory to guide practice for Finding 4, I participated in a real case to explore the feasibility of such an application to respond to Phenomenon 4. Therefore, Findings 2-4 explain how to attain the goals delineated earlier in this paper. Figure 3-1 demonstrates the basic research design roadmap with why, what, and how.

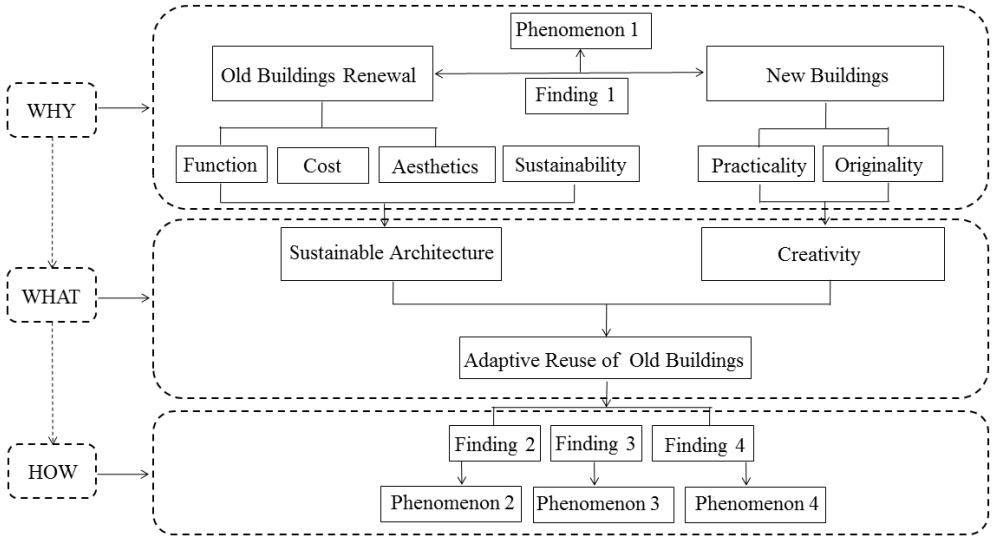

Figure 3-1: System thinking of research design

3.2 Research Method

Any research method has limitations. Therefore, in this study, various mixed research methods were used to achieve complementary advantages. Three specific aspects are outlined below.

3.2.1 Quantitative and qualitative research

Quantitative research is often regarded as being purely scientific, justifiable, and precise based on facts often reflected in exact figures. Conversely, qualitative research is often regarded as 'messing around', being 'vague', unscientific, or not following a structured plan (Jonker & Pennink, 2010). Quantitative research is applied to the theoretical analysis of the model after combining certain mathematical methods, mainly expressed by data, patterns, and graphs; qualitative research mainly uses methods of logical reasoning and historical comparison, and research conclusions are mostly based on textual description. The two methods depend on each other. Qualitative research is the basis of quantitative, quantitative is the specification of qualitative research—the combination of the two can be used to achieve the best results (Luo & Hong, 2015).

This study followed a mixed-method approach that combines quantitative and qualitative research methods, including semi-structured interviews, questionnaire, the semantic differential method, expert assessment (Delphi method) and experiment in quantitative research. The qualitative research relied upon comparative analysis, inductive analysis, deductive analysis, and literary review. Scholars and researchers are debating the merits of mixing methods, but it seems to be significant promise for the revolutionary design (Hesse, 2010).

In general, in Chapters 1–3 and Chapter 8, qualitative research is the focus. This paper refers to the current literature review for an overview and general description of the article. In

Chapters 4–6, the quantitative experimental method is used as the primary approach to conduct Experiments 1–3, and an auxiliary analysis, that is, the process of comparison-induction-deduction, was used to explain the three research questions (SRQ1, MRQ, and SRQ2), respectively.

Qualitative comparative analysis (QCA), has been complemented by other related methods and techniques, such as some current debates are also summarized (Rihoux, 2006). This method mainly was used in chapter 4.

Inductive analyse might condense varied raw data into a brief, summary format and findings to develop a model or theory about the underlying structure of experiences (Thomas, 2006). This method was mainly used in chapter 5.

Deductive analysis means reach a correct answers always, but no new information, which is less common in qualitative research but is increasingly being used (Pope & Mays, 2000). This method was used in chapter 6.

3.2.2 Interdisciplinary research approach

According to Pohl & Hadorn (2007), interdisciplinary research refers to a form of support and integration-oriented cooperation between researchers from different disciplines. In this study, architecture and interior design, economics, innovation and Extenics were used as a variety of crossed disciplines, such as graphical analysis, and Extenics analysis. It is consensus that interdisciplinary research method is a unique useful for understanding complex problems (Repko, 2008).

Generally speaking, the interdisciplinary research approach is more reflected in the Chapter 7 to explain SRQ3. In the process of design, construction and evaluation process, from the user's mental needs, this study tried to combine with psychology, Extenics, Kansei engineering, architecture, and interior design. While the innovation perspectives in the evaluation were applied for Chapters 4 and 5.

3.2.3 Mixed research method of combining theory with practice

In the case study in Chapter 7, I participated in a case of adaptive reuse of old building in Dalian. The theory that I had mastered in the early stage was applied on this case, which actively guided the development of practice and made an effective attempt in the interior of innovative design in order to reach the integration of theory and practice. Some fundamental explanatory in design might offer some practical guidance in addressing those issues (Ivankova, et al., 2006).

Combined with the framework of this paper, various mixed research methods were shown below:

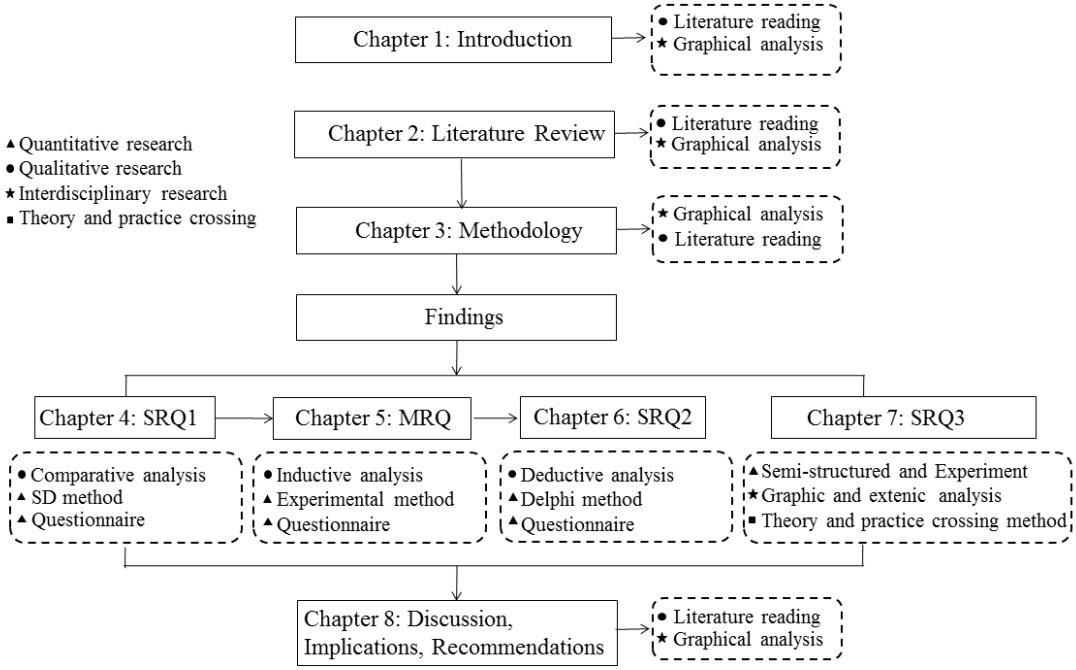

Figure 3-2: Applied main research methods in each chapter

3.3 Research Procedures

3.3.1 Procedures of this study

Through the framework, it was easily seen that the main body about findings in four chapters.

The first step I had to conduct was not only to learn that old building renewal was more effective than new building from the literature review but also prove this opinion from the experiment, thus explaining the necessity of the research, and verify the result adaptive reuse of old buildings could be integrated with sustainability and innovation in architecture and interior design, which was Motivation 1.

The second step addressed the main research focus. It was necessary to classify some design cases of adaptive reuse of old buildings and summarize the typology of adaptive reuse of old buildings from the perspective of innovative design in response to MRQ. Meanwhile, it was found the type of innovation which had an effect on higher creativity for exploring the creative direction in future design, which was Motivation 2.

The third step was to evaluate four innovative design typologies in the adaptive reuse of old buildings, combing with adaptSTAR model standards in each type. From the experiment, it not only proved that the previous result that technological innovation had higher influence but also found more effective evaluation criterion in each type in response to SRQ2, which was Motivation 3. Thus, through the guidance for designers to optimize transformation effect for the future design in order to build a resource-saving and environment-friendly society.

The fourth step was to combine the considerations of knowledge innovation, which not only to require the previous knowledge-based theory, but also to combine knowledge application research and analysis. Therefore, based on the practice of adaptive reuse of old building case that I participated, combined with the user's mental needs, this case study from the investigation of user needs, design, construction, evaluation process demonstrated an entire cycle process in response to SRQ3 for pursuing the feasibility of such a practice, that was Motivation 4.

3.3.2 Target object, adjective, and participant selection

At the beginning of Experiment 1, in order to select the old building renewal cases with innovative features, 18 cases of new and old buildings were firstly selected which belonging to different countries from more than 50 cases after discussion by group experts. Then, from the cases of more than 500 old buildings, through the professionals' discussion, 24 cases of representing different countries were selected for Experiment 2. See Figure 3-3 for the case picture selection process.

Figure 3-3: Selection of cases pictures

For the selection of perceptual vocabulary, professionals chose them according to the needs of architecture and interior design field. The number of perceptual vocabulary ranging from 16 to 50 adjectives pairs were applied in Chapter 4 for Experiment 1 and the 11 adjective pairs are in Chapter 7 for Experiment 4. The participants were asked to consider their feelings by the pictures and then answer questions. Such as: 'Do you think this space is beautiful or ugly?' The left side is the lowest score, the right side is the highest score, and the middle is the grade between the two levels. Usually, each set of pictures combined with adjective pairs is controlled within 1 minute.

Since this research was aimed at professionals and enthusiasts of architecture and interior design, the target group was divided into two categories: the first was designers with rich practical experience and professional teachers with profound theoretical experience, and the other was students majoring in architecture or interior design who would be the designers in the future.

3.3.3 Data collection instruments

This study required the questionnaire design to adhere to the principle of 'simple and easy to understand' in which participants can answer the most questions in the shortest time. A sufficient number and type of participants were required to fill out the questionnaire carefully.

Questionnaire Star software was used for the questionnaire design, which collected a large amount of data in the computer, and Excel or Spss software was used to carry out relevant grade evaluation. Figure 3-4 outlines the design and discussion process of questionnaire, and Figures 3-5 and 3-6 are samples of questionnaire star in Experiment 1.

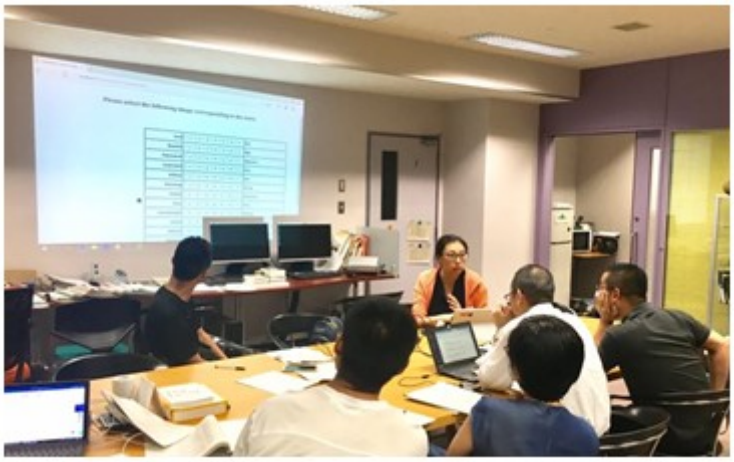

Figure 3-4: Design and discussion process of questionnaire

We are conducting a survey of design cases for old buildings renewal and new buildings.

We would like to ask you to fill out this form. This questionnaire is used for anonymous systems. All data are for statistical analysis only. In the case of a 7-point scoring system, please score each case according to your own expertise and text hint. It will take 20 mins to finish.

Thank you for your cooperation!

我们正在进行一项关于旧建筑改造创新设计案例的调查，想请您用二十分钟时间帮忙填写这个表格。
本问卷实行匿名制，所有数据只用于学术统计分析，请放心填写。采用7分制打分标准，请按自己的专业知识和文字提示给每个案例进行评分。
谢谢您的合作！

ご協力いただきありがとうございます。
リニューアルされた建物、新しい建物のデザインについて調査をしています。

これ以降のシートへご回答ください。
頂いた回答は統計処理のために利用されます。

左の語句から右の語句までの７段階のボタンのうち、直感的に該当すると思われるボタンを選んでください。同じページ内であれば後から変更もできます。

写真は18枚あり、次の写真へ移るには下にあるボタンを押してください。
全ての回答には２０分程を要しますが、ご協力を何卒お願いします。

Figure 3-5: Sample 1 of questionnaire star

16.

	1	2	3	4	5	6	7	
坏的 / 悪	○	○	○	○	○	○	○	好的 / 良い
丑的 / 醜い和谐的 / 調和した	○	○	○	○	○	○	○	美的 / 美しい
不和谐的 / 不調和な	○	○	○	○	○	○	○	和谐的 / 調和な
受限的 / 制約された	○	○	○	○	○	○	○	自由的 / 自由な
昏暗的 / くすんだ	○	○	○	○	○	○	○	敞亮的 / 鮮やかな
无聊的 / つまらない	○	○	○	○	○	○	○	有趣的 / 面白い
无序的 / 乱れた	○	○	○	○	○	○	○	有序的 / 整った
脏乱的 / 不潔な	○	○	○	○	○	○	○	整洁的 / 清潔な
不舒适的 / 不快な	○	○	○	○	○	○	○	愉悦的 / 快適な
紊乱的 / 混乱した	○	○	○	○	○	○	○	稳定的 / 穏やかな
无机的 / 物質的	○	○	○	○	○	○	○	有机的 / 生命的
低级的 / 低級	○	○	○	○	○	○	○	高级的 / 高級

Figure 3-6: Sample 2 of questionnaire star

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PART TWO

Part Two Contains…

Chapter 4: Design for Sustainability and Innovation

Chapter 5: Innovative Design Typology for Adaptive Reuse of Old Buildings in Public Spaces

Chapter 6: Evaluation Criterion of Innovative Design for Adaptive Reuse of Old Buildings

Chapter 7: Case Study of a Creative Practice for an Art Studio Design Based on Users' Mental Needs

CHAPTER 4 Design for Sustainability and Innovation

In this chapter…

- Introduction and Literature Review
- Research Aim and Motivation
- Research Method
- Results
- Discussion
- A Project Illustration
- Summary
- References

4. Design for Sustainability and Innovation

How may sustainability and innovation be integrated in a better environmental design for our future society? The aim of this chapter was to use semantic differential (SD) method Evaluation to verify the renewal of old buildings with sustainability and innovation by comparing to new buildings. First, a questionnaire survey was conducted, with 84 participants, on 18 buildings from Asian and European countries; the survey used 16 adjectives. Second, it was studied the characteristics of new and renewed old buildings in terms of the elements crucial to sustainable and innovative design. The results suggest that more general an effect of the adaptive reuse of old buildings is more effective than constructing new buildings. Further, the adjectives preferred by the survey show that the adaptive reuse of old buildings has higher influence with character of 'settled' and 'creative' from the viewpoint of sustainability and innovation. This chapter presents a project to address sustainability and innovation of adaptive reused of old building at a later stage. This study contributes to the renewal of existing infrastructure to improve its longevity and chance of future reuse, and to ensure environmental sustainability for future society.

4.1 Introduction and Literature Review

Design for sustainability invites designers to re-examine the relationship between human development and environmental issues, constantly seeking change in practice (Vezzoli & Manzini, 2008). Sustainable design is of increasing relevance not only for the design of new buildings, but also for the renewal of old buildings (Sayigh, 2013). Upgrading old buildings presents clear advantages over new buildings (TEC, 2008). Adaptive reuse of old buildings is a process that transforms an obsolete or ineffective project into a new one, by renovating and reusing existing structures for new uses (Reuse, 2004). The adaptive reuse of old buildings could extend a building's lifecycle, reducing the influence on the environment. The trend towards increasing sustainability by finding new functional aims for old buildings, rather than demolishing them and constructing a new one, has shed light on the importance of the concept of future building (Conejos et al., 2014).

Meanwhile, much of the contemporary architecture looks the same, as it is not sustainable for local climates (Lechner, 2014). Against a backdrop of globalization, strengthening the regional and cultural characteristics and enhancing the heterogeneous structure of buildings through innovative design is one of our considerations. Design innovations are those that make a significant difference in the market through the creation of new meanings (Verganti & Dell'Era, 2009). Opportunities for design innovation are also present in the adaptive reuse of old designs (Henderson & Clark, 1990).

The main research questions that guide this work include: How may the adaptive reuse of old buildings lead to innovative and sustainable designs? How may sustainability and innovation be integrated in a better environmental design for our future society? What specific characteristics should such buildings have? This research seeks to understand the combination of sustainability and innovation in the adaptive reuse of old buildings across geographic

contexts.

4.2 Research Aim and Motivation

The current research on the adaptive reuse of old buildings mostly focuses on advantages from the perspective of sustainable design. Many abandoned old buildings hold great potential for adaptive reuse (Stas, 2007). Studies tend to focus on the analysis of individual cases and there is an emphasis on radical innovation driven by technology. A wide range of examples analyze the merits of individual cases (Bloszies, 2013). Only a few studies combine the two aspects of sustainability and innovation into one category.

Designers can translate users' preferences into their redesigns of old buildings by including characteristics that people identify and value (Govers et al., 2003). Users' emotional needs should be considered as a design criterion (Luo & Hong, 2015). Therefore, a questionnaire was developed for designers to analyze two types of buildings using adjectives to describe the characteristics of buildings with the Kansei Engineering method. A powerful consumer oriented technology for design development, Kansei engineering translates participant's feelings (Nagamachi, 2010). This paper aims to:

1. Determine if the adaptive reuse of old buildings is more effective than the perceived value of sustainability of new buildings.

2. Identify adjectives that can highlight sustainability and innovation in renewal of old buildings, in order to assist designers to integrate the emotional information into their designs.

3. Illustrate a specific case study of an adaptive reuse of an old building that combines sustainability and innovation.

4.2.1 Hypotheses

This study is informed by the 5R's (Revalue, Renew, Reuse, Reduce, and Recycle) of Sustainability (Zhou, 2011) and the two elements (practicality and originality) of innovative design (Finke et al., 1992). In order to study the perception of 84 participants using pictures of new buildings and adaptive reuse of old buildings, this paper uses the SD method to evaluate the two types of buildings, in examining the following hypotheses.

4.2.1.1 Hypothesis 1 (H1)

By comparing the respondents' evaluation of the cases selected, it is supposed to look for differences in perception between the old and new buildings, in trying to assess whether the adaptive reuse of old buildings for sustainability is preferable to constructing new buildings.

4.2.1.2 Hypothesis 2 (H2)

What kind of adjectives may accurately highlight sustainability and innovation? The suitable adjectives that express the perception of innovation of the adaptive reuse of old buildings is expected to be derived from the questionnaire.

According to the characteristic of sustainability of environmental design. The ecosystem itself has ecological balance ability and strong closure, that is, the ability to regulate and restore its own stable state or reach equilibrium (Hao Ming, 2011). Therefore, hypothesis 2 was that "settled" adjective words might play a positive role in sustainable environmental design.

Meanwhile, Finke, Ward, and Smith (1992) believed that the elements of innovation design from the two viewpoints of practicality (the ideas of achievability and feasibility) and originality (the ideas of innovation and novelty), the last one was more significant. It is assumed that "creative" adjective words was the vital character of the adaptive reuse of old buildings.

4.3 Methodology

4.3.1 Data collection

4.3.1.1 Collect picture samples

Through the investigation of adaptive reuse of old buildings in books and networks, 50 prominent cases were used to collect samples from two Asian countries (Japan and China) and developed European countries (including France, Italy, Swiss, and UK etc.). Irrespective of their location, it was found that the old buildings in the living space are demolished and replaced by new buildings, even if the original function was a living space, which was more generally transformed into public spaces such as hotels and offices. Hence, the type of buildings were chose by characterizing the public space.

After group discussion and multi-scale analysis (a general description has been introduced in Section 3.3.2 and 3.3.3), 4 cases were found in each type of architectural sample: Chinese, Japanese, and European countries including a total of 12 cases of adaptive reuse of old buildings; in order to explain the problem more favorably, the same method were used to find each type of architectural sample with 2 cases in China, Japan, and European, resulting in a total of 6 cases of new buildings. Also, the pictures were selected with the highest number and most explicit features from each case that could be easier to recognize by national characteristics, such as which pic is more like Chinese style. Followed the target selection method in Chapter 3, the chosen cases from the websites are shown in the Appendix of the thesis. The 18 samples are shown in Figure 4-1.

4.3.1.2 Screen representative vocabularies

The researchers developed a semantic differential vocabulary for evaluation through brainstorming, Internet, and suggestions of experts (comprising professional teachers and senior designers). Through initial screening, modifying, and classifying, 16 pairs of adjectives conveying a clear intention were chosen as shown in Table 4-1.

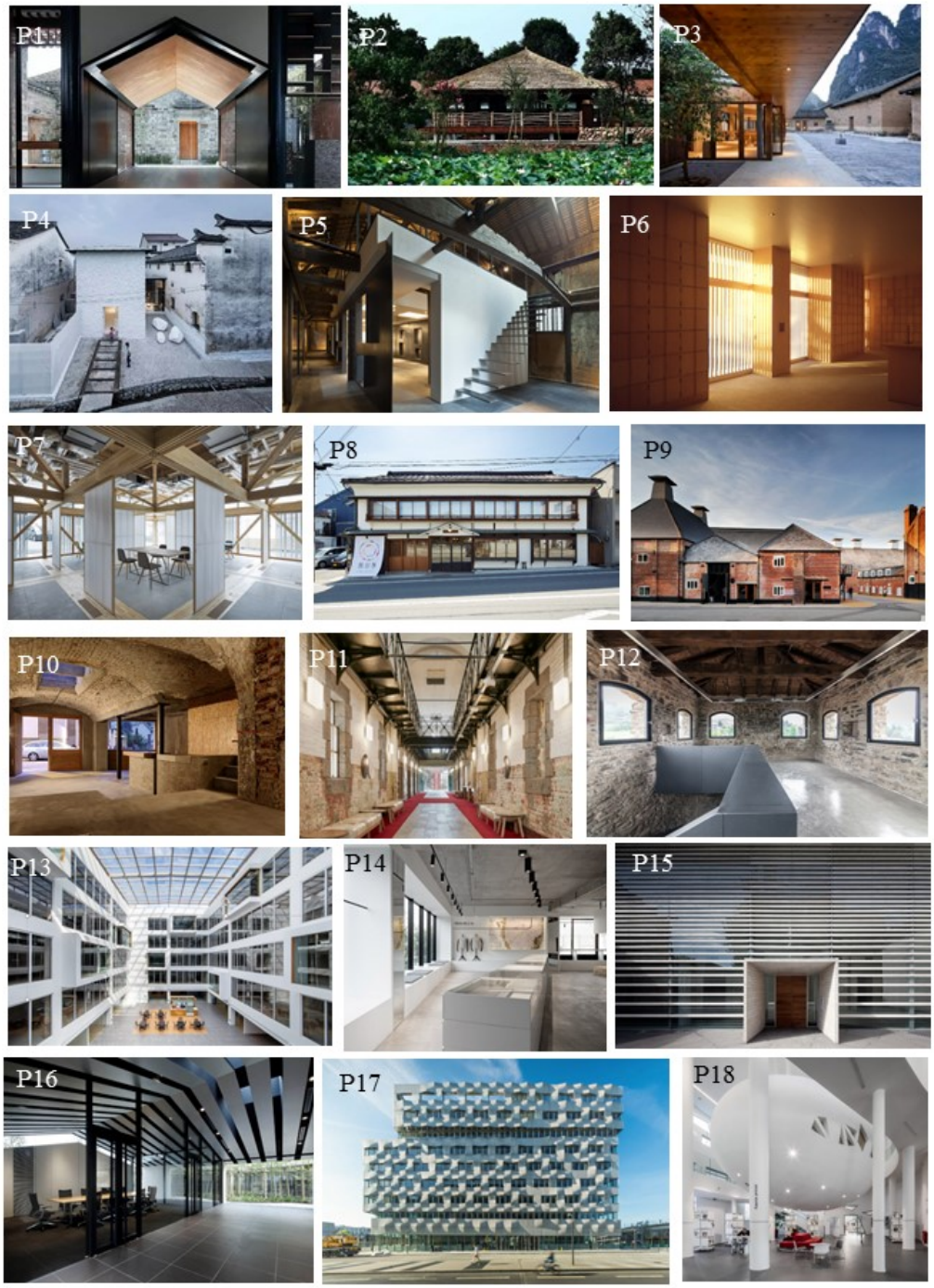

Figure 4-1: Selected representative samples

Table 4-1: Sixteen selected pairs of adjectives to assess the buildings

Bad – Good	Ugly – Beautiful	Dissonant – Harmonious	Constrained –Free
Dull – Brilliant	Boring–Interesting	Disorderly– Orderly	Dirty – Clean
Uncomfortable – Pleasant	Disturbed –Settled	Inorganic–Organic	Impoverished–Luxurious
Unsafe – Safe	Calm – Excitable	Conservative –Creative	Unfamiliar– Familiar

4.3.3.3 Design questionnaire

The questionnaire included interior and exterior pictures in old buildings and new buildings. The semantic differential (SD) method was used to evaluate the selected 18 samples. The SD method (Osgood et al. 1957) had a seven-point scale (1: low and 7: high) and was used with 16 pairs of adjectives to form a survey (see examples in table 4-2). Each adjective pair took 2-3 seconds and each case took 48 seconds to complete, and the overall time for each participant was about 20minutes.

Table 4-2: Example of the SD method for adjective pairs of ugly-beautiful

Very ugly	Quite ugly	Slightly ugly	Neutral	Slightly beautiful	Quite beautiful	Very beautiful
1	2	3	4	5	6	7

4.3.3.4 Evaluate semantically differential words

This study used a network evaluation method through the ‘questionnaire star’ software by selecting 84 participants of undergraduates in grade four in China, with males were 31, females were 53, who had a basic background in environmental design and will be designers in the future. During these four years of study, environmental design students had their understanding of the current theory and practical knowledge. Every answer represents their judgment about the questions. Questionnaires were distributed and semi-structured interviews were conducted.

4.3.2 Data analysis

There were 18 pictures of two types of buildings. The adaptive reuse of old buildings was divided for three groups: China, represented by P1, P2, P3, and P4; Japan, represented by P5, P6, P7, and P8; European countries, represented by P9, P10, P11, and P12. New buildings included P13 and P14 in China, P15 and P16 in Japan, and P17, P18 in European countries. An abbreviation T was used to express adjective pairs (T1: Bad – Good; T2: Ugly – Beautiful; T3: Dissonant – Harmonious; T4: Constrained – Free; T5: Dull – Brilliant; T6: Boring – Interesting; T7: Disorderly – Orderly; T8: Dirty – Clean; T9: Uncomfortable – Pleasant; T10: Disturbed – Settled; T11: Inorganic–Organic; T12: Impoverished–Luxurious; T13: Unsafe – Safe; T14:

Calm – Excitable; T15: Conservative – Creative; and T16: Unfamiliar – Familiar). For this stage, it got the mean scores on each pair of adjectives for the 18 pictures, as demonstrated below in Table 4-3.

Table 4-3: Data of semantic differential evaluation

Pic.	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16
P1	5.18	5.04	5.28	4.54	4.52	4.23	5.52	5.74	4.69	5.52	4.62	5.31	4.84	5.86	4.24	4.17
P2	5.02	5.02	5.21	5.05	4.95	4.76	4.7	4.67	5.08	4.69	5.85	4.43	4.6	5.52	3.74	4.9
P3	6.12	5.99	5.75	5.74	6.02	5.82	5.86	5.88	6.00	5.65	6.05	5.67	5.7	5.93	5.52	5.77
P4	6.02	6.1	5.9	5.64	5.83	5.62	5.58	5.8	5.88	5.69	5.6	5.62	5.66	6.00	5.01	5.76
P5	5.49	5.25	5.35	4.94	4.45	5.08	5.18	5.63	4.83	5.19	4.68	5.3	4.39	4.93	5.27	4.68
P6	5.30	5.21	5.43	4.67	5.07	4.55	5.45	5.73	5.1	5.49	4.8	5.12	5.27	5.55	4.5	5.12
P7	5.63	5.49	5.58	5.17	5.92	5.37	5.51	5.73	5.13	5.17	4.85	5.19	4.88	5.21	5.21	4.82
P8	5.58	5.38	5.64	4.83	5.32	4.83	5.58	5.64	5.23	5.44	4.81	4.94	5.5	5.64	4.57	5.23
P9	5.09	5.46	5.13	5.7	5.9	5.54	5.7	5.42	5.56	5.72	5.92	4.8	5.42	4.96	3.75	4.35
P10	4.89	4.51	4.76	4.45	4.21	4.5	4.68	4.73	4.35	4.94	4.18	4.44	4.64	4.94	4.13	4.24
P11	5.43	5.27	5.01	4.9	5.24	5.01	5.35	5.21	4.89	4.99	4.58	5.02	4.84	4.77	4.57	4.68
P12	5.01	4.8	4.6	4.56	4.85	4.43	4.65	5.06	4.36	4.96	4.58	4.65	4.42	4.87	4.85	4.4
P13	5.35	5.05	5.18	4.46	6.1	4.39	5.92	5.98	4.71	5.81	4.00	5.02	4.84	5.38	4.76	4.31
P14	5.48	5.42	5.52	5.24	5.77	5.19	5.37	5.85	5.05	5.45	4.36	5.46	5.08	5.48	5.35	4.79
P15	5.19	5.06	5.05	4.31	4.92	4.81	5.6	5.52	4.53	5.3	4.05	5.14	4.64	4.87	5.25	4.37
P16	5.25	5.17	4.93	4.71	4.51	4.69	4.79	4.99	4.65	4.92	4.2	4.51	4.79	4.92	5.07	4.39
P17	5.4	4.94	4.96	4.95	5.25	5.26	5.01	5.44	4.85	4.92	4.29	5.27	4.61	4.23	5.65	4.46
P18	5.7	5.6	5.27	5.33	5.83	5.36	5.23	5.64	5.36	5.15	4.82	5.36	4.94	4.95	5.6	4.81

4.4 Results

4.4.1 Relationship between adaptive reuse of old buildings and new buildings (H1)

According to the 'mean' of each picture, 'mean' was the average of each score which represent the preferences of participants, the left adjectives represent the lowest score, the right ones were the high score. The pictures in one group of old buildings renewal were collected which were P1 (4.96), P2 (4.89), P3 (5.84), P4 (5.73), P5 (5.04), P6 (5.15), P7 (5.3), P8 (5.26), P9 (5.49), P10 (4.54), P11 (4.99) & P12 (4.69) respectively, the average of old building renewal was 5.16; while in the other groups of new buildings which were P13 (5.08), P14 (5.3), P15 (4.91), P16 (4.82), P17 (4.97) & P18 (5.31) respectively; the average of new buildings was 5.06. Therefore, whilst the difference is marginal between two groups, 5.16 of old buildings renewal is preliminary overweight the 5.06 of new buildings.

Meanwhile, Georgiev et al. (2012) state that 'comfort' which is a pleasurable feeling of ease and well-being experienced, in other words, 'uncomfortable– pleasant' this adjectives pair of T9 extremely express the level of preference. From the result P1(4.69) to P12 (4.36) in old buildings renewal in this pair, the average is 5.19; from P13(4.71) to P17(5.36) in new buildings,

the average is 4.86. Hence, 5.19 higher than 4.86， from the viewpoint of this adjective pair, old buildings renewal also tentatively exceed to new one.

It is known that a comprehensive description of a column of data should consider not only the average but also the standard deviation (Zhang, 1995). If the standard deviation is larger, it means that most of the values differ significantly from the average. If the standard deviation is smaller, it means that most of the values are closer to the mean.

Although in the group of old building renewal, the mean value is 5.16, but the gap ranges from 4.54 to 5.84. The data is put into Excel software, and the standard deviation of the old building renewal (P1-P12) is 0.39; while the mean value of the new building (P13-P18) is 5.06. However, the standard deviation is 0.20. In another adjective pair of data T9, the old building average is 5.09, the variable is from 4.35 to 6.00, the standard deviation is 0.52; while the new building average is 4.85, and the standard deviation is 0.3.

Therefore, from the viewpoint of the mean and standard deviation, it seems that the variables of the old buildings renewal are relatively larger, and the variables of old buildings are less uniform and predictable than new buildings. It is more generally an effect of old buildings renewal is more effective than new buildings and could be further explored in the next. Just like Bergman (2012) stated, adaptive reuse of old buildings can produce higher levels of sustainable design.

4.4.2 Preferred adjectives words of two kinds of architecture (H2)

Principal component analysis (PCA) was carried out to identify the perceptions that were related or similar. PCA was applied to investigate relationships between adjectives in both types of buildings (Hypothesis 2). The purpose of the PCA is to reduce dimensionality in datasets where there are several interrelated variables, and preserve the variation in the dataset as much as possible (Jolliffe, 2002).

The data was input into SPSS to analyze the factors according to the Kaiser-Meyer-Olkin (KMO) and Batlett Test measure of sampling adequacy. The main role of the KMO statistic is to detect the adequacy of the collected samples and to test the degree of partial correlation between the variables. That is, whether is to perform factor analysis. According to Kaiser (1974), the KMO value should be between 0 and 1. The more closer to 1, the more suitable for factor analysis. If the score was over 0.7, the result is more credible. It was 0.957 for renewal of old buildings and 0.929 for new buildings; Table 4-4 shows the KMO scores for the two types of buildings, so it is regarded the mean of result on table 4-3 as believable.

Table 4-4: KMO and Bartlett's Test scores in the two types of buildings

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.957
Bartlett's Test of	Sphericity	9353.775
	df	120
	Sig.	.000

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.929
Bartlett's Test of	Sphericity	3952.814
	df	120
	Sig.	.000

The Bartlett sphere test is a test of whether variables are independent of one another. However, when the p value reached a significant level ($p<0.05$), it was suitable for factor analysis (Wu, 2010). It was found from the table that Barlett's ball value was 0.000, reaching a significant level of 0.05, indicating that the scale is suitable for factor analysis. Therefore, two types of buildings of factor analysis can be used to test the validity of the scale through KMO and Bartlett's Test.

4.4.2.1 Adjectives in adaptive reuse of old buildings

Table 4-5 shows the comparison of the principal components' factor loadings in renewal of old buildings for the two clusters. The top five factors in component 1 denoting Creative scoring .782, Interesting scoring .769, Free scoring .690, Alive scoring .668, and Pleasant scoring .644; and component 2 with the top five factors being Settled scoring .769; Calm scoring .769; Orderly scoring.719; Clean scoring .671, and Harmonious scoring .643. The left adjectives with the lower scores, we ignore them. Table 4-5 is shown below.

Table 4-5: Rotated component matrix[a] in the renewal of old building

	Component	
	1	2
Conservative - Creative	.782	
Boring-Interesting	.769	
Constrained -Free	.690	
Inorganic - Organic	.668	
Uncomfortable - Pleasant	.644	
Impoverished - Luxurious	.608	
Unfamiliar - Familiar	.583	
Dull - Brilliant	.576	
Ugly-Beautiful	.574	.524
Disturbed - Settled		.769
Excitable - Calm		.769
Disorderly- Orderly		.719
Dirty - Clean		.671
Dissonant-Harmonious		.643
Unsafe - Safe		.579
Bad - Good	.562	.578

a. Rotation converged in 3 iterations

4.4.2.2 Adjectives in new buildings

Table 4-6 shows the comparison of the principal components' factor loadings in new

buildings for the three clusters. The higher score meant a similar relationship with the new buildings. Component 1 with the top five factors being Creative scoring .756, Free scoring .754, Interesting scoring .752, Pleasant scoring .605, and Good scoring .599; component 2 with the top four factors being Clean scoring .773, Settled scoring .699, Orderly scoring .699; Brilliant scoring .661, and Harmonious scoring .562; and component 3 with the top three factors being calm scoring.691, Safe scoring .682, and Familiar scoring.676.

Table 4-6: Rotated component matrix[a] in the new buildings

	Component		
	1	2	3
Conservative - Creative	.756		
Constrained -Free	.754		
Boring-Interesting	.752		
Uncomfortable - Pleasant	.605		
Bad - Good	.599		
Ugly-Beautiful	.590	.505	
Impoverished - Luxurious	.580		
Dirty - Clean		.773	
Disorderly- Orderly		.699	
Disturbed - Settled		.699	
Dull - Brilliant		.661	
Dissonant-Harmonious		.562	
Excitable - Calm			.691
Unsafe - Safe			.682
Unfamiliar - Familiar			.676
Inorganic - Organic	.542		.586

a. Rotation converged in 3 iterations

4.4.4.3 Summarizing the semantically differential words

Through PCA and Rotation Sums of Squared Loadings, we got the results. The percentage of variance in renewal of old buildings was 31.031% in component 1 and 29.149% in component 2.The cumulative variance contribution rate was 60.18%, which meant that the two factors explain the information 60.18 percentage, reaching the 60% minimum standard, and the factor load of each item in the grid dimension was greater than 0.5, indicating that the extracted factor could be accepted. Through the above analysis, the scale of this study had good construct validity. The respective higher scoring words were Creative.782 and Interesting .769 in component 1 and Settled .769 in component 2; hence, the adjectives to highlight the adaptive reuse of old buildings were creative, interesting, and settled.

The percentage of variance in new buildings was 24.818% in component 1 with Creative.756, Free .754, and Interesting .752; 21.976 % in component 2with Clean .773; and 14.928% in component 3, in which the others with lower influence was discarded. The

cumulative variance contribution rate was 61.722%, and the factor load of each item in the grid dimension was greater than 0.5, the same as previous analysis, the scale of this study also had a good construction validity. Therefore, this study used adjectives creative, free, and interesting to describe the new buildings. To see words clearly, the polar attributes were chosen to express two types of buildings (Figure 4-2, 4-3).

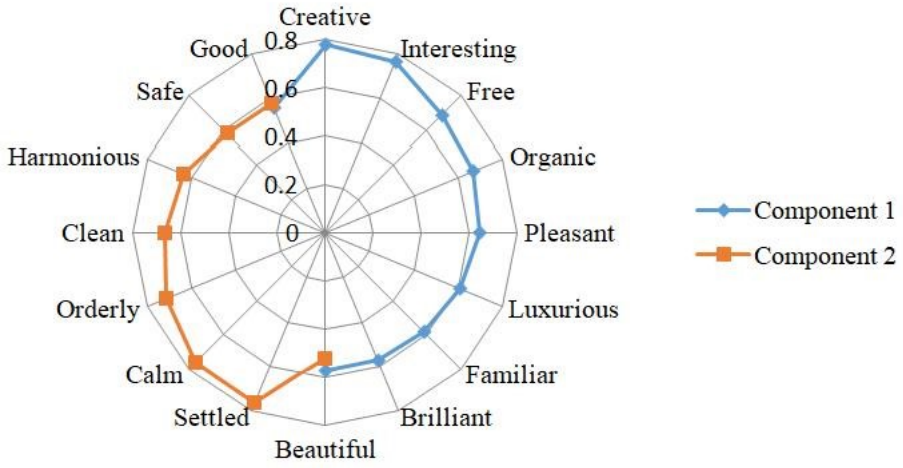

Figure 4-2: Radar plot of adjective words in the renewal of old buildings

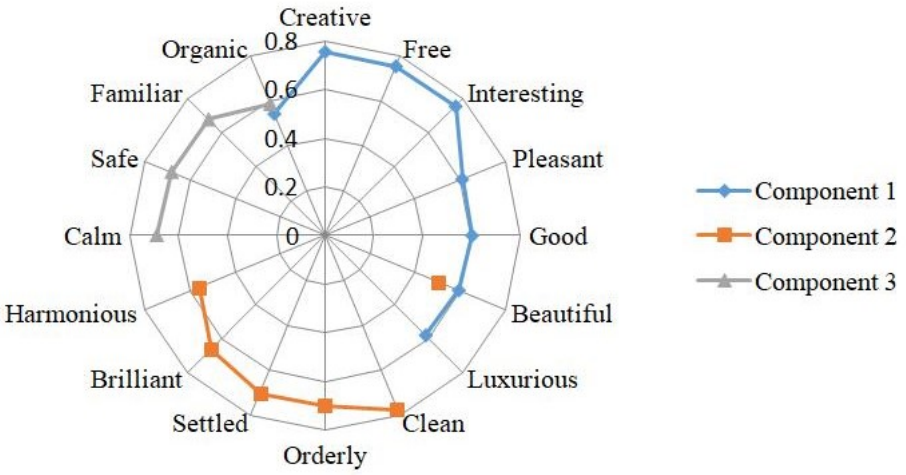

Figure 4-3: Radar plot of adjective words in the new buildings

4.5 Discussion

4.5.1 Old buildings renewal is more effective than constructing of new buildings

From the results of Hypothesis 1, it can be concluded that standard deviation variable of the old buildings renewal is larger, which should be explore more in the future.

It is related to the participants' understanding of the old buildings renewal. Although under the background of global sustainable context and the old buildings renewal is an essential part

of sustainable development, the people who genuinely realize its significance are not yet widespread. In the survey of respondents, it can be found that although all the students are engaged in design majors. They are basically at the university study stage, and they have not experienced the real benefits of the old building renewal for the environment and resources, so the gap leading to the standard deviation is larger, someone felt the advantages of old buildings renewal, while the rest do not. However, from the feedback semi-structured interviews, most of the respondents realized the importance of revitalizing old buildings, as shown in the followings.

Firstly, there are clear environmental sustainability benefits that can make this option better than constructing new buildings. New buildings increase the new environmental burden in the construction process. For instance, they generate new resources and energy consumption, produce new waste, and occupy more land. Such as the total cost is 10 M€ excluding VAT in P18.However, for the adaptive reuse of old buildings, the potential of the buildings will be maximized if they are reused before they are completely useless, take P9 for example, recycling materials with agricultural roofing sheet and manmade slates are used for economy but also to maintain a simple, unadorned aesthetic. It could therefore be reasonably argued that adaptive reuse is a method of extending the useful life of buildings and hence their sustainability through a combination of improvement and conversion (Bullen, 2007).

Secondly, there are some social sustainability benefits. Renewal of old buildings may have a characteristic that significantly contributes to the culture of the society. Such as P10, the project is a contextual dialogue with history, all the elements were put into the raw original state or it was rebuilt raw – a tribute to the material. The architectonic-social aspect is playing a minor part but it is still the same house from the outside. The reuse of these old buildings is important and maintains their intrinsic cultural values, while new buildings do not have such features. Therefore, from asocial sustainability perspective, it is preferable to perform adaptive reuse of old buildings.

4.5.2 The reason for preferred adjective words

Results showed the preferred adjectives in old buildings renewal were: creative, interesting, and settled, which response to H2. It means ‘settled’ and ‘creative’ would positively correlate with the sustainability and innovation. The reasons why these words were preferred by participants are as following.

On the one hand, the mean of ‘settled’ in the old buildings renewal is 5.25, and same as the new buildings. From the feedback of participants in semi-structured interviews, they are convinced that architecture is formed by an interface of enclosed space, and its spatial extension and shape are also determined. Just like Zhou (2011) argue that the ecosystem itself has ecological balance ability and strong closure in the previous paragraph. Therefore, the building is an ecological subsystem with a relatively stable operation mode at a microscopic level. The old building is no exception. It is a link and stage of continuous energy and material flow in the ecosystem. From this point of view, it is stable. ‘Settled’ adjective might play a positive role in sustainable environmental design.

On the other hand, as it mentioned before, originality is the most important element in

innovation design. The corresponding adjective is ‘creative’. In component 1 in two types of buildings, ‘creative’ denoted scoring is .782 and .756, which got the highest scores than other words. In the old buildings’ renewal, these old and weather-resistant old buildings retain their most essential things when they meet with the new materials and new technology in modern architectural vocabulary. It is easier for designers to develop creative spatial effects after balance the old structure and new material. This approach can inject fresh blood into the old buildings, so that the participants can feel the creative effects in the old buildings’ renewal. As creative and settled were used to describe them, it could be inferred that these adjectives are the preferred ones for describing the reuse of old buildings.

4.6 A Project Illustration

Here, a project for the adaptive reuse of an old building was described, called the Harvard House Zero Laboratory (Snøhetta, 2018), see figure 4-4. The project considered the adaptive reuse of the pre-1940s building in Cambridge that housed this laboratory’s headquarters. The aim was to help us understand the renewal of old buildings in new ways. The building represents an exemplary case of sustainability and innovation. Its design was driven by ambitious performance targets from the outset, including the implementation of near zero energy heating and cooling, zero electric lighting during the day, 100% natural ventilation, and zero carbon emissions. The intention for all this is for the building to produce more energy over its lifetime than was used in its renovation and subsequent operation. House Zero Laboratory challenged us to rethink the routine of building design and make a stable operation mode at a sustainable level to express the adjective ‘settled’.

The laboratory provides users with creative technological skill for research and exploration. The building’s architecture also comprises cutting-edge technology and applications of established, low-tech architectural design solutions. Take the natural ventilation as an example: the ventilation is controlled by a window actuation system that employs sophisticated software and sensor arrays to automatically open and close windows as required maintaining a quality internal environment throughout the year. This way above mentioned to express ‘creative’.

This laboratory can function as a new model of sustainability and innovation in old buildings renewed for future society.

Figure 4-4: Harvard house zero laboratory

4.7 Summary

The research presented in this chapter shows two results in relation to sustainability and innovation of adaptive design. One is that adaptive reuse of old buildings is more effective to explore by comparing the new buildings, and the other is that 'creative' and 'settled' represented by innovation and sustainability are relatively easy to express the adaptive reuse of old buildings.

Since buildings impact the environment significantly, Architects have both the responsibility and the opportunity to lead efforts toward sustainable and creative lifestyles in the future. The adaptive reuse of old buildings is an appropriate way to achieve this goal. Further research will show the typology of the adaptive reuse of old buildings in the public space.

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CHAPTER 5 Innovative Design Typology for Adaptive Reuse of Old Buildings in Public Spaces

In this chapter…

- Introduction
- Examples of Innovative Design
- Analysis and Discussion
- Reflection
- Summary
- References

5. Innovative Design Typology for Adaptive Reuse of Old Buildings in Public Spaces

The aim of this chapter is intended to challenge traditional approaches to classifying innovative design by clarifying its typology through evidence from adaptive reuse of old buildings in the public space. Using both theoretical and empirical approaches, this study summarizes the characteristics of old-building renewal and reuse, and builds a foundation for further research on the theoretical evaluation of innovative design. In the theoretical part, 24 examples are examined from seven categories of innovative design according to adaptSTAR model, which are grouped into four types: function, aesthetic, technology, and location. Then, this study explore the relationships between those four types and the geographical regions they are situated in. For the empirical part, questionnaires are administered to verify the results obtained in the theoretical analysis. The results suggest that the most important element of innovative design for adaptive reuse of old buildings is technological innovation, which is found to have an effect on higher creativity.

5.1 Introduction

The adaptive reuse of old buildings has been a hot topic in the field of architectural design. It is defined as an important modification to an existing building function when the former function has become disused (Douglas, 2006). Working with historic structures is more environmentally sustainable and cost-effective than constructing new buildings, and many believe the best designs occur at the intersection of old and new (Bollack & Frampton, 2013). From a functional perspective, old buildings have often outlived their purposes, but in terms of architecture and cultural history, they represent an asset, which is increasingly being recognized and utilized in both publicly and privately financed urban renewal projects (Palle, 1992). In developed countries, there are many examples of abandoned buildings (such as factories and warehouses) being converted into useful alternative spaces such as commercial, recreational, and residential buildings.

Innovative design is defined as a practical process by which designer uses his or her ability to generate some novel and valuable ideas, solutions, or products (Sarkar & Chakrabarti, 2011). The essence of innovative design in architecture is reconfiguring an established system which link together existing elements in a new way (Henderson & Clark, 1990). Innovative design of space could efficiently work as a place identity generator (Gospodini, 2004). The significance of this trend is that extending the lifespan of existing buildings supports the core concepts of sustainability by reducing materials, transport, pollution and energy consumption (Gregory, 2004; Douglas, 2002).

Many cases, however, are based solely on an individual's motivation to discover his or her own innovative design ideas, which are transformed by functional and aesthetic requirements in completing the dialogue during the process of adaptive reuse. Most research on design innovation has focused on such individual innovation (Smith, 2003). Few of the successful

cases of old-building renewal have been comprehensively classified from the perspective of innovative design. The adaptive reused old buildings present a true challenge to architects and designers to find innovative solutions (Reuse, 2004).

A new observation tool named adaptSTAR is used as a guideline, which offers a holistic and unified design standard compatible for assessing the adaptive reuse of old buildings. The criteria can be identified 7 categories according to physical, economic, functional, technological, social, legal and contextual parts (Conejos et al., 2013).

Therefore, this study first selects randomly 24 successful cases (Abbreviations in the front of dissertation) of adaptive reuse buildings representing the 'reconstruction of existing public space' by the discussion with the scholars and designers. From the perspective of adaptSTAR model, these are classified into seven categories of innovative design which above mentioned. Second, this study redefine the seven categories and induce them into four types of innovative design (function, aesthetic, technology, and location) related to geographical region. Questionnaires are administered from 40 participants with the backgrounds in architecture and interior design according to creativity criterion to verify this induction and discover higher innovation type in the design process for adaptive reuse of old-building. Finally, it is concluded that technological innovation has the higher creativity in adaptive reuse of old-buildings design in public space (Figure 5-1).

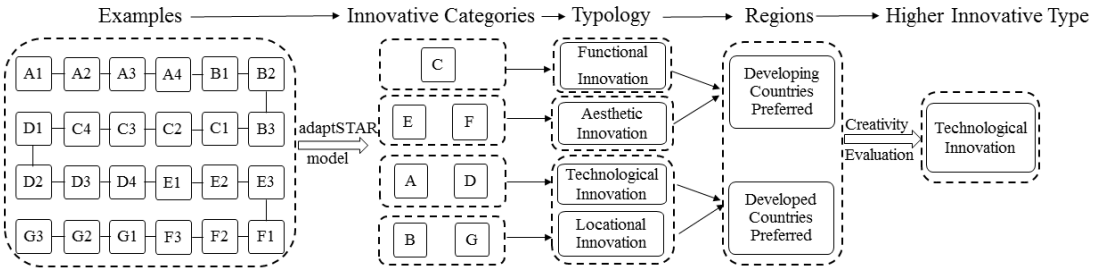

Figure 5-1: Framework for adaptive reuse of old-building in an innovative-design typology

The purposes of this chapter are shown as following: First, this study inductively classify the types of innovative design according to the criterion of adaptSTAR model in adaptive reuse of old buildings with examples to present a basic summary from existing buildings in public spaces. Second, it explores the important types affecting innovative design via questionnaires to establish a foundation for the theoretical model of innovative design in the adaptive reuse of old buildings.

5.2 Examples of Innovative Design

Many studies have investigated the characteristics of design thought processes in terms of innovation (Nagai & Taura, 2006), and there are some excellent examples of creative designs in old building renewal. The adaptSTAR model is an extension to the existing sustainability tools used to measure a building's adaptability, which may produce future successful adaptive reuse of buildings (Conejos et al., 2014).

Based on adaptSTAR model, 24 cases of renewed old buildings in the public space were chosen in terms of seven representative types – physical (long life), economic (location), functional (loose fit), technological (low energy), social (sense of place), legal (quality standard) and contextual (politic) innovation (Conejos et al., 2013). Following the general case selection method in Section 3.3.2, the cases in the chapter are chosen from the website https://www.archdaily.com/category/adaptive-reuse. In this website, more than 500 examples of adaptive reuse buildings can be found. The samples also should be randomly selected. Although many have outstanding architectural and historical features, high-quality original materials, and great locations with excellent facilities, these cases have individual innovative features to create a revitalized character in its own distinct way (Figure 5-2).

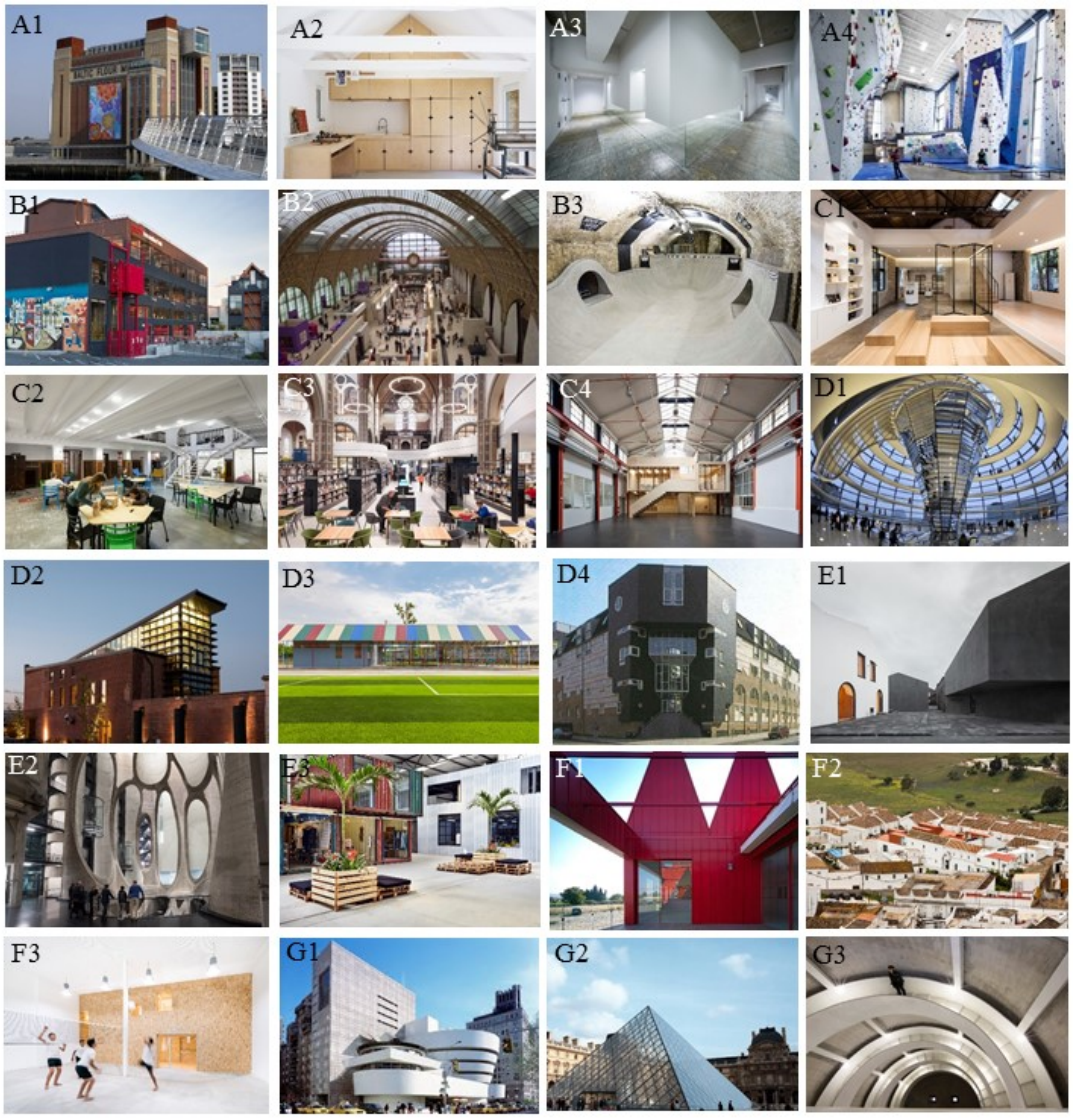

Figure 5-2: The 24 selected cases studies

A. Physical innovation

The criterion for physical innovation includes four elements: Structural Integrity-structural design of the building to fit to future uses and loads; Material Durability-developed innovatively long-lasting materials in space during the building cycle; Workmanship-used craftsmanship of

structure which different to traditional way； Design Complexity-various geometries relevant to the building's design and creativity (Conejos et al., 2013). The followings focused on these aspects respectively.

A1. Baltic Centre for Contemporary Art, UK

Structural innovation concerns finding solutions to structural problems (Wang, 2007). Baltic Centre for Contemporary Art, located in the UK, was originally a flour mill that was transformed in 2002. The most difficult aspect of its transformation involved its structure. A new floor was required to ensure the internal connectivity of the two main facades of the original flour mill. A certain degree of innovation was needed in the new structure to avoid destroying the original building. Aside from the newly added floors, the viewing platform and entrance hall allow the museum to have flexible exhibition and performance spaces to meet future uses.

A2. An Old Breton Barn Converted into an Artist Studio， France

In order to meet new uses, the art studio totally cleared the previous functions in 2014. To refurbish the interior space, a concrete floor had to be made. It was finished by the sealing of air gaps and the insulation of the walls by throwing lime and finally new water and electricity networks. After the timber frames being strengthened, a coat of insulating material has been set (Sabrina, 2016). In this space, it was used creatively a new concrete material to get the long-time durability.

A3. Wall Cloud, Japan

This building was reused in 2014. Due to the attic part of the former discotheque on the second floor had a low ceiling, designer felt like creating an open space with floating walls and pillars. The beams and other elements were reconsidered as different spatial components, and were rebuilt in the space. The ceilings were eliminated, and the beams now surround the space as floating walls, while lights are used to enhance the sense of drifting. The oppressive attic-like space of a symbol of the past was transformed like a wall cloud and renewed as an impressive space because of craftsmanship of structure.

A4. Allez UP Rock Climbing Gym, Canada

This building was transformed from anabandoned silo into a rock-climbing gym in 2013, which was a special way to maximize various geometries in design creativity. The climbing wall formations actually resemble sugar cliffs, reminding visitors of the original function of the Red path silos. These geometrical climbing walls offer various routes for different levels of climbers. The multi-coloured climbing-holds speckled across the walls add to the dynamic charm of this distinctive interior space (Sabrina, 2016).

B. Economic innovation

The criterion for economic innovation more concentrates on location, it involves three aspects: Market Proximity-distance to major city, CBD etc.; Site Access-proximity or link to access roads; Planning Constraints-utilize restricted site condition to convert into beneficial elements in space (Conejos et al., 2013). The cases in these aspects are demonstrated below:

B1. PCH International Innovation Hub, USA

PCH International Innovation Hub was adaptively renovated from a warehouse in 2014.The location was convenient to downtown, where was visible from highway, the on-ramp to Silicon Valley, and in close proximity to many of the city's creative makers, mover, and shakers. This project was designed and constructed to achieve LEED ID+C Gold Certification.

B2. Musée d'Orsay, France

This museum was renewed from an abandoned train station in 1986, which was located on the left bank of the Seine, near Louvre Museum and Tuileries Gardens. Because its original function was a station, this museum has a unique location and people can easily arrive both in land and water transportation. The site reflects the convenience of the accessing.

B3. House of Vans London, UK

The new uses from Vans were to provide a cultural hub for skateboarding, art, film and music. Utilizing the previous tunnels, the site was delineated into the four main functions in 2014, so that each was housed within a specific tunnel. Such as a tunnel for skateboarding - a skate park for all levels of skateboarding ability, in particular a skateboarder samples the environment who is about to ride. The overall aim was to use the previous site constraint for a new creative space (Sabrina, 2016).

C. Functional innovation

Most old-building renewals involve a functional transformation due to the requirements of the new situation. Here, functional innovation refers to four elements in details: Flexibility-space capability to change according to newly requirements, plug and play elements, etc.; Disassembly-options for reuse, recycle, demountable systems, modularity, etc.; Spatial flow-mobility, open plan, fluid and continuous; Convertibility-divisibility, elasticity, multi-functionality (Conejos et al., 2013).

C1. Town Folktales, China

This was transformed from a movable-type printing plant into a public activity centre in 2017, where including dining space, reading space, all of which helps provide high-end service for customers. The wooden steps in book bar area, along with the movable display shelves, can be combined and arranged freely and ideally to fulfil different functions, which was an exemplification of flexibility of space.

C2. Impact Hub Belgrade, Serbia

This is a renovation of the Events Hall in the former house of the headquarters in 2014. Within the project, a special working desk was designed with functional, economical and suitable idea. The original design offers a folding table with minimum sizes, easy to store and transport. According to the users' needs, trapezoidal shaped workspace becomes a module for a great number of different combinations. Users freely gathered the desks together for different needs.The intention was to enable users to be more focused on each other by using the modularity of desks.

C3. Library, Museum and Community Center 'De Petrus', Netherland

An extensive renovation the church was reused into a public centre in 2018, containing a library, a museum but also a bar and shops. All functions were blended into a large open space to the public. The most striking feature was the mezzanine floor. This unique element gave the church a new look fitting for its new function. Because the church floor can be used in a highly flexible way, it provides space for events on all scales as well as function as a library. Meanwhile, the bookshelves are placed on a rail system so they could be moved to the aisles of the church. All of these are the good examples of spatial flow.

C4. Wooden Structure at Launchlabs, Switzerland

The main assembly hall of the former machine factory in Basel, Switzerland, has been served as a convertible and multifunctional working environment since 2014.The goal was to create a space, adaptable to various uses, offering countless possibilities – co-working, regular office workstations, areas for informal and cultural activities, workshops – all while still being able to host bigger events. The main intervention consist in the insertion of an autonomous wooden installation. In order to preserve a maximum of elasticity on the ground floor, most of the construction was lifted and suspended on wooden beams (Sabrina , 2016).

D. Technological innovation

Technological innovation focuses on low energy, mainly refers to introducing energy-saving technologies to gain sustainable low-carbon emissions. It includes: Solar Access-use of solar power by measuring for summer and winter sun to energy-saving; Building Control Systems- storm water collection system which control water operations and performance systems to achieve efficiency; Natural Lighting and Ventilation- -inclusion for natural daylight, efficient lighting systems, and optimise airflow, quality fresh air, etc. (Conejos et al., 2013); Reuse and recycle items- through the reuse and recycle of waste items to achieve energy efficient. The corresponding cases were shown below.

D1. Parliament building, German

The German parliament building was modernized in the 1990s, taking into account ecological issues. In terms of energy efficiency, the building's heating and energy systems employ solar technology, mechanical ventilation, the use of strata for cold and heat storage, thermal power plants, heat power generation from waste, and renewable materials. In particular, the vault of the building incorporates energy-saving technology.

D2. The Green Building, USA

Based on the relationship between design and sustainability, this studio used a 115-year-old previous dry goods store to create a commercial space in 2008, which employs sustainable technologies like storm water collection system. For example, storm water is either absorbed by the green roof, collected in three large rain barrels, or directed into a rain garden, where the toxins are eliminated by plant material before re-entering the ground water system (Sabrina, 2016). It represents the water-efficiency.

D3. Rainbow, Vietnam

The contribution of the project was dealt with ventilation and natural lighting efficiently in 2015. Solar energy is transformed into electricity for lighting facilities and heating water for daily use. A collection and reuse of various old and broken construction materials such as scaffolding steel pipes, sheet metals, bricks, ashlars, bathroom ware, tables and chairs. It is a multifunctional project includes health station, art performance theatre, refreshment tent etc.

D4. Garvergården, Denmark

Many Danish towns have examples of abandoned commercial or industrial buildings. A former shoe factory, the Garvergården in Vestergade was converted into a new building. Containing common areas and a restaurant, the structure was built using recycled materials from other demolished buildings, including recycled cement, wood, slate, and brick (Palle, 1992). Reusing existing material stock—especially as a result of performance upgrades—has been regarded as having a positive impact on the sustainability of the built environment (Bromley et al., 2005; Rohracher, 2001; Kohler, 1999; Kendall, 1999).

E. Social innovation

Innovation for social aspect mainly refers to sense of place, including the following three elements: Image/Identity-social and cultural attributes, values, etc.; Aesthetics-architectural beauty, good appearance, proportion; Amenity-provides comfort and convenience facilities (Conejos et al., 2013).

E1. ArquipélagoContemporary Arts Centre, Portugal

In 2014, an old tobacco warehouse was transformed into the Arquipélago Contemporary Arts Centre, which was located in Ribeira Grande, Portugal. The new building adds meaning to the social and cultural context of the place where it is built, represents the social and cultural identity of a specific place. The building achieves its identity by the quiet variation between the pre-existence and the two new buildings. Certain sustainable design effects were observed as well (Jouer, 2016).

E2. Zeitz Museum of Contemporary Art Africa, South Africa

The silo, disused since 1990, stands as a monument to the industrial past of Cape Town, once the tallest building in South Africa, given new life by the transformation in 2017.The galleries and the atrium space at the centre of the museum have been carved from the silos' dense cellular structure of forty-two tubes that pack the building. This form of reconstruction was d and creative， which combines the 100 years old concrete structure with modern glass building, making the interior of the building creative and achieving aesthetic innovation.

E3. MALHA Architecture，Brazil

A warehouse space was chosen and was built to be an innovative platform for the fashion commercial space (a photographic studio, a sewing studio, natural food restaurant and so on) in 2016. The using of containers as the main constructive factor was built up throughout the hangar, as well as a quick and clean construction. Some pallets have been spread throughout the space, serving as seating, and small plant beds have been set up, which combined with sofas, benches, and tables, create comfortable and convenient facilities that mixes the ambiance of a house with that of a public

space.

F. Legal innovation

Legal innovation concentrates on a quality standard, mainly refers to three elements: Disability Concern -provision for disability easement, facilities, etc.; IEQ safety and security - provisions for non-hazardous materials, natural fabrics, etc.; Comfort-hygiene and clean environment, etc. (Conejos et al., 2013). The relevant cases are the followings:

F1. Centre for Individuals with Disabilities, Spain

One of the important methods to make old building energetic is an expansion (Zheng, 2002). This is an expansion project, which adopts the stimulation and cares for disabilities by using the symbolic meaning of colour and the arrangement of space. For example, façade and roof are covered with red zinc coated sheet which is a symbol that makes them visible; it provides a courtyard to capture sunlight and allows disabled people to stay there in summer. Therefore, this project encourages the users to communicate with others from the perspective of visual to be considerate for the users.

F2. Professional Cooking School in Ancient Slaughterhouse, Spain

The project proposes building this space through a new ceramic roof that limits the new construction and consolidates the original building. The Professional Cooking School used this idea of the molded ceramic plane to draw its geometry in 2011. This roof lends unity to the built complication and indicates the traditional construction of the place, ceramic roofs and whitewashed walls (Sabrina, 2016). This non-hazardous new materials benefit for enhancing the Indoor Environment Quality.

F3. Box in the Box, Spain

In 2017, the project entailed the renovation of a warehouse located in Madrid and its conversion into a building that provides spaces for a cultural organization and sporting activities for young people. The use of clean lines and neutral-toned materials gave the spaces a homogeneous looking. The white palette of translucent, transparent and opaque walls and grey continuous polished-concrete floors were utilized in the space, which reflexes a hygiene and clean environment.

G. Contextual innovation

Contextual innovation refers to political sides. Here relates with two elements: one is adjacent buildings-adjacent enclosures, vertical and visual obstacles, which include the harmonious and contrastive relationship between new and old in architectural environments; the other is community interest/participation-stakeholder relationship and support (Conejos et al., 2013).

G1. Guggenheim Museum, USA

Following the addition of a ten-floor tower of simple buildings in the 1990s, the Guggenheim Museum can be seen as a gallery of vertical traffic space. Traffic is assisted by the spiral ramp, and it follows a simple grid line with the design elements of the facade. A

square box became a “green leaf building.” A conch-shaped body with a simple background makes the Guggenheim appear as a sculpture. With both new and old elements, this building stands harmoniously with its environment and can be considered a model for keeping the faith and understanding context.

G2. Glass Pyramid at the Louvre Museum, France

Regarding this controversial example (Nowogońska, 2016), architect I. M. Pei commented that it contains vast contrast and a little harmony. Contrasting with the surrounding buildings of the Louvre, the delicate glass pyramid creates a special artistic effect that can be characterized as contrasting bright and dark, light and heavy.

G3. O-office, China

It was a refurbishment projects in 2017. Designers are known for exploring what architecture can do within the contemporary Chinese context. They transformed an abandoned Shenzhen factory into a dynamic cultural and community centre, where get the support of participation. Through the innovative use of space and material, they intended to “reweave” the urban fabric so as to revive urban life.

5.3 Analysis and Discussion

5.3.1 Similarities

It can be identified some similarities in the innovative design cases described above.

5.3.1.1 Change of original function

Except for the original architectural skin elements, in these 24 cases, only C2, D1, D3 and F1 retain their original function while the rest do not. The majority of internal functions and spaces were completely transformed, losing their original function in the reconstruction. Some elements—such as masonry walls, pipes, chimneys, and machine tool equipment—were transformed in the ways that differed from their original use.

In these 20 cases of functional changes, three transformation directions are identified - artistic creation (art centre, studio) including A2 and E1 (2 of 20), accounting for 10%;leisure and cultural display (art galleries, museums) such as A1, A3, A4,B1, B2, B3, C1,C3,C4,E2, F2, F3,G1, G2 & G3 (15 of 20), accounting for 75%, and commercial entertainment (shopping centres, hotels) like D2, D4 and E3 (3 of 20), accounting for 15%.

Table 5-1 shows these three directions of functional changes in the adaptive reuse of old buildings in details. Hence, it may be concluded the leisure and cultural display was the mainstream in the transformation directions.

Using SWOT analysis (statistical analysis method) to theoretically analyze the above three models, establish SWOT matrix, that is SO (strengths - opportunities), ST (strengths - threats),

WO (weaknesses - opportunities), and WT (weaknesses - threats) combination respectively, which are compared to determine the three transformation modes. $Z=[z_1, z_2, z_3]=[0.75, 0.15, 0.1]$, which means that 75% of the old building functions are transformed into Leisure and Cultural Display, 15% of the old building functions are changed into Commercial Entertainment, and 10% of the old building functions transformed into Artistic Creation. Here the range of z_1- z_3 is [0, 1], and the sum is to 1 consistently (Formula 5-1).

Table 5-1: Directions of functional change

Type	Example	Original Function	Current Function	Proportion
Artistic Creation	A2	Barn	Artist Studio	10%
	E1	Warehouse	Arts Centre	
Leisure and Cultural Display	A1	Flour mill	Art museum	75%
	A3	Discotheque	Office	
	A4	Silos	Rock-climbing gym	
	B1	Warehouse	Innovation hub	
	B2	Train station	Museum	
	B3	Tunnel	Cultural hub	
	C1	Printing plant	Activity centre	
	C3	Church	Multifunctional centre	
	C4	Machine factory	Office	
	E2	Silo	Art museum	
	F2	Slaughterhouse	Cooking School	
	F3	Warehouse	Cultural and sporting space	
	G1	Office building	Art museum	
	G2	Square	Art museum	
	G3	Factory	Cultural centre	
Commercial Entertainment	D2	Dry goods store	Commercial space	15%
	D4	Shoe factory	Restaurant	
	E3	Warehouse	Commercial space	

$$Z=[z_1, z_2, z_3]^T=\begin{pmatrix}\text{Leisure and Cultural Display}\\ \text{Commercial Entertainment}\\ \text{Artistic Creation}\end{pmatrix}$$

Formula 5-1: Three transformation modes for adaptive reuse of old buildings

5.3.1.2 Change of users and their psychology

Owners and users are the subjects behind the space, and they play important roles. Such changes have led to functional changes. The original owners of factories and warehouses were farmers and workers. However, now the owners represent an emerging public (based on class and education) that includes the petit bourgeoisie, white-collar professionals, freelancers,

SOHO residents, and so forth. Meanwhile, abandoned factories have mostly been transformed into leisure and cultural displays. The spaces changed from noisy, dull, broken places from the past into relaxed, creative, and stylish environments. Such change leads to a change in the psychology of users, from negative emotional responses to positive high-end experiences. This indicates that old buildings are more sustainable for long life cycles and for people's higher spiritual pursuits.

5.3.1.3 Change of development trend

The new purposes of these buildings reflect the shift away from heavy industry. These buildings are located relatively close to the classical urban centres from which they derive their visitors. However, the changes in the use of the buildings—or more generally, their adaptation to economic needs—reflect trends in urban development with the changes in industrial structures and urban functions—namely, from the industrial age to the information age. For example, B1, C1, F3 and G3are the conversion of factories to leisure pursuits and they are indicative of the expansion of the leisure economy.

5.3.2 Differences

At the same time, it also be observed some differences.

5.3.2.1 From the perspective of innovative design typology

Hong and Xia (2009) suggested that the aesthetical value of old buildings reuse in ecological context should consider function, technology, and context. We tried to classify innovative design typology from the following four sides:

Function reflects the use of the building. Functionalism emphasizes purpose, practical utility, and applicability (Runco and Pritzker (Eds.), 1999). The new features of old buildings need to meet the needs of human health and comfort within this dual goal (Hong and Xia, 2009). However, it seems that functional change makes the majority of these cases. Therefore, functional innovation is given as a type (C).

Aesthetic and technology are two basic attributes of architecture (Zhou, 2011). Aesthetic decisions are made with respect to beauty, proportion, concinnity etc. (Runco and Pritzker (Eds.), 1999). Comfortable interior environment benefits to enhance the quality of aesthetic requirement. The sub-factors of aesthetic appeal include hygiene and high indoor environment quality (Lee & Weber, 1984). Therefore, aesthetic innovation at the formal level includes social innovation (E) and legal innovation (F).

Technology influences the innovation of interior design through the development of structure, construction, and so forth (Wang, 2007). Regarding technological innovation, Crysler et al. (Eds.) suggested that perhaps in 15 years, there will be new sustainable materials that can optimize the various subcomponents of buildings. Kebir et al. (Eds.) also claimed that it seems to crystallize around materials, equipment (heating, lighting) and information technology

systems. Various renewable energy have effected on technological innovation (Johnstone et al., 2010). Hence, technological innovation belonging to the content level includes physical innovation (A) and low energy innovation (D).

Context could be a part of location. Location should think about the site of present condition and contextual background (Xiao, 2014). Present location refers to the basic condition of site, which was represented by type B, belonging to the external level. Meanwhile, just like Alvar Alto said: nothing is as dangerous in architecture as dealing with separated issues. If we split life into separated problems, we split the possibilities to make good building art (Krygiel & Nies, 2008). Old buildings record the development of urban civilization and exhibit the urban development history. It is better to maintain a high degree of integration in context, which is also an innovation. It belongs to the internal level of emotional identity which is represented by type G. That is why the economic innovation (B) and contextual innovation (G) belong to this category.

Of these 24 selected cases, functional innovation C, includes C1, C2, C3 and C4 (4 out of 24) accounted for 16.7%. There were six cases (E1, E2, E3, F1, F2, F3) affecting aesthetic innovation (6 of 24), accounting for 25%. Similarly, eight cases (A1, A2, A3, A4, D1, D2, D3, D4) affected technological innovation (8 of 24), accounting for 33.3%, and six cases (B1, B2, B3, G1, G2, G3) focused on location innovation (6 of the 24), accounting for 25%. Table 5-2 summarizes the innovative design typology in four types.

Table 5-2: Innovative design typology in adaptive reuse of old buildings

Innovation type	Case	Time	Region	Way
Functional Innovation	C1	2017	China	Tradition
	C2	2014	Serbia	Tradition
	C3	2018	Netherland	Tradition
	C4	2014	Switzerland	Tradition
Aesthetic Innovation	E1	2014	Portugal	Ecology
	E2	2017	South Africa	Tradition
	E3	2016	Brazil	Tradition
	F1	2011	Spain	Tradition
	F2	2011	Spain	Ecology
	F3	2017	Spain	Tradition
Technological Innovation	A1	2002	UK	Tradition
	A2	2014	France	Ecology
	A3	2014	Japan	Tradition
	A4	2013	Canada	Tradition
	D1	1992	German	Ecology
	D2	2008	USA	Ecology
	D3	2015	Vietnam	Ecology
	D4	1990s	Denmark	Ecology
Locational Innovation	B1	2014	USA	Ecology
	B2	1986	France	Tradition
	B3	2014	UK	Tradition

	G1	2008	USA	Tradition
	G2	1989	France	Tradition
	G3	2017	China	Tradition

The knowledge innovation lies in the central place in the sustainable competitive environment (Andreeva & Ikhilchik, 2011). With reference to the knowledge innovation model in management field, this study try to find an innovation model in architecture and interior design field among these four types. It can be called TFAL model (Figure 5-3). Each innovation type matches corresponding knowledge. The specific explanation will be talked in chapter 8.2.1.2.

Technological Innovation • Collective Knowledge	Functional Innovation • Individual Knowledge
Locational Innovation • Tacit Knowledge	Aesthetic Innovation • Explicit Knowledge

Figure 5-3: Innovation model of the four types

5.3.2.2 From the perspective of geographical regions

Adaptive reuse of old building got underway in the early 1960s and 1970s. In terms of the aspects of time and region, it has developed significantly since the 1980s. From the Table 5-2, we found that in these 24 cases, the United States and some developed European countries (18 of the 24) are actively engaged in exploration and practice, accounting for 75%, with outstanding performances. Meanwhile, developing countries such as China, Serbia (6 of the 24) account for 25%.

Two type cases study are selected equally and randomly according to the geographical regions. There are 5 developed countries (USA, France, UK, German, Spain) which are represented by B1, A2, A1, D1, F1 and 5 developing countries (China, Serbia, South Africa, Brazil, Vietnam) which are represented by G3, C2, E2, E3, D3.

From the ten chosen cases, 2 cases (A1, A2) are in type A, named after 2A, the same as 1B, 1C, 2D, 2E, 1F, 1G. Because technological innovation is summarized by A and D, which are total 4 cases (2A & 2D); Aesthetic Innovation is summarized by E and F, which are 3 cases (2E & 1F); Locational Innovation is summarized by B and G, which are 2 cases (1B &1G); Functional Innovation is summarized by C, which is 1 case (1C). We can see that technological innovation is the major innovation possessing diverse forms.

In this 4 cases in technological innovation, A1, A2, D1 and D3 which represent 3 developed countries (UK, France, German)and 1 developing country (Vietnam). Therefore, it

can be seen that in the renewal of old buildings through innovative design, developed countries place more emphasis on technological innovation, which is an internal design pursuit; and developing country is strived on positive practice.

The 3 cases in aesthetic innovation (E2, E3, and F1) are presented by South Africa, Brazil and Spain. It means 2 developing countries preferred to this type.1 case C2 means functional innovation that is also represented by developing country. Meanwhile, in the whole cases, developing countries (China, Serbia, South Africa, and Brazil) are represented by C1, C2, E2 and E3, which belong to function and aesthetics concerning the external mode of innovation. Thus, there is room for growth in the rest of innovation.

In the chosen 2 cases in locational innovation, B1 is developed country and G3 is developing country, which are the same in number. So B and G are typical in the locational innovation in whole cases. Five cases (B1, B2, B3, G1 and G2) are developed countries and 1 case (G3) is developing country. Therefore, most developed countries prefer the locational innovation.

In one word, developed countries prefer to technological and locational innovation, while developing countries like aesthetics and functional innovation.

In addition, there are two perspectives on transformation. Traditional transformation involves using traditional technology and materials to change a building's structure, appearance, and indoor environment to meet users' needs, emphasizing the shape of the change. Ecological transformation refers to applying ecological technology and materials to the original building environment, including function and resource utilization, emphasizing quality changes. Seen from the Table 2, it is found that traditional transformation (16 out of 24) account for 66.7% while ecological transformation (8 of the 24) account for 33.3%. Hence, ecological transformation needs improvement in the future.

5.4 Reflection

Questionnaires are used to obtain views from 40 respondents regarding which are the higher innovative design types in adaptive reuse of old buildings and to verify the technological innovation that is the major innovations possessing diverse forms.

5.4.1 Method

Questionnaires are conducted through semi-structured interviews and online surveys in PowerPoint using two colourful pictures and text with the typical characteristics to guarantee each case with the same condition. Designers and teachers with backgrounds in architecture and interior design are invited to participate, who also have the foundation and judgement of art design.

5.4.2 Evaluation of creativity

In the field of creativity studies, it is generally acknowledged that there are two major components of creativity. The first is novelty, and the second is value or usefulness (Runco and Pritzker (Eds.), 1999). Similarly, this design results are evaluated based on the method of Finke et al.—that is, from the two viewpoints of practicality (the idea for achievability and feasibility) and originality (the idea for innovation and novelty), on a five-point scale (1: low and 5: high) (Finke et al., 1992). The aim is to discover which example scores the highest in terms of creativity. Accordingly, the type of innovation it represents has the highest impact. Due to 24 cases are classified into seven categories, four types have three examples, and three types have four examples, so participants synthesize each examples and score in one type.

5.4.3 Analysis

Table 5-3 shows the average rate for each innovation type by seven categories in practicality, originality and order of high creativity. To judge the scores clearly, this study uses a scatter chart (Figure 5-4). The abscissa indicates practicality, and the ordinate indicates originality.

Table 5-3: Creativity evaluation

Innovation Type	Functional Innovation	Aesthetic Innovation		Technological Innovation		Location Innovation	
Example	C	E	F	A	D	B	G
Practicality	3.95	4.08	3.73	3.98	4.13	4.00	3.93
Originality	3.70	3.95	3.75	4.00	4.08	4.03	3.82
Order of high creativity	7	4	6	3	1	2	5

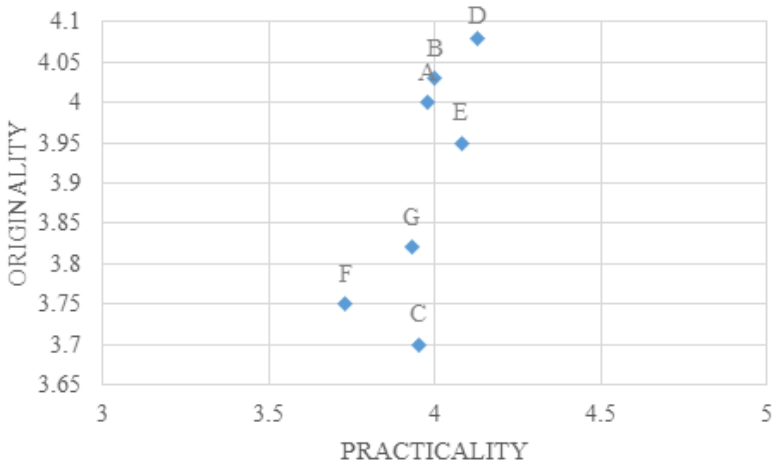

Figure 5-4: Creativity evaluation for eight examples

According to the creativity criterion, originality is high in the order of category D, B, A, E, G, F and C. Originality is the most vital one for creativity (Runco and Jaeger, 2012), it is

said that creativity evaluation is also high in this order. Obtaining the results as shown, we choose the top three, D (4.08), B (4.03), and A (4.00). At the same time D (4.13), E (4.08), and B (4.00) are high in practicality. Moreover, in the conversation with the participants, half of respondents (22 of the 40) say that the technological type is more important about the innovative design.

As a result, D and B, which represent the technological and contextual types of innovative design, may have an effect on higher creativity in the adaptive reuse of old buildings preferred by developed countries. The result is in line with the one in 5.3.2.2.

5.4.4 Results

According to the questionnaire, nearly half of respondents (19 of 40) believe that D has the highest originality with 5 points; they insist the parliamentary plenary hall uses technical means of top-hanging funnel-shaped pillar. The "funnel" is inlaid with mirrors all around. The sun refracts into the parliamentary hall, thereby it reduces energy consumption for lighting.

Over half participants (22 of the 40) consider that D is the most practical with 5 points, because the designers installed a removable aluminium network within the glass dome. A computer automatically adjusts the position according to the movement of the sun.

Therefore, the total score of D is the highest with 4.08 in originality and 4.13 in practicality. From this result, we find that technology innovation (D) is more likely affect the creativity. The emergence of novel technologies has often held a central place in the creative design (Shao and Nagai, 2017).

5.4.5 Discussion

The results indicate that the most important element of innovative design for adaptive reuse of old buildings is technological innovation, which is found to have an effect on higher creativity. The predominant point of view about sustainable future of the art buildings is to utilize energy efficient design (Reuse, 2004). The most typical case with D1 building is an example of green architecture by using technological means to achieve energy conservation, reflecting the building's sustainability.

Hence, technological innovation is more representative for innovative design. It shows the higher creativity and sustainability awareness is the main direction, which is also consistent with the previous analysis in 5.3.2.2.Without excellent service equipment, such as energy-saving system, it is difficult to make a vital breakthrough in innovation (Fernandez, 2006).

5.5 Summary

In this chapter, two results are examined. First, the typology of innovative design for adaptive reuse of old buildings in public spaces is clarified from 24 representative examples. Then, by analysing their similarities and differences, it is synthesized into four types of

innovative design: functional, aesthetic, technological and locational innovation. Meanwhile, it is found that different countries have different preferences regarding innovation types. Developed countries focus more on technological and locational innovation, while developing countries emphasize aesthetic and functional innovation. In future studies, it will focus on the theoretical evaluation of innovative design in the adaptive reuse of old buildings in public spaces.

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CHAPTER 6 Evaluation Criterion of Innovative Design for Adaptive Reuse of Old Buildings

In this chapter…

- Introduction and Literature Review
- Research Aim and Motivation
- Research Method
- Results
- Discussion
- Summary
- References

6. Evaluation Criteria of Innovative Design for the Adaptive Reuse of Old Buildings

This chapter describes the evaluation criteria of the adaptive reuse of old buildings from the viewpoint of sustainability. The aim of this chapter is to find the most influential type in four innovative type and more effective criterion in each type for adaptive reuse of old buildings, which guides designers to optimize the transformation effect for the future design in order to build a resource-saving and environment-friendly society. Three stages are used. First, the evaluation criterion, evaluation object and subject are defined. Second, the results of 23 evaluation criterion are obtained from experts by using the Delphi method to judge the most influential type to validate the previous results and find the key criterion in each innovative design type. Third, it is found that the specific details from the two groups of professionals and each recognition criterion.

6.1 Introduction and Literature Review

In discussions on the adaptive reuse of old buildings, sustainability is an inevitable topic. Conejos et al. (2015) state that enhancing sustainability through design for adaptive reuse from the outset. For the assessment of building sustainability, Atkinson et al. (2009) demonstrates that there is a rapidly growing tendency for rating methodologies that can be used to define the environmental performance of our activities, ranging from personal carbon emission tools to complex sustainability assessments and standards for buildings. There are some evaluation systems of sustainable architecture in the worlds.

6.1.1 BREEAM System in UK

Founded in 1990, BREEAM (Building Research Establishment Environmental Assessment Method) is the first widely used sustainability evaluation system in the world. The core concept is to adapt to local conditions and balanced benefits. A clause-based evaluation system is adopted to consider the environmental impact during the whole life cycle of buildings. The scoring content is about the environmental performance in each stage of the life cycle, including site selection, design phase, construction phase, use process, and final dismantling (BREEAM, 2000).

6.1.2 Energy and environmental design Pilot program LEED in USA

The LEED standard is developed on the basis of BREEAM. Since its implementation in 1998, the LEED standard has gradually become the most comprehensive and influential sustainable building evaluation system in various countries. The main goal is to meet the basic requirements of sustainable assessment while improving the environment and economy. The obvious feature is the more detailed and specific classification of the participating buildings.

Measures are examined by a wide metric of criteria, including sustainable site selection, water efficiency, energy savings, materials and resources and indoor environmental quality (Council, U. G. B. 2008).

6.1.3 CASBEE in Japan

CASBEE (Comprehensive Assessment System for Building Environment Efficiency) is the first sustainable building evaluation system for Asian countries. The objects are non-residential buildings and residential buildings (Ling, 2011). The aim is to reduce the environmental load (energy, resources, and area of the building environment) and the improvement of the environmental quality and performance in buildings (indoor environment, service performance, and outdoor environment). The Green Olympic Building Assessment System (GOBAS) in China is established with reference to CASBEE.

6.1.4 Green building evaluation standards in China

The Green Building Evaluation Standard was officially implemented in June 2006, and a revised version was released in 2014 (GB/T 50378-2014). The evaluation targets are two categories—residential buildings and public buildings—including six major indicators such as land saving, outdoor environment, energy saving, and energy utilization. It is based on the experience of foreign countries, combined with China's national conditions and focuses on environmental protection and savings requirements. The implementation effect in China has been widely recognized (Li et al., 2017).

The research time, technical level, and operational concept of the above-mentioned evaluation systems vary from country to country, but some commonalities from the results of their evaluation systems are still found:

- Common frame and goal. The evaluations of all countries are conducted under the guidance of clear principles of sustainable development. The motivation can be achieved, which is to provide a universal standard for the society. They guide the decision-making and selection of sustainable buildings.

- Common concerns. Evaluation systems in each country have a clear classification and organization system that links the guiding object (sustainable development of buildings) with evaluation criteria. There are a number of key issues, including qualitative and quantitative, which may be analysed. They reflect the thinking on the technical and cultural aspects of sustainable building practices in various countries.

- Constantly updated and developed. Sustainable building systems are complex and evolving; evaluations should be repeatable, adaptable, and responsive to changes and uncertain performance in a timely manner. Such as the LEED evaluation system, it is required to update one version each five years.

Due to the constraints of knowledge and technology, countries have not fully understood the relationship between architecture and the environment, and evaluation systems have some

limitations. These include the simplification of certain evaluation factors. Take China, for example; sustainable building evaluation standards still have problems that magnify the effects of energy-saving technologies and poor implementation (Li et al., 2017). Meanwhile, most current rating tools are focused on new construction and operation and maintenance of existing buildings (Brandon & Lombardi, 2011).

Because the ecological assessment of buildings is a highly complex system, many social and cultural factors impair the determination of evaluation indicators; thus, quantitative method is not easy. Meanwhile, there are few evaluation systems for the adaptive reuse of old buildings in sustainable buildings. The adaptSTAR model, which was mentioned in Chapter 5, is a decision-making tool that contributes to climate change adaptation for built assets (Conejos et al., 2015). However, few studies focus on the specific criteria of innovative design in adaptive reuse of old buildings.

Hence, the study of innovation typology with the specific criteria of the adaptSTAR model are combined to explore the key factors in each type of innovation in adaptive reuse of old buildings.

6.2 Research Aim and Motivation

The adaptSTAR model involves seven representative categories—physical, economic, functional, technological, social, legal, and contextual innovation (Conejos et al., 2013). The AdaptSTAR model can empower designers to make key decisions that contribute to improving longevity and future reuse (Conejos et al., 2014).

From the results of previous analysis in Chapter 5, there are four types of innovative design in adaptive reuse of old buildings: functional, aesthetic, technological, and locational innovation.

According to adaptSTAR model and four innovative design typologies in adaptive reuse of old buildings, the aim is to find the most influential type in four innovative type and more effective criterion in each type for adaptive reuse of old buildings, which guides designers to optimize transformation effect for the future design in order to build a resource-saving and environment-friendly society.

In this chapter, three stages are conducted. First, the evaluation criterion, evaluation object, and evaluation subject are defined. Second, the result of 23 evaluation criteria are obtained from experts by using the Delphi method to judge the most influential type to validate the previous results, and to find the key criterion in each innovative design type. Third, the specific details from two groups and each recognition criterion are found.

6.3 Research Method

6.3.1 Evaluation criterion

The first step is to choose evaluation criteria for evaluation activities during a whole process (Wang, 2007). There are 7 categories in adaptSTAR model, A: physical (long life), B: economic (location), C: functional (loose fit), D: technological (low energy), E: social (sense of place), F: legal (quality standard) and G: contextual (politic) innovation (Conejos et al., 2013). According to previous research, this study have synthesized and inducted each category as functional innovation includes C; aesthetic innovation includes social innovation (E) and legal innovation (F); technological innovation includes physical innovation (A) and low energy innovation (D). Economic innovation (B) and contextual innovation (G) belong to locational innovation.

23 evaluation criterion are gathered into a formal table. According to the Extenics method, this study use the letter R to represent the related element, which is taken to describe the relationship between things, and numbers represent corresponding criterions. See Table 6-1.

Table 6-1: 23 selected criterions were used to assess the innovative type

Types of Innovative Design	Measure Criterion
Functional Innovation R_1	R_{11}: Flexibility
	R_{12}: Disassembly
	R_{13}: Spatial Flow
	R_{14}: Convertibility
Aesthetic innovation R_2	R_{21}: Image / Identity
	R_{22}: Aesthetics
	R_{23}: Amenity
	R_{24}: Disability Concern
	R_{25}: IEQ Safety and Security
	R_{26}: Comfort
Technological innovation R_3	R_{31}: Structural Integrity
	R_{32}: Material Durability
	R_{33}: Workmanship
	R_{34}: Design Complexity
	R_{35}: Solar Access
	R_{36}: Building Control Systems
	R_{37}: Natural Lighting and Ventilation

	R_{38}: Reuse and Recycle Items
Locational innovation R_4	R_{41}: Market Proximity
	R_{42}: Site Access
	R_{43}: Planning Constraints
	R_{44}: Adjacent Buildings
	R_{45}: Community Interest / Participation

6.3.2 Evaluation object

The second step is to use the evaluation criteria to standardize the evaluation objects. There are four objects to be evaluated by the subject.

6.3.2.1 Functional innovation evaluation

The aim of buildings are to meet the needs of people with specific functions, and the task of space design is to facilitate these function. The motivation of innovative design of the adaptive reuse of old buildings is to create new functional spaces to meet new demands on the basic functional requirements so that the functions were perfect and there is room for manoeuvrability. Therefore, in the innovation activities, there is vital work to be done regarding functional evaluation.

6.3.2.2 Aesthetic innovation evaluation

The evaluation of aesthetic innovation in old building renewal is based on the aesthetic law of understanding the spatial form, especially the feelings of formal beauty, such as balance and stability, melody and rhythm, proportion and scale, which are judged by personal experience, and the feelings of aesthetics varied from person to person. Therefore, the judging of aesthetic innovation in old buildings renewal could be viewed from two perspectives. It followed the formal law of the beauty, whether the spatial form makes people feel new and happy; it is also judged on whether it had the novelty of subverting the conventional. For this case, the judgment lied in the visual and psychological stimuli of its originality.

6.3.2.3 Technological innovation evaluation

In order to realize its design intent, the adaptive reuse of old buildings design must be supported by technical conditions for people to use. The evaluation of technological innovation includes structural and constructed factors. The innovative evaluation of structural factors of old buildings renewal included the addition of carriers (partitions, bookshelves, etc.)，materials, and floor connections and functions; adaptive reuse is a tool that can be utilized in the

exploration of how to add to the existing fabric of a structure in order to continue the story of the building (Kersting, 2006). Innovative evaluation of constructed factors referred to whether the node structure was creative.

6.3.2.4 Locational innovation evaluation

One must think about the site of present condition and contextual background. Every site or place has its own unique individual conditions in regard to orientation, rain, humidity, prevailing wind direction, shading, lighting, noise, and air pollution (Lehmann, 2010). Each site is different, and the drivers for generate existing districts must understand how to take full advantage of each location's potential because architecture does not happen by an individual, it is a kind of existence that has environmental significance and cannot be separated from the natural environment. Old buildings could be a part of culture, witness the development process of the city. Therefore, combining the present place condition and strengthening the belongings and identities in the sense of place, it could be a locational innovation in adaptive reuse of old buildings.

6.3.3 Evaluation subject

In the process of innovative design, the evaluation subject refers to the person who carries out the innovation evaluation activity (Wang, 2007). Generally speaking, the level of innovation evaluation of the old building renewal consists of the general public, professionals and authoritative person (Figure 6-1). Users, designers and authorities were the representative of the subjects, who have different evaluation criteria for different needs of innovative design and their own interests, resulting in different evaluation results. From the perspective of their own experiences, evaluation subjects should lead to a reasonable evaluation.

Figure 6-1: The composition of the innovative evaluation subject

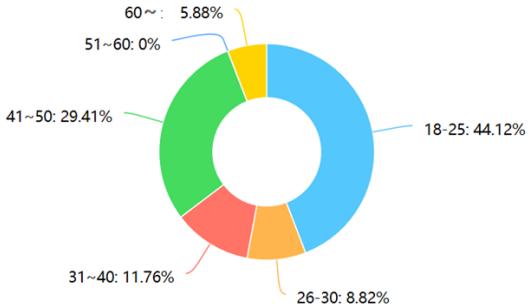

Figure 6-2: Pie chart composition of the participants

The evaluation was conducted by two groups. The group of senior professionals is comprised of 17 designers and teachers, and 17 design students comprise another group of future designers; in total, 34 participants were selected. Male was 13, and the female was 21. Age from 25-60, including 18 participants under 30 years old, while 16 people over 30 years old, specific details as Figure 6-2 shown.

The working time for the group of experts is over above six years. Two people have worked for 6-10 years, two people participant this filed for 10-15 years, thirteen people have engaged in professional practice for over 15years.

Design students are postgraduate students in grade three in environmental design. Typically, during grade two in the master study, they have a practical course named 'Internship Practice.' They are required to have the internship to gain practical experience at related Design Company and pass the evaluation. So they have four years of academic background in bachelor period and nearly three years of academic and practice background in the master period, they will be designers in several months later.

Therefore, both designers, teachers and postgraduate students are chosen, who have backgrounds and their evaluations are often more scientific and rational. At the same time, they could get the valuable information through the process of evaluation—improvement— and re-evaluation, which guide them for future innovative design.

6.3.4 Evaluation process

Firstly, the assessment of the importance of each impact factors was obtained by experts using the Delphi method. The 17 participants assessed the impact of various factors.

For example, the experts were consulted separately, and the experts submitted their opinions anonymously. After several consultations and feedbacks, the opinions of the experts group were concentrated, they agreed with the index of table 6-1, and the judgment results were obtained with high accuracy.

According to the degree of influence, the above criteria were divided into 5 levels, and the scores were divided into 5 points, presenting in order from least positive influence to most positive influence. This is shown in the table 6-2.

Table 6-2: Indicator quantization table

Impact level	Little Affected	Slightly Affected	Normal Affected	Quite Affected	Greatly Affected
Score	1	2	3	4	5

Secondly, 34 participants, including expert group and design students group answered the questionnaire according to the 23 selected criterions and indicator by using the 'questionnaire star' software online. They could answer the questions by mobile phone or computer due to the QR code could be scanned, and was distributed one by one.

6.4 Results

Based on the feedback from the 34 participants, the specific scores of the evaluation criteria in the four innovative design types are shown in Table 6-3. The results in the table are based on the mean for each item in these four types. The higher score of mean, the more positive impact, vice versa. The mean score ranges from 3.15 to 4.09.

Table 6-3: Average of each evaluation criterion in each type

Types	Criterion	Little Affected	Slightly Affected	Normal Affected	Quite Affected	Greatly Affected	Mean
Functional Innovation R_1	R_{11}	0	2	9	11	12	3.97
	R_{12}	0	4	11	11	8	3.68
	R_{13}	1	1	12	15	5	3.65
	R_{14}	2	4	2	13	13	3.91
Aesthetic Innovation R_2	R_{21}	1	4	12	10	7	3.53
	R_{22}	2	3	9	10	10	3.68
	R_{23}	0	5	5	14	10	3.85
	R_{24}	1	4	13	6	10	3.59
	R_{25}	2	3	10	7	12	3.71
	R_{26}	1	1	9	9	14	4
Technological Innovation R_3	R_{31}	1	2	4	13	14	4.09
	R_{32}	0	1	8	13	12	4.06
	R_{33}	0	6	9	13	6	3.56
	R_{34}	1	4	11	7	11	3.68
	R_{35}	2	3	6	13	10	3.62
	R_{36}	2	4	9	9	10	3.62
	R_{37}	1	2	9	13	9	3.79
	R_{38}	2	4	7	11	10	3.68
Locational Innovation R_4	R_{41}	2	5	16	8	3	3.15
	R_{42}	2	0	16	13	3	3.44
	R_{43}	2	3	9	16	4	3.5
	R_{44}	2	3	8	10	11	3.74
	R_{45}	3	3	9	13	6	3.47

For clarity, the results of evaluation in four innovation types are shown in Figure 6-3, 6-4,

6-5, 6-6, it can be seen clearly the specific criterions were affected in each type.

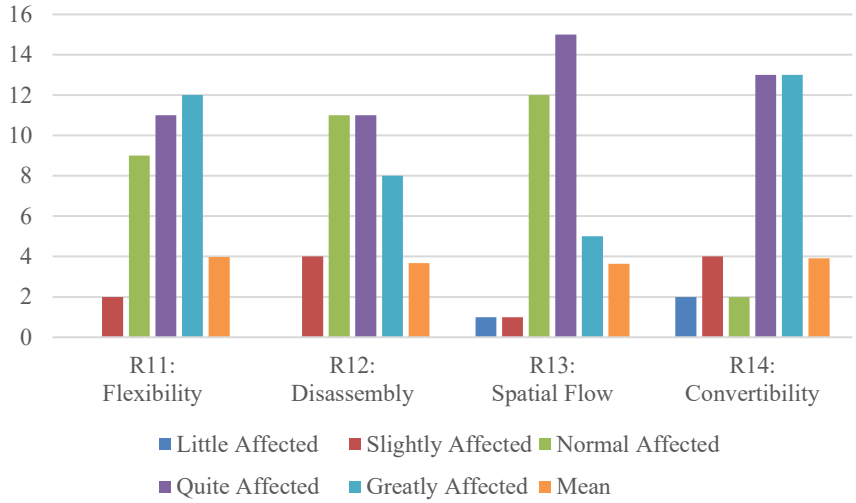

Figure 6-3: The result of the evaluation criterion in functional innovation R_1

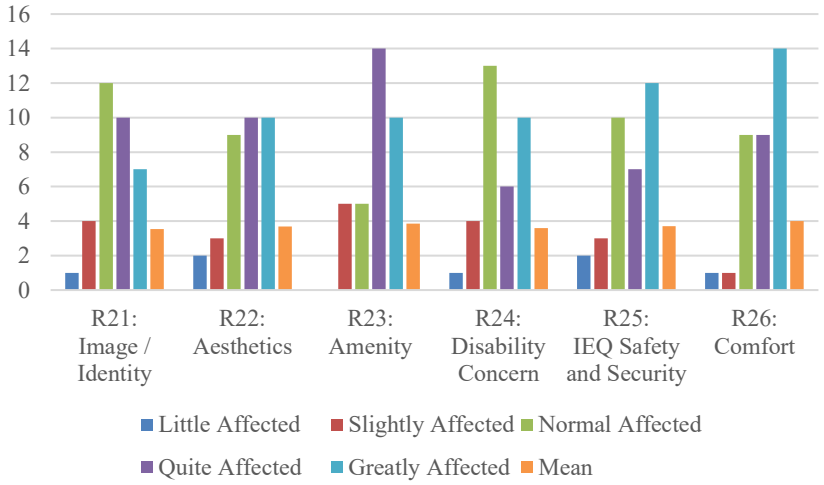

Figure 6-4: The result of the evaluation criterion in aesthetic innovation R_2

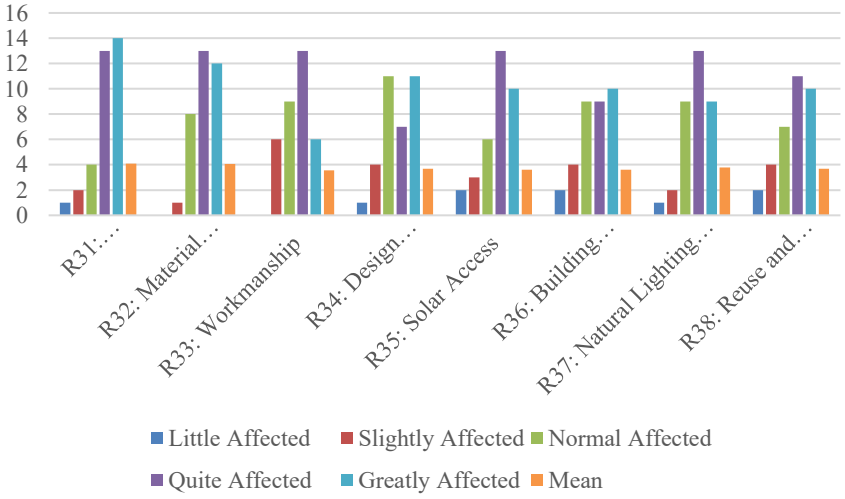

Figure 6-5: The result of the evaluation criterion in technological innovation R_3

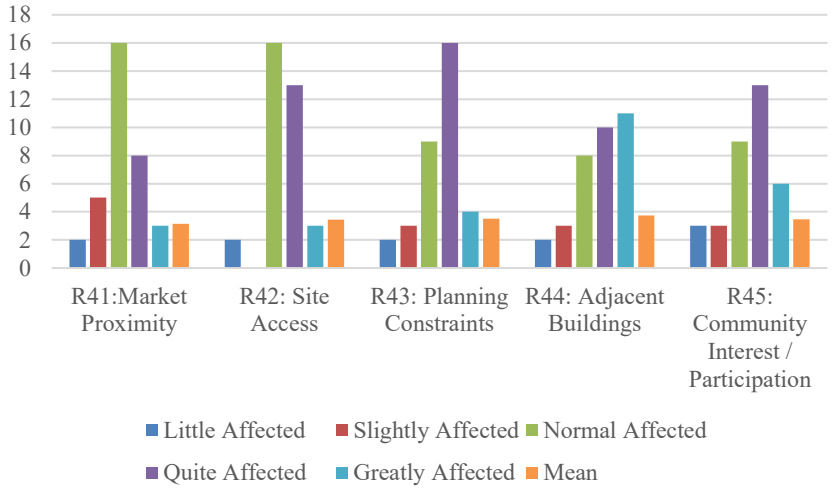

Figure 6-6: The result of the evaluation criterion in locational innovation R_4

6.5 Discussion

6.5.1 The most influential type in this innovation typology design

It can be seen that the most influential factor in functional innovation is R_{11} Flexibility, with a score of 3.97, R_{14} Convertibility score of 3.91, ranked second. In aesthetic innovation, the most influential factor is R_{26} Comfort, with a score of 4, the second one is R_{23} Amenity with a score of 3.85. In technical innovation, R_{31} Structural Integrity has the highest score, 4.09, R_{32} Material Durability reaches 4.06, and the rest scores are lower than 4. In locational innovation, R_{44} Adjacent buildings scores are higher, score 3.74, 3.5 in R_{43} Planning Constraints.

The top three scores of factors are R_{31} Structural Integrity (4.09), R_{32} Material Durability (4.06), and R_{26} Comfort (4). As it is mentioned in Section 4.4.1, a comprehensive description of a column of data should consider not only the average but also the standard deviation (Zhang, 1995). It is seen from table 6-4, which is the description of these three criteria. The Std. deviation in R_{31} and R_{32} are 1.026 and .851, the Std. deviation in R_{26} is 1.044 that is the standard deviation of R_{26} is more significant than others. Therefore, the highest scores R_{31} and R_{32}, which belong to technological innovations, are consistent with previous analysis results 5.4.4, which prove that technological innovation has the most prominent impact among the four types.

Table 6-4: Descriptive statistics of R_{31}, R_{32} and R_{26}

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
(R_{31}: Structural Integrity)	34	1	5	4.09	1.026	1.053
Valid N (listwise)	34					

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
(R_{32}: Material Durability)	34	2	5	4.06	.851	.724
Valid N (listwise)	34					

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
(R_{26}: Comfort)	34	1	5	4.00	1.044	1.091
Valid N (listwise)	34					

The reason why technology innovation is the most influential type could be shown as follows. Structural Integrity refers to structural design of the building to fit to future uses and loads (Conejos et al., 2013). The assessment procedures are the techniques used to evaluate the fitness-for-purpose of important components and welded structures (Webster & Bannister, 2000). Such methods can be used in the design period to provide assurance for new structures to ensure integrity in the construction and provide guarantee throughout the life of the structure (Carroon, 2010).

Material Durability refers to the use of innovatively developed, long-lasting materials in space during the building cycle (Conejos et al., 2013). The appropriate use of local material is one of the many lessons that adaptive reuse of old buildings can teach the design community. Nowadays, designers more pay attention to using the healthy and local materials in interior space design to make a better indoor environment, which can reduce the pollution to the environment and protect the users' health to create a sustainable society. The future of societies is not just a technical matter of finding more eco-friendly material solutions but a question of holistic environmental and social sustainability (Lehmann, 2010).

6.5.2 The most effective criteria of each type in two groups

As shown in Figure 6-1, designers or teachers comprise a senior expert group and design students comprise a future designer group. Results were obtained from these two groups.

Through the comparison of the two groups, it is clear that, in functional innovation, the scores of senior expert group are significantly higher than those of students group, reflecting Verganti's (2008) affirmation that functional innovation may imply an incremental or radical improvement of technical performance, which also implies the important of technical innovation. The two groups of people have the same level of cognition of each criterion, they all think R_{11} Flexibility and R_{14} Convertibility have greater impact on functional innovation, especially R_{11} Flexibility (Figure 6-7).

In aesthetic innovation, the two groups had the same understanding of R_{11} Flexibility and R_{23} Amenity; for R_{21} Image/Identity and R_{24} Disability Concern, the cognitive differences between the two groups were obvious. The designers group believed that R_{21} Image/Identity has a higher impact, with a score of 3.76. A good image should have a higher visual impact. The students group believed that disability concern can influence aesthetic innovation, with a score of 3.82. They believe that consideration of vulnerable groups should affect aesthetic innovation (Figure 6-8).

In technological innovation, the two groups have the same cognition (Figure 6-9). The highest scores are R_{31} Structural Integrity and R_{32} Material Durability in sequent as shown: designers group got 4.06 and 3.94 respectively; students group gave 4.12 and 4.18 respectively.

Therefore, the average score of the two criterions were 4.09 and 4.06.

In locational innovation, the students group scores basically the same for each criterion. Only the designers group paid more attention to the R_{44} Adjacent buildings, scoring of 3.94 (Figure 6-10). They believed that it was very important to deal with the adjacent buildings, and there was no isolation when considering the single building. Instead, it was vital to put the building in the overall location and to consider it comprehensively.

Therefore, it is clear that the designer and student group basically have consistent professional judgments, with only slightly different examinations of notable criteria. For example, the designers were more concerned about the functional innovation and image of the buildings as well as the relationship between buildings and surrounding environment. The student group has not yet had too much practical experience and were more focused on the theoretical level, considering only the relatively ideal status, such as paying more attention to vulnerable groups.

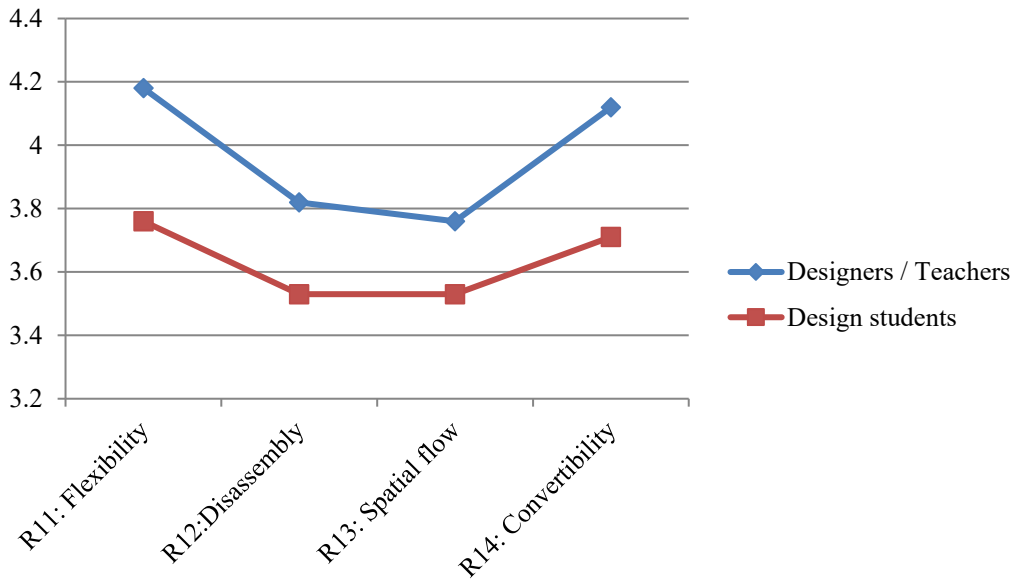

Figure 6-7: The result of the evaluation criterion in R_1 from two groups

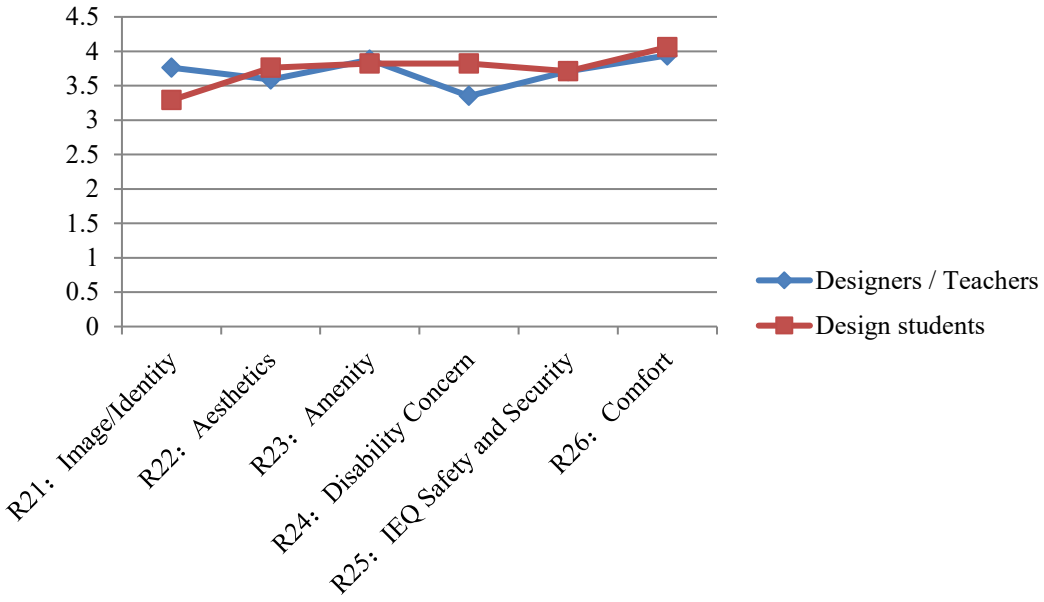

Figure 6-8: The result of the evaluation criterion in R_2 from two groups

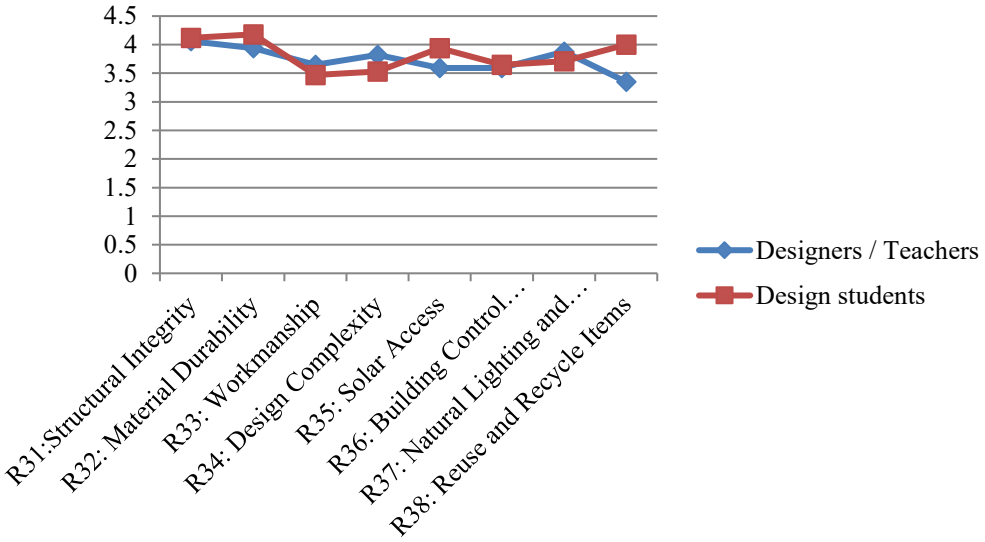

Figure 6-9: The result of the evaluation criterion in R_3 from two groups

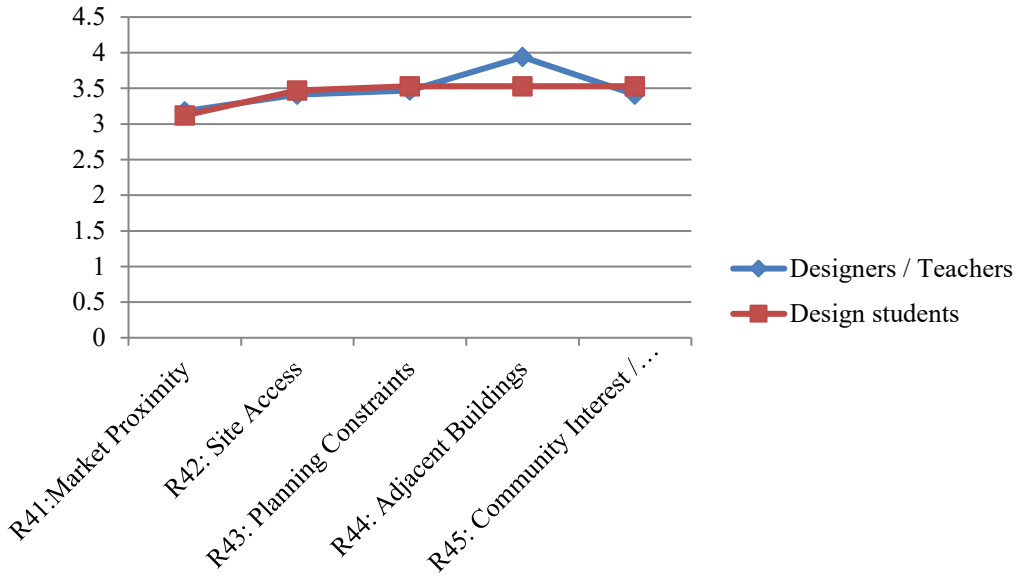

Figure 6-10: The result of the evaluation criterion in R_4 from two groups

6.6 Summary

In this study, two primary results were obtained. The first is that technological innovation has the most prominent impact of the four types of innovation, which also verified the previous results in Chapter 5. The second are the key criteria for each type of innovation. In functional innovation, the higher impact indicators are flexibility and convertibility; in aesthetic innovation, the higher impact indicators are comfort and amenity; in technological innovation, the more important indicators are structural integrity and material durability; and adjacent buildings and planning constraints have higher influences in locational innovation. The comparison between two groups had an overall consistency evaluation criterion for each type of innovation, although a slight difference due to learning and work experience was exhibited. Comprehensive studies that track changes in cognition in two groups of evaluation subject should be implemented in the future.

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CHAPTER 7 Case Study of a Creative Practice for an Art Studio Design Based on Users' Mental Needs

In this chapter…

- Introduction
- Research Methods
- Analysis and Discussion
- Design Process
- Construction Process
- Evaluation
- Summary
- References

7. Case Study of a Creative Practice for an Art Studio Design Based on Users' Mental Needs

This chapter is aimed at building a creative practice for old building renewal considering an art studio space designed from the perspective of users' needs. The adaptive reuse of a 90-year-olddining hall served as a prototype for exploring the feasibility of such a practice. First, semi-structured interviews were conducted with the employees of the workspace to uncover problems within the existing office space, and then, a questionnaire was used to capture the specific elements that affected user needs. Second, a set of thinking models were created to express users' needs during the design processes. Finally, applying semantic differential method, the art studio space was evaluated after the work was completed to clarify the progress with regard to users' satisfaction. Thus, this study made a practical contribution that brought new life to an old building and built a creative space for users by employing a sustainable environmental design.

7.1 Introduction

In the field of architectural design, renewing old buildings has been explored by some pioneers. As it mentioned in Section 2.1.1, it can be seen that in most cases renewing an old building involves restoration, repairing, or remodeling. Because of their durability and reparability, old buildings have almost unlimited potential for renewability. The practice of renewing old buildings has profound implications for sustainable development (Carroon, 2011).

However, most renewals are focused on the building itself, that is, the objective dimension of aesthetics, which is carried out for aesthetic reasons. They focus on reusing old buildings by transforming in different ways the texture, color, and other aspects related to elements of aesthetics (Guo, 2011). Aesthetics includes shape and form evoke desired perceptions are of interest to designers and customers (Mata et al., 2017). Few studies have examined these renewals from the perspective of the users of the space, that is, the subjective dimension of aesthetics. In design, the result must be meaningful for people (Nagai & Taura, 2006). Hence, we explored this aspect, the users' point of view, in remodeling an old building with new usage.

The chosen art studio, named 'Between', is located near centre on Bayi Road, Dalian, China. Among the few historic buildings in this region, this building, named Number 20, is the only one that has retained its original façade, with full of vertical green plants. There are only pillar and wall structure kept, and windows and doors are shabby. It had been used as a dining hall since 1927 and was discarded a few years ago. The life cycle of this building is 90 years. It possesses unique regional characteristics and has witnessed the development of the city from the colonial period to the present era of urban civilization. It can be considered a material transporter of the history and culture of Dalian and, hence, is precious, and deserves to be treasured.

Therefore, when the original function of the old building could no longer meet the requirements of the owners, they decided to transform the old dining hall into an office space

for art designersto adapt new usage. Whatever its size or type, the most important role of an office space is to serve as a home for the people who work in it, and its design greatly affects their performance (Kohn & Katz, 2002). Our belief is that people's workplaces can not only influence their productivity but also shape their attitudes and beliefs. This demonstrates that the workplace can be part of a holistic strategy to increase engagement (Jim, 2016).

In short, transforming a space into an office space and establishing a truly creative design with no boundaries between designers and clients are the main aims of this case study. This paper intends to explore the process of renewing an old building from the users' perspective and discussing what specific elements of space affects user needs. In this way, an old building can be revitalized using a scientific method rather than by using a traditional form.

7.2 Research Methods

In conducting this creative practice in early stage, we used two methods in Quantitative method with a semi-structure interviews and a questionnaire survey emphasising on users' viewpoints. Space relates strongly to people's mental well-being (Kristensen, 2004). It should be respected the value of users' during the design process (Siu, 2003).

In the middle stage, a quantitative method of graphical thinking were used in the design process. The innovative method of graphical thinking is the most applied method, the means of connecting thinking and expression, and the method of transforming the design thinking in the mind into visible visual graphics. The graphical thinking approach is closest to the visual representation of spatial representation, so in the interior design language, the graphical approach is preferred. The graphical thinking method uses different tools to draw different graphs and analyze the thinking methods. (Paul, 2002) We used this method in the fourth chapter.

In the later stage, a qualitative method of Extenics was adopted in the evaluation process. If the process of graphic thinking is a process from visual thinking to graphic thinking, the extension method provided by Extenics is a mathematical thinking method that is an effective method for interior design innovation research. The extension method directly combines the means of character expression with words and numbers or letters to make up for the lack of expression of image thinking in the past. In the past, the innovative thinking relies on visual graphics. The process of logical reasoning is included in the graphical method. It can be said that it is a supplement to the previous innovative methods, and it can also be said to apply a new language to the process of design thinking. This approach was used when applying assessments in Section 7.6.2.

7.2.1 Semi-structured interviews

The first set of semi-structured interviews was intended to uncover problems within the existing office space where the interviewers' offices located in, and draw up the outline of an ideal creative office environment. These interviews were conducted in the early stages of the design process.

- Participants

The target population was 26 people with 15 of professional background and 11of non-professional background who worked in the ordinary office 8 hours a day. Each people have the different situation.

- Procedure

In order to understand the current state of the office environment, different people were interviewed about the space's disadvantages, and the survey outline was prepared in advance; it took the form of a free conversation on sensory, material, and economic aspects such as spatial functions, feelings, etc. Through this, information on the ideal creative office space as imagined by users was acquired.

7.2.2 Questionnaire survey

The second questionnaire was designed to capture the specific elements of space that affected users' mental needs. It was conducted in the early stages of the design process.

- Participants

The survey was conducted between two groups of people. One group consisted of 48 designers who provided services, and the other included 26 prospective clients (total = 74).

- Procedure

Participants were instructed to fill out the questionnaire, which covered aesthetics, indoor physical conditions, space layout, and so on which elements were chosen through the discussion by designers; each participant selected the main affective elements from among four options from their mental needs.

7.3 Analysis and Discussion

7.3.1 Analysis of the semi-structured interviews

From the conversation of the semi-structured interviews, it was realised that people were not satisfied with the existing office space, the questions are focused on the following mentioned:

- Lack of emotional communication

It was gathered from the interviews that most traditional layout was single function. The design of the office space, fails to consider human physiological and psychological needs. The design of office spaces is often not related to the needs of the organizations that use them (Worthington, 2006). Actually, office spaces, in addition to meeting the basic functional requirements of the related division, need to emphasize freedom of design and human mental appeal.

- Lack of creativity

Based on division of labor, nowadays most interior office spaces are segregated such that workers ‘sit in rows’, with the office partition layout forming a single-space model to which a machine-like adherence is expected. There has been increase in office density, but little attention has been paid to ensuring that people can work in comfort in a creative space environment. The lack of creativity in spaces makes users reluctant to work more effectively. Originality is a core element in creative study (Runco& Jaeger, 2012). To ensure that employees produce effective work, it is essential to create original space that stimulate people’s creativity in various ways.

- Lack of cultural connotations

Because most interior spaces were designed by architects in the early period, attention was more on the relationship between interior modelling and structure based on feasibility and technical breakthroughs, while the cultural connotations of space received very little attention. Therefore, interior spaces were often used to display company logos or other text with relatively simple and superficial expression. Hence, deep-level cultural connotations came to be pursued by interior designers through various design languages to express the values of spaces. This not only enhanced the companies’ cultural connotations, but also deepened employees’ sense of ownership and belonging.

7.3.2 Analysis of the questionnaire

The questionnaire revealed that users more pay attention to the influence of space on their feelings. Although this includes aesthetic and physical factors, the specific performances of different groups produced their own related factors (Figure 7-1).

The designer group preferred a public communication space to acquire fresh information (32 people), an open working space to benefit team cooperation (29 people), a space for exclusive personalised and creative performance (27 people), and a relaxation area that can soothe people’s moods (25 people). In their opinion, only these kinds of spaces can serve clients effectively.

The customer group wanted an exclusive discussion area for negotiations (18 people), a space that evokes certain memories and meets emotional or cultural needs (14 people), a healthy and comfortable interior space (13 people), and a natural environment with green plants (12 people). They believed that such spaces would be ideal creative space for an art studio.

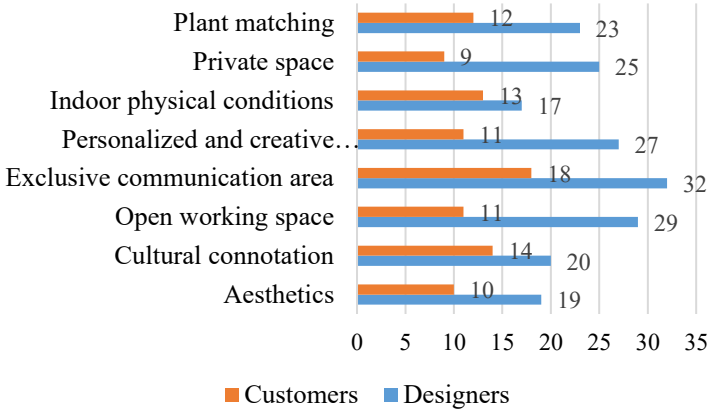

Figure 7-1: Mental need elements affecting two groups

In short, the main factors of concern related to space for the two groups include the following: Fifty people (67.6%) preferred an open and spacious communication area; 40 (54.1%) preferred an office space conducive to discussion and cooperation; 38 people (51.4%) wanted an innovative space with personality; 35 (47.3%) felt that space should have a touch of nature; 34 people (45.9%) wanted a relaxation area that can soothe one's mood; and the same number of people required space to have cultural connotations. The top four elements are open and spacious communication area, space suit for discussion and cooperation, innovative space with personality, and spacious touch of nature.

7.3.3 Data results

From the semi-structure interviews and a questionnaire survey, all the above-mentioned results can be summarised as follows:

- Psychological demand for openness and privacy

Openness is a concept corresponding to privacy. Research has indicated that work efficiency can be multiplied in a group; open offices improve production efficiency, which is essential in the present era (Marquardt et al., 2002). Privacy, however, emphasises choice and control over people's interactions with each other, that is, individuals or groups choose to be close to others and decide when, in what way, and to what extent information exchange should happen with others. Therefore, an office space should maintain an effective transition or a flexible balance between open and private spaces, with separate spaces are flexible and colourful areas to meet the functional requirements of different users' needs for privacy and publicity.

- Psychological need for personalization and creativity

As most users were part of the designer group, they had a certain artistic background, and hence, their requirements for space included personality and innovation. Personalities is different (Zhou, 2011), and therefore injecting more personalised elements through function and shape is important. Creativity is often defined simply as a new idea. Most methods to

evaluate creative ideas were based on comparing the present ones with past ideas (Eckert, & Earl, 2005). Making an office more creative however involves abandoning old ideas of space analysis and allocation. New approaches to space planning need to break away from the efficiency of rectangular grids in favour of more innovative and unusual solutions that create unexpected environments within buildings. Creating memorable workplaces can support and enrich the lives of the people who work there (Worthington, 2006).

- Psychological demand for cultural connotations and nature

As mentioned earlier, an old building itself is a carrier of a special cultural complex. Since the basic principle of transforming old buildings is 'Repair the old as old', certain materials and old objects can be used in the renovation to kindle the psychological need for nostalgia among people. This awareness can help in the selection of an office space's form, materials, and furnishings. Meanwhile, from the results of the questionnaire, it was obvious that people had a yearning for natural environments. It has been said that a green visual field exceeding 25% makes people comfortable, both physically and psychologically. It can add a sense of taste, eliminate fatigue, and stimulate people in a positive and dynamic fashion by meeting their psychological need to be close to nature.

In summary, the three kinds of psychological needs mentioned above are the important elements extracted from the questionnaire. Next, we discuss how these needs were met during the design process.

7.4 Design Process

The design process was aimed at creative practice to transform the project into a real space. In this case, it involved the following steps: schematic design, preliminary design, final design plan, shop drawings, and construction, corresponding to interior design innovative procedures, including innovative impulse, innovative goals, innovative means, innovative design, innovation evaluation (Figure 7-2).

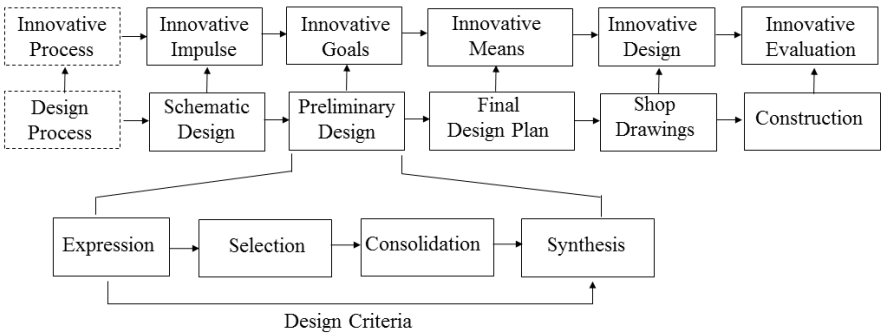

Figure 7-2: A relationship between the design process and innovative process

For example, in each step, the designers took effective measures to meet the specific requirements that were set. It could be described by a four-step model during the preliminary design as shown below.

7.4.1 Expression

To achieve the design goals of creating a creative space that meets users' mental needs and to develop the preliminary design, the following needs were considered.

- Psychological need for openness and privacy

From the first result in section 7.3.3, it is shown that psychological need for openness and privacy. The method optimized public spaces such as massive open areas for communication in the central space, a space for designer cooperation and discussion in a common area, and a public negotiation space for customers. The method also optimized private spaces such as a private relaxation area for tired designers to enhance or lighten their mood, a private space or exclusive design area for design directors on the second floor, and a greenhouse space for customers (Figure 7-3).

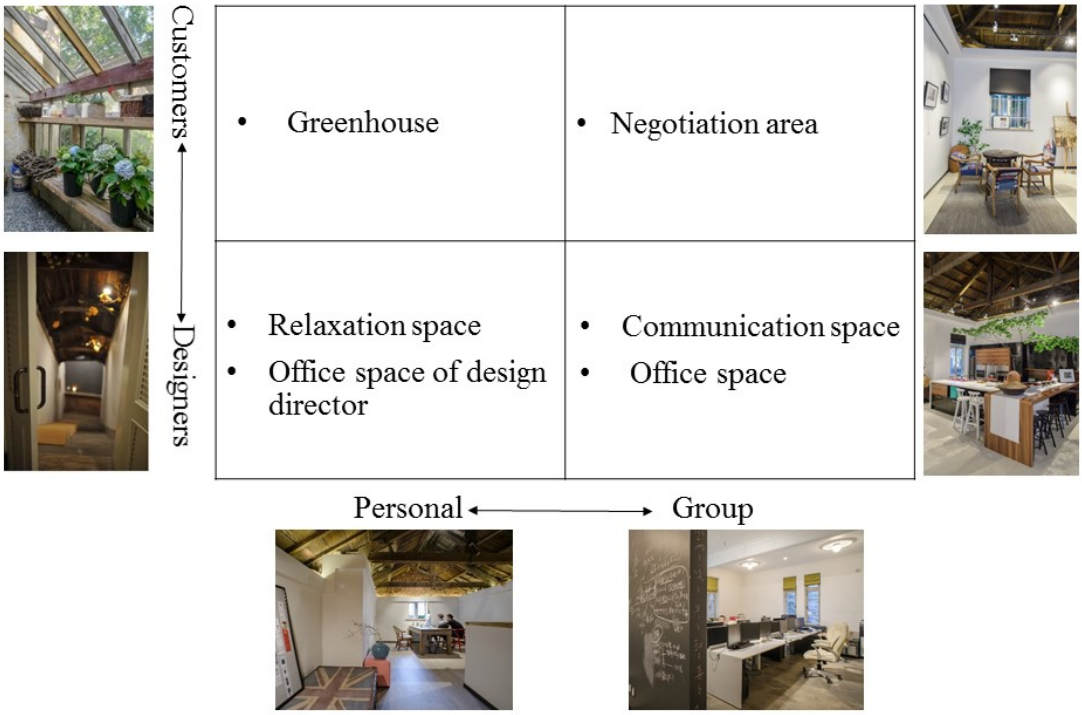

Figure 7-3: Optimization method for openness and private area

- Psychological need for personalization and innovation

From the second result in section 7.3.3, it is shown that psychological need for personalization and innovation. Bearing in mind users' psychological needs, this case employed a new Chinese style art space to add personality to the spaces. A special type of 'brainwave' music is played in the relaxation area and technological innovations were used to ensure an emotional communication experience for indoor users as well as for space interactions.

- Psychological need for cultural connotations and nature

From the third result in section 7.3.3, it is shown that psychological need for cultural connotations and nature. In order to preserve its architectural values, we must understand a

building's ties to the past (Ministry of Housing Agency, 1992). In particular, special old material can be chosen to create a nostalgic effect and remind users of the past. For example, some representative objects used to invoke an older time were used, such as wooden beams, wooden windows, red bricks, and an old glass table. Meanwhile, an old-fashioned greenhouse and used plants were placed to bring in an element of nature into the space.

7.4.2 Selection

Based on the design goals, designers selected appropriate methods to develop the overall program, especially when it came to 'brainwave' music in the relaxation area, which is meant to soothe the listeners. 'Brainwave' music helps designers relax, and it enhances their creativity. According to a music specialist who graduated from the Music Department at the University of Melbourne, 'brainwave' music is related to improving learning efficiency. It also awakens people's creativity, inspires creative thinking, and helps people feel relaxed and comfortable (Zhuang et al., 2009).

7.4.3 Consolidation

This step involved optimising the various design elements to meet users' psychological needs and make the design program relatively complete.

7.4.4 Synthesis

Synthesising all other subsidiary elements related to this case, such as electricity, plumbing, air conditioning, etc., and then finishing the whole design plan was the next step. The preliminary design was completed in terms of design criteria.

7.5 Construction Process

Based on the shop drawings, construction began in 2016. Designers gathered the main goal of the project, as well as others that needed to be taken into consideration.

Firstly, it was optimized the site and the interior environment. To be maximized the use of existing trees and redundant plants on the original building, the exterior walls were cleaned selectively to ensure the site and landscaping was integrated into a harmonious environment. We maintained the exterior walls' structural safety and cleaned up the pavement in the courtyard; it was necessary to remove particular internal non-structural walls and the old floor.

Secondly, this case entered the interior space reconstruction phase. The extra work involved plumbing renovation, laying of heating system, home door renovation, attic transformation, turning the original basement entrance block into a rest area with a ladder.

Finally, it entered the repair stage. The original wooden structure was preserved and consolidated so that it was adaptable for reuse during its life cycle; the original wood windows

were cleaned and repaired, and the previous greenhouse was organized and maintained. Designers prioritized the use of old objects in the new space to meet people's psychological need for nostalgia (Figure 7-4).

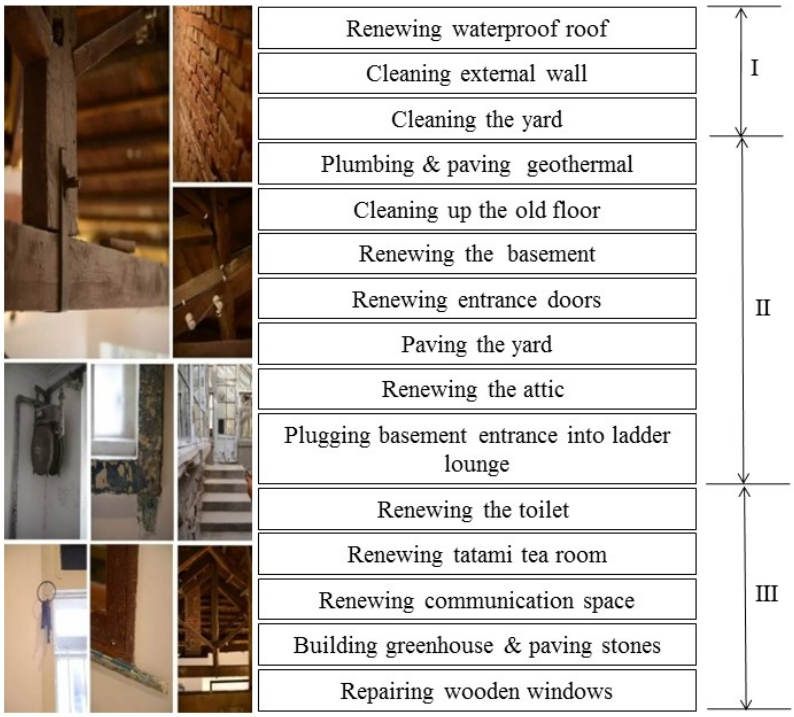

Figure 7-4: Construction process

7.6 Evaluation

7.6.1 Semantic differential method

After the shop drawings, construction began in early 2017. Three months later, the old building had a new look. To verify whether the space satisfied users' requirements, a questionnaire survey was conducted among 26 users after a month of using the space. To obtain their evaluation of the new space, three properties (sensory, material, and economic) were measured in proportion by the Semantic Differential method.

SD method is a rating scale designed for measuring the connotative meaningof objects, events, and concepts. It mainly investigates human cognitive activities related to observation of objects in order to analyze the inner relationship between human's perceptual knowledge and the object evaluated. Using the method of two polar adjectives to indicate the degree of preference of users, this case compared two types of office space: the existing office space from the semi-structured interviews mentioned earlier and the art studio space, on a seven-point scale; the final score was the average evaluation (see Table 7-1).

Table 7-1: Emotional indicators evaluation

Evaluation attributes	Evaluation of emotional indicators	Existing office space	Art studio space
Sensory properties	Space feel: stiff ~ modern	3.63	6.25
	Space layout: dull ~ lively	3.25	6.38
	Work place: ordinary ~ creative	4.13	5.25
	Private space: inadequate ~ exclusive	3.63	5.00
	Communication space: narrow ~ open	4.13	5.75
	Relaxation space: incomplete ~ perfect	3.63	5.75
	Plant accessories: mimic ~natural	2.88	5.63
	Cultural connotation: poor～unique	3.00	5.63
	Mean	3.54	5.71
Weighted score（52.69%）		1.87	3.01
Material properties	Space function: decorative ~ practical	3.38	5.88
	Space structure: perishable ~ durable	5.25	4.70
	Mean	4.32	5.29
Weighted score（40.54%）		1.75	2.14
Economic property	Space grade: cheap ~ expensive	3.38	5.50
Weighted score（6.77%）		0.23	0.37
Final score		3.85	5.52

In Section 4.4.1, Zhang (1995) stated that a comprehensive description of a column of data should consider the average and the standard deviation. Hence, the data is put into Excel, and the standard deviation is gotten from the software. To clearly determine the scores, this study uses an error bar showing users' psychological evaluations (Figure 7-5). The abscissa indicates the elements affected by psychological needs, and the ordinate indicates the score.

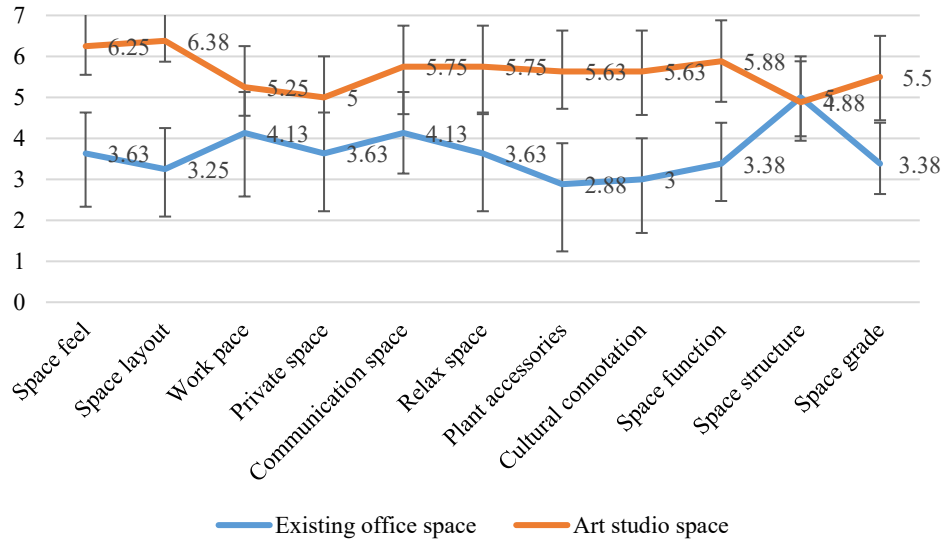

Figure 7-5: Psychological evaluation chart of users

As the data and the comprehensive evaluation of the weighted calculation show, except

for the structural elements, all elements in the art studio space received higher scores than those of the existing office space. The final score for the art studio space was 5.52, which is obviously higher than 3.85. Hence, it may conclude that the art studio space had make a substantial progress in creative design and construction.

7.6.2 Evaluation of Extenics in interior innovation

Extenics is a new science founded by Chinese scholars led by Professor Cai Wen. In 1983, Cai Wen published his first paper *Extension Sets and Incompatibility Issues*, marking the creation of extenics. Extenics believes that things are scalable, including divergence, relevance, scalability, and implication (Cai et al., 2003).

The method of applying extenics to practical engineering is called an extenic method, and the extenic analysis method is used to comprehensively analyze the objects of interior design innovation to find out the corresponding transformation strategy. For reference matter element expansion methods, use R = (N, c, v), R is the matter element, N is the substance, c is the name of the feature, and v is the N value of c. It is called the three aspects of material elements (Cai Wen, 1999). When has a plurality of features, c_1, c_2 ... c_n, and corresponding sizes v_1, v_2, ... v_n, which can be described as formula 7-1.

$$R=\begin{pmatrix} N, c_1, v_1 \\ c_2, v_2 \\ \cdots \cdots \\ c_3, v_3 \end{pmatrix}$$

Formula 7-1: Model of matter element

Take the long and narrow rest area, which is mainly composed of stairs, as an example. Any steps have their property, function, material, and form. Such as form, what kind of the way it should be used in this case? Used technical means, some of the stairs will be given the sound of ‘brainwave’ music to make the long strip space no longer boring. When people are sitting, resting, thinking, they can achieve the purpose of relaxation, cleverly solve the problem of narrow space and increase the utilization of space.

The establishment of the relaxation room’s matter element of extenic evaluation, see formula 7-2.

$$R=\begin{pmatrix} \text{Step, Property, Leisure and Relaxation} \\ \text{Function, Sit and Step} \\ \text{Material, Wood} \\ \text{Form, Brainwave Music} \end{pmatrix}$$

Formula 7-2: Matter element of Extenic evaluation in the relaxation room

7.7 Summary

Based on the whole process from initial design through post occupancy evaluation, this

study made a practical contribution from the perspective of users' mental needs. As Figure 7-6 reveals, the original building was old and shabby; after investigating the status quo, analysing the problem areas, improving the design plan, constructing, and developing the final evaluation, the whole building has taken on an entirely new look. New Chinese-style interior space combining the original wooden structure with modern decorations was the final look designed for the creative office space, and the evaluation of this space was 5.52. The implementation in this case not only extended the life cycle of the old building, which was a sustainable environmental design strategy, but also considered users' mental needs focusing on their priorities to create an innovative space. In the future, this study plan to carry out old building renewal based on the perspective of users' physiological needs.

Figure 7-6: Before and after

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PART THREE

Part Three Contains:

Chapter 8: Discussion, Implications, Recommendations

CHAPTER 8 Discussion, Implications, Recommendations

In this chapter…

- Discuss all the Findings from Study 1-4
- Original Contribution to Knowledge Science
- Limitations and Recommendations
- Conclusion
- References

8. Discussion, Implications, Recommendations

This chapter includes a discussion, implications, and recommendations. It begins with a discussion about the overall findings of Studies 1 to 4 (from Chapters 4 to 7) to provide direct insight into an interpretation of the study's results. Then, it focuses on this paper's original contribution to knowledge science, included the originality of the research, theoretical implications that guide designers to make a critical reference, and practical implications. Finally, this chapter outlines the limitations of this study and recommendations for further studies and new building development, ending with a conclusion.

8.1 Discuss all the Findings from Studies 1- 4

8.1.1 Summary and discussion of results

From Finding 1 related to SRQ1, it is clear that old building renewal is more preferable to constructing new buildings; this is not only highlighted in the literature review but also in the experimental method that verifies the hypothesis. The other result is that 'creative' and 'settled' represented by innovation and sustainability are easy to express in old building renewal to assist designers in integrating accurate adjective words into their future designs.

Based on Finding 1, the following study is continued to find the typology of adaptive reuse of old buildings from the perspective of innovative design, which leads to Finding 2 related to MRQ. In this part, two results are examined: First, the typology of innovative design for the adaptive reuse of old buildings in public spaces is clarified from 24 representative examples. Then, by analysing their similarities and differences, it is synthesized into four types of innovative design: functional, aesthetic, technological, and locational innovation. The results suggest that the most important element of innovative design for the adaptive reuse of old buildings is technological innovation, which is found to have an effect on higher creativity.

From the results of the previous analysis in Finding 2, there were four types of innovative design in the adaptive reuse of old buildings combined with adaptSTAR model; Finding 3 related to SRQ2 also outlines two results. The first is that technological innovation has the most prominent impact of the four types of innovation, which is also verified by Finding 2. The second is which criteria in each type is most effective for the adaptive reuse of old buildings. In functional innovation, the higher impact indicators are flexibility and convertibility; in aesthetic innovation, the higher impact indicators are comfort and amenity; in technological innovation, the more important indicators are structural integrity and material durability; and adjacent buildings and planning constraints have higher influences in locational innovation.

A case study is illustrated based on the whole process from initial design through post-occupancy evaluation; Finding 4 related to SRQ3 made a practical contribution from the perspective of users' mental needs. The implementation in this case not only extended the life cycle of the old building, which was a sustainable environmental design strategy, but also considered users' mental needs focusing on their priorities to create an innovative interior space.

8.1.2 Conclusion based on the results

It is necessary to verify the necessity of the research from the comparison analysis, which proves that old building renewal is effective than new building development. Based on this premise, the four types of innovative design for the adaptive reuse of old buildings are summarized from many cases by induction; then, part of the evaluation combines the four innovative types and the adaptSTAR model to discover the higher influence type, which is technological innovation—a result consistent with Finding 2. The higher-effect criteria in this type are structural integrity and material durability. In the last case study, Finding 4 combines with the previous theoretical analysis by using an art studio as a prototype to explore the application of innovative design of adaptive reuse of old buildings in practice.

In sum, this study combines theory as a foundation with practice as a subsidiary. In basic foundation part, it could be like a triangle, the basic premise is adaptive reuse old buildings is worth exploring in finding 1, then finding 2 and finding 3 are focus on the typology and criterion. Finding 3 are based on the result of finding 2. From finding 1-3 are related to basic research, the higher concept to describe this part could be evaluation of the adaptive reuse of old buildings. Finding 4 is related to applied research, it is a real case study. General speaking, it is hope that using the foundation research to guide the practice research.

8.2 Original Contribution to Knowledge Science

8.2.1 Originality of this research

The concept of knowledge innovation is known to be the process of obtaining knowledge of new basic science and technical science through scientific research, including basic research and applied research. Through the basic research in Chapters 4–6, this paper summarizes the knowledge theory of innovative design for the adaptive reuse of old buildings. Applied research is attempted in Chapter 7 by combining the basic knowledge of the previous chapters into practical application. These basic and applied research provide new theoretical research for the innovative design of old buildings to achieve knowledge innovation. This is specifically reflected in the following.

8.2.1.1 Mixed research method to update the concept

As it is known, traditional architectural and interior design only focuses on the buildings themselves, thinking about the aesthetic element, seldom focus on the aspect of people and the environment. While in this thesis, three systems for knowledge are proposed among buildings, person, and environment for the adaptive reuse of old buildings, which rely upon mutual penetration and mutual support. Sustainability should not only consider the system within its boundaries but should also be understood concerning the systems' total environment (Avgeriou et al., 2013). This study applies the innovative design system of the adaptive reuse of old buildings in various subjects, including architecture, design, ecology, innovation, psychology,

Kansei engineering, Extenics, economic, and other knowledge theory, which have achieved specific creative results.

The relationship among old buildings, user experience, and sustainable environmental practices to achieve innovation should be appropriately handled. In old buildings, functional, aesthetic, and technological innovation in knowledge should be considered and combined with the SD method and Extenic method in method innovation and further contextualized by the economic and contextual elements of locational innovation in sustainable environment. These three elements affect each other and achieve balance in order to obtain complementary profit and develop knowledge system for adaptive reuse of old buildings (see Figure 8-1).

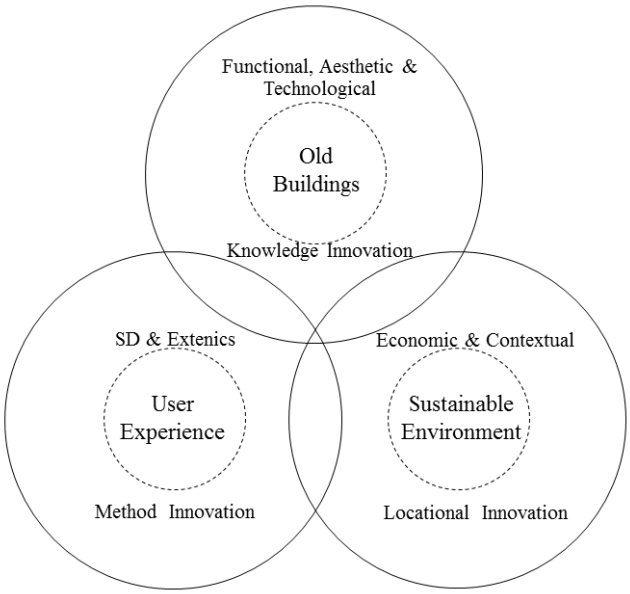

Figure 8-1: Innovative knowledge system for adaptability design of old buildings

To update the definition in 2.3.3, the innovative design of the adaptive reuse of old buildings mainly refers to the following. Adaptive reuse of old buildings is furnished by distinguished performance in these four aspects: functional, aesthetic, technological, and locational innovation, which on the background of sustainability and innovation to obtain a harmonious balance, especially in technological innovation and users' mental needs in practice as well. The aim of it is conducive to old buildings, user experience, and a sustainable environment.

Therefore, this new concept provides a useful reference for both environmental designers and academics to guide future sustainable and creative research trends. It is the further exploration and in-depth sustainable study from the viewpoint of innovative design. These results contribute to the development of the theory and practice of innovative design of adaptive reuse of old buildings.

8.2.1.2 TFAL model in innovative design typology for adaptive reuse of old buildings

Knowledge innovation is central in the sustainable competitive environment (Andreeva & Ikhilchik, 2011). Nonaka's theory of knowledge management creation, focusing on the SECI

model, is probably the most widely accepted. The aim of the SECI model is to understand the dynamic process in which an organisation creates, maintains, and exploits knowledge (Nonaka et al., 2000). They propose a model of knowledge creation through the conversion of tacit and explicit knowledge.

According to Schon (1983), explicit knowledge can be displayed in formal and systematic language and shared in the form of data, scientific formulae, specifications, and manuals. It can be processed, transmitted, and stored simply. While tacit knowledge is relatively personal and hard to formalise, this is deeply rooted in action, procedures, routines, commitment, ideals, values, and emotions.

Considering the knowledge innovation model in management, this study tries to find an innovation model in architecture and interior design field among these four types: this can be called the TFAL model (technological, functional, aesthetic and locational) according to finding 2 of Chapter 5, which is a major research question.

How to use this model in design to get the innovative effect? In order to achieve the goal of authentic technological innovation (structural and constructed factors) in adaptive reuse of old buildings which has higher innovative influence, it is suggested that designers utilize their individual knowledge as a single group to meet the functional innovation (new usage) in first step, combining aesthetic (form, colour, material, etc.) and with explicit knowledge (preliminary design idea etc.) secondly, synthesizing locational innovation (present condition and contextual background) with tacit knowledge (environment, culture, economy, politics, etc.), and integrate all factors (collective knowledge as a group) into a new space through various expression (draft, final design plan, shop drawings and animate etc.), which then achieve the most influential innovation type (technological innovation), and yields the innovative effect. The movement through the four modes continues again and forms a spiral (Figure 8-2).

It is the first model for adaptive reuse of old buildings from the perspective of innovative design, and it will guide professional designers in how to obtain authentic and creative space effect.

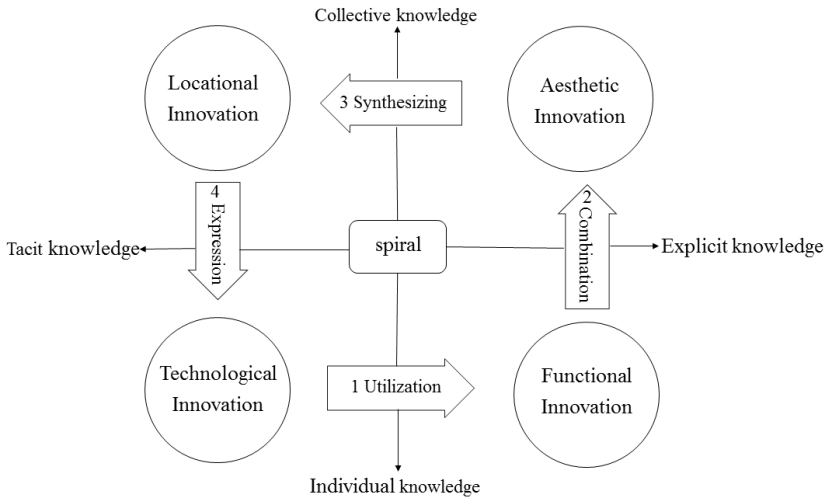

Figure 8-2: Four innovative types of model of knowledge creation

This study systematically analyses these four innovation types in Chapter 5, with reference to the SECI model. Although the form is similar, the contents are different. This model will contribute to an understanding of how innovative types can be used to support the adaptive reuse of old buildings.

8.2.1.3 More highly effective innovative design types and criteria

Technological innovation is an extended concept of innovation, which is related to materials, equipment (heating and lighting), information technology systems, and various renewable energy sources (Kebir et al., 2017).

In Chapter 5, the results suggest that the most important elements of innovative design for the adaptive reuse of old buildings is technological innovation, which is found to have an effect on higher creativity. In Chapter 6, the key criteria for innovative technology type are shown, highlighting that the important indicators are structural integrity and material durability (Figure 8-3).

If designers more focus on the specific criterion in each type, who could get a better innovative effect. For example, the more attention to structural integrity and material durability in technological innovation, which had been verified the finding 2 in Chapter 5 and the criterion of finding 3 in Chapter 6, the higher creativity they will get. Designers can think about these higher influence elements to guide their future design work and achieve sustainability and innovation.

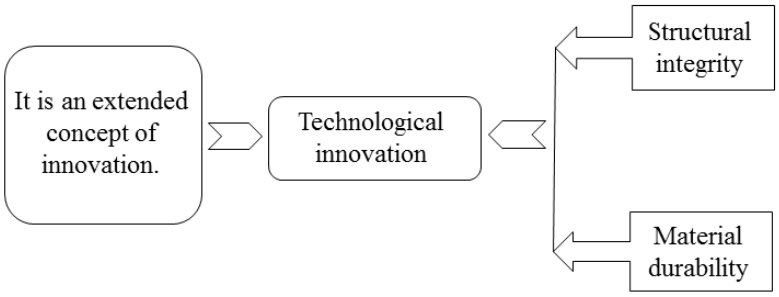

Figure 8-3: The higher influence of innovative design type and criterions

8.2.2 Theoretical implications

The introduction of innovation and sustainability into the adaptive reuse of old buildings design field has great theoretical implications for architecture and interior design theory and innovation and sustainable design research.

First, the introduction of innovation leads to the enrichment and deepening of the theory of architecture and interior design. The discussion of the principles and design methods in architecture and interior design is common in the theoretical world, but it is rare to see problems from the perspective of innovation. This will further enrich the research content of architecture and interior design and refine the research focus of the design discipline, which is reflected in

Chapters 4 and 5. Concurrently, the concept and meaning of contemporary innovation are unclear, which creates misunderstanding during innovation practice. Through this research, gaps in the research of innovation theory in the adaptive reuse of old buildings are filled.

Second, the introduction of sustainable design into the field of architectural and interior design leads to the enrichment and expansion of sustainable theory, especially for the adaptive reuse of old buildings. In fact, various countries are actively exploring individual cases and assessments of sustainable buildings. However, for overall typology research and evaluation, studies specifically on the adaptive reuse of old buildings are rare. The fifth chapter summarizes the typology of the adaptive reuse of old buildings from the perspective of innovation. The sixth chapter evaluates the innovative type of the adaptive reuse of old building from the perspective of sustainability, which fills a gap on the adaptive reuse of old building design research in innovative type and sustainable evaluation.

Hence, the theoretical significance of this study is the presentation of specific typologies and evaluation methods for old building renewal in public fields to allow for a comprehensive understanding of innovative design based on original research that include observations and experiments. It will guide professional designers in how to develop evaluation criteria of innovative design for specific cases as well.

This study will also provide a useful reference for both environmental design practitioners and academics that are interested in sustainable design developments, especially those who make critical design decisions that contribute to sustainable environmental development and construct new buildings with greater adaptive reuse potential.

8.2.3 Practical implication

The practice of renewing old buildings has profound implications for sustainable development (Carroon, 2011). Reuse is one of the 5R principles in sustainable environmental design (Zhou, 2011). The fundamental purpose of adaptive reuse is to take full advantage of the potential value of old buildings from the perspective of material or social and cultural resources and integrate an ecological value foundation (Hong & Xia, 2009). The adaptive reuse of old buildings exerts significant environmental, economic, and social influence on society. As a resource, old buildings can be used through renewal and reuse, which can further effectively reduce resource consumption and environmental pollution and damage (Zuo & Zhao, 2014).

As a comprehensive vehicle of technology and art, architecture and interior design are closely related to the development of various industries. The development of innovation will inevitably drive the development of architectural and interior design. The innovative development of production technology affects the structure and craft of buildings. The development of the innovative design process affects interior design and furnishings. Thus, creative thinking affects all aspects of people's lives.

Human thoughts and feelings will also be part of architectural design considerations. Chapter 7 considers users' feeling in renewed space, from the users' needs to sketch, design, and evaluate the renewal space through the case study, which challenges traditional

architectural aesthetic approaches.

Furthermore, the innovative design of the adaptive reuse of old buildings is intended to meet the needs of sustainable development of the current environment as well as the needs of people's lives and environmental protection. It extends the achievements of technological development, reflects the development of the latest technological achievements, indicates the direction of human life, and has a high practical significance for innovative design research of old building renewal.

8.3 Limitations and Recommendations

8.3.1 Limitations

Although this study has been accomplished by utilizing logical analysis, there are still some limitations that should be improved upon to enhance the existing result.

On one hand, the number of participants in different countries should be expanded to yield more comprehensive results. The questionnaire was first designed by a professional group that consisted of Chinese and Japanese people, and it was planned to invite people from China, Japan, and other countries. The questionnaire was created in three languages (Chinese, Japanese, and English). However, due to the limitations in space and time, only Chinese participants completed the questionnaire. Furthermore, expanding the age group from that which is examined in this study would benefit future studies.

On the other hand, expanding the number of examined old building renewal and new building development projects could be beneficial. In Chapter 4, 12 old building renewal projects and 6 new buildings were chosen by the professional group, leading to a total of 18 cases to compare. If the numbers of cases increases, the result of the comparison might be more obvious.

Moreover, the procedure of selecting the cases or participants might be not introduced carefully, and more details of selecting objective should be explained in every experiment.

Last but not least, the application of Extenics in Chapter 7 is solely introductory. The use of Extenics' extension analysis method to solve interior design innovation is currently in a preliminary application and exploration stage. It is believed that after long-term research and practice, the extension innovation method will be improved.

8.3.2 Recommendations for further research

This study mainly focused on innovative design for the adaptive reuse of old buildings in public space because most old building renewal projects transform these buildings into public space, such as commercial, recreational, and cultural spaces. However, there are still some alternative spaces, such as residential buildings. The adaptive reuse of residential buildings should be explored as another category in further research. The act of breathing new life into

existing residential buildings carries with it environmental and social benefits and helps to retain our assets (Langston, 2008).

Although the innovative problem of solving architectural and interior design is still in the exploration stage, the mixed-subject methodology in this study is also applicable to residential building renewal. The viewpoint of innovation and sustainability could be explored in the adaptive reuse of residential buildings in the near future.

8.3.3 Inspiration for new buildings

Currently, new buildings are springing up and some designers are pursuing unconventionality in architecture and interior design. However, they are not aware of all the important factors and have insufficient experience in terms of environmental protection. The relationship between new buildings and old buildings is a significant problem. This is a complex and vast subject in which researchers are constantly seeking a balance between coordination and conflict, conservation and innovation. If it is not handled well, it may cause irreversible damage in the urban context, and the local characteristics of the city will disappear.

Therefore, the inspiration of adaptive reuse of old buildings to new buildings exhibits vital significance. Reducing the amount of new construction and extending the life cycle of existing buildings is an important consideration on the path to sustainability, as is discovering different innovative characteristics in design, such as the FATL model in the four above-mentioned innovative aspects. The adaptSTAR model provides a weighted criteria of design strategies that improve the development of new buildings that can be successfully reused in the future (Conejos et al., 2015). The criteria of adaptSTAR may also be used as a reference for new buildings.

8.4 Conclusion

This thesis focuses on the theoretical research of the innovative design for the adaptive reuse of old buildings in public space, combining the aspects of sustainability, innovation, and user experience design. Starting from the necessity of old building renewal research, moving toward examining a typology of innovative design and evaluation standard for adaptive reuse of old buildings, and ending with a case study in practice, I attempt to organize the whole process of knowledge innovation in the adaptive reuse of old buildings.

China is currently in a period of rapid development. Due to a large number of new construction activities, the renewal of old buildings is difficult to focus on, but we should note that 50 years later, today's new buildings will become old buildings whose quality and function will be unsuitable. At the time, we will face a large number of old building renewal needs. It is time for realizing this measure is ripe at this stage, and I will continue to extend the breadth and depth of this research to contribute to a sustainable and innovative society.

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Publications, Award and Activity

Papers Published in Journals

1. Dan Shao, Yukari Nagai, Masami Maekawa, Fei Fei (2018). Innovative Design Typology for Adaptive Reuse of Old Buildings in Public Spaces, Journal of Engineering Science and Technology, Vol. 13, No. 11 (2018) 3547 – 3565.

2. Dan Shao, Yukari Nagai (2017). The Innovative Application of Eco-Technology in Architectural Design, Journal of Engineering and Applied Science, Volume: 12, Issue: 10, Page No.: 2592-2596.

Peer Reviewed International Conferences

1. Dan Shao, Yukari Nagai (2017). The Innovative Application of Eco-Technology in Architectural Design, *2nd International Conference on Sciences, Technology and Social Sciences*, 2592-2596. July, 11, 2017, Oral presentation in Malaysia, Kuala Lumpur.

2. Dan Shao, Yukari Nagai, Xun Gu (2017). Innovative-Design Typology in Old-Building Renewal, *International Conference on Management Science and Engineering 2017, International Conference on Management Science and Engineering 2017,* 190-195. August, 18, 2017, Oral presentation in Japan, Nomi.
3. Dan Shao, Yukari Nagai, Ricardo Sosa (2019). Design for Sustainability and Innovation: A Kansei Engineering Evaluation of the Adaptive Reuse of Old Buildings. *ICED19 22nd International Conference on Engineering Design*, 3221-3230. August, 7, 2019, Oral presentation and Marketplace, August, 5, PhD Forum in the Netherlands, Delft.

4. Dan Shao, Yukari Nagai (2018). Old Building, New Usage: Case Study of a Creative Practice for an Art Studio Design Based on Users' Mental Needs, 5th International Conference on Design Creativity (ICDC 2018), 77-84. January, 31, 2018, Short presentation in the UK, Bath.

Award

1. Best paper award: Dan Shao (2017). Best paper, The Innovative Application of Eco-Technology in Architectural Design, 2nd International Conference on Sciences, Technology and Social Sciences.
2. The Murata Science Foundation overseas travel grant (2019), 300,000 yen.

Activity

1. 2019.2-2019.5, A three-month research visit at CoLab Creative Technologies, Faculty of Design and Creative Technologies, Auckland University of Technology, New Zealand.

APPENDIX

Website of pictures in Chapter 4.
P1: https://www.cool-de.com/thread-1214305-1-1.html
P2: https://sanwen8.cn/p/2f4uVVc.html
P3: https://sanwen8.cn/p/2f4uVVc.html
P4: http://blog.sina.com.cn/s/blog_49c38be10102vzv3.html
P5: http://yha.jpprojectkfg-gallery
P6: http://arcdog.com/portfolio/charnel-in-kamakura/
P7: https://www.gooood.cn/substrate-factory-ayase-by-aki-hamada-architects.htm
P8: https://www.usm.com/media/thumbs/images/asobism-4.jpg.500x0_q90_detail.jpg
P9: https://www.gooood.cn/aldeburgh-music-creative-campus.htm
P10: https://www.gooood.cn/house-z22-und-warehouse-f88-gus-wustemann-architects.htm
P11: https://www.gooood.cn/ulumbarra-theatre-y2-architecture.htm
P12: https://www.gooood.cn/torre-del-borgo.htm
P13: https://www.gooood.cn/zhongguancun-tonghang-plaza-by-helix-architects.htm
P14: https://www.gooood.cn/principle-m-showroom-by-mddm-studio.htm
P15: https://architizer.com/projects/iis-anniversary-hall-the-univ-of-tokyo/media/863618/
P16: http://www.gooood.hk/Aquaplannet-headquarters.htm
P17: https://www.gooood.cn/be-open-by-brenac-gonzalez-et-associes.htm
P18: https://www.gooood.cn/media-library-of-vitrolles-jean-pierre-lott.htm