基于建筑策划理论的建筑改造功能定位与决策机制研究

Research on Function Identification and Decision-making Mechanisms of Existing Building Renovation Based on Architectural Programming Theory

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Research on Function Identification and Decision-making Mechanisms of Existing Building Renovation Based on Architectural Programming Theory

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《基于建筑策划理论的建筑改造功能定位与决策机制研究》论文简介

1. 问题的提出及研究目标

经过三十年的快速城市化，我国建筑行业进入存量时代，既有建筑改造项目由于缺乏科学合理的策划和分析论证，出现片面追求单一价值、同质化重复性改造等现象。针对改造项目中有关功能策划的决策理性不足问题，本论文将面向普适性项目的建筑策划理论引入既有建筑改造中，完善构建改造建筑策划的流程框架，并为改造项目的功能定位决策提供相应的方法技术。

2. 研究科学问题

1)既有建筑改造的建筑策划特征提取和流程框架；
2)既有建筑改造的功能定位解析与决策方法；
3)既有建筑改造的功能空间适配度分析评价。

3. 研究主要内容：特征提取——流程框架——方法技术

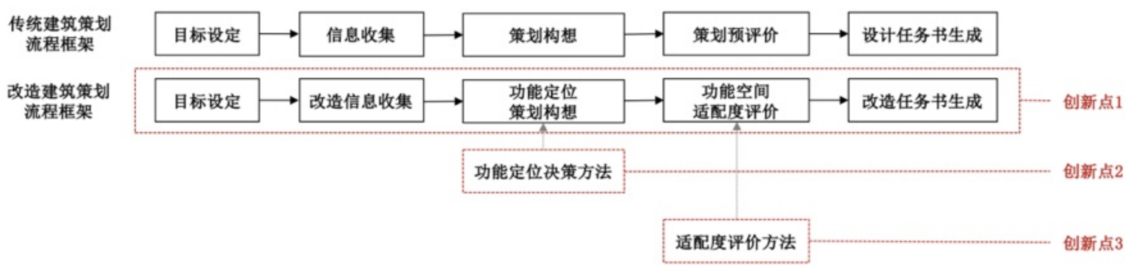
1)既有建筑改造项目的建筑策划特征、决策机制和问题诉求；
2)既有建筑改造的建筑策划流程框架；
3)既有建筑改造策划的信息收集过程和清单；
4)既有建筑改造功能定位的决策技术和策划方法。

4. 研究创新点*

1)**系统性地完善了既有建筑改造的建筑策划流程框架**：在传统建筑策划流程框架的基础上，通过补充改造信息收集、改造功能定位、改造功能空间适配度评价三个环节，完善了既有建筑改造的建筑策划流程框架，实现既有建筑改造项目前期策划流程的科学性；

2)**提供了既有建筑改造中功能定位的决策方法**：基于多准则决策理论，提出改造功能定位决策的解析与决策方法，实现功能定位决策流程的透明性和功能定位决策的合理性；

3)**提供了既有建筑改造中功能空间适配度评价方法**：提出改造功能策划与既有空间的适配度评价方法，以检验改造功能策划决策，并最终生成科学合理的既有建筑改造设计任务书。



5. 研究成果概述

1)已发表本论文相关研究成果 5 篇，其中以第一作者身份发表学术论文 4 篇（3 篇核心期刊文章、1 篇国际会议论文集收录文章）；

2)参与本论文相关研究课题 4 项（2 项国家自然科学基金课题、1 项中国工程院课题、1 项住建部课题）；

3)参与两项城市既有建筑改造策划与设计实际工程项目。

* 本研究三个创新点于 2022 年 5 月经国家一级科技查新咨询单位查新认证，国内外未见文献报道，成果具有创新性。

Thesis Overview

1. Problem statement and research purposes

After thirty-year rapid urbanization, building stock in China has reached a tremendous quantity. Due to the lack of scientific and rational analysis and verification in the pre-design phase of renovation projects, problems have risen these years such as bias in pursuit of project values and homogeneous reuse strategies. To cope with irrational and unscientific decision-making regarding renovation function programs, this thesis engages architectural programming theory for universal construction projects into the pre-design phase of renovation projects. It is intended to enhance the process and framework of architectural programming for existing building renovation, and to provide corresponding scientific methods for making decisions on renovation functions.

2. Research questions

1) What are **characteristics and framework** of architectural programming for renovation projects?
2) What is the decision-making method for **identifying new functions** of the existing building?
3) How to **analyze and evaluate the suitability** of existing building **spaces** and **function program**?

3. Research contents: Cognize characteristics——Enhance framework——Provide methods

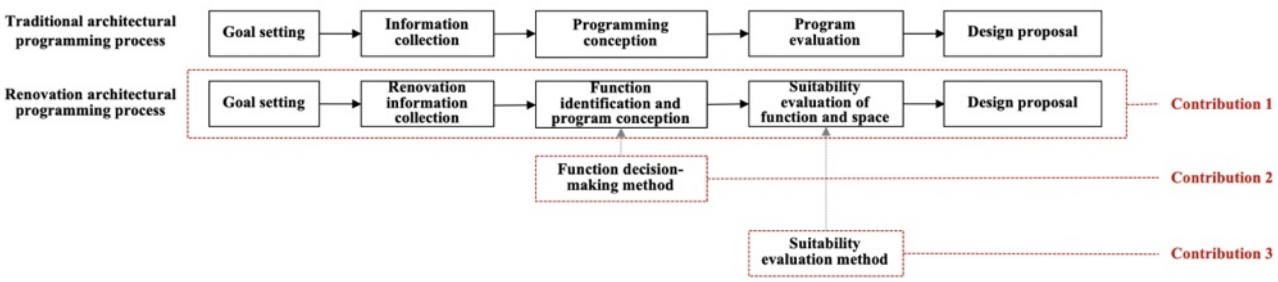
1) Features of architectural programming, decision-making mechanisms, problems and concerns of existing building renovation;
2) A holistic process and framework of architectural programming for existing building renovation;
3) Checklists of information collection in the pre-design phase of existing building renovation;
4) Methods of decision making and programming for identifying function programs in existing building renovation.

4. Research contributions*

1) Structure the process and framework of architectural programming in existing building renovation: it supplements three steps to the traditional process of architectural programming theory, which are renovation information collection, function identification and suitability evaluation of function and space, to enhance the process and framework of architectural programing in existing building renovation for a scientific pre-design phase.

2) Provide decision-making methods for function identification in existing building renovation: based on multiple criteria decision analysis (MCDA) theory, it proposes methods for analysis and decision-making of the function of the existing building, to facilitate a transparent and rational decision-making process for renovation function identification.

3) Provide evaluation methods for suitability of function and space in existing building renovation: it proposes evaluation method for evaluating the suitability between the new function program and existing spaces, to verify the decision on function programs, in order to generate a scientific and rational design proposal of existing building renovation.



5. Research outputs

1) The author published 5 academic articles relevant to the research topic, including 4 articles as the first-author (3 articles in core journals and 1 article in an International conference proceeding);
2) The author participated in 4 research projects (2 projects sponsored by National Natural Science Foundation of China, one by Chinese Academy of Engineering, and one by the Ministry of Housing and Urban-Rural Development)
3) The author participated in 2 practical projects of existing building renovation, working on the architectural programming and design.

* The three contributions have been verified by a national-level institute of sci-tech novelty search in May, 2022, that the research results are innovative in existing academic databases.

摘　要

经过三十年的快速城市化，我国建筑行业进入存量时代，相关问题逐渐凸显，大量既有建筑处于闲置废弃状态，构件老化，承载的功能落后于时代需求，其中部分建筑具有一定的历史价值和社会价值。多元的价值导向和参与主体增加了建筑改造的难度。由于国内相关制度尚未健全，决策方法缺乏科学性，近几年既有建筑改造在功能定位方面出现了片面追求项目单一价值，同质化重复性改造等问题。既有建筑改造的前期阶段需要一种科学理性的策划方法以应对复杂的改造项目。

建筑策划理论是应对复杂性建设项目而提出的认知设计对象、找寻关键设计问题和设计依据的方法体系。传统的建筑策划理论面向普适性的建设项目。针对改造中有关功能策划的决策理性不足问题，本论文将普适性的建筑策划理论引入既有建筑改造中，完善改造建筑策划的流程框架，并为改造项目的功能定位决策提供相应的方法技术。

本论文首先从改造动机、改造内容、参与者特征和决策机制四个方面分析既有建筑改造的策划特征，并明晰其与新建项目策划的六个不同点，总结目前既有建筑改造前期决策的问题和诉求。接着，针对这些特征和问题，从理论和实践两个层面，基于经典建筑策划流程框架和中意两国的案例对比研究，在普适性建筑策划流程中补充了改造信息收集、改造功能定位、功能空间适配度评价三个环节，提出了既有建筑改造的建筑策划流程框架。之后，针对上述三个环节的具体操作进行研究。信息收集环节提出了改造信息收集清单，包含城市、建筑及个体三个层级的既有建筑相关信息。功能定位环节的研究基于多准则决策理论和技术，提供了既有建筑改造中功能定位的决策方法；功能空间适配度评价环节，综合利用距离算法、相似度计算方法以及空间句法等技术，提供了功能策划和既有空间的适配度评价方法，验证改造功能策划决策，最终生成科学合理的改造设计任务书。

本研究将普适性的建筑策划理论延伸到既有建筑改造项目，补充完善了经典建筑策划理论的方法体系架构，为改造建筑实践的前期策划提供了相应的操作流程和方法工具，以期为我国城市更新中的既有建筑改造提供有效的决策支持。

关键词：建筑策划；既有建筑改造；空间功能定位；多准则决策分析；城市更新

ABSTRACT

After thirty-year rapid urbanization, building stock in China has reached a tremendous quantity and hence related problems have risen over these years. Numbers of existing buildings become obsolete or even abandoned. They have aging components and may not fit required new uses, but some of them have historic and social values. The diversified value orientation and multiple stakeholders increase the difficulty of building renovation. Due to the lack of sound regulations and scientific methods for decision-making, some problems of identifying functions in renovation projects have occurred over the past few years, such as biased pursuit of a single benefit, homogeneous and repetitive reuse strategies, and so on. It requires a rational and scientific approach for decision-making in the pre-design phase of complex renovation projects.

Architectural programming theory provides a scientific methodology system for architects to cognize design objects, seek correct design problems and basis for complex construction projects. Traditional architectural programming theory deals with universal construction projects. In response to irrational decisions on the function program of renovation projects, the thesis introduces universal architectural programming theory into the pre-design phase of existing building renovation. It is intended to structure an updated framework of architectural programming in existing building renovation and to provide corresponding methods for decision-making on renovation function programs.

The thesis first analyzes characteristics of architectural programming in renovation projects from motivation, content, stakeholder participation and decision-making mechanisms in architectural programming of renovation, identifies six distinguishing features from new construction projects, and summarizes problems and concerns of decision-making in the pre-design phase. For these characteristics and problems, it then supplements three steps to the process of traditional architectural programming framework, which are renovation information collection, function identification and suitability evaluation of function and space, based on comparative case study in Italy and China, to enhance the process and framework of renovation programming from theoretical and practical perspectives. Next, it researches on the three supplemented steps. Information collection step proposes a renovation information checklist from three levels of urban, building and user. Function identification step provides a decision-making approach to identify new functions for existing building renovation, based on theory and methods of multiple criteria decision analysis. As for the suitability evaluation of function and space, it provides corresponding evaluation methods with comprehensive use of distance measure, similarity measure and space syntax, in order to verify the decision on function programs, and to generate a scientific and rational renovation design proposals.

This research extends the architectural programming theory from universal construction projects to renovation projects of urban existing buildings, enhances the method system of traditional architectural programming theory, and provides corresponding process and methods for the pre-design phase of renovation practice, in order to support effective decisions in existing building renovation in urban renewal.

Keywords: architectural programming; existing building renovation; spatial function identification; multiple criteria decision analysis; urban renewal

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CHAPTER 1 INTRODUCTION

This chapter will answer the following questions:

1) What are the background and problems in reality of this research?

2) What is architectural programming theory and why is it introduced in this research?

3) What are the research objects and questions that this research focuses on?

4) How will this thesis organize the research?

1.1 Background and problem statement

1.1.1 Policy: urban renewal and architect responsibility system

After thirty-year rapid urbanization, the percentage of urban population in China exceeded 60% for the first time in 2019 (Figure 1.1), with more than 12 billion square meters of public building stock[1]. As the era of stock started, related issues and problems have become increasingly prominent. Large number of existing buildings in urban areas in China are obsolescent or even abandoned. They are either vacant for outdated industry, unable to meet update using requirement, or cannot satisfy the present standards and building codes, etc. However, some of these buildings have a significant historical and social value which brings more difficulties to building renovation. Under the situation that relevant management systems, supervision and regulations of urban renewal are still to be well developed, it is challenging to achieve sustainable development and preservation of historic, social and cultural values in complex renovation projects of urban existing buildings.

[1] This number is calculated based on *2020 Annual Report on China Building Energy Efficiency* and data published on the National Bureau of Statistics in 2020, seeing at http://data.stats.gov.cn/.

Figure 1.1 Urbanization rate of China from 2000 to 2021 (Source from National Bureau of Statistics; image drawn by the author)

The past few years have witnessed a powerful trend in China to transform from large-scale incremental construction to equal emphasis on improving quality of urban stock and adjusting the structure of increment, focusing much more on urban renewal and existing building renovation. Table 1.1 shows the relevant documents of laws, regulations, and policies of urban renewal and urban existing building renovation in China recently. To prevent biased pursuit of the financial return in the development of urban renewal, which causes waste of resources, environmental pollution, and damages the urban context, etc., On September 28, 2018, the Ministry of Housing and Urban-Rural Development issued the *Notice by the Ministry of Housing and Urban-Rural Development on Further Promoting the Preservation, Utilization, and Renovation of Urban Existing Buildings*, and clearly stated that urban existing buildings "have characteristics of different eras and have both technical and artistic values" (Ministry of Housing and Urban-Rural Development of China, 2018). Several cities have undertaken urban renewal activities in the last few years, but the year 2021 is a turning point in urban renewal at the national level. The *Outline of the 14th Five-Year Plan for the National Economic and Social Development and Vision 2035 of the People's Republic of China* points out explicitly to “implement urban renewal actions to promote the structural optimization and quality of urban spaces”, which is the first time to contain urban renewal in the Five-Year Plan of the PRC. Cities from the first-tier to the second-tier have issued relevant regulations and policies successively in this year, including general regulations, urban planning, governmental opinions and also attempts from the technical perspective such as design guides for fire protection in renovation, etc.

Table 1.1 Relevant documents of laws, regulations, and policies of urban renewal and urban existing building renovation in China

Year	Level	Department	Document
2018-09-28	national	Ministry of Housing and Urban-Rural Development	Notice by the Ministry of Housing and Urban-Rural Development on Further promoting the Preservation, Utilization, and Renovation of Urban Existing Buildings
2021-02-18	municipal	Standing Committee of Shenzhen Municipal People's Congress	Regulations of the Shenzhen Special Economic Zone on Urban Renewal
2021-03-12	national		Outline of the 14th Five-Year Plan for the National Economic and Social Development and Vision 2035 of the People's Republic of China
2021-08-21	municipal	People’s government of Beijing Municipality	Action Plan for Beijing Municipality Urban Renewal (2021-2025)
2021-08-25	municipal	Standing Committee of Shanghai Municipal People's Congress	Regulations of Shanghai Municipality on Urban Renewal
2022-05-18	municipal	People’s government of Beijing Municipality	Sectoral Plan of Beijing Municipality Urban Renewal (Beijing Municipality Urban Renewal Plan during the 14th Five-Year Plan Period)

On the other hand, the supervision on the project cycle and process of construction projects, the mode of project management and rights of architects is being improved at the same time. The **Architect Responsibility System** was first proposed by the Ministry of Housing and Urban-Rural Development in March 2015, and was first implemented in Pudong New District of Shanghai as a pilot. From 2016 to 2021, six cities have been approved by the Ministry of Housing and Urban-Rural Development of trial implementation of the architect responsibility system (Table 1.2). Besides, many other cities such as Hangzhou, Chongqing, Jinan, etc., have promoted the pilot program as well. Taking Beijing as an example, the Beijing Municipal Commission of Planning and Natural Resources officially issued the *Guidance on the Pilot Architect Responsibility System in Beijing* on January 27, 2021. This opinion stipulates the basic services of the architect responsibility system, including all or part of the six stages of planning and design, programming and consultation, engineering design, bidding and procurement, contract management, operation and maintenance, and other additional services(Beijing Municipal Commission of Planning and Natural Resources, 2021c). Among them, design is a traditional architect's business, and the stage of architectural programming and consultation is located in the early stage of the project, which is an important stage to connect architectural design and urban planning, clarify design objectives and problems, and identify design requirements, and is the basis of subsequent design.

Table 1.2 Implementation of the pilot program of Architect Responsibility System

Year	Level	Department/Location	Document/implementation
2015-01-22	national	Ministry of Housing and Urban-Rural Development	*Major Tasks of Department of Market Supervision in 2015*: "promote architects to play a leading role in the whole process of project implementation"
2016-11-04	municipal	Pudong New District of Shanghai	*Implementation Opinions of Promoting the Pilot Program of Architect Responsibility System in Construction Projects in Pudong New District of Shanghai*
2017-08-27	municipal	Guangxi Zhuang Autonomous Region	Approved of the pilot program of Architect Responsibility System
2017-11-01	municipal	Xiamen area of China (Fujian) Free Trade Zone	Approved of the pilot program of Architect Responsibility System
2018-12-06	municipal	Hebei Xiongan New Area	Approved of the pilot program of Architect Responsibility System
2019-02-13	municipal	Shenzhen Municipality	*Implementation Plan for the Pilot Program of Architect Responsibility System of Shenzhen Municipality*
2020-06-08	municipal	Beijing Municipality	Approved of the pilot program of Architect Responsibility System
2021-01-27	municipal	Beijing Municipal Commission of Planning and Natural Resources	*Guidance on the Pilot Architect Responsibility System*

Existing buildings in cities that constitute the cultural symbol of a specific historical period, and increasingly become parts of urban distinctive image and the public's memory, should be highly valued and strengthened for their preservation, use, and renovation. However, in the field of urban existing building renovation and transformation, the relevant domestic systems have not yet been well developed, and the relevant renovation regulations are mainly focused on the energy-saving and retrofit, while the operation methods lack scientific and rational guidelines. As the decision rights and responsibilities of architects in construction projects has been increased due to implementation of the architect responsibility system, how to improve the adaptability, practicality and comfort of the building as much as possible in accordance with the requirements of sustainable development under the premise of respecting historical culture, inject new vitality into the existing building and the surrounding built environment, is an important issue to be discussed for architects.

1.1.2 Practice: irrational decisions regarding renovation function programs

At present, existing domestic buildings are being renovated. Many issues such as function analysis under building renovation, how they should be renewed, and the formulation of the mission statement, etc., decisions often depend on the wishes of local governments and developers. Parts of them rely on architectures' inspiration. The lack of rationality in decision-making of renovation projects involves three situations.

The first situation is bias in pursuit of project values. For example, the Hankou Water Tower, a historical building built in 1909 in Wuhan, Hubei province, was once transformed to be a shopping mall overnight because of the government's arbitrary decision in the early 1980s, when it has not become a listed heritage (赵煌, 2019). Due to biased pursuit of economic value regardless of historic and social values of the existing building, the tower was completely covered by advertisements on facades, and was added a newly built three-story commercial building next to it (Figure 1.2). The strategy not only brought little vitality to the building and the district, but also caused great damage to the building façade. Renovation projects always involves various kinds of value due to the existing building and urban environment, which should be considered comprehensively and balanced to achieve optimal benefits.

The second type of irrational decision is the homogeneous reuse strategy. Reuse projects may take the same reuse function and strategies of previous successful projects without diligent investigation and careful consideration. For example, the success of the Beijing 798 Art Park stimulated the transformation of many obsolescent industrial building clusters into cultural and creative parks. However, 798 Art Park is a down-to-up organic renewal practice with cultivation of many years(王科, 2007). The arbitrary decision of copying function programs into other projects easily results in high rate of vacancy and bad performance in rental market, which can make the reused building obsolescent again. Complicated renovation projects require more analysis on specific conditions to make rational decision for the sustainable development.

The third irrational situation is repetitive renovation due to ineffective strategy. Due to unscientific analysis and arbitrary decision-making, existing buildings can become abandoned or poorly behaved again after several times of renovation, which wastes quantities of resources and time. For example, Longfu Building (Figure 1.3), one of Beijing's four major modern shopping malls, has been transformed several times to be snack streets, clothing markets, and digital product market during the last 20 years, which all resulted in obsolescence again (柴培根 and 周凯, 2020). It is difficult to identify function program for renovation projects since the decision involves many constraints and conditions.

The three situations above show that rigorous analysis and rational decisions on function programs play a significant role in the success of renovation projects. If the reuse function is unsuitable for the existing building, or the enhanced functional program cannot satisfy the updated using requirement, the renovation strategy fails. As a consequence, quantities of resources are wasted, the carbon emission and environmental pollution are aggravated, the historical, cultural and social value of the existing building itself can be damaged, and even the urban contexts and memories would be fragmented.

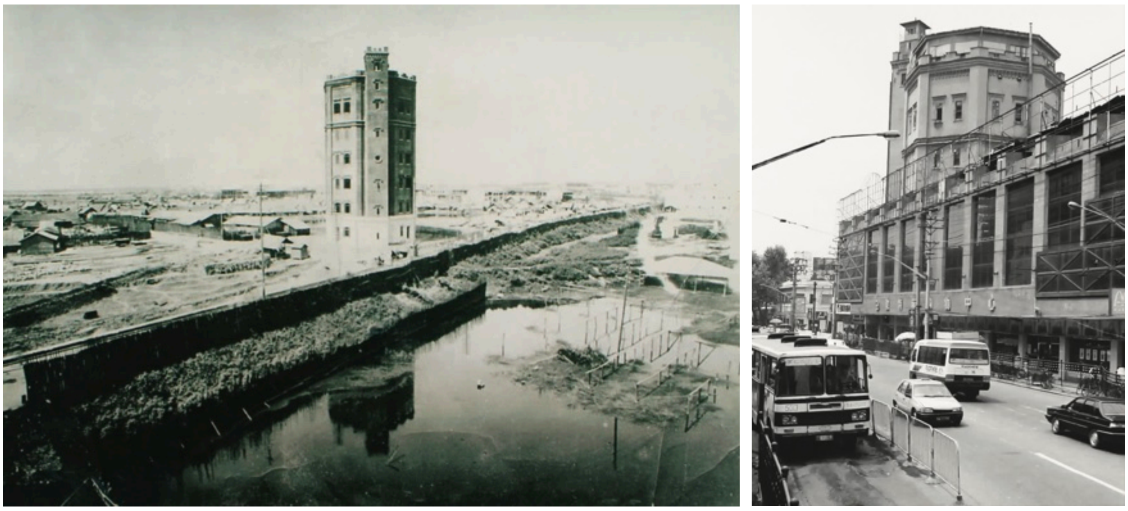

Figure 1.2 Hankou Water Tower (张垠, 2021) Left: Hankou Water Tower in 1900s; Right: Hankou Water Tower transformed to a shopping mall in 1980s

Figure 1.3 Longfu Building renovated for many times. Left: Longfu Building in 1990s (https://www.sohu.com/a/79587887_407820); Right: Longfu Building in 2012 (photo by Zhou Kai)

1.1.3 Theory: transformation of renovation mechanisms

Furthermore, the mechanism of renovating existing buildings has changed overtime, while more attention has been paid to the pre-design phase of architecture design in the worldwide including China[2].

[2] On Sep 15, 2019, The General Office of the State Council, PRC with the Ministry of Housing and Urban-Rural Development, PRC published *Guidance on Improving the Quality Assurance System and Enhancing the Quality of Construction Projects*, in which they demanded “establish the ‘pre-design programming and post-occupancy evaluation’ system, to improve the mechanism for review and make decisions on alternative design schemes.”

1) Generalization of renovation targets

At the beginning of the 20th century, Gustavo Giovannoni, a famous Italian architect, put forward that in the process of protecting urban texture, it is of great significance to pay attention to minor architecture(Jokilehto, 2002 [219-220]). He thought that the minor architecture. were more representative of the public's will than the important and splendid palaces. The "less important works in the past" mentioned in the 1964 Venice Charter and the " minor architecture." mentioned in the 1975 European Charter of architectural heritage are both proposed to be included in the scope of the objects of architectural heritage protection, once again giving high attention to the secondary buildings. In the 21st century, on the one hand, the era of "big demolition and big construction" has passed, and the requirements of sustainable development in the stock age make people pay more attention to the renovation of buildings; on the other hand, the classification management of cultural relics and historical buildings has been gradually improved, and the protection mode is more cautious. Therefore, the " minor architecture." or general existing buildings in the city have become more and more the goal of renovation, resulting in many types of existing buildings with artistic value, social value and cultural value. The existing building renovation gradually change from important historical buildings to general buildings of different types and values.

2) Diversification of renovating dimensions

In the past, the renovation of existing buildings emphasized the reuse based on the social and economic level, or the energy-saving transformation based on the environmental level, and now with the continuous enrichment of the connotation of the sustainable development of buildings, the renovation of existing buildings has changed from a single dimension to a multi-dimensional and comprehensive renovation. The Rio Declaration on environment and development, adopted in 1992, proposes that sustainability consists of three dimensions: economic, environmental and social (Declaration, 1992). The Johannesburg Declaration on sustainable development in 2002 complements the fourth dimension, namely, cultural dimension (Declaration, 2002). Since then, there have been more than 100 explanations for the connotation of sustainable development. The multi-dimensional trend of building renovation also means that the analysis process is more comprehensive, more complex and more difficult to make decisions (贺静, 2004 ;贺耀萱, 2011). In recent years, multi-objective and multi criteria methods are widely used to study the decision-making of building renewal and renovation

(Wang and Zeng, 2010 ;Kamari et al., 2019). With the development of BIM, big data and machine learning, the interdisciplinary research trend of building renovation is also increasing (Juan et al., 2010 ;Joblot et al., 2019)。

3) Transformation of renovating modes

The common method of existing buildings renovation includes the overall and comprehensive renovation. But recently, Over-time renovation and Partial renovation of existing buildings have become a trend in Europe(Hoppe, 2012 ;Femenías et al., 2018). In the past, progressive renovation has been widely used in urban renovation and historic district renovation. For example, Academician Wu Liangyong's "organic renovation" theory adopted a "microcirculation" renovation mode with courtyard as the unit for Historic District, and properly handled the relationship between the present and the future(吴良镛, 1994). Now, this mode is also used in the single building, to renovate the building in stages or to transform the part first. This renovation method is conducive to properly handling the relevant social problems, dealing with the temporary shortage of funds, and strengthening the recognition of the building in history and culture. At the same time, this way also enables the building to gradually add the latest technology, or in the long run, it will reach a higher energy-saving standard (Femenías et al., 2018). These two renovation methods have their own characteristics, and their implementation needs further study, but the way of recycling and dynamic renovation provides more possibilities for the renovation and transformation of existing buildings.

4) Expansion of renovation scope

The building and its built environment are always closely related. The expansion of the renovation scope here refers to more consideration of the non-material environment related to the existing buildings, such as human and social environment. Zhang Li said that the renovation of buildings must positively answer the demographic problems, and respond to the "demographic changes of the people used in the space renovation"(张利, 2016). The renovation of existing buildings will affect the original users, new users and even the surrounding residents, and may also provide some answers to the local social problems. For example, the SESC comprehensive leisure center renovation project, designed by Brazilian architect Paul Mendes Da Rocha and completed in 17 years, has transformed the urban heritage into an urban public space open to all levels of society, fully considered the changes of people's social customs and lifestyle, and effectively promoted the revival of the urban core area(2018). In addition, de flat kleiburg, the first renovation project to win the Mies award in history, fully considers the changes of the living concepts of the new and old residents. As a symbol of the city's history and life memory, architecture can help the building and its surrounding environment by encouraging users to transform their own residential units, putting in more public functions, activating the ground floor, etc (2017).

Figure 1.4 Transformation of renovation mechanisms

The renovation of existing buildings today is facing many new changes and challenges. All the above problems call for a scientific, logical and rational method to deal with the comprehensive and highly complex projects in the early programming stage of the renovation. Based on this, this study introduces the theory of architectural programming into the study of urban renovation of existing buildings.

1.2 Engaging architectural programming into existing building renovation

Architectural programming was first put forward in 1950s in America, providing scientific methodology for architects to seek the right problem for design and to propose a rational architectural program with empirical studies (Pena and Caudill, 1959 ;Pena and Pena, 1969). Today, it is one of the basic requirements for architects in UIA (International Union of Architects) and AIA (American Institute of Architects)[3]. Many researches have transferred the theory and framework in China based on its realities (庄惟敏, 2001 ;邹广天, 2010 ;涂慧君, 2015 ;庄惟敏, 2016). However, existing researches of architectural programming mainly target new construction projects, lacking a holistic framework and empirical study on renovation projects.

1.2.1 Development history of architectural programming theory

In the 1950s, with the continuous expansion of urban construction in the United States, the complexity of construction projects continued to increase, and the demands of multi stakeholders became more and more difficult to balance. Under this background, the theory of architectural programming was put forward. Architectural programming theory system can provide owners and architects with a set of cognitive design objects, search for key design methods, which is scientific, logical and comprehensive, and specially deal with highly complex and comprehensive construction projects. The position of architectural programming in the project cycle is usually after urban planning and approval of project initiation, and before architectural design phase (Figure 1.5).Through decades of development, at present, architectural programming has become

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[3] The requirements can be found in *AIA Document B202TM-2009 Standard Form of Architect's Services: Programming and Accord on Recommended International Standards of Professionalism in Architectural Practice* (1999, amended 2017)

a necessary part of architectural design clearly defined by many countries, and its research and practice have also developed vigorously. The introduction of architectural programming theory into the study of urban reconstruction of existing public buildings is not only a direct response to the lack of rational renewal operation at present, but also a breakthrough to help traditional architectural design methods cope with the change of renewal mechanism. How to construct the research framework of urban existing building renovation is the first problem to be solved in this study. Before that, it is necessary to clarify the development trend and limitations of the existing programming theories and methods.

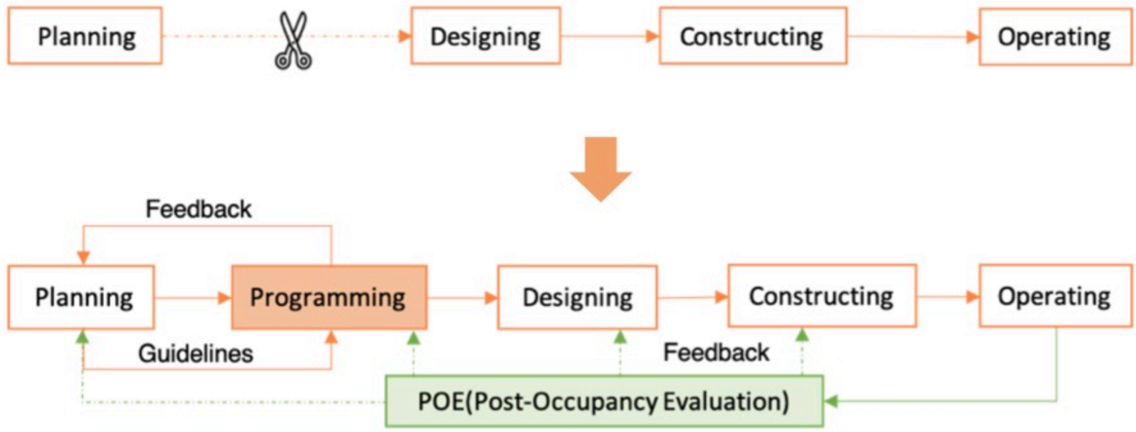


Figure 1.5 Architectural Programming in the traditional construction procedure

It is now generally accepted that the theory of architectural programming was born in the United States in the 1950s, when William M. Peña and Willian W. Caudill of CRS published an article in Architectural Record in 1959 entitled "Architectural Analysis - Prelude to Good Design". -Architectural Analysis - Prelude to Good Design," in Architectural Record, introduced the concept of "architectural analysis," the predecessor of architectural programming. The concept of Architectural Analysis was introduced. The most important task was to discover the owner's real needs through inquiry and communication, to analyze the scale and quality of the space, and to write a design brief. Later, William Peña and John Focke published the first edition of Problem Seeking: An Architectural Programming Primer in 1969, which formally introduced the concept of architectural programming. CRS Architects and Peña's Texas A&M University have also become the center of architectural programming theory research in the United States. In 1969, the Environmental Design Research Association (EDRA) was founded.

In 1969, the Environmental Design Research Association (EDRA) was founded in the United States, introducing environmental psychology, sociology, and other methods to study design methods. *Methods of Architectural Programming* in 1977 (Sanoff, 1977), followed by a series of publications, such as *Integrating Programming, Evaluation and Participation in Design: A Theory Z Approach* (Sanoff, 1992)and so on. Sanoff introduced social science research methods into the theoretical study of architectural programming, including information retrieval methods, methods of converting raw information into design information, etc., which laid the foundation for the later multidisciplinary intersection of architectural programming. In the same period, Wolfgang F. E. Preiser published Facility Programming: Methods and Applications in 1978 (Preiser, 1978)and Programming the Built Environment in 1985(Preiser, 1985).

In the 1970s and 1980s, on the other side of the Pacific, Japanese scholars developed many theoretical studies on architectural programming. In Japan, the research on architectural programming is generally referred to as "architectural programming" or "architectural planning", and the major works include *Research on architectural planning - Architectural planning research on how buildings are used* (吉武泰水, 1964), *The Science of Planning* (加藤昭吉, 1965), Architectural Programming (鈴木成文, 1975)(Nakajima I, 1974), *Introduction to Architectural Planning: The Science of Architectural Space and People* (大佛俊泰 et al., 2009), etc.

In the 1990s, architectural programming theory began to flourish, with a large number of researchers and a large number of publications during this period. In the United States, Dona Duerk published Architectural Programming: Information Management for Design in 1993, with a particular emphasis on prioritizing multiple issues based on values(Duerk, 1993). Duerk also introduced environmental behavioral research theory, as well as programming evaluation and post-occupancy evaluation to complete and enrich the programming process. Robert Kumlin, a student of Peña's, published Architectural Programming: Creative Techniques for Design Professionals in 1995(Kumlin, 1995). Design Professionals. Edith Cherry published "Programming for Design: From Theory to Practice" in 1999(Cherry, 1999). In addition, Robert Hershberger published Architectural programming and predesign manager in 1999, analyzing the advantages and disadvantages of design-oriented, knowledge-oriented, and contract-oriented approaches to architectural programming in turn, and combining previous research He proposed a theory of architectural programming based on eight values, emphasizing the judgment and ranking of multiple values by planners or designers (Hershberger, 1999), and Hershberger is regarded as the "second generation of architectural programming masters". In the UK, Frank Salisbury published The Architect's Handbook for Client Briefing (Salisbury, 1990), and Briefing Your Architect (Salisbury, 1997), which mainly provides the owner who commissions an architect how to analyze the objectives of the building project he or she wants to undertake, and communicate his or her needs and requirements about the building to the architect clearly and effectively, and prepare an accurate building project task statement according to the procedure. mission statement.

At the same time, systematic architectural programming research has begun to emerge in China. Zhuang (1991) published a doctoral dissertation "Architectural Programming Theory - A Discussion of Design Methodology". After that, he integrated the advanced achievements of Japanese architectural programming and architectural programming research in the United States and other countries, and proposed the orientation, method and operation process of architectural programming in the light of various problems in China's architectural design process, combined with the basic procedures of China's architectural production, and published *Introduction to Architectural Programming* (庄惟敏, 2001), which also became the first book on architectural programming in China, followed by other books including *Architectural Programming and Design* (庄惟敏, 2016), and *Architectural Programming and Post-occupancy Evaluation* ((庄惟敏 et al., 2018)).

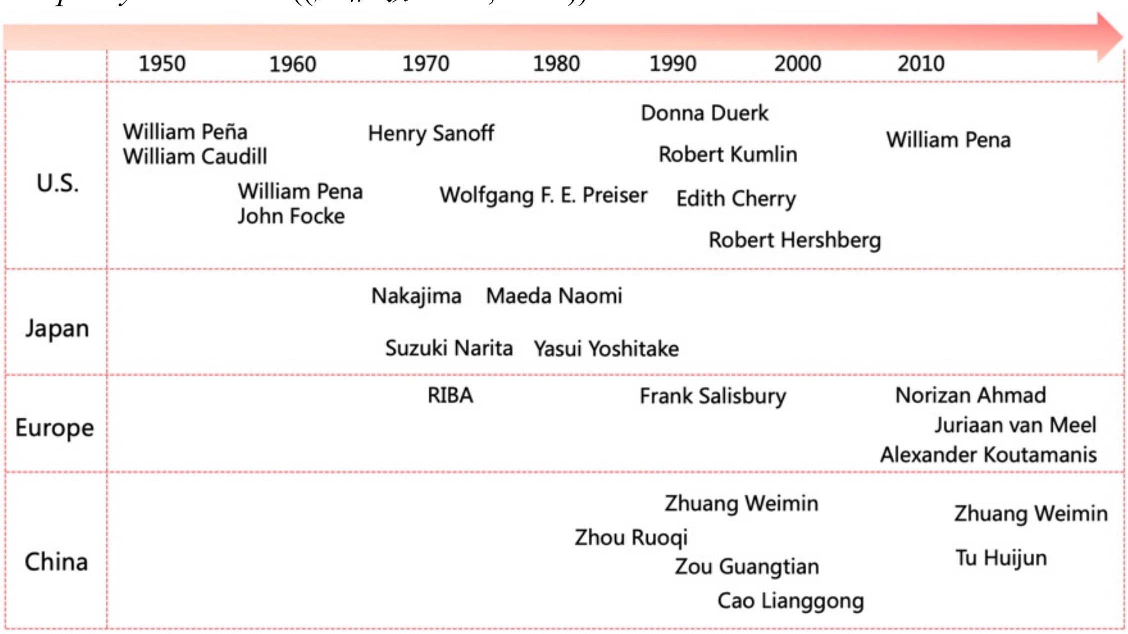


Figure 1.6 Development of Architectural Programming around the world

1.2.2 Development trend and limitation of architectural programming method

Architectural programming is a comprehensive decision-making process, different project types face different construction environment and conditions. The traditional operation method of architectural programming deals with all general new projects. However, with the increasing complexity of the construction conditions and the improvement of the requirements for comprehensive decision-making, in recent years, the research of architectural programming has gradually moved towards the development direction of fine differentiation and precision. In China, Qu (2015) introduced the collaborative mode of architectural programming into the research of new projects of historical environment, and expanded the operational mode of programming from the architectural level to the urban design level . On the other hand, Dang (2019) introduced the theory and method of architectural programming into rural construction projects and conceived the operational procedures of architectural programming in rural construction. In other countries, the subdivision and precision of architectural programming research are reflected in the specific steps, such as the methods and tools of a single step such as goal setting, decision-making, scheme pre-evaluation, etc. (Thuvander et al., 2012 ;Nielsen et al., 2016). However, for the programming of the renovation of existing buildings, the domestic research is not mature, while the foreign research is based on the local policy conditions, operation mode and energy consumption standards, which only has reference for the actual operation of domestic projects.

At the level of methods and tools, the rise of big data and the involvement of digital technology provide an opportunity for the development of programming tools. On the one hand, on the basis of qualitative research, many new quantitative research methods have been added. Miao (2016) studies the group decision-making method of architectural programming based on fuzzy preference relation. Liu (2017)uses data processing and analysis technology to establish a sample library of the assignment to evaluate the assignment. On the other hand, large amount, real-time generation and diversification of big data have similar characteristics with information with high complexity, high latitude and high relevance required by architectural design and programming. There are many interdisciplinary platforms for architectural programming, such as APIM (党雨田 and 庄惟敏, 2016) and DSAD (常镪 et al., 2015) . However, for the renovation of existing buildings, there are many obstacles, such as the difficulty in obtaining the information of existing buildings, the difficulty in establishing the database, etc., which make the early programming method still rely on the traditional sociological and statistical methods, and it is difficult to respond to the new demands of complex information processing and high efficiency in the information age. The existing tools have high technical threshold, difficult to use and long processing time, which also makes it difficult to popularize the programming methods and tools.

In 2019, it is stated for the first time in the government document in China to "establish the 'pre-programming and post-evaluation system' of architecture to improve the decision-making level of architectural design" (General Office of the State Council of the People's Republic of China, 2019). It is a necessary trend to apply architectural programming theory in more kinds of practical projects, which requires more researches in this field.

1.3 Research objects and questions

1.3.1 Relative concepts

1) Existing Building

The term *existing building* covers a wide range of buildings and should be first identified its scope in this research. Existing buildings are literally buildings that have already existed, or buildings that have been used for a period of time. Therefore, new construction projects that have not yet been built or completed but not yet put into use are excluded from this study. The existing building in this study should have two basic attributes, they can carry the function of use and have the internal physical space for users' activities, so the archaeological sites and parks, monuments, and construction[4] are excluded from this study. According to the definition of the current use status, the existing buildings studied in this paper include those that are no longer in use being abandoned and unused, as well as those that are still in use, but functionally obsolete, energy wasting, or aging. The research objects here in this study include not only historical buildings, industrial heritage and other buildings with historical, cultural or social values, but also

4 Construction (构筑物): a generic term for special engineering structures, referring to engineering entities or accessory building facilities that generally do not directly carry out production and living activities inside. (建筑学名词审定委员会[编], 2014. 建筑学名词[M]. 北京:科学出版社.)

common and minor buildings that are better renovated then reconstructed. Building renovation in China currently includes the following types of buildings: historical buildings protection, industrial heritage reuse, historical district renewal, old residential quarter renovation, and other general renovation of existing buildings.

2）Renovation and functional renovation

Renovation and relevant terms contain many construction activities. The following are the concepts related to the renovation of existing buildings, which are compared in Table 1.3.

Urban renewal: also called urban regeneration, is the planning and construction activities and systems to renovate and redevelop urban built-up areas for reasons such as urban industrial transformation, functional improvement, facility optimization, etc(城乡规划学名词审定委员会, 2021). It refers not only to the building itself, but also to the revitalization of the area, district, or communities.

Retrofit: according to Oxford dictionary, it refers to the old things, especially buildings to a good state of repair activities, including restoration, renovation and repainting, etc. But it currently indicates renovation activities related to energy-consuming and saving, as *green retrofit* or *energy-saving retrofit*(Webb, 2017).

Refurbishment: according to Oxford dictionary, it refers to the act or process of cleaning and renovating rooms, buildings, etc., to make them more attractive and useful.

Reconstruction: Oxford dictionary refers to the activity of building again a building that has been damaged or destroyed, emphasizing the step of demolition, reconstruction does not necessarily follow the original.

Addition or expansion: belongs to a kind of transformation, is the construction activities attached to the existing building, the existing building may remain unchanged, or may be updated and transformed along with the addition part.

Re-use: also known as "adaptive reuse", emphasizing the conversion of functions, placing new functions in the original building, which is more common used in historic buildings.

Maintenance: emphasizes maintenance and upkeep, without major changes, to restore it to a good operating condition.

Restoration: repair and preserve old buildings or heritages to restore them to their original good condition, maintaining their historical and architectural values (Grecchi, 2022a [43]).

Rehabilitation: to restore or alternate a building to its formal condition, or the condition of utility (Jokilehto, 2002 [268]); it can also indicate the preservation of an environmental area.

The term *renovation* is a more general concept, which can refer to any intervention to enhance the existing building (Grecchi, 2022b [2]). In this research it includes meanings from two perspective: the first is from the individual level, it refers to the activity on the building itself, in order to preserve the value and achieve sustainable development; the second meaning considers the relations between the building and its surrounding environment, so the renovation activity generates an interaction that can both regenerate the building and the built environment.

Table 1.3 Comparison of concepts relevant to renovation

Concept	Main object	Intention	If changes function program?
Urban renewal	Urban area	Regenerate area or district	possible
Retrofit	Existing building	Reduce energy-consuming	possible
Refurbishment	Existing building and the interior	Clean and renovate the interior	
Reconstruction	Existing building	Demolish and rebuilt	possible
Addition of expansion	Existing building	Add new parts attached	yes
Re-use	Existing building, more in historic buildings	Replace the original function	yes
Maintenance	Existing building	Keep in good conditions	no
Restoration	Historic or old buildings	Repair to be the original good condition	no
Rehabilitation	Existing building, city or environmental area	Return to the former or utility condition	possible
Renovation	Existing building, less in historic heritage	General concept involving retrofit, addition, re-use, etc.	yes

Furthermore, since the contents of renovation in practice still cover a wide scope and this research focus on function identification and decision-making in the process, it emphasizes **functional renovation** especially in chapter 5 and 6. In detail, functional renovation consists of function transformation and function enhancement. Function transformation projects transform the original function to new uses such as reuse projects.

Function enhancement, on the contrary, doesn't change the original use but improve and update the function program in the existing building. These will be introduced in detail in section 2.2.

3) Function identification

For function transformation renovation project, it is necessary to identify functions for the existing building before starting to design for this kind of project. Function identification in this research indicates the research and decision on the new use of the existing building. In urban planning, function orientation or identification is to identify the function for a district, an area or even a city(Zhuo et al., 2019 ;Li and Sun, 2020 ;Feng et al., 2021). For example, the main function zone is a spatial unit with core function orientation in the city (城乡规划学名词审定委员会, 2021). This research is intended to facilitate decision-making on the new use of the transformation of an individual existing building or a building cluster, based on the function orientation of this district or area. Therefore, it uses function identification to indicate this kind of decision in the pre-design phase of function transformation renovation projects, as an initiation condition for the project and design.

1.3.2 Research object and content

The research object of this thesis is the framework and methods of architectural programming in urban functional renovation projects, focusing on function identification and decision-making mechanism. The "functional renovation" in this research refers to interventions to improve the original conditions of any kind of existing buildings, including common buildings and historic buildings, in which the function programs are either totally transformed or partially changed.

The research is based on the classic architectural programming theory which is for general construction projects, especially new-built projects. Therefore, the research path is first to identify the distinguishing characteristics of renovation projects from new construction projects, then identify the problems to be solved in classic framework, and at last develops the enhancing framework and corresponding methods for urban functional renovation projects.

• Framework of architectural programming: it researches on how to develop the traditional framework and process and adapt it to the urban renovation projects. This adaption is based on theoretical researches as well as case study in practice.

• Methods of architectural programming in urban functional renovation projects: the thesis focus on two prominent problems occurred in the adaption of traditional architectural programming framework in renovation projects. One problem is how to make decisions on new functions for existing buildings; the other one is how to match the new function program with existing spaces. These two advised methods are supplement to the existing tool set of architectural programming in the pre-design phase of projects.

1.3.3 Research questions

This study attempts to cope with the irrational decisions in the pre-design phase of existing building renovation projects, and thus first proposes a single research goal: *how can architects or programmers provide a rational and scientific design proposal (or design brief) for renovation projects of existing public buildings, that could regenerate the building itself and the surrounding urban areas?*

Based on this research goal, the thesis introduces architectural programming theory in the pre-design phase of renovation project for **two purposes**:

First, it is intended to enhance the traditional framework of architectural programming theory for universal construction projects to be specific for renovation projects;

Second, it attempts to supplement methods and tools to the method system of architectural programming theory, in order to facilitate architects in reality.

These two research purposes further develop three detailed research questions below:

1) What are **characteristics and framework** of architectural programming for existing building renovation projects that satisfy multiple objectives and benefits of different stakeholders?

2) What are methods to facilitate **identification of suitable new functions** for the existing building that could regenerate both the building and the surrounding urban spaces?

3) How can architects analyze the **suitability** of existing building **space** and potential **functional program** to generate renovation design proposal?

The research path and framework to solve these questions are introduced in section 1.5.

1.4 Methodology and expected contributions

1.4.1 Methodology

1）Literature review

This research is based on the classical architectural programming theory and the latest research progress at home and abroad, and literature research is one of the main research methods in this thesis, including classical theories, journals, dissertations, reports and so on. The literature review mainly contains two fields: one is architectural programming and the other one is renovation of existing building renovation. Literature resources include databases such as Web of Science, Elsevier, Emerald, JSTOR, Taylor and Francis, China National Knowledge Infrastructure (CNKI), etc., published monographs, government documents published online, and so forth. In addition, the author, as the second translator, translates the fifth edition of the classic monograph: *Problem seeking: an architectural programming primer*, which is helpful to the research and writing of this thesis.

2) Comparative research

Based on the joint degree PhD research program at the Politecnico di Torino in Italy, this study highlights the comparative study between Italy and China in terms of practices, policies, technologies and development trends of renovation and pre-design phase from both eastern and western perspectives. Italy is one of the leading countries in the world in terms of architectural heritage conservation and renovation, not only with leading methods and technologies, but also with a large number of practical projects and successful cases. This research studies the advanced decision-making process and methods of renovation and reuse in Italy, to supplement and develop theories, methods and tools for the renovation programming of existing buildings in China. Besides, the research on architectural programming in the pre-design phase also provides criticism to the practice in Italy.

3) Case Study

This study is developed from both theoretical and practical perspectives. As for practical aspects, it conducts field research on many excellent renovation projects in Italy and China, applying questionnaire and interviews with architects about the problems and experience in practice to summarize the process of existing building renovation. It analyzes the detailed situation of each practice, the requirements and concerns of users and other stakeholders, and the decision-making mechanisms behind. Through case studies, it identifies problems and summarizes experiences, and synthesize various internal and external conditions to optimize the process of architectural programming for renovation projects.

4) Data science methods

This study introduces the data science method as the analysis method for architectural programming of existing building renovation. Traditional architectural programming methodology is based on empirical and empirical research and analyzes the problems in architectural design through logical deduction and analytical induction. There are also empirical studies using sociological research methods. The introduction of data science methods such as similarity measure, multiple criteria decision analysis, etc. and tools like python and SPSS can provide quantitative analysis to make the programming methods more scientific and logical.

1.4.2 Expected contributions

The thesis has two research purposes (Figure 1.7). The first purpose is to engage architectural programming theory to the pre-design phase of renovation projects, to solve the problem of irrational decisions on function programs. The other purpose is to extend the architectural programming theory and method system from universal construction projects to renovation of urban existing buildings, enhancing the classic theory to adapt to specific renovation projects. Urban existing building renovation in this research is considered as a specific building type, to be studied from perspectives of design characteristics, programming process, methods and tools. It is not only due to the necessity in the development of the era of stock, but also helps to enhance the theory system of architectural programming, which can better facilitate practice. However, the existing building renovation should consider comprehensively the characteristics of the building itself, its multiple values, elements to be preserved, the identification for its new functions, feasibility of regulatory, technical, and financial aspects, in order to achieve sustainable development in the long run for the existing building and surrounding urban spaces.

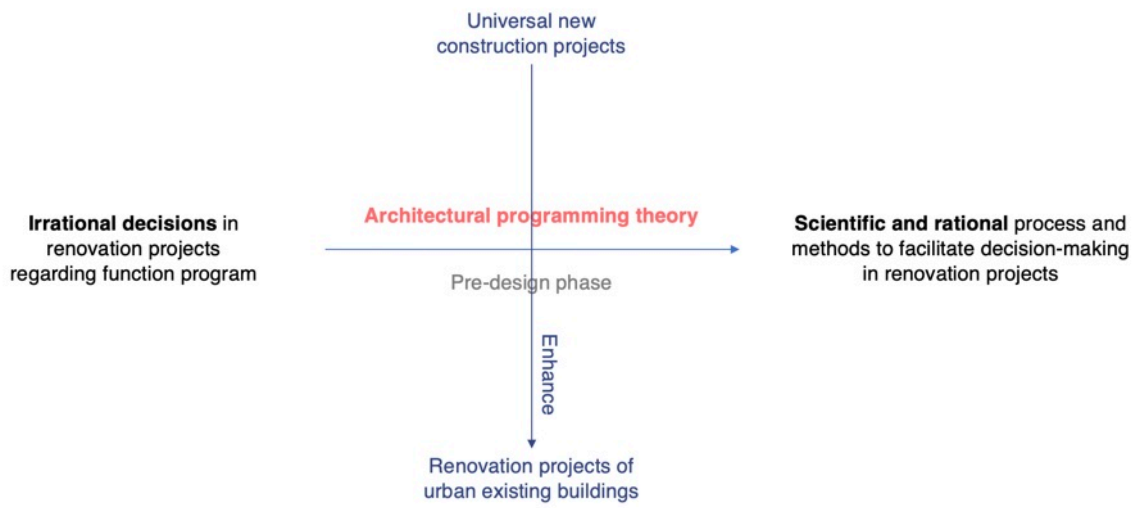


Figure 1.7 Research purposes of the thesis

Based on research purposes, the thesis is intended to achieve three expected contributions as below, to answer the three research questions.

(1) Structure the process and framework of architectural programming in existing building renovation

Traditional process of architectural programming includes five steps of goal setting, information collection, program conception, program evaluation and generation of the design proposal. Based on the traditional process, renovation characteristics and practice, the research supplements renovation information collection, function identification and suitability evaluation of function and space into three steps of the universal framework of architectural programing, which are information collection, program conception and program evaluation. The structure of process and framework of architectural programming in existing building renovation extends the universal architectural programming theory into the existing building renovation projects in order to achieve a scientific and rational pre-design phase in renovation projects.

(2) Provide decision-making method to facilitate function identification of existing building renovation

For the function identification step in architectural programming of existing building renovation, the research is based on multiple criteria decision analysis (MCDA) theory and proposes a basic decision-making process with multi-stakeholder participation, including three steps of structuring the decision situation, structuring the MCDA model, and evaluating the function alternatives. It provides a criteria index of function identification for reference from social, economic, environmental, cultural, aesthetic and technical dimensions. With the help of ELECTRE III method, it can obtain the final ranking of function alternatives. The structured multi-criteria decision-making process and method can facilitate a transparent and rational decision-making for identifying the new function.

(3) Provide methods for suitability evaluation of function program and existing spaces

For the step of suitability evaluation of function and space in program evaluation, the research proposes evaluation contents for evaluating the suitability between new functions and existing spaces in architectural programming, including rationality of the function program, analysis of spatial potential based on topology, suitability of function unit as well as suitability of function relationship. It utilizes topology theory to generate potential space organization, and comprehensively applies distance measure, similarity measure and space syntax, to evaluate the three contents above, in order to generate at last the design proposal for the existing building renovation projects.

1.5 Research framework

Since the thesis is intended to extend architectural programming theory from universal construction projects to renovation projects of urban existing buildings, the research path follows a set of questions as Figure 1.8 shows. First, it cognizes the distinguishing characteristics of renovation projects; second, it analyzes the concept and core idea of traditional architectural programming theory, and then summarizes the limitations of it when dealing with renovation projects. After that, it absorbs experience from practice to supplement the theoretical research. At last, it improves the framework and methods of architectural programming to solve the problems in renovation of urban existing buildings.

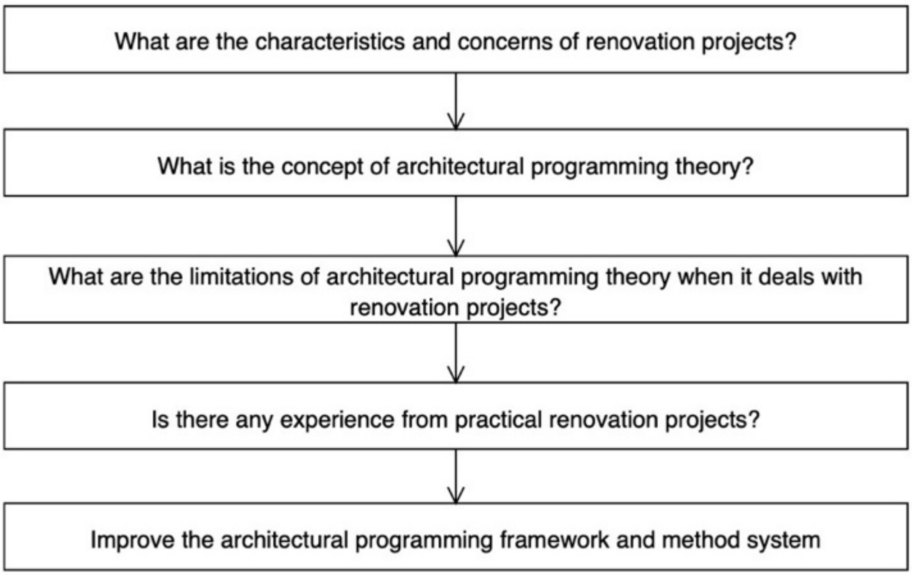


Figure 1.8 Research path of the thesis

Figure 1.9 below shows the research framework in general. To conclude, it follows the research path of cognizing, analyzing, and resolving. It improves and structures the architectural programming framework for renovation projects, identifies three most significant steps to be supplemented to the traditional framework, and then provides solutions of detailed procedure and method for each supplemented step to be implemented in practice. Below is the brief introduction of each chapter.

Chapter 2 analyzes the features of functional renovation of existing buildings from four perspectives, which are motivations, working contents, stakeholder parcipation and decision-making mechanisms. At last, it concludes the six main distinguishing features compared with new construction projects, and indicates the concerns and problems of decision-making in architectural programming. It is the distinguishing features of renovation projects from universal construction projects that define the working process and methodology of renovation programming. Hence the research on those features would lay a significant foundation for establishing the framework of architectural programming in existing building renovation.

Chapter 3 intends to engage architectural programming with renovation projects and establish a holistic framework of renovation programming, based on both theoretical and practical researches. It first concludes the experience form traditional architectural programming theory regarding working procedure, and reviews existing researches regarding the procedure and pre-design phase of renovation projects. For the practical perspective, it conducts a comparison research between four projects in Italy and China with the help of the joint PhD program of these two countries, in order to obtain critical experience from the construction projects in reality. Last, it presents an updated renovation programming procedure and indicates the supplement to the traditional framework.

Chapter 4 introduces the **first step** that should be supplemented to the traditional architectural programming theory, which is cognizing the existing building in the information collection. It first reviews the information collection in existing architectural programming theories. Next, it analyzes the characteristics of information gathering in renovation projects and establish a framework for this collection following the three scale of physical space: urban, building, and user. In the section of each scale, it further classifies the information into 3 categories to analyze the necessary and general information and facts that influence the architectural programming of renovation projects. At last, it introduces a case study underway from the perspective of information gathering and how it influences the decision-making among multiple stakeholders.

Chapter 5 introduces the **second step** that should be supplemented to the traditional architectural programming theory, which is the identification of new functions before conceiving the program. It first analyzes the features of decision-making on identifying new functions for the existing building, then structures the procedure of identifying functions based on multiple criteria decision analysis (MCDA) theory. Applying one of the MCDA tools, it can obtain the recommending function alternatives for making decisions on the new primary function for transforming the existing building. The procedure is experimented in a practical project as last.

After identifying the reuse function, Chapter 6 introduces the **third step** that should be supplemented to the traditional architectural programming theory, which is the suitability evaluation of function and space in the program evaluation step. This step is intended to verify the compatibility of reuse function and existing buildings, and to improve the detailed function program for the final design proposal. It defines the contents and provides methods for the evaluation, and verify the research in two cases in China.

Chapter 7 summarizes contributions, discusses remaining questions and offer implications for future research and practice.

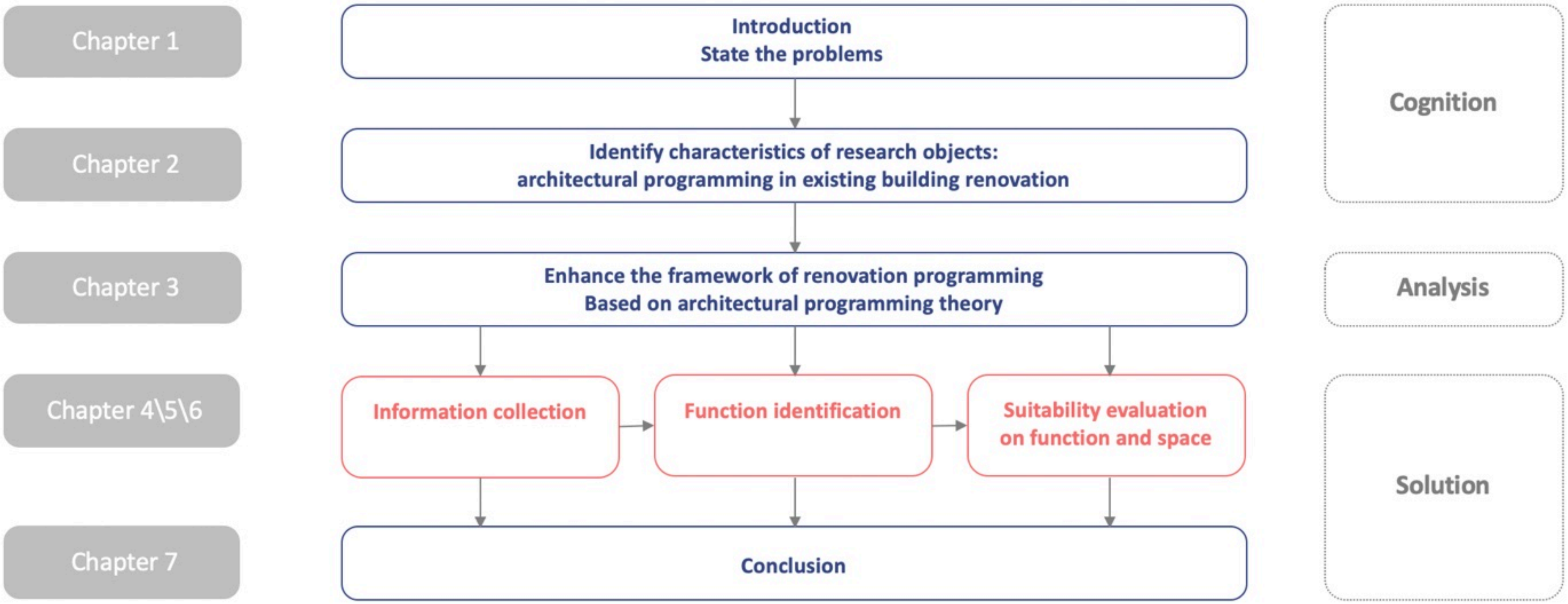


Figure 1.9 Research framework

CHAPTER 2 Characteristics of architectural programming in existing building renovation

This chapter is to identify the characteristics of architectural programming in existing building renovation, especially regarding the functional identification and decision-making mechanisms. It is the distinguishing features of renovation projects from new construction projects that define the working process and methodology of renovation programming. The research on those features lays a significant foundation for establishing the framework of architectural programming in existing building renovation in the next chapter.

The methodology implemented in this chapter includes questionnaire (Appendix A) and interviews to the experienced architects, archival analysis and case study (Appendix B). It analyzes the features from three perspectives, which are motivations, working contents, and decision-making mechanisms. At last, it concludes the six main distinguishing features compared with new construction projects, and indicates the concerns and problems of decision-making in architectural programming.

This chapter will answer the following questions:

1) What are the motivations and contents of functional renovation?

2) Who participate in the functional renovation projects and what are the kinds of decision-making mechanisms?

3) What are the main problems and challenges in functional renovation projects nowadays?

4) What are the distinguishing characteristics of renovation project compared with new construction project?

2.1 Motivations and contents of functional renovation of urban existing buildings

2.1.1 Motivations of functional renovation of urban existing buildings

A number of reasons can stand for renovation and reusing instead of redevelopment, such as limited budget, energy saving, legal constraints, etc. (Douglas, 2006). Some are the current problems of the existing buildings that hinder them for continuing use; others are the reasons for renovation instead of demolition and reconstruction; while there are also factors that motivate decision-makers to transform the building function or enhance the functional program. This section analyzes those motivations and reasons behind the renovation projects, in order to better understand the goals and decision-making in the pre-design process.

2.1.1.1 Current problems of existing buildings

The needs for renovating existing buildings are based on the current problems. The existing building can either be totally obsolescent or still in use with bad performance. The research thus studies the problems of these two categories.

1) Obsolescence

Obsolescence of existing buildings indicates the building is not in operation. It does not all result from the physical or technical problems, but also from economic and social degradation in many cases (Grecchi, 2022a [4]).

- Technical obsolescence

The necessity for using is the safety of the building. The aging of the structure, building elements and other damages threaten the solidity and safety of the building, and thus should be suspended using. Failing to meet the current building codes which has risk in fire protection and structure can also be prohibited from continuing operation.

- Functional obsolescence

Function obsolescence indicates that the function of the existing building is outdated or transferred to other places. It is most common in industrial buildings with industry transfer and upgrading. The original industries can either be shut down or transferred to other places out of urban area, leaving the existing factories or plants disused. The relocation of governmental functions may also leave public buildings obsolescent.

- Economic obsolescence

Economic obsolescence happens when the costs of maintenance and operation of the building are higher than the revenue of lease. It is influenced by market factors such as fluctuations of land value, real estate market, and by internal factors like energy consumption, degree of degradation, etc.

2) Bad performance

Bad performance indicates the poor status of operation in the existing building, which can lead to obsolescence without any intervention. Building performance includes various aspects.

- Functional performance

Existing buildings cannot satisfy the upgrading functional requirements of the users, due to the space distribution, flow organization, low degree of flexibility or existing equipment, and thus have poor performance in functions. Poor capability to adapt to functional changes and enhancement requires renovation to reorganize the spaces and update the equipment.

- Technical performance

Aging components, outdated equipment and other technical problems in the existing building can cause high cost of maintenance and discomfort when using the spaces. Severe problems regarding safety can even lead to obsolescence.

- Environmental performance

Aging buildings with poor performance of envelopes, windows, doors, roofs can cause high energy consumption and be harmful to the environment. Energy retrofit is one of the most significant renovation types since the construction and maintenance of buildings occupies considerable proportion in the total energy consuming of a country.

- Economic performance

Existing buildings can have poor performance in the real estate and tenancy market or have vacancy rate, which are common in office building, commercial building, hotel and so on. Renovation can improve the interior quality and support facilities which can raise the rental revenue and occupancy rate.

- Social performance

Social performance indicates the role the existing building plays in the urban area and its relationship with the surrounding spaces. Social problems include traffic problems, high crime rate in the district, commercial degradation of the community, high rate of unemployment, scarcity of housing or student dormitories, and so on. Some of them are resulted from negative interface of the existing building to the urban spaces, closed ground floor, or insufficient open spaces, which can be improved with renovation activity.

2.1.1.2 Reasons for renovation instead of reconstruction

The reasons for renovation instead of reconstruction are also the advantages of renovation compared with reconstruction. To identify the reasons for renovation, is to better understand the core demands of the client or key limitations in decision-making process.

- Economic limit

The renovation project has relatively fewer construction cost in most cases than that of new construction project, and it is advantageous in cases with limited budget. Land leasing, property transfer, cost of resettlement can all cause high cost in demolition and redevelopment, while they are not included in renovation in most cases.

- Time limit

Time limit is another reason supporting renovation instead of reconstruction. Reconstruction necessarily involves land transfer and redevelopment and construct building from vacant site, while renovation regards partially demolition and modification of the existing building, thus has shorter time of the project cycle. For projects demanding delivery in a limited time, renovation can be a better choice.

- Values

Buildings with historic values, or high social and cultural values should be preserved and can be prohibited from demolishing. Apart from listed buildings that must be protected and restored, buildings which play significant roles in the urban history, or influence many people and remain in citizens' memories should also be renovated to preserve the image, features and contexts of a city.

- Policy and regulation limit

Due to regulations of plot ratio, building height, floors, and complex of building property distribution, land use, etc., clients may also prefer renovating the existing buildings to improve the performance. It happens when it is difficult to demolish the building and resettle the original residents, or it is impossible to redevelopment the land and achieve the original development density.

2.1.1.3 Drivers for functional renovation

Drivers for functional renovation are sometimes the same as the goals of the projects. To identify the drivers for the project can understand the core concerns of the clients. The drivers for functional renovation can also reflect the core decision-makers in the projects.

1) Transforming industries

This motivation of transforming industries for renovation is mostly seen in reuse projects. Due to industrial transformation and upgrading, the original factory buildings with outdated industries, are forced to be idle or abandoned, but still have certain potential for use. The new industries can be either updated industry based on the original one, or totally different industry. There are several advantages of reusing the abandoned factories to contain an innovative industry:

- *Spatial organization based on production lines*: the factories were built according to the organization of product lines, and will be easy to transformed to factories of similar products. Therefore, reusing factories will save a lot of time for renovation and also decrease the construction cost.
- *Relatively high structural bearing capacity*: the structural performance standards of industrial buildings are generally higher than those of civil buildings, and if the factory buildings are well preserved, they can be transformed into civil buildings without major structural adjustments.
- *Industrial features to evoke memories and to be symbolic*: urban industrial sites carry the characteristics of industrial society and the historical memories of the life and work in the last century, and can even become the symbol of a city or an era. Therefore, the reuse of industrial heritage has become an important research and practice fields for urban renewal in various countries.

Beijing Municipal Commission of Planning and Natural Resources (2021b) released *Comments on carrying out the renovation of old factories* in 2021, encouraging to transform factories to hold high-tech industries such as intelligent manufacturing industries, science and technology innovation industries, and others like new kind of infrastructure, cultural industries and so on. Industrial transformation and iteration have driven the renovation and reuse of a large number of factories in China nowadays. This industrial transformation in old plant will supplement the deficiency of urban functions, improve the economic development and also environmental quality.

2) Increasing economic value

The motivation to increase the value of property is more common in the real estate market. It includes two types of property enhancement: one is to renovate non-performing assets (NPA) through pledge, acquisition or auction; the other one is to renovate facilities in order to increase the revenue of lease or sale.

In Europe and the United States, due to the adoption of private land ownership, land and housing titles are privately owned. When owners are faced with declining rents and rising vacancy rates, they choose to update and renovate their properties to increase the value of their properties. Real estate investment companies specialize in evaluating non-performing assets, renovation costs and return on investment, and renovate existing buildings through financing acquisitions, and then choose to sell or rent them out after the renovation is completed in order to obtain a return on investment. The building types are mainly office buildings and commercial buildings.

In China, there is also a demand for value enhancement for some of the buildings with corporate ownership. In this case, the owner needs to apply for permission for renovation to the local planning bureau and construction bureau, and the renovation work can be carried out only after the approval. Generally speaking, the ways to enhance the value of a property include improving facilities and equipment, interior renovation, façade renovation, and updating the space pattern. Cost control and calculation of ROI are the most critical points for such projects. Some real estate capital companies have already conducted investment calculations specifically for the renovation of non-performing assets.

3) Promoting social benefits

Renovating urban existing buildings can not only facilitate economic development, but also promote many social benefits through increasing public services, infrastructure, public spaces, landscapes, and so on. In public renovation projects, this can be the primary motivation for renovation projects. For example, commonly found in public buildings, the overall enhancement of building functions based on changes in usage needs, such as the upgrading of school buildings, elderly facilities, or the reuse of old public facilities in cities, such as train stations, city halls, and other renovation projects, and also includes projects to save and conserve historic buildings and preserve the city's architectural heritage. Projects based on this motive are partly invested by the government, but also in the form of cooperation between the government and private companies.

In 2021, many cities in China announced urban renewal regulations or action plans, such as *Beijing Urban Renewal Action Plan (2021-2025)*, *Urban Renewal Regulations of Shenzhen Special Economic Zone* and *Urban Renewal Regulations of Shanghai.* All of them clearly point out that "urban renewal should promote social public interest", which includes several aspects: construction of urban public facilities, improvement of urban living environment, environmental protection and green development, historical and cultural preservation, and enhancement of urban development momentum (上海市人民代表大会常务委员会, 2021 ;北京市人民政府办公厅, 2021 ;深圳市人民代表大会常

务委员会, 2021). Social benefits should be one of the most significant motivations and goals in urban renewal.

The governments play an important role in promoting social benefits in renovation projects, especially function transformation and enhancement projects. They can announce encouraging policies such as subsidies, tax reliefs and incentives to stimulate certain kinds of function transformation projects or to reward the public benefits in the project. Section 4.3 will introduce detailed information and cases regarding this kind of projects.

4) Driven by mega-events

Apart from motivations mentioned above, there is another special kind of renovation project that is driven by mega-events. Mega-events, including global or national events such as Olympic Games, World Expositions, and so on, are huge stimulations for urban renewal and regeneration, not only promoting social and economic benefits, but also facilitating construction and diffusion of urban images (Broudehoux, 2017). The Olympic committee promote maximum use of existing facilities, as well as temporary and demountable venues instead of new construction venues (Committee, 2014). Table 2.1 below shows that more and more renovated venues used in Winter Olympic Games and the number of renovated venues exceeds that of new construction venues.

Table 2.1 Overview of the recent Winter Olympic Games renovation and expansion of competition and training venues, translated from(郑方, 2019)

	2006 Turin	2010 Vancouver	2014 Sochi	2018 PyeongChang	2022 Beijing
Total number of training and competition venues	15	15	12	12	16
New construction	7	6	11	9	7
Renovation	8	9	1	3	9

However, this kind of renovation driven by mega-events also have some problems such as the after-event operation. Mega-events happen at a certain time and only last for a period, which means the renovated building only serves the mega-events for some time, and would be vacant in the rest of the time. For mega-events like Olympics and international expos, post-use is an important element to be considered; For events occurring at intervals like biennale, film festivals, book festivals, it is necessary to consider the flexibility of use adjusting to both in-event and out-event time. These phenomenon asks for more considerations of post-use strategies in the pre-design phase by means of architectural programming, in order to prevent wasting sources and regenerating the urban area in the long run.

2.1.2 Contents of functional renovation of existing buildings

2.1.2.1 Function transformation

Function transformation refers to inserting new functions in the existing building space that are different from the original use, without demolishing the main body of the building. Function transformation can fundamentally solve the problems of obsolescence and regenerate the building. Identifying accurate and appropriate function for the existing building is one of the most important factors in the success of the renovation project.

The most common project type is the abandoned factory transformed into new industries or museums, cultural and creative parks, etc. This kind of projects can promote industry transformation and upgrading, improve the structure of urban functions, supplement public service and increase public spaces (Beijing Municipal Commission of Planning and Natural Resources, 2021b). There are also civil building types such as commercial, residential and public buildings to be transformed to other types due to bad performance. For example, on June 3, 2016, the General Office of the State Council (2016) issued *Several Opinions on Accelerating the Cultivation and Development of the Housing Rental Market*, in which Article 12 clearly proposes to allow the transformation of commercial buildings into rental housing and the change of land nature from commercial land to residential land, in order to realize the de-stocking of non-performing assets in commercial buildings and solve the residential challenges at the same time.

Several challenges make function transformation projects become one of the most complex renovation types. First, it involves the change of land use nature and the building nature of existing buildings, which may take a long time for negotiation and verification before approval of the project initiation. Second, it demands feasibility and compatibility between new functions and existing building spaces, which requires diligent consideration of functional performance, technical feasibility, and economical efficiency. The required function program, modification of the structure and elements, and compatibility between building codes of different building types are all challenges in function transformation projects.

2.1.2.2 Function enhancement and spatial pattern adjustment

Function enhancement refers to remaining the main function of the existing building and improving the functional program so that the building can satisfy new use requirements with better functional performance.

This type of renovation focuses on improving the building functional performance including supplementing new functions, deleting outdated functions, reorganizing spaces, redistributing floor area of each function, and so on. A rational and scientific function program plays a significant role to achieve better functional performances, which should be based on complete investigation of current using problems and future using requirements. Along with changing the function program, the spatial pattern of the existing building is necessarily modified and adjusted, accompanied with structural change, calculation of plan efficiency, reorganization of the flows, insertion of new equipment, environmental performance improvement, etc. Because this type of renovation usually does not change building volume ratio or shape, the adjustment of the main structure of the building is relatively small. But it always comes with removal or construction of new partition walls, removal or addition of stairs and other traffic spaces, addition of inter-building corridors, partial demolition or addition, etc.

For example, Rijnstraat 8 in Netherlands is a public building built in 1992 and was completed renovation in 2017 designed by OMA (Figure 2.1). The function of this building remains institutional office, but the previous functions and spaces lacked flexibility and openness for today's working pattern (OMA, 2020). The new function program is adapted to the working pattern of new departments and governmental organizations, adding new functions of restaurant, retail, and city lobby on the ground floor open to the public (Figure 2.2). As for the spatial pattern, the renovation strategy is to create open plan for working, with a new walkaway going through the entire building, squares, and interior landscapes.

The first challenge for function enhancement project is to comprehensively uncover the current using problems, and to facilitate users to explore feasible requirements and future using patterns, which requires a scientific approach for collecting information and analyzing requirements. The second challenge is to improve the technical performance to meet the current building codes, even though it doesn't have to change the land use and building type.

Figure 2.1 Renovation of Rijnstraat 8 (photo by Delfino Sisto Legnani and Marco Cappelletti)

Figure 2.2 Diagram of function program of Rijnstraat 8 (image by OMA)

2.1.2.3 Renewal of the building-urban interface

Renovation projects are always accompanied with the goal of regenerating the surrounding environment. No matter function transformation or enhancement renovation projects, the working contents necessarily involve updating of site plan and the interface between the building and its surrounding urban space. The renewal of the interface of the building and urban spaces is for several reasons. First, for function transformation projects, different building types have different requirements for site design standards and building entrances, which change the connection of building and urban spaces. Second, no matter for function transformation or enhancement project, renovation changes spatial patterns and organizations, which result in reorganization of flows on site.

Working contents of re-designing the building-urban interface include:

• Change the main entrance of the building

• Reorganize flows of vehicles and pedestrians on the ground floor on site

• Insert public squares or pedestrian footbridges on the ground floor or first floor to connect with surrounding environment

• Renovate outdoor spaces

• Identify the parking needs, relocate or expand the parking area

• Renovate the facades or corridors facing to urban spaces

For example, in the latest renovation of Longfu Building project, the streets in urban spaces are introduced to the ground floor of the building (Figure 2.3). Elevators connect the urban spaces with the second floor of commercial spaces and the third floor of the office lobby, to regenerate the inner spaces as much as possible (周凯 and 柴培根, 2020).

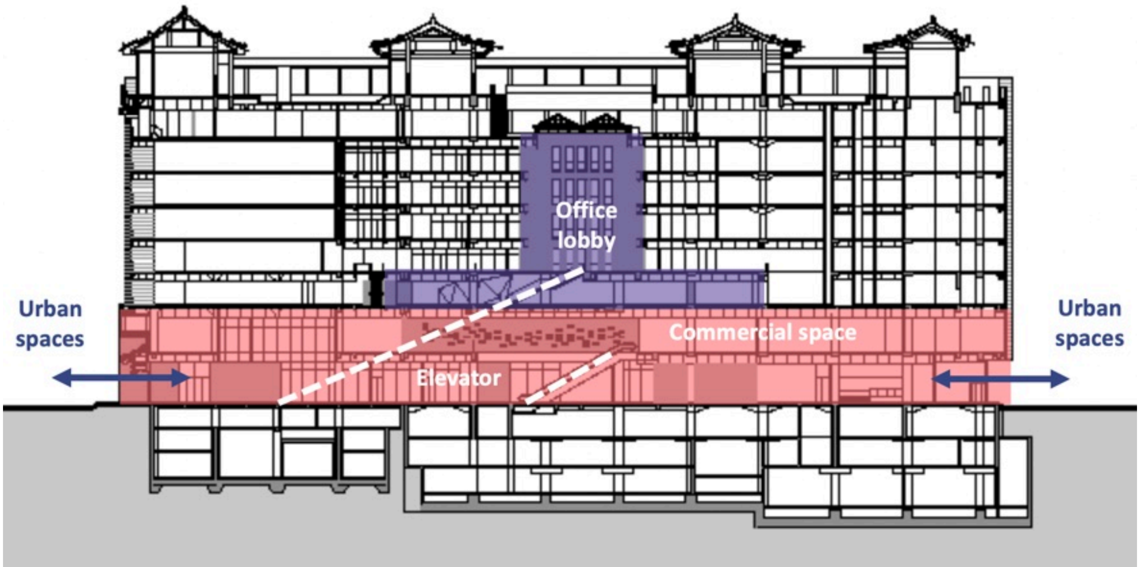


Figure 2.3 Renewal of building-urban interface in Longfu Building

The first challenge of renewal of the building-urban interface is to collect comprehensive information about the urban environment. Another challenge is to obtain the approval of the modification on the master plan of the project, which involves adjustment of detailed urban plan. Besides, composition and distribution of the function program in renovation projects is closely related to the connection with urban spaces, which should be considered simultaneously in the pre-design phase.

2.1.2.4 Other renovation contents accompanying function transformation and enhancement

Apart from the main contents regarding functional renovation, there are other important tasks that are necessary during the working process, to improve the building performance and ensure the renovation feasibility.

• *Facade renovation*: the common renovation content includes adding a new facade, removing the original facade and replacing it with a new one. This task not only increases the aesthetic value of the building, but also improves the functional and environmental performance for envelop safety, sunshade, ventilation, acoustic insulation, and so on.

• *Equipment restoration*: due to aging facilities, or the pursuit of carbon neutrality, energy saving and emission reduction, etc., it is important to implement new equipment to the building under the condition of existing spaces and building codes.

• *Structural reinforcement*: when the building has security risks, or does not meet the seismic requirement, there is the need for structural reinforcement, replacement of materials and other technical transformation; besides, in function transformation projects, the structural standards for different building types may also require reinforcement of the structure;

• *Building codes*: the building does not satisfy the current building codes, in which the fire protection code is the most important and common for renovation. Function transformation or reuse of a building would result in demands for meeting the codes of a different type of building.

All of these working contents require comprehensive uncover of problems in the pre-design phase, and integrative consideration of multiple goals and criteria to make optimal decisions.

2.2 Decision-making mechanisms in functional renovation projects

Multiple stakeholders in renovation projects are mainly composed of municipalities, enterprise, architects, users, citizens, etc. Considering the decision power and cooperation modes in current practical cases, the following research classifies functional renovation projects into three categories led by different stakeholders, which are government-led, enterprise-led, expert-led renovation projects. The analysis of decision-making mechanisms in each kind of project consists of three aspects as goals, investments, and stakeholder participation and cooperation.

Different stakeholders represent various benefits and thus they have different goals in one project. Investing patterns in urban renewal is another significant research field, which will not be studied in detail in this thesis. However, the investing pattern involves property right in renovation projects, and has close relations with stakeholders and decision-makers participating in renovation projects, and has large influence on the goals and decision-making mechanisms. The organization of decision-makers, and the participation and cooperation among all stakeholders are the core part of decision-making mechanisms. Therefore, these are the three aspects in the analysis of decision-making mechanisms in the three types of renovation projects.

2.2.1 Government-led renovation projects

The meaning of "government" here includes the government and its subordinate institutions, such as state-owned financing platform companies. Among all kinds of projects, governments take the lead in the project and have maximum decision-making power. This mode is the most common transformation mode in China at present, with several different situations.

- Goals

The government takes the responsibility of protecting the public interest, hence the goals of government-led renovation projects always include public benefits and the mitigate of urban problems. The following Table 2.2 summarizes the multi-value-oriented goals for urban renewal of typical cities in China. The general goals provided by the government focus on the urban development, improvement of infrastructure, public spaces and living quality, and preservation of history, culture and urban features.

Table 2.2 Goals of urban renewal projects in regulations

	Economic	Social	Environmental	Cultural
Urban Renewal Regulations of Shenzhen Special Economic Zone (深圳市人民代表大会常务委员会, 2021)	• Optimize the urban overall layout; • Enhance the development momentum of the city	• Strengthen the construction of public facilities; • Enhance the functional quality of the city	• Expand activity spaces; • Improve the urban living environment; • Promote energy-saving retrofit; • Realize urban sustainable development	• Pay attention to historical and cultural protection; • Maintain the urban iconic features
Urban Renewal Regulations of Shanghai (上海市人民代表大会常务委员会, 2021)	• Optimize the regional function layout; • Shape a new urban space pattern	• Strengthen the construction of infrastructure and public facilities; • Improve the service level of mega cities	• Enhance the overall living quality; • Improve the urban living environment	• Strengthen the protection of history and culture; • Shape the urban iconic features
Beijing Urban Renewal Action	• Further improve the	• Accelerate the solution of	• Effectively improve the	• Expand the effective

	Economic	Social	Environmental	Cultural
Plan (2021-2025)(北京市人民政府办公厅, 2021)	spatial structure and urban functional layout; • Promote the upgrading of industrial structure and consumption upgrading	incomplete public service facilities, inadequate public space and poor fire safety infrastructure	human living environment and safety conditions	supply of culture

There are several types of government-led renovation projects. First, state-owned enterprises originally hold old factories, plants or office buildings, which are abandoned or idle due to industrial transformation or factory relocation, and need to increase the asset value through transformation; second, local governments acquire factories and parks in the process of urban development to promote industrial transformation, and carry out transformation to preserve urban memory, stimulate the vitality of urban areas, and even promote urban industrial transformation; the third is the urban renewal of historical neighborhoods, where the government has planned to organize housing vacations, acquisitions and renewals; the fourth type is properties owned by government subordinate agencies, such as water conservancy bureau pumping stations and other facilities, which need to be renovated.

- Investments

There are two most-common investment modes in Government-led renovation projects. The first is government investment. Government investment refers to "the use of budgeted funds for fixed asset investment and construction activities in China, including new construction, expansion, renovation, and technological transformation," mainly for non-operating projects for which the market cannot allocate resources effectively (中华人民共和国国务院, 2019). Local governments generally participate in projects by direct investment, but also by injecting capital, declaring investment estimates according to the specific circumstances of the project, and after approval by the competent investment authorities, the project starts for implementation. This model existed in the past before the rapid development of urbanization and was a method to complete large construction projects and solve outstanding problems in a short period of time, which was later gradually replaced by the second mode - state-owned financing platform investment.

The second investment mode, which is more common in China nowadays, is invested and managed by state-owned financing platform companies (国有融资平台公司). State-owned financing platform companies are economic entities established by local governments and their departments and agencies through financial allocations or injection of assets such as land and equity to undertake the financing function of government investment projects and have independent legal personality (Guo Fa [2010] No. 19). State-owned financing platform companies are the products of rapid urban construction since China's reform and opening up, and have played a positive role in promoting infrastructure construction and local economic development for a certain period of time. However, in the face of urban renewal projects in the stock era, state-owned financing platform companies need to strengthen the management and control of debt risk and assume social responsibility.

Figure 2.4 Pingyao Film Palace reuse projects invested by People’s government of Pingyao County (photo by Su Shengliang)

Figure 2.5 Shougang industrial park reuse project invested by Beijing Shougang Construction Group Co., LTD. (photo by Wang Dong)

- Decision-makers

In the government-led renovation projects, the local government plays roles of project initiator, manager, investor, most of time the owner of the property, and a major part of decision-makers. The advantages of government investment are the strong-control over the project, considering more on public benefits and promote the urban development. Besides, in some undeveloped towns and counties, this model can cope with financing difficulties of attracting investment. However, the concentration of decision-making power also has some disadvantages. Researchers also point out that governments sometimes are unilateral decision-makers to represent the public benefits, which results in the absolute control over urban redevelopment and renewal decisions without enough supervision and correction (谢国权, 2008). In recent years, the government tends to improve the administration system and cooperate more with private investment, attracting multiple stakeholders to actively participate in the urban renewal while ensuring the public interests (苏聪 et al., 2022). The government-led renovation projects promote multi-stakeholder participation and a more transparent decision-making process with professionals and experts instead of unilateral decision-makers.

- Stakeholder participation and cooperation

Urban renewal projects directly invested by the government are usually public utilities with major public welfare nature or event-driven renovation projects. Therefore, this kind of project usually involves various kinds of stakeholders including original property owners with separated ownership, the operators, the public, etc. And it requires participation of experts and consultants since this kind of renovation projects generally have important historical and cultural values, such as the protection and renewal of historical and cultural neighborhoods, the reuse of historical buildings, and the renovation of industrial buildings that carry important urban memories. The experts and professionals are effective negotiators and decision-making facilitators among all the stakeholders. The system of responsible planners in Beijing is a good example in urban renewal activities. The responsible planners are independent third-party personnel selected and hired by the district government to provide professional guidance and technical services for the planning, construction and management of a district or a community. The main responsibilities of the responsible planner include participation in the review of initiation, planning, design, and implementation, provision of independent written comments, while they are generally not responsible for the planning, design and construction project design tasks within the scope of responsibility (北京市规划和自然资源委员会, 2019).

2.2.2 Enterprise-led renovation projects

- Goals

As for enterprise-led renovation projects, there are two most-common types as renovation of self-sustained properties and asset investment for transaction. In the first situation, the enterprise has the ownership of the existing building and intends to enhance the building performance, increase the rent revenue or reuse the idle property. In the second situation, professional asset management companies or real estate companies select and acquired non-performing assets to be renovated for higher values and then transact the renovated assets on the market to obtain equity returns. Both of the two kinds of projects mainly focus on the project return based on improvement of the existing buildings, as well as regeneration of surrounding areas. The return not only includes economic revenue, but also policy support, images of enterprises, etc. in some cases.

- Investments

The investment for self-sustained building assets relies on the cash flow and loans of the enterprise itself. While the investors of the second type enterprise-led renovation projects with the aim of investment and return, are real estate investment enterprises or asset management companies (AMC). AMCs use real estate funds to finance for the renovation investment. Multiple established private investors will appraise the property, acquire it, renovate and upgrade it and then lease or sell it in the market to gain revenue through property value enhancement. This model tends to take economic benefits as the main renovation goal, with investment amount, budget and ROI target as the prior conditions, and the design mission statement based on construction cost, quality level and economic attributes of each function to invert the allocable area of each function. For example, BlackRock Investment and Hanes Real Estate Company in the United States, which own several renovation and upgrading properties, invite architects to carry out renovation design based on the given design task book by organizing competitions and bidding, and sell or rent the properties after renovation to obtain income. Besides, Corporate-sponsored philanthropic funds or certain philanthropic organizations can realize certain social benefits and enhance the enterprise image by investing in renewal projects. This model is mostly seen in public building projects that benefit the public, such as the renewal and upgrading of school facilities.

- Decision-makers and stakeholder cooperation

The enterprises take the lead in enterprise-led projects in most cases, as the role of project initiator, manager, investor, and even operator and users. The most important issues here are the feasibility study, internal return rate (IRR), payback time and other financial indicators. Especially for asset management companies or real estate enterprises, they have professional analysts and experts to manage the whole project cycle. Due to the main goals of this kind of projects, the building types are limited in offices, commercial buildings, or mixed-functional industrial parks. Therefore, the stakeholders participated in enterprise-led renovation projects are relatively unilateral due to the nature of this project. However, in some commonweal projects intended to promote the image of the enterprise, the decision-makers may include experts, or public sectors, even citizens and residents. This kind of projects aims at multiple benefits including public benefits, and is more likely to obtain policy support. Besides, these projects contain more building types with public feature such as schools, museums, etc.

Even in private-enterprise-led renovation project, the government also plays a significant role in balancing the development and social benefits by means of regulations of urban planning and supervision over architectural design and construction. The most common approach is to demand for public functions or outdoor spaces with certain floor area. For example, in the renovation of La Samaritaine department store in Paris (Figure 2.6), the municipality approved the investor and property owner to restored the historic building of 1870, and develop a new five-star hotel facing the Seine River, and a new stunning department store on Rue de Rivoli designed by SANNA. Meanwhile, the government requires a nursery accommodating 80 children, a public housing with 96 units inside the projects, and also a public square with 5000 m^2 (LVMH, 2021). This requirement is intended to provide more public service and increase the public housing proportion in the overall housing stock in Paris, which should rise to 25% by 2025 according to Solidarity and Urban Renewal Act of France issued in 2000 (O'Sullivan, 2021).

Figure 2.6 La Samaritaine department store after enterprise-led renovation with a public square, a nursery and affordable public housing units (www.dezeen.com)

2.2.3 Expert-led renovation projects

The expert-led renovation projects are projects with experts taking the lead, such as urban planners, architects, professors, professionals, artists, etc. They play a role of main decision makers or principal managers to balance all kinds of benefits, with the help of professional knowledge and researches.

- Goals

Expert-led renovation projects are less common and are mostly seen in non-profit pilot projects such as curatorial architecture, experiment architecture and so on. This kind of renovation fully shows the thinking and concepts of experts, especially the thinking of social problems, and can be pilot and inspiring. The advantages of this kind of projects is that experts like planners and architects have more power over decision-making in this kind of projects to conduct detailed research and programming before designing the projects. Besides, it is more likely to explore pilot approaches in urban renewal process, methods, cooperation and so on, with more consideration of requirements and benefits of multiple stakeholders especially the public.

- Investments

The investors of expert-led renovation projects can either be public or private. Public investment can be fiscal expenditure spent on public projects or funds for architecture and art. For example, the 2015 and 2017 Bi-city Biennale of Urbanism\Architecture in Shenzhen and Hongkong (UABB) focus on urban renewal with the theme of "Re-Living the City" and "Cities, Grow in Difference" respectively. The government sponsored the Biennale events with pilot projects led by architects and planners for urban renewal. As for 2017 UABB, Yantian Dameisha urban village in Shenzhen, as one of the sub-exhibition districts, invited five architects to each renovate two buildings. NODE Architectural & Urbanism, as a leading architect in this area, explored the potentials of urban renewal through an approach of literature review, field observation, practical makings and transdisciplinary cooperation in Dameisha village. (Liu, 2018). It chose 10 target buildings for renovation, and renovate a 500-meter street and squares to organize the ten projects (Figure 2.7). The new functions, using pattern, and design strategies were all decided by architects, to explore the potential of the urban village, improve the living quality and regenerate this district.

Figure 2.7 Urban village renovation projects in Dameisha village led by architects (Liu, 2018)

As for private investors, the investment can be private foundations of public benefits or non-profit organizations. This kind of projects give a certain degree of power to the experts and consultants for researches and suggestions. Even though the private foundations make the final decisions, they are likely to adopt most of advice made by experts, and invite the third-party to evaluate the program, in order to ensure a transparent process and a scientific decision.

- Decision-makers and stakeholder participation

In expert-led renovation projects, the experts, either as architects, urban planners, or professors, are main decision makers or principal mangers to balance all kinds of benefits. There are possibly multiple stakeholders participating in the projects. Since this kind of projects is pilot and reflecting, it is most likely to involve the public and various stakeholders, even to explore the successful modes of public participation in terms of working process, cooperation modes, multi-stakeholder decision-making approaches, etc.

The architectural ateliers renovated by architects are a special kind of expert-led renovation projects. Architects here are both investors, decision makers, designers and users. For example, the architects' studio renovation project. For example, Mochen Architects and Engineers rented an old office building in Xicheng District of Beijing and transformed it into a 5-story office space for the firm (Figure 2.8). O-office architects transformed a top-floor space in an abandoned silo building in Guangzhou to be their office space (Figure 2.9). The architects in these projects have greater or even full decision-making power, so they can start programming from functional identification and develop a design brief with full consideration of usage needs, urban conditions, etc. Therefore, this model is characterized by a comprehensive consideration of economic, social, environmental and other multi-dimensional benefits, and the integration of programming, design and construction, which is conducive to preserving the value of existing buildings and achieving the goal of sustainable urban and architectural development.

Figure 2.8 Mochen New Office (photo by Mochen Architects and Engineers)

Figure 2.9 Silo-top studio by O-office Architects (photo by LIKYFOTO)

2.2.4 Trends of participation and cooperation in renovation projects

The Outline of the PRC's 14th Five-Year Plan emphasizes that "it should expand the sources of funds for urban construction, and establish a financing model with matching maturity, multiple channels and financial sustainability" (新华社, 2021). Corporation of government and enterprise. The third basic principle of the *Beijing Urban Renewal Action Plan (2021-2025)* is "guided by governments and operated by markets ", "should fully stimulate market vitality, mobilize the enthusiasm of real estate property owners, market entity and social parties, etc., and introduce social capital in various ways. Renovated spaces are mainly to be owned and operated, to explore multi-channel investment models" (北京市人民政府办公厅, 2021). The investing pattern of absorbing social capital in various ways is a long-term way of urban renewal development.

For some government-held building assets, enterprises can invest in the renovation of existing buildings by replacing the use rights. In this model, the enterprise can plan the use and functional combination of the existing building according to its own needs, while the property right holder, usually the government, may require the flexibility of the building's future renovation and reserved functional space. The enterprise and the government agree on a loan period of use rights, and upon expiration, the enterprise will return the renovated building to the government. This model is suitable for idle assets held by the government that have a certain historical, cultural or social value.

In addition, the government can also adopt some policies to encourage enterprises to invest. For example, the government encourages the conversion of shopping malls into rentable residences by approving the conversion of commercial land into residential land with the same prices for water, electricity and gas as residential land after paying land premiums. The price of water and electricity for commercial land is three times that of residential land, a policy that reduces the operating costs of the converted building and shortens the project's return on investment.

The Eataly project in Turin, Italy, provides us with a special case study. Before the renovation, the original building, the Carpano factory, was bought by a private company, Fernand, and the owner did not know what function the factory should be transformed into, so he invited Negozio Blu & Associates to conduct a study and make a programming proposal (Ambrosini, 2017). The building was then acquired by the government, and a private investor, and operator, Eataly, was brought in through a tender process to renovate and operate the building (黄也桐 et al., 2021). The decision makers ultimately included government-affiliated departments, professional bodies, the private operator, and the architectural heritage regulator. Architects are the only parties involved in the whole process, making crucial suggestions on functional identification, setting renovation goals, renovation programming and later design and construction, and to a certain extent leading the whole process.

Although this model is still essentially a corporate investment, the government can oversee the entire renovation process as the building property rights still belong to the government, preventing the value of the existing building from being damaged by the corporate pursuit of return on investment, and reducing its own gearing. The enterprise can skip the process of land transfer and property rights transfer, and focus on the design and operation of the renovation of existing buildings, thus achieving a win-win situation for both parties.

2.3 Concerns of decision-making in architectural programming of renovation projects

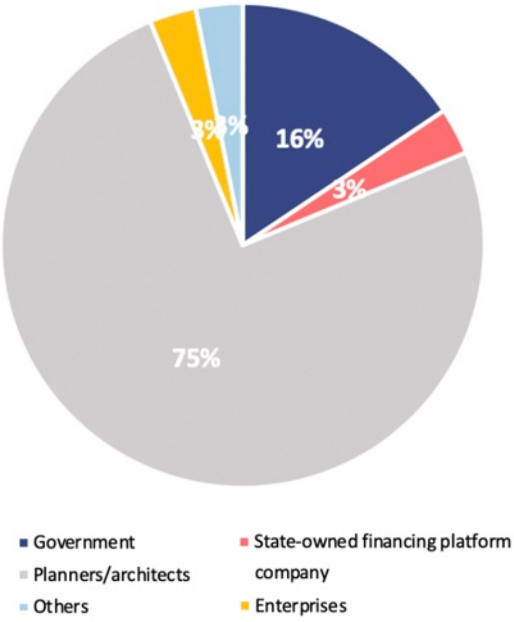
Before identifying the characteristics of functional renovation of existing buildings, and researching on the architectural programming of functional renovation, this section should first identify concerns of participators in architectural programming of renovation projects and problems in practice. To obtain a better understanding of the reality, the author did a preliminary questionnaire and conducted interviews with architects and relative stakeholders to collect information about their concerns

2.3.1 Preliminary questionnaire and interviews

In order to uncover the problem in renovation practice, the author conducted a questionnaire in China interviewed some of stakeholders for the detailed information (Table 2.3). Questionnaires are distributed in the Second Annual Academic Conference of Building Renovation and Urban Renewal, hosted by Architectural Society of China in Hangzhou on December 4, 2020, and in interviews with architects afterwards. We received 35 results in total and the final result analysis is based on 32 effective questionnaires. Among all the interviewees filling in effective questionnaires, more than 60% of them have participated in urban renovation projects. The complete questionnaire is presented in Appendix A. Since the questions focus on the decision-making mechanisms in architectural programming of renovation projects, the major part of participators are architects or planners, taking account of three quarters (Figure 2.10). As for the type of renovation projects, most participated types are the government-led renovation project (Figure 2.11).

Table 2.3 Basic information of the architects interviewed

Category	Sub-category	Count	Ratio
Gender	Female	17	47.06%
	Male	18	52.94%
Age	20-29	11	32.35%
	30-39	15	41.18%
	40-49	1	2.94%
	50-59	5	14.71%
	>60	3	8.82%
Education	Bachelor	9	26.47%
	Master	19	52.94%
	PhD and post doc	7	20.59%
Whether have participated in renovation projects of existing buildings	Participate in the whole process	12	32.35%
	Participate in the project evaluation and preliminary research	8	23.53%
	Not involved, but have some understanding	12	35.29%
	Not involve and have no idea	3	8.82%



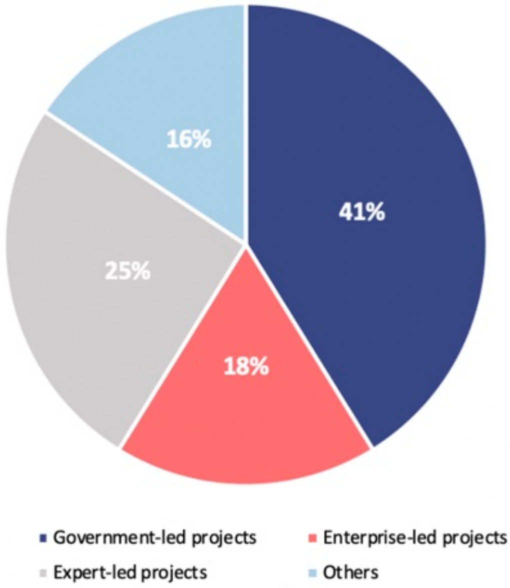


Figure 2.10 Occupations distribution

Figure 2.11 Project type of participation

After obtaining the general picture of renovation projects through a preliminary questionnaire, the writer conducted interviews with architects, investors, managers and such relative stakeholders, in order to further uncover the problems in the practice and get a better understanding of the reality. As seen in the Table 2.4 below, these interviewees are from different types of company including public or private company, design institute and studio. All of them completed at least one renovation projects with whole-process participation, within a broad range of building types such as factories, schools, office buildings and historic buildings.

The interviews are semi-structured focusing on the theme of renovation projects, and especially on the pre-design phase:

1. Please briefly introduce the background of previous renovation projects.

2. How did you participate in the pre-design phase of renovation projects?

3. What problems are the most difficult to cope with when you designed the renovation projects?

4. What are the most significant issues that hinder the renovation projects?

Most of the interviews are conducted as face-to-face, while some are online interviews resulted from the pandemic situation across the research period, several interviews are conducted in emails and the interviewees answered the questions with writing. The author transformed each interview recording into texts and reorganized all the texts from the interviewees, obtaining the outcome of text materials for analysis.

Next two sections are analysis of the concerns of main participators in architectural programming of renovation projects, and are intended to uncover problems in decision-making in architectural programming of renovation projects.

Table 2.4 List of architects interviewed

	Interviewee	Role	Type of company	Type of renovation	Format of interview	Interview date
1	Lai Jun	Architect, investor	Private company	Factory, office building, school, historic building (courtyard)	Face-to-face	2020-11-06
2	Ambrosini Gustavo	Architect, professor	Private design studio, university	Factory, office building, residence	Online meeting	2020-11-12
3	Hu Yue	Architect,	Design institute	Factory, office building, venue, historic building (courtyard)	Face-to-face, questionnaire	2020-11-22
4	Li Mingyang	Planner	Urban planning	Historic building	Face-to-face	2020-11-22
5	Bo Hongtao	Architect	Design institute	Factory, office building	Face-to-face, questionnaire	2020-12-04
6	Simona Della Roca	Architect	Private design studio	School, factory	Online meeting	2021-01-08
7	Liu Heng	Architect	Private design studio, university	Factory, infrastructure	Online meeting	2021-02-04
8	Raffela Valente	Client, project manager	Private foundations	School	Online meeting	2021-07-16
9	Liu Jianing	Architect	Design institute	Factory	Face-to-face, questionnaire	2021-08-11
10	Ren Fei	Architect, project manager	Design institute	Factory	Face-to-face	2021-09-01
11	Zhao Jingxian	Architect	Design institute	School	Face-to-face, questionnaire	2021-09-14
12	Carlo Deregibus	Architect, project manager	Urban planning, university	School	Face-to-face	2021-12-15
13	Caterina Barioglio	Architect, professor	University	School	Online meeting	2022-01-20

2.3.2 Concerns of participation in architectural programming of renovation projects

This section analyzes the concerns of participation in architectural programming of renovation projects based on the results of questionnaire and the record of interviews, from decision power, degree of participation, key factors encouraging successful functional renovation projects and those of inversely limiting projects.

- Decision power on function identification of renovation projects

As for the decision power of different stakeholders on reuse functions, the three types of projects which are government-led, enterprise-led, and expert-led, have different decision-making mechanisms. The result shows that the municipalities play the leading role in both government-led and expert-led renovation projects. Even in the enterprise-led renovation projects, some decision-makers stated their decisions about function would be influence much by the public policies. On the contrary, experts like planners and architects have less power in decision making of renovation projects. But government-led and expert-led projects have much more possibilities of taking opinions of citizens and residents than enterprise-led projects.

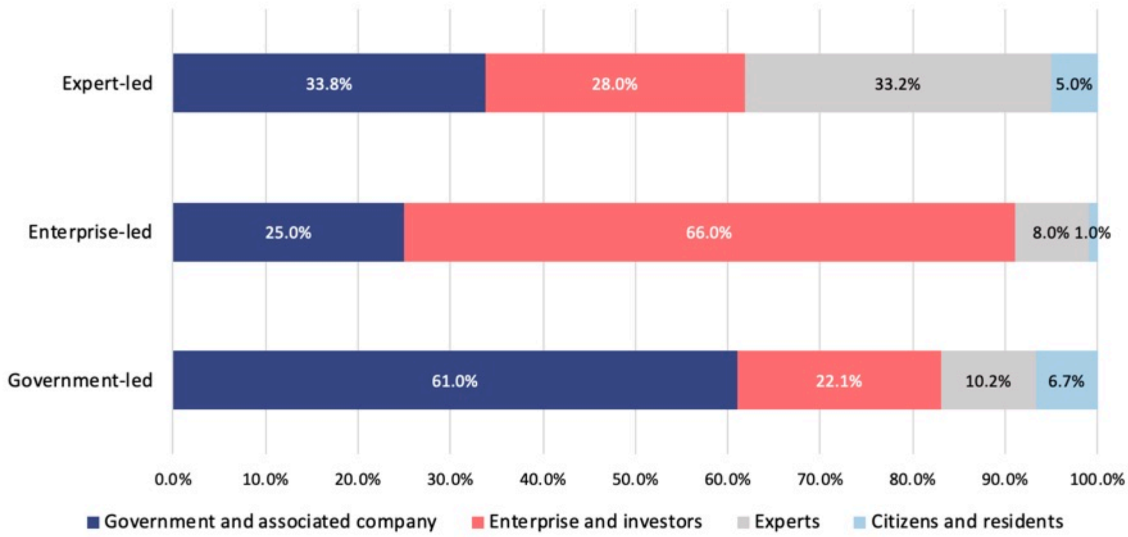


Figure 2.12 Ratio of decision power of different stakeholders in function identification of renovation projects

- Participation in pre-design phase of renovation projects

This question provides 10 main contents in the architectural programming phase of renovation projects and investigates the degree of participation in each one. The score represents the concerns of participation in the opinions of interviewees. The function identification, analysis of urban conditions, and cost control are three most concerns in participation in the pre-design phase. In the interview with architects and experts, the new function of the existing building is recognized as one of the most significant decisions, while it is also the least transparent and subjective decisions made by unitary decision makers, or based on only policy or market analysis excluding the architectural analysis on the potential of the building space.

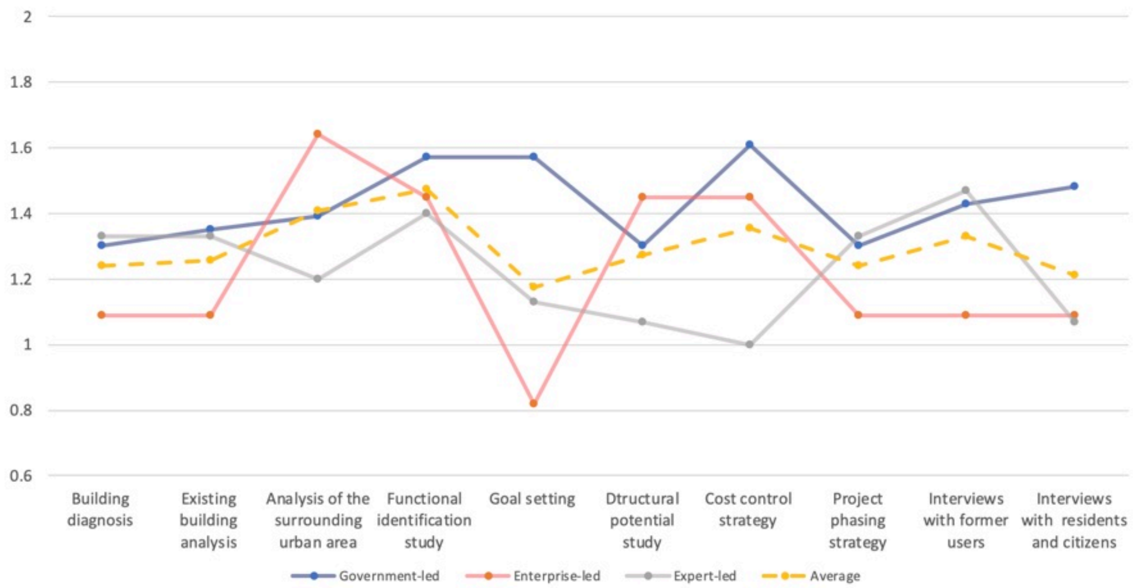


Figure 2.13 Participation in pre-design phase of different types of renovation projects[5]

- Key factors to regenerate existing buildings and urban spaces

The questionnaire lists seven potential factors and one blank option to investigate the key factors of achieving successful projects to regenerate existing buildings and urban spaces. The question uses a five-point Likert scale, with 1-5 indicating not important, slight important, important, fairly important and very important respectively. Table 2.5 shows the score of each factor. The ability to maintain operation in the long run is a most significant factors deciding the success of the renovation projects. Architects always have few impacts on the project after it is delivered, while the client and programmers can

5 This question uses a three-point Likert scale, with 0-2 indicating not ever involved and think it's unnecessary to participate in, not ever involved but want to participate in, and involved, respectively.

discuss the post-occupancy operation in the architectural programming phase to ensure the continuity of the design concepts, using patterns and post occupation. The accurate functional identification, which is suitable for the building's characteristics and urban development strategy, and a good connection between the existing building and urban environment are the other two most influential factors. The two factors decide the nature of the reborn building, and the relationship with the surroundings, which are essential to the outcome of renovation projects.

Table 2.5 Key factors to regenerate existing buildings and urban spaces

Factors	Average score[6]
Full understanding and exploitation of the value of existing buildings	4.03
Accurate functional identification (fitting the building's characteristics and urban development strategy)	4.21
Good integration of the building with the urban environment	4.21
Visually attractive renovation solutions	3.53
Building performance enhancement	3.85
Consideration of phased renovation (e.g. micro-renewal, incremental renewal)	3.76
Ability to sustain operations in the long run	4.24
Others (if not, please click very small)	2

- Key factors to restrain existing building renovation projects

Table 2.6 shows the key factors to restrain existing building renovation projects. The higher the score is, the more importance of this factor contribute to the limitation of existing building renovation projects. As we can see, government decision-making capacity and preferences is the main limited factor, as well as lack of policy support, lack of pre-programming steps and methods and high investment risk. It reflects the lack of transparent decision-making process and unilateral decision-making phenomenon in China especially in the government-led renovation projects.

6 This question uses a five-point Likert scale, with 1-5 indicating not important, slight important, important, fairly important and very important respectively.

Table 2.6 Key factors of limiting renovation of urban existing buildings

Factors	Average score[7]
Lack of policy support	3.68
Inadequate industry standards and norms	3.59
Government decision-making capacity and preferences	3.74
Lack of pre-programming steps and methods	3.62
Single investment model / high investment risk	3.62
Professional level of designers	3.21
Deficiencies in retrofitting construction techniques	3.15
Lack of post-operation	4
Deficiency of design and construction cycle	3.53
Others (If not, please click very small)	2.32
Subtotal	3.44

According to the results, the problems in todays practice in China are uncovered to a certain degree. Government or municipalities has a decisive role, experts have less decision-making power and feel powerless in the process. Besides, appropriate functions and the good operations in the long run are the main factors in the regeneration of existing buildings and urban areas. The decision-making ability and preference of the government is currently an obvious factor limiting the renewal and renovation of existing public buildings. Therefore, the methods for the pre-design phase to assist the decision-making of stakeholders are particularly important.

2.3.3 Problems in decision-making in architectural programming of functional renovation projects

Previous sections analyze the characteristics of renovation programming, and concerns of participators in the decision-making of renovation. This section states problems and challenges of decision-making in architectural programming of renovation

7 This question uses a five-point Likert scale, with 1-5 indicating not important, slight important, important, fairly important and very important respectively.

projects nowadays requiring for solutions. Because this research focus on the functional renovation project, the problems to be solved are related to such kind of projects.

1) Non-transparent decision-making process of function identification

New construction projects are based on the approval of design and construction, with definite design conditions and certain building types. Different building types respectively have function programs, featured spaces and even matched forms, and should comply with building codes of the certain building type except for some general codes such as fire codes and energy-saving standards (游亚鹏 and 胡越, 2022). As for renovation projects with function transformed, the building type may differ to a large degree, resulting in the transfer of land use and building type, requirement of building code of another building type and so on. Therefore, the decision-making process is more complicated and requires more comprehensive investigation and studies. Inappropriate new function for existing buildings will not only damage the original value of the building, but also result in a second failure or abandonment in the long run. This significant decision for renovation projects, advocates for a transparent and multi-stakeholder-participating decision-making process with scientific and rational methods to consider multiple values, balance multi-lateral benefits, and maximize the comprehensive performance.

2) Decisions on event-driven building functions in the short term

The second problem regarding decision-making in architectural programming of functional renovation projects is the instant functions in the short term for the existing building, which are common in event-driven renovation projects. Due to the limited time of construction to be delivered on time for the event, the design focuses on the instant new functions and can hardly consider the post-use. The architectural programming process should continue through the project life cycle and should consider the post-use operation in pre-design phase in advance, especially for event-driven renovation projects which are often left unused again after the event. In China, because of unwell developed system, lots of renovation projects are stimulated by mega events of culture, sport, and convention, such as Olympics, international cultural events, biennales, etc. Nevertheless, many instant decisions on the event-driven renovation don't have comprehensive considerations due to urgent demands on on-time delivery. Some cases in Torino renovated for mega events more than ten years ago now are abandoned again (Figure 2.14). These phenomenon asks for more considerations in the pre-design phase by means of architectural programming.

Figure 2.14 Ex Moi in Torino became abandoned again after the 2006 Turin Winter Olympics (https://mole24.it/)

3) Huge cost to match space and function

In the interview, almost all the architects admit that most technical problems regarding structure and other equipment can be solved with existing technologies when leaving alone the budget and cost. While at the same time, coping with structural problems such as reinforcement is at great dispense, and may take a huge proportion in the construction cost. Architects' experience is pretty beneficial to make balance between design and cost taking all elements into account. It happens in most cases in Italy and some projects committed by private companies in China. While in China nowadays, due to system of public ownership of land and property rights, most renovation projects are public projects committed by the municipalities. Their authoritative opinions occupy the main superiority in the decision-making process, which pay more attention to the requirement than to the of existing spaces and the suitability of space and functions.

4) Undeveloped system of functional renovation projects

The system of administration and supervision is un-well developed in several aspects that influence the decision-making of functional renovation projects. The first is the system of property rights transaction. There are lots of old buildings with complex property rights distribution in China, which hinders achieving consensus of renovation decisions. The second one is adapting building codes. The difficulty for existing buildings to satisfy new building codes is a main obstacle in today's renovation projects. Besides, the charging standards of renovation design fee is identical with that of new construction project. In China, the proportion of design fee to the whole construction cost is around 2%-3% for common construction projects. While in renovation projects, the construction fee can be much lower than that of new construction projects. Consequently, the renovation design fee is much less than the normal, which prevent many companies, especially large design institutes in China from selecting renovation projects except for some large policy-driven or event-driven projects.

Since the research studies functional renovation projects and particularly architectural programming in the pre-design phase, we mainly focus on the relative problems of function transformation. In the following chapters, the research will apply architectural programming theory to address the problems uncovered in the functional renovation projects.

2.3.4 Distinguishing characteristics of renovation project compared with new construction project

The six characteristics embraces: 1) There being the existing building is the fundamental element of the programming, composing particular "site information"; 2) The original users' experience and opinions on the existing building make sense, and their settlement is to be considered in some projects; 3) Economic programming should consider renovation costs and payback time, a key indicator to the feasibility; 4) Technical programming emphasizes the compatibility of the new functions and the existing structure, complying with today's building codes and requirements; 5) Time programming takes the construction stages or over-time renovation into account to cope with related social obstacles and cultural identity. 6) Post-occupancy evaluation could quantify the improvement of renovation, and verify whether the results meet the goals set in program.

1. Existing building | The fundamental element of renovation programming is the existing building. Different from the new construction project that seeks design problems in the site and considers future requirements, the renovation project has one more constraint——the existing building, which contextualizes the brief and design in the following steps. Due to the existing structure, spaces, elements and related historical, social and cultural values, renovation projects must respect and cope with those features with caution, selecting which elements to retain and then implementing new interventions. The existing building is considered as a special “site” in renovation projects, and then architects or programmers should collect information about existing structural, mechanical, and electrical systems, site photos, potential view perspectives and so on (Cherry, 1999). Cherry also articulates that renovation programming demands demonstrating the compatibility of new uses in the existing facility, which is additional to the brief for new construction projects. It should be noted that some new functions could be excluded for the exiting building. Taking a historical building used as dormitory before as an example, it is hardly transformed into a lecture theatre or a lecture hall, not only because such new uses would damage the existing structure, but also because of extraordinary high cost (Pyburn, 2017). However, the challenge of dealing with the new use and the old parts could also be the catalyst of innovation. Therefore, it is significant to conduct comprehensive diagnosis for the existing building and discuss all the potential renovation feasibilities in the pre-design phase. The main design problems about the existing building include: 1) Which existing elements are worth retaining, and which are supposed to be demolished or restored? 2) What are the new uses that are compatible with the existing structure? 3) How could the new uses enhance the values of the existing building and regenerate its surrounding environments? These research questions will be discussed in the ensuing chapters.

2. Existing users | The second distinguishing feature of the existing building is that it has original users or occupants. Whether those people would continue to occupy the renovated building or not, it is necessary to investigate their using experience and satisfaction that are clues for programming. Traditional methods for the investigation include questionnaire, interviews, SD method, map of behavior, etc. According to users’ feedback, architects could Figure out accurate problems of the existing building and then seek solutions precisely, such as discomfort of interior spaces, inconsequence of zonings and flows, lack of delights in spaces and so on (龚敏 and 朱益飞, 2015). Comments collecting methods in post-occupancy evaluation (POE) could also be used in the diagnosis of existing buildings, such as online comments with NVIVO qualitative analysis software (高蕾, 2019)and online reviews with SD method (王昭雨 and 庄惟敏, 2019). In terms of renovation projects that original occupants would continue to use, like office and hospital refurbishment, programmers should consider mitigating impacts on users in the construction phase, even the placement of those people during the whole renovation process. For instance, during the whole construction of Hanwha headquarter building's revamp in Seoul, designed by UN Studio, employees kept on working in the existing building. The strategy is to refurbish 3 floors as a group each time from bottom to top, revamping interior spaces and façade simultaneously.

Figure 2.15 Hanhua Headquarter in renovation construction https://skyrisecities.com/forum

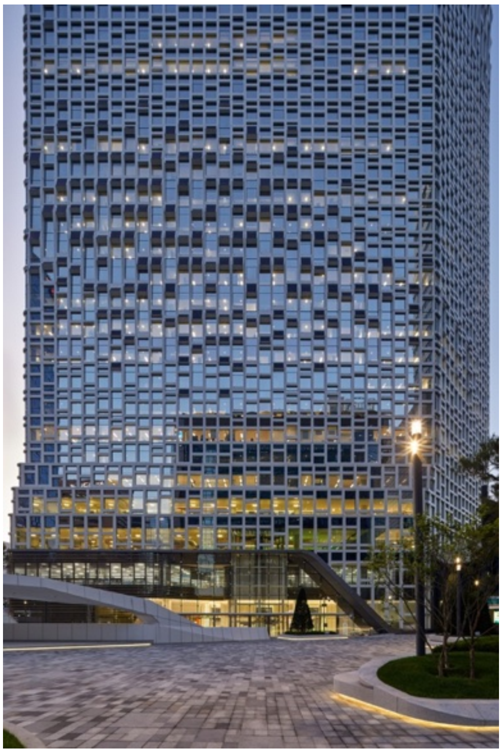


Figure 2.16 Hanhua Headquarter after renovation ©UN studio

3. Technical Programming | Peña(2012) lists many technical challenges in renovation projects, such as bringing the existing building up to the new codes of structure and fire protection, enhancement of plan efficiency to meet the demand of new uses, site secondary development for expanding parking lots and other facilities, etc. These difficult problems make renovation projects more complex than new construction projects. Furthermore, technical programming is closely related to economic programming. Inadequate attention to technical difficulties in pre-design phase would result in higher cost than that of new construction projects and over time. It is thus really significant to take full account of new uses, existing structure and other features in realistic practice to avoid lack of rationality. Classified by renovating elements, technical programming includes structure strengthening or demolishing, expansion, bridging, façades and interior refurbishment, etc. In terms of purposes, it could be classified as: 1) replace aging elements for extending the service life of structure; 2) bring the building up to the new codes, such us earthquake resistant retrofitting and fire system renovation; 3) place green technology facilities for sustainable retrofit. Because of the existing building, technical programming for renovation projects should pay more attention to the compatibility of the new and the old parts in terms of structure, function, space and materials. In addition, renovation construction has higher standard than new construction, especially for historic buildings, to protect important elements from secondary damage. Expansion projects should also consider how to connect different parts appropriately, preserving the original facades at the intersection.

For example, the original façade of the BK-CITY building at the Delft University of Technology's School of Architecture in the Netherlands was characterized by an open lion's head (Figure 2.17). The renovation of the building restored the façade and incorporated a series of energy-saving measures. In particular, the new interior ventilation ducts were combined with the lion's head on the façade, transforming it from a decorative detail into an indispensable structure in terms of performance, and continuing the life of the building in its details. Also in the Silo Erlenmatt renovation project in Basel, Switzerland, the existing building has a funnel device for storing grain and cocoa beans, the architect retains these structures and installs ring-shaped strip lights on them to make them auxiliary lighting functions, while the light strip illuminates the funnel device and highlights the industrial mark and architectural characteristics of the existing building (Figure 2.18).

Figure 2.17 Facades of BK CITY © TU Deft

Figure 2.18 Silo Erlenmatt renovation project © Christian Kahl

4. Economic programming | Economic programming embodies two aspects. First, the existing building itself is of considerable economic value; Second, renovation could enhance its future value. Taking these two aspects into consideration helps to compare the renovation with the reconstruction, and to select or optimize renovation strategies. The historical, social and cultural value of existing buildings could be transformed into economic value for assessment by the means of several appraisal approaches(Xu, 2015). Martinaitis(2007) applies a two-factor method for appraising building renovation and energy efficiency improvement, helping clients to make decisions. Apart from construction cost, operation cost, asset valuation and increment tax on land value that are common in appraisal of new construction projects, renovation projects should also calculate ROI (return on investment), amount of loss and indirect costs due to renovation process. Payback time is considered as a critical factor in feasibility studies of renovation projects, which is a simplified factor regarding initial investment, saved operation cost after renovation and the time value of the funds (Jensen et al., 2017).

Although financial feasibility is a significant factor in renovation project, it still requires the balance between the development revenue and social benefits. The function program in renovation projects should consider comprehensively the development density, spaces open to the public, function of public service that meets the deficiency of the area, and so on, in order to mitigate social problems and promote sustainable development in urban renewal activities.

5. Time programming | Time is one of the four basic elements in Peña's programming theory. Under the circumstance of limited budget, long-term financing or growing functional needs, projects require phased construction according to a time-and cost schedule (Peña, 2012 [65-57]). In terms of renovation projects, they may have another constraint of the existing structure, thereby sometimes programming should propose several plans of phasing to cope with various conditions of budget, and technologies. Different degrees of renovation embody deep renovation, over-time renovation and micro-renovation. Deep renovation aims mainly at improving energy performance through entire and comprehensive measures, and are encouraged by European energy policies like EU's Horizon 2020 program. Over-time renovation rises in housing nowadays, especially in European countries such as Sweden. This kind of partial renovation is beneficial to coping with social issues, respecting for cultural identity and limiting resource usage. It also allows later insertion of new technologies and thus achieve higher energy efficiency in the long run (Femenías et al., 2018). In addition, some renovation briefs are supposed to prepare for the growing functions or site expansion in the future.

6. Post-occupancy evaluation | Post-occupancy evaluation (POE) for renovation projects is to evaluate the improvement and to give feedbacks to the strategy, in order to better program and implement for future projects. The index of assessment includes performance, user satisfaction, economy, social benefit and many other aspects. Different from POE for new construction projects, POE for renovation needs to compare the result with the initial building data, quantifying the degree of performance improvement in terms of each criterion. Jiang used ASTM system to evaluate the reuse of modern building heritage from the perspective of supply and demand matching (Jiang, 2017). Other researches conduct the assessment from different dimensions. As for the environment, international certification systems such as BREEAM, LEED, CASBEE and DGNB have improved their score systems intended for renovation projects. As for the economy, methods apply many kinds of criteria such as payback time, net present value (NPV), internal rate of return (IRR), etc. (Martinaitis et al., 2007). As for the society, Liu established POE system consisted of social impact, built environment and project dynamic for creative industrial parks of industrial heritage in China (Liu et al., 2019). Other methods include AHP, fuzzy appraisal, Delphi method, etc. (李慧民 et al., 2014 ; 芮光晔 and 李睿, 2015).

2.4 Conclusion

Because this research is developed from classic architectural programming theory for universal construction projects, it is necessary to first identify the features of renovation projects, especially those distinguished from new construction projects, in order to improve and enhance the general framework and process afterwards.

The conclusions in this chapter are as below:

1) **Identify the features of functional renovation projects regarding architectural programming**. This chapter analyzes the features of functional renovation of existing buildings from four perspectives, which are motivations, working contents, stakeholder participation and decision-making mechanisms. Based on analysis of main motivations including transforming industries, increasing economic value, promoting social benefits and mega-events and the working contents including function transformation, functional enhancement, spatial pattern adjustment, renewal of the building-urban interface, etc. For the decision-making mechanisms, it classifies three types of projects based on stakeholders and participation, which are government-led, enterprise-led, and expert-led project, and then analyzes goals, investments, decision-makers and stakeholder cooperation for each type. It is shown that motivations, contents and decision-making mechanisms have close relations to each other and a transparent and rational pre-design phase of renovation projects with multi-stakeholders has huge impacts on the success of the projects.

2) **Identify the concerns and problems of decision-making and participation in renovation projects.** This chapter uses a preliminary questionnaire, interviews, and case study to investigate the concerns and problems in decision-making and participation in renovation projects. Concerns include lack of expert knowledge and decision support on function identification of renovation projects, limited participation of architects and experts in pre-design phase of renovation projects. Scientific identification of function programs is seen as one of the most significant factors to regenerate the building and urban spaces, while preference of the government and non-transparent and irrational decision-making process in the pre-design phase are two of the most restrictions. Problems in pre-design phase of renovation projects includes non-transparent decision-making process of function identification, decisions on event-driven building functions in the short term, huge cost to match space and function, and undeveloped system of functional renovation projects**.** At last, it concludes the six main features compared with

new construction projects from six aspects, which are existing building, existing users, technical programming, economic programming, time programming and post-occupancy evaluation.

The characteristics of architectural programming in existing building renovation helps to cognize the renovation projects and would lay a significant foundation for establishing the framework of architectural programming in existing building renovation in the next chapter.

CHAPTER 3 Framework of architectural programming process in existing building renovation

This chapter intends to engage architectural programming with renovation projects and establish a holistic framework of architectural programming procedure for renovation, based on both theoretical and practical researches. The methodology includes literature review, case study, archive analysis and comparison research between cases in Italy and China. It first summarizes the core idea in traditional architectural programming theories regarding working procedure as well as their limitations in renovation projects, then reviews existing researches regarding the procedure and pre-design phase of renovation projects. For the practical perspective, it conducts a comparison research on four projects in Italy and China, in order to obtain critical experience from projects in reality. Last, it presents an updated renovation programming procedure and indicates the supplement to the traditional framework.

This chapter will answer the following questions:

1) What are the shortcomings of existing process and framework of architectural programming when coping with renovation projects?

2) What are the problems and experience in the pre-design phase of practical renovation projects in both Italy and China?

3) How many steps should be supplemented to the general process of architectural programming for renovation projects, and what is the architectural programming framework for renovation of existing buildings?

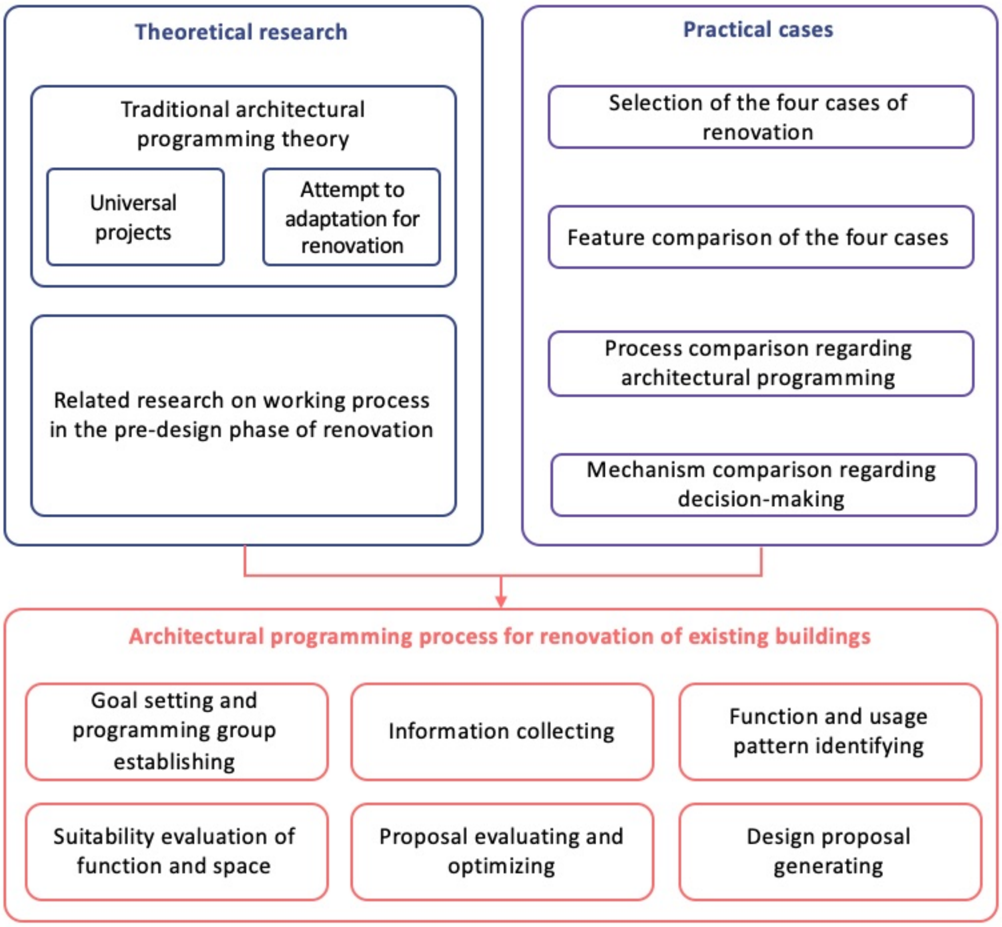


Figure 3.1 Framework of Chapter 3

3.1 Traditional theories of architectural programming and its adaptation to renovation projects

The architectural programming theory is established on a basis that it should be applied to a kind of universal circumstances, that means it could be commonly implemented in construction projects regardless of the building function and typology (Peña, 2012 ;庄惟敏, 2016); the processes proposed by previous researchers have many similarities and share a common logic from a comprehensive perspective, which have been verified through quantities of projects in reality. Nevertheless, these universal processes could not neglect the distinguishing characteristics of renovation projects out of common construction projects. Many researchers have pointed out some modifications to the process, while do not propose a wholistic procedure or guidelines. This section will review those researches from a traditional theoretical perspective.

3.1.1 Architectural programming process for universal projects

The process of architectural programming in essence is from cognition, analysis to solution and evaluation. Although the terms used in previous programming processes are different, the logic in the whole procedure is similar regarding the activity and order. Table 3.1 compares typical process and frameworks of different architectural programming. It is seen in the table that the similarity of these frameworks lies in the basic process, the order and organization between phases, which can be concluded as four main phases: **cognition, analysis, solution and evaluation**.

The first phase is cognition, which is to collect information about current situations and existing conditions to make a general cognition of the projects. The information here is also called data, facts, conditions in researches. Peña (2012)[18] classifies all the information, issues and problems into four categories as function, form, economy and time. Duerk (1993)[56] proposes issue-based programming methods to separate issues into sub-issues of different level, and then identify goals and corresponding requirements and concepts oriented by different values. 庄惟敏 (2016)[21-22] investigates the construction premise through external and internal conditions. Duerk

Before collecting the information, some researchers indicate another step of establishing goals for the projects (Peña, 2012 [14];庄惟敏, 2016 [20]) and even have a general understanding of the project context before setting goals(Cherry, 1999 [99]) .

The next phase is analysis, which is to transform the collected information, identify preliminary design problems and conceive the programming concepts. This phase is in which various kinds of theories and frameworks differ, since they have distinguishing structures to analyze conditions and problems. The analysis process in Cherry (1999) ‘s framework consists of two contents as defining programming-level strategies and specifying quantitative requirements. Peña (2012)[150-152] still uses four quadrants to uncover the programming concepts and determine the needs. Hershberger (1999) suggests to classify all the information in 8 values and generate concepts of primary values. 庄惟敏 (2016)[26] indicates to conceive programming strategies from spatial, economic and technical perspectives (Figure 3.2).

The third phase is solution, which is to state the problem and generate the design program or briefs. The two most important issues in this phase are to clarify the requirements and to state design problems to guide design afterwards(Peña, 2012). Cherry (1999) also suggests to summarize design issues, save documentation, and synthesize the programming task in generation of the design briefs.

For the last step, some of the architectural programming framework end in the third phase to generate final reports. But researches have been more likely to emphasize the evaluation and optimization before providing the final report. Therefore, the last phase is the evaluation, which is to assess the risks of program and optimize it for the final report. Hershberger (1999 [435]) positions the evaluation work into the end of programming, each phase of design, after-construction, before-delivery, and post-occupancy. process of architectural programming: preparation, gathering information, work sessions, preparing program and evaluating program. Zhuang(2016) proposes two important evaluation work as pre-evaluation or program evaluation, and post-occupancy evaluation (POE) into the whole framework of architectural programming theory.

Table 3.1 Comparison of different architectural programming processes

Theories	Cognition	Analysis	Solution	Evaluation
William Peña (1969)	Establish goals Collect and analyze facts	Uncover and test concepts;	Determine needs; State the problem	
Henry Sanoff (1977)	Retrieve information	Transform design information	Generate program	
Donna Duerk (1993)	Gather information	Assess needs Study feasibility Design research	Structure a program document	Evaluate program
Kumlin (1995)	Gather information data	Program workshop	Draft program Prepare final program document	Program cost evaluation
Robert Hershberger (1999)	Preparation Gather information	Work sessions	Prepare program	Evaluate program
Edith Cherry (1999)	Researching the project context Define goals Gathering and analyzing information	Define programming-level strategies Specify quantitative requirements	Summarize design issues Document documentation Synthesis of programming tasks	
Theo van der Voordt (2005)	Collect precedents	Function analysis	Define program of requirements	

Theories	Cognition	Analysis	Solution	Evaluation
	Visit comparable projects Study relative information			
Alexander Koutamanis (2013)	Gather information	Process information	Develop briefs	Test and evaluate briefs
Zhuang (2016)	Set goals Investigate external and internal conditions	Program conception	Generate design proposals or briefs	Evaluate program (pre-evaluation)

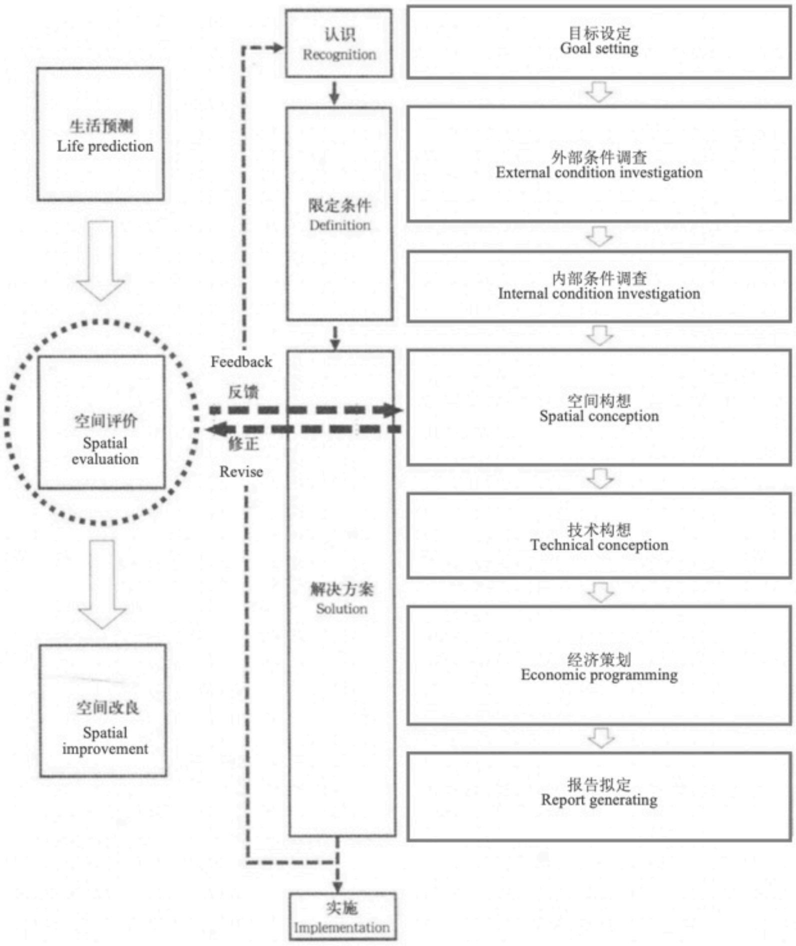


Figure 3.2 Programming framework of Zhuang (2016), translated by author

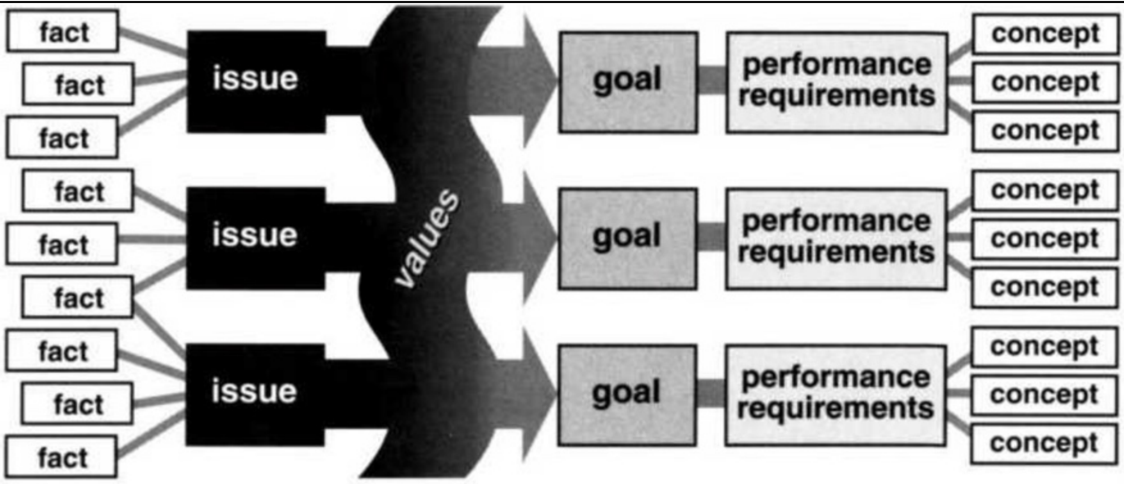


Figure 3.3 Schematic design programming, from (Duerk, 1993 [56])

3.1.2 Adaptation for architectural programming of renovation in previous researches

The classical architectural programming theories described in the previous subsection are mostly universal theoretical and methodological systems, and generally regard architectural renovation projects as a special type of general new construction projects, which are slightly mentioned in some chapters, but there is no complete discussion for architectural renovation projects alone. Therefore, the author will review the parts of classical architectural programming theory involving building renovation projects to provide a basis and reference for subsequent research.

(1) Peña's architectural renovation programming

William Peña published "Problem Seeking: An Architectural Programming Primer" in 1969, which has been reprinted four times since then. Peña mentioned building renovation in the section of "Requirements" in the second part of "Terminology", he thought that in the environment at that time, many existing buildings could not meet the existing codes, and there were even many harmful materials In his view, many existing buildings did not meet existing codes and even had a lot of hazardous materials that needed to be cleaned up, so renovation projects were often more complex and expensive than new construction projects. In addition, he mentioned the need to consider the efficiency of the floor plan required for the new use of the building, the affordability of utilities and site development costs such as parking, and whether the structure meets the new code requirements. For these reasons, Peña argues that even if existing buildings have high historical value, there is still a need to compare them with new construction projects before proceeding with a renovation project, determine the extent of the renovation based on the results of the existing building assessment, and hire a professional cost estimator to calculate a credible renovation budget (Peña, 2012). It can be seen that at that time, new construction projects dominated the mainstream market, and the value and significance of renewal and renovation had not yet been reflected, so Peña covered renovation in a very limited way and did not give a specific process and method for building renovation programming.

2）Kumlin's building renovation programming

Robert Kumlin published Architectural Programming: Creative Techniques for Design Professionals in 1995. Professionals), which does not summarize the programming process but rather gives a detailed "list of programming elements", including an "analysis of existing facilities (if the project is to renovate an existing building)" (Kumlin, 1995), the purpose of which may be either the renovation of an existing building or the renovation of an existing building. The purpose may be both the renovation of an existing building and the operational programming of the building. According to Kumlin, there are three components to the programming of a building renovation: **condition analysis, suitability evaluation, and cost evaluation**. For the condition analysis, Kumlin summarizes three scenarios and possible ways to obtain information, including the building being sold, the building being rented, and the building being reused with new functions. The author believes that the assessment of existing buildings only needs to identify the shortcomings of the current situation and the possibility of later operation, and does not need to be very detailed. Suitability assessment refers to the ability of the building to accommodate programming, and requires consideration of total area, structural load capacity, layout, code compliance of new features, vertical traffic, interior clear height, entrances, etc. The cost assessment requires a rough design strategy and then a list of improvements needed for the existing building before economic programming is made. In addition, in the information gathering checklist, Kumlin also mentioned that the assessment of existing buildings in renovation projects should be carried out in parallel with the programming, with a separate assessment team of architects and other professional engineers; if it is difficult to obtain the current status of facilities, a "facilities audit" (facilities audit) should be conducted to assess how the current state of the facility meets the requirements of the planned concept, which also requires a report to guide the subsequent design.

In the cost assessment section, Kumlin also used a brief description of the differences between renovation projects. He argued that most of the cost assessment steps for new construction projects can be used for renovation projects, but that the cost assessment for renovation projects should focus on closing the gap between the current state and the planned vision. In order to estimate the cost per square meter, a complete assessment of the existing building's current condition, including architectural as well as various engineering disciplines, is required. There are two types of reports: one gives a reference cost Figure based on expected quality standards and calculates an upper Figure beyond which it would be better to build a new project; the other is a fixed retrofit cost that requires prioritization of each conceived retrofit measure, and then a list of priorities to invert which retrofit measures can be achieved when the budget limit is met. Both are characterized by a combination of top-down and bottom-up programming, which Kumlin also calls a feasibility study that he believes should be richer and more detailed than the programming itself. The author understands that top-down means controlling the programming concept through programming goals or budget limits, while bottom-up means gathering information from existing buildings and revising the concept. This process also allows the various professionals to agree on design, technology, etc. As Kumlin says, the goal of programming is not only to get a programming report, but also to reach agreement and gain the support of project stakeholders through this process.

However, Kumlin does not discuss in detail how to assess the current facility issues, how to assess the suitability of new features and the ways to make existing buildings meet the programming needs. The case of Atlanta Community College is only a brief description of the programming process, showing that programming a renovation project requires an evaluation and budget development report, including programming and existing building analysis, and a cost estimating workbook.

3) Cherry's building renovation programming

In the Gathering and Analyzing Information section, Cherry explains in a relatively short space what to look for in a renovation project when the building itself is used as the site. She argued that photographs of the existing building's structure and current condition, and views from existing windows, are valuable and need to be documented. Structural and mechanical equipment as well as electrical systems should also be evaluated, and existing codes should be checked to see what improvements need to be made to existing buildings to meet code requirements. The authors argue that programming and design are easily linked or even intertwined in retrofit projects, so the appropriateness of new features can be argued, but should not interfere too much with subsequent design solutions (Cherry, 1999). However, Sherry does not discuss in detail the methods for evaluating existing buildings, nor does he describe how to make decisions about appropriate new features.

4) Building renovation in Hershberger's programming theory

Hershberger mentions matters about building renovation in some chapters of his book, Building Programming and Pre-Management. In the second sheet on values and architecture, Hershberger gives the actual case of Hallelujah Lutheran Church, a renovation and addition project in which an existing building, a residence, was added to a church on the campus. The author describes the programming process, analyzing the cultural, historical, aesthetic and technical characteristics of the existing building as the primary value issue to be considered, followed by a description of the process by which functional needs gave way to budgetary constraints, material quality, etc., as well as the consideration of secondary values and the resolution of secondary issues, resulting in a generally satisfactory solution. However, in this case, the authors do not give a quantitative basis for the value assessment and ranking, nor do they have a process for decision comparison, which is more like a description of the inverse process from the results, with some reference. In addition, in section 3.7 the authors mention that in the form issue, it is necessary to consider that certain owners want the new building to blend with the existing building. Section 3.8 also mentions considerations such as the chemical substances to be released when renovating the building (Hershberger, 1999).

Other classical programming theories also slightly mention renovation projects, for example, Zhuang Weimin in Architectural programming and Design gives an example of architectural programming research on renovation of residential areas in old cities in Beijing, which mainly introduces the questionnaire research method of programming research and has some reference significance, but does not specify the similarities and differences between renovation projects and new construction projects. From the above summary, it can be seen that the classical architectural programming theory has slightly involved in building renewal, and has also shown some matters that need more attention in building renewal compared with new construction projects, but the classical architectural programming theory has not systematically introduced the operational guidelines or methodological tools for building renewal and renovation, which is influenced by the background of the times on the one hand, the demand for renewal of existing buildings was not strong enough at that time; on the other hand, it was also limited by the academic viewpoint of renewal and renovation, which mainly stayed on the protection of historical value, and the connotation of sustainable development was not yet enriched. In the following section, we will introduce the recent research developments in the preliminary programming stage of building renovation.

Table 3.2 shows the summary of the main attempts to adapt architectural programming theory to renovation above.

Table 3.2 Comparison of adaptations for architectural programming of renovation in previous researches

Author	Pros	Cons
William Peña	Mention several considerations of renovation	Focus on universal construction projects and not consider renovation projects systematically
Robert Kumlin	Provide three elements to programming of renovation	Not summarize the programming process of renovation
Edith Cherry	Supplements points for renovation in information gathering and analyzing	Not provide detailed method for practice
Robert Hershberger	Generally describe the process and provide renovation cases	Not give detailed methods

3.1.3 Working process in the pre-design phase of existing building renovation

Apart from traditional researches in the field of architectural programming, other researchers focus on the working procedure of renovation projects in the field of urban renewal, which should be also reviewed although they are not specifically on the pre-design phase in order to propose the program. The points in the existing researches of the renovation process are summarized as below.

• Emphasis on the pre-design phase of renovation projects. These researches on the renovation design process are developed based on new construction projects and through comparison studies, in terms of the similarity steps in the whole process. However, renovation projects usually requires more attention, resources and time spent in the pre-design phase due to the incomplete data and documentation of the existing building

(Femenias and Fudge, 2010). The preliminary investigation to survey special conditions and organize relevant documentation is a legal requirement in Sweden concerning the existing building and its environment, such as local contexts, building history, user requirements and so on (Figure 3.4) (Thuvander et al., 2012).

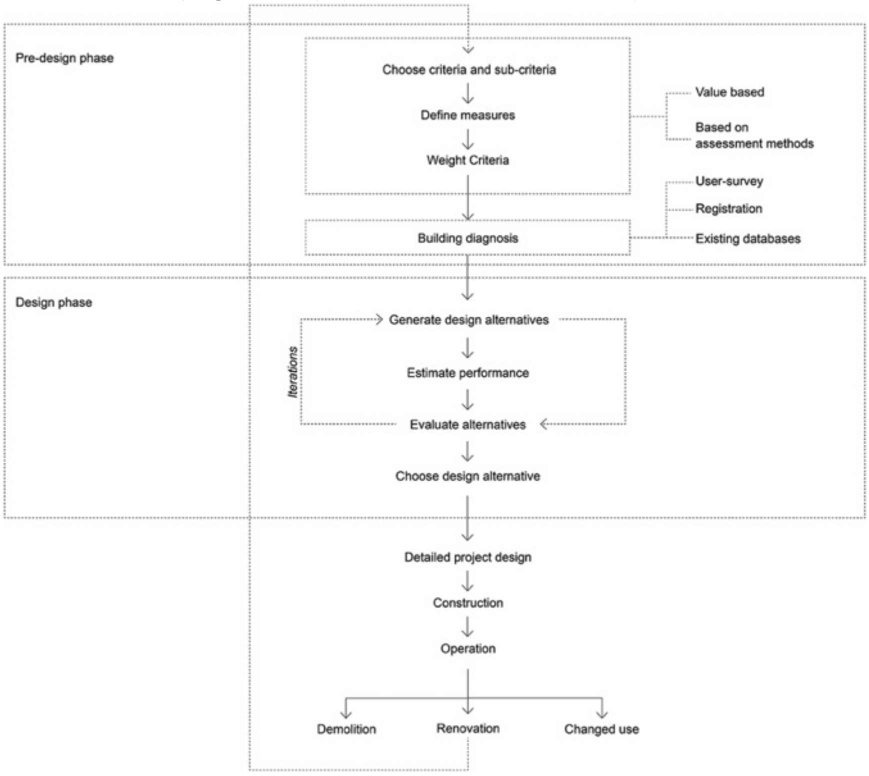


Figure 3.4 The building renovation process (Nielsen et al., 2016 [167])

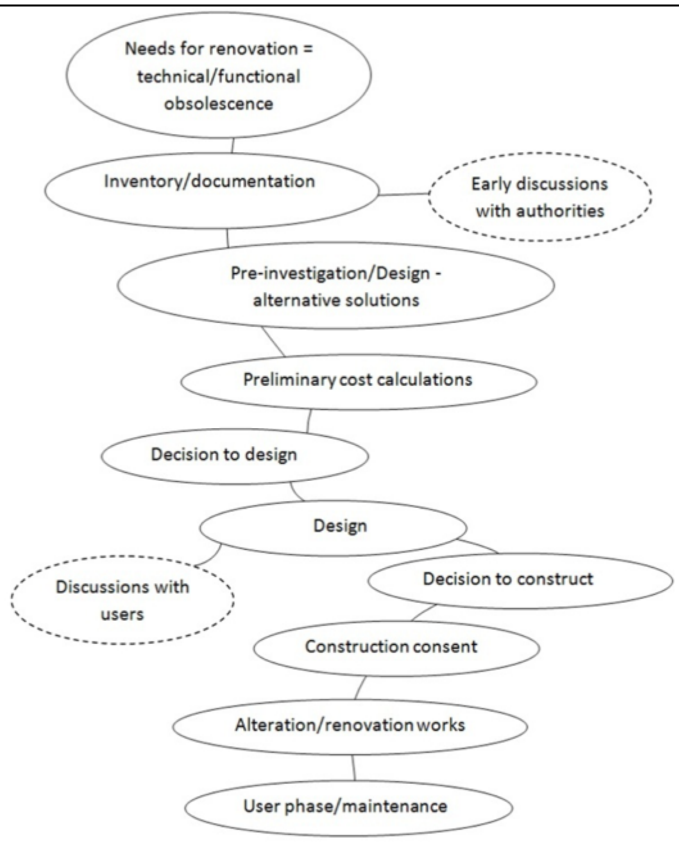


Figure 3.5 Schematic overview of a renovation process (Thuvander et al., 2012 [1193])

• Investigation and analysis focus on existing buildings. Nielsen et al. (2016) supplements the building diagnosis phase in the pre-design process of renovation projects, with the help of user survey, registration, and existing databases, and applies decision-making structure of criteria system to identify value-based potential solutions. Grecchi (2022b)[13-15] summarizes the kinds of data in the re-investigation of renovation projects, as the evolution of building in history, general characteristics, deterioration, performance analysis and so on (Figure 3.6).

• Propose and evaluation of renovation program in a decision-making process of cognition, analysis, solutions and evaluation. Although existing researches differ in detailed steps and working contents, their logic and order of the pre-design process are similar to the architectural programming process, which are cognition, analysis, solutions and evaluation as summarized in section 3.1.1. For example, Matsumura (2019) proposed that the programming stage includes the intention of architectural regeneration, prior research, basic policy determination and judgment of project establishment, and product programming. The decision-making process is driven-by multi-criteria analysis, which should first define the goals and guidelines, then develop the criteria and weights, generate strategies, and finally evaluate them and optimize the proposal (Bazerman and Moore, 2012).

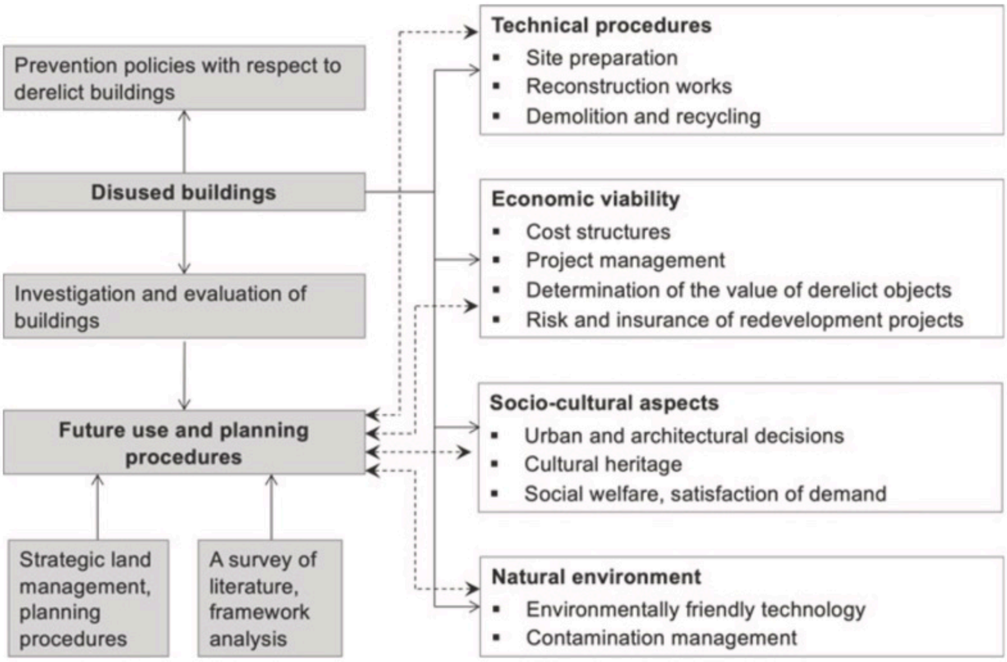


Figure 3.6 Scheme of different stages of the process. (Grecchi, 2022b [12])

3.2 Practical process of pre-design phase in renovation projects

This section is intended to supplement experience in practice to theoretical researches regarding the framework of architectural programming in renovation projects. It analyzes four renovation projects and conduct comparison study on the process and outcomes.

3.2.1 Brief comparison between Italy and China in renovation

Due to the author’s engagement in a joint PhD research curriculum of China and Italy, the research is able to be conducted through the lens of comparison between practice in Italy and China, synthesize experience from both contexts on renovation projects. Although Italy started to pay attention to architectural programming several years ago, it has engaged in urban renewal or regeneration development including building reuse projects since last 70s (Salata and Fior, 2017), with a relatively sound system and abundant building transformation cases until today.

Italy experienced Fordism with large numbers of industrial buildings before the world war 1st. After the world war 2nd, modern architecture appeared in Italy including multiple-story public buildings. In China, lots of factories built before 1960s were demolished and it didn't build mass industrial buildings and public buildings until 1978 reform and opening-up. It is common to see these two kinds in China's urban renewal development today. Considering the difference of the land systems in these two countries in terms of land property and management, facility property and so forth, this research would focus on the similarity of building typology in urban renewal, especially buildings completely or partially open to the public. Therefore, the research focuses primarily on two specific building types in the following chapters. One is the abandoned industrial building that could be transformed into urban catalysts to regenerate the whole areas. The other one is obsolete post-war multi-floor buildings that could be renovated to prolong the service life and to maintain the prestige of contemporary architecture.

Italy has a sound system from legislation to design guidelines, to protect and reuse heritage buildings. Public buildings constructed before 70 years ago are automatically listed in heritage buildings, while private buildings of that age can apply for the protection of heritage buildings. Public buildings with history of less than 70 years, can also become listed heritage buildings depending on the historic and cultural values (2004). There is a "grey space" between the listed building and normal building without strict limitations of intervention requiring discussion. While in China, there are many issues regarding renovation and reuse still in discussion and to be refined, such as the classification of heritage buildings, the feasible degree and intervention, the building types for reuse, approval of function transformation, etc. The heritage buildings are evaluated from three perspectives of historic value, art value and science value(文化部, 2005). The listed buildings are strictly limited of reuse or intervention, with the most common protection approach to preserve and exhibit the heritage. Domestic amount of renovation buildings are normal buildings constructed around 20-30 years ago, which were occurred with the rapid urban development in the past 40 years.

3.2.2 Selection of the four cases

Multiple-case study has an advantage of robust with more convincing evidence than single-case study (Herriott and Firestone, 1983). The selection of multiple cases follows the principle of replication rather than sampling, to obtain similar or distinguishing results (Yin and Campbell, 2018). Due to the author's engagement in a joint PhD research program of Italy and China, the research is able to be conducted through the lens of comparison between the two countries, expecting to synthesize experience from both contexts on renovation projects. Although Italy started to pay attention to architectural programming several years ago, it has engaged in urban renewal or regeneration development including industrial reuse projects since the last 70s(Salata and Fior, 2017), with a relatively sound system and abundant renovation cases until today. Considering the difference of the land systems in these two countries in terms of land property and management, property ownership and so forth, this research would focus on the similarity of building typology in urban renewal, and the process of pre-design phase led by programmers or architects rather than the influence of different administration system.

The research focuses on functional renovation projects including function transformation and function enhancement projects, hence the selected cases should cover these two types with similar features. The principles to selecting multiple cases includes the features of the research object, as well as similarities in the pre-design phases, which are in detail as below:

• Functional renovation: the function program of the existing building changes after the renovation, either transformed or enhanced from the original function;

• Multiple-stakeholder and government participation: the project involves multiple stakeholders with the government or relevant public organization participation. Therefore, the project should consider multiple goals and benefits;

• Main spaces open to the public: the existing building have main spaces open to the public so that it should consider the requirement and using pattern of the public, excluding some enclosing building type such as traditional residential building, private houses and so on;

• Having pre-design phase to provide guidelines for design: since the research focuses on the pre-design phase and its influence on the design, the case should go through this phase before design and achieve good results in guiding the design and final outcomes;

Based on these principles, the author first reviews cases in Appendix B and then selects typical building types in urban renewal of both Italy and China. Italy experienced Fordism with large numbers of industrial buildings before the World War I. After the World War II, modern architecture appeared in Italy including multiple-story frame buildings. In China, lots of factories built before 1960s were demolished and it didn’t build mass industrial buildings and frame buildings for public use until 1978 reform and opening-up. It is also common to see these two kinds in China's urban renewal development today. Therefore, the research focuses primarily on two specific building types in the following chapters. One is the abandoned industrial building that could be transformed into urban catalysts to regenerate the whole areas. The other one is obsolete post-war multi-floor buildings that could be renovated to prolong the service life and to maintain the prestige of contemporary architecture.

This section takes four projects of two types among collected cases as examples to compare different decision-making processes in both China and Italy according to the principles above (Table 3.3): Eataly Lingotto and Enrico Fermi School in Italy, and Pingyao Film Palace and School of Future Design of Beijing Normal University (BNU) in China. Section 3.2.2 will introduce detailed information of these four cases. The author conducted filed researches and had deep interviews with the architects of the four cases, collecting relatively complete information data about the working process, especially about their pre-design phases. Below is the general information about four selected cases.

Table 3.3 Selection of four renovation cases

	Eataly Lingotto	Enrico Fermi School	Pingyao Film Palace	School of Future Design of BNU
Location	Italy	Italy	China	China
Functional renovation	Transformation	Enhancement	Transformation	Enhancement
Multiple-stakeholder	•	•	•	•
Government participation	•	•	•	•
Spaces open to the public	Commercial and cultural center	Education	Film venue and exhibition	Education
Pre-design phase	•	•	•	•

1) Eataly Lingotto, Turin

Figure 3.7 Project overview of Eataly Lingotto, Torino ©Filippo Gallino

Figure 3.8 Master plan of Eataly Lingotto

The building of Eataly was formerly the famous Carpano vermouth factory in Turin, built in the early 20th century, with gross floor area of 11400 m^2. After two expansions in

1923 and 1927, and partial additions in the 1950s, the factory formed the spatial pattern with two long, narrow and courtyards in east-to-west direction. In 1995, the brand was acquired by Branca, the production of vermouth was thus transferred to Milan and the building was left unused. The factory was then acquired by the government City of Turin and Eataly[8] enterprise won the bidding for investment and operation. The project has been a hit since its opening in 2007, and has been one of the most popular food and beverage center in Turin (黄也桐 et al., 2021).

Negozio Blu Architetti Associati[9] has been invited to explore the possibility of reusing the factory since 2001, in order to preserve the main features of the building and its historical memory. Although at that time the Carpano factory was not on the heritage list and could theoretically be renovated or even demolished, the department of urban planning department of the municipality invited Soprintendenza ai Beni Architettonici (Superintendence of Architectural Heritage)[10] to supervise the parts to be preserved and demolished due to its historical value, as well as the colors and materials of the renovated building.

2) Enrico Fermi School, Turin

[8] Eataly is an Italian restaurant company combining restaurants, food market, retail, and cooking school etc. together to promote natural and biological food and materials, which expand its business all over the world.

[9] The architects of this project are Gustavo Ambrosini, Cristiana Catino, Paola Gatti, Carlo Grometto, and Mauro Penna.

[10] Two years after the completion of the project, the Carpano factory was included in the list of industrial heritage of Turin.

Figure 3.9 Enrico Fermi School ©Simone Bossi

Figure 3.10 Master plan of Enrico Fermi School

The Enrico Fermi Secondary School in Turin, Italy, as an exemplary renovation project of secondary school by the municipalities in cooperation with two private foundations[11], was awarded the 2019 Best Renovation and Reuse Project Award by the Italian National Building Council (Figure 3.9). It is a frame building with the gross floor area of 3850 m^2, originally built in 1965 and completed renovation in 2019. Thanks to scientific and systematic programming in the pre-design phase, close cooperation between multi-stakeholders, and parallel research and design, the project not only achieved significant functional improvement and precise control of costs and periods, but also promoted the improvement of the school's pedagogical concepts and teaching methods, with some facilities open to the community to enhance the utilization of school resources and social impacts.

3) Pingyao Film Palace, Pingyao

[11] The two private foundations are Fondazione Agnelli and Compagnia di San Paolo.

Figure 3.11 Project overview of Pingyao International Film Festival Venue ©Su Shengliang

Figure 3.12 Master plan of Pingyao International Film Festival Venue

Pingyao Film Palace is a renovation project of Pingyao Diesel Engine Factory built in the last 70s, located in Pingyao, Shanxi Province, which was designed by Architectural

Design and Research Institute of Tsinghua University. Due to the contributions to diversified revenue sources, it was awarded 2020 UNESCO Asia-Pacific Awards for Cultural Heritage Conservation Awards for Merit, 2016-2018 WA China Architecture Award for Urban Contribution, 2016-2018 WA China Architecture Awards Urban Contribution Award for Best Work, 2019 Hong Kong Institute of Architects Award, Cross-Strait Architectural Design Forum Community, Culture and Recreation Excellence Award and many other architectural awards. The project is now used as the venues of Pingyao Crouching Tiger Hidden Dragon International Film Festival (平遥国际电影展), also as a theatre for the public at ordinary times. The reuse the industrial site with total floor area of 11000 m^2 has contributed to the diversification of revenue sources in the Ancient City of Pingyao – UNESCO World Heritage Site, expanded the diversity of tourist groups and enhanced local socio-economic sustainability. It has also improved community residents' quality of life by adding new public spaces and facilities for cultural activities.

4) School of Future Design of Beijing Normal University, Zhuhai

Figure 3.13 Project overview of School of Future Design of Beijing Normal University © Wu Qingshan

Figure 3.14 Master plan of School of Future Design of Beijing Normal University

School of Future Design of Beijing Normal University (BNU), located in Zhuhai, Guangdong Province, is a renovation project of educational buildings in universities in China. Architectural Design and Research Institute of Tsinghua University is the designer of this project, with architectural programming service as well in the pre-design phase. The project is composed of two buildings built in 2004 opposite to each other, the southern building with floor area of 899 m^2 and the northern one with 13532 m^2. The northern building was in bad physical and functional performance before the renovation, while the southern building was an unfinished building with only frame structure. The two buildings are now educational spaces for School of Future Design of BNU.

The author made interviews with the main architects of all four cases and one manager represent of the client as below:

Gustavo Ambrosini, the co-founder of Negozio Blu Architteti, designing Eataly Lingotto Project;

Simona Della Rocca, the co-founder of BDR bureau, designing Enrico Fermi school project;

Raffaella Valente, the project manager from Agnelli foundation responsible Torino Fa Scuola Project;

REN Fei, vice dean of Architectural Design and Research Institute of Tsinghua University, who is one of the two main architects of Pingyao Film Palace;

ZHAO Jingxian, from Architectural Design and Research Institute of Tsinghua University, who is the main architect of Design and Study center of Beijing Normal University.

3.2.3 Feature comparison of the four cases

These four cases are selected because of their typical characteristics representing functional transformation or enhancement in renovation projects, but also their similarities and distinguishing features at the same time. The Table 3.4 below shows the backgrounds of the four cases, including the stakeholders, schedules and existing buildings. We analyze the features of the four cases from the perspectives of similarity and difference in order to explain reasons for selecting and comparing them.

Table 3.4 Feature comparison of the four selected cases

	Eataly Lingotto	Enrico Fermi School	Pingyao Film Palace	School of Future Design of BNU
Clients	Eataly LLC. City of Turin	School Board of Enrico Fermi School	Pingyao International Film Festival LLC. People's government of Pingyao County	University Board of Beijing Normal University
Existing building ownership	City of Turin	City of Turin	People's government of Pingyao County	Beijing Normal University
Investors	Eataly LLC.	Agnelli Foundation San Paolo Foundation	People's government of Pingyao County	Beijing Normal University
Government participation	City of Turin Superintendence of Architectural Heritage of Turin	City of Turin Regional School Office for Piedmont Mission Structure for School Construction	Communication Department of Shanxi Provincial Committee People's government of Pingyao County	Housing and Urban-Rural Development Bureau of Zhuhai
Architects	Negozio Blu Architetti Associati	BDR Bureau	Architectural Design and Research Institute of Tsinghua University	Architectural Design and Research Institute of Tsinghua University
Initiation time	2001	September 2015	December 2016	October 2018
Delivery time	January 2007	September 2019	October 2017	November 2019 May 2021
Gross Floor Area (m^2)	11400	3850	11000	899+13532
Building floors	2 + 1 basement	3 + 1 basement	1	5

	Eataly Lingotto	Enrico Fermi School	Pingyao Film Palace	School of Future Design of BNU
Construction year of the existing building	1900s	1965	1970s	2004
Original function	Vermouth factory	Secondary school	Diesel factory	Pedagogical building
Function renovation	Transformation to mixed-use center of food market, restaurant, museum, meeting hall	Function enhancement of educational building	Transformation to cultural building of theater, meeting hall, exhibition hall, etc.	Function enhancement of educational building
Structure of the existing building	Frame structure	Frame structure	Truss structure Masonry-concrete structure	Frame structure
Renovation content	Partial demolishment and new construction Spatial pattern adjustment Renewal of the building-urban interface Facade renovation	Partial demolishment and addition Spatial pattern adjustment Renewal of the building-urban interface Facade renovation	Partial addition Spatial pattern adjustment Renewal of the building-urban interface Facade renovation	Spatial pattern adjustment Renewal of the building-urban interface Facade renovation
Decision-makers	City of Turin Eataly LLC.	Agnelli Foundation and San Paolo Foundation School Board of Enrico Fermi School	Pingyao International Film Festival LLC. People’s government of Pingyao County	School of Future Design, Beijing Normal University
Architectural programming team	Negozio Blu Architetti Associati Founder of Eataly LLC	MoDus Architects Education professor Working group of students, parents and teaching staff	Architectural Design and Research Institute of Tsinghua University Pingyao International Film Festival LLC.	Architectural Design and Research Institute of Tsinghua University Teaching staff

The **similarities** between these four projects are as follows:

1) **The motivations of renovation or reuse**: the two factories had been abandoned for years due to relocation of industries so that the goals were to input new kinds of industries into the existing spaces. The two academic buildings, although established for different kinds of study, had outdated space plan and equipment which couldn't meet the present requirements of pedagogy. Therefore, their goals are to update the functional spaces and implement new technologies.

2) **Government participation**: the government or the municipality participated in all four projects, regardless of the level of involvement. First of all, the land of all four projects is owned by the government, three of which are appended with legitimate estate ownership. The study center of Beijing Normal University is the only one whose estate ownership belongs to the university, thus government's involvement in this project is relatively low, mainly playing the role of reviewing and approving the project. In the other three projects, the government was more or less involved in the pre-design phase and played a role in both monitoring and advising.

3) **The phase of architectural programming**: all four projects went through different forms and durations of architectural programming prior to the formal design process. The Eataly project had the longest pre-design phase, while the two projects in China had relatively limited time for architectural programming corresponding to the short project cycles. Enrico Fermi School project had a relatively moderate duration of the pre-design phase, with the most comprehensive architectural programming process, and a clear demarcation between the programming and design phases. Besides, all of the four cases involve architects in the team of architectural programming of pre-design phase to help decision-makers to generate design proposals. The next section will analyze their process of architectural programming in detail.

Apart from the similarities, there are **difference** of the basic information among the four cases as below:

1) **Investment pattern**: the two projects in Italy are sponsored by private investors, while the buildings are still possessed by the municipalities. Eataly has the right to use and operate the building for 60 years, while Agnelli foundation and San Paolo foundation returned the renovated outcome back to Fermi school upon the delivery. The two projects in China have public investments. Pingyao film palace is the only project invested by the

government. The study center of BNU is invested by the university, which is a kind of public investment. It is corresponding to the investment patterns of most renovation projects in Italy and China nowadays.

2) **Project cycle**: there are significant differences in the project cycle between the two countries due to the different national conditions. The cycles for the two projects in Italy are 7 years and 4 years respectively, while those for projects in China are shorter, about 1 year and 2.5 years. The longest cycle of the Eataly project is due to the special reason that the land and facility property were acquired by the government after the owner changed, which led to a longer pre-design period. The two Italian projects had a larger proportion of pre-design time and construction took more than 1 year. The two projects in China had more limited schedules due to tight delivery dates, with construction taking less than six months.

3) **Renovation contents and locations**: the two factories focus mainly on function transformation, while the new functions necessarily demand for partial demolishment and new construction or addition, and placement of new technologies and equipment. On the contrary, the two education buildings are function enhancement projects, which only update and improve their functional programs. All the four cases adjust the spatial pattern, renovate façades, and pay attention to the interface between architecture and urban spaces, accompanied with structure strengthening, facades renovation and equipment improvement. Considering the location of the four cases, we select one function-transformation project and one function-enhancement project for each country, in order to compare different situations in different countries.

The text above introduces the basic information of the four selected cases. The next two following sections analyze the other distinguished characteristics and conduct critical comparisons from the perspectives of the architectural programming process and decision-making mechanisms.

3.2.4 Process comparison regarding architectural programming

This section first compares the project cycle of four cases, and then focus on the process of architectural programming in the pre-design phase, attempted to conclude the practical experience when implementing architectural programming in renovation projects. Although the project cycles of the four cases vary widely, the sequence and content of the individual steps are essentially the same. Figure 3.15 provides project cycles and duration of each phase in the four cases. The horizontal axis shows the months spent in each phase. Eataly Lingotto has longest project cycle of more than four and a half years in total from the initiation of pre-design phase to project delivery; while Pingyao Film Palace has the shortest period with over a year. Although they have different duration of project cycle, the division of project phases are similar including architectural programming in the pre-design phase, including architectural programming, schematic design, design development, construction drawing and construction. It is introduced briefly the project cycle of each case as below.

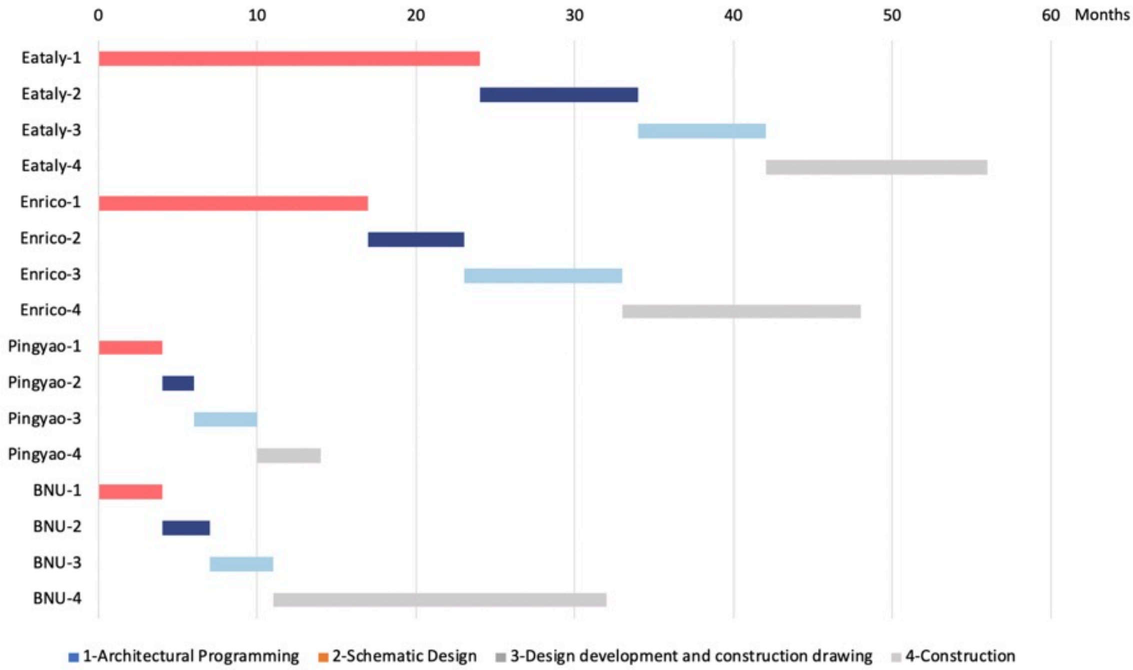


Figure 3.15 Duration of each phase in the project cycle of four cases

3.2.4.1 Project cycles of four cases

1) Eataly Lingotto

The Eataly Lingotto project had initiated architectural programming in 2001, was then transferred to City of Turin in 2003, and was finally delivered in January 2007, lasting for 6 years with the following four phases.

The first pre-design phase (2001 to 2002): Architects provided programming consultation to a private enterprise, studying the values and renovation feasibility of existing buildings.

The second pre-design phase (2002 to 2004): Municipalities joined and purchased the site and existing buildings; architects provided proposal of function orientation for reusing the site; the municipality approved the proposal and established an urban renewal zone in 2003.

Design phase (2004 to November 2005): Architects identified the function program with potential operators and users; Eataly LLC. obtained the building use right for 60 years in April 2005; architects completed the design development and construction drawing including the integrative design of architecture, interior and landscape of outdoor public spaces.

Construction phase (December 2005 to January 2007): the project began construction phase and Eataly Lingotto started the operation in January 2017.

2) Enrico Fermi school

The Enrico Fermi school project was launched in September 2015 and delivered in September 2019, lasting for four years with the following four phases.

Pre-design phase (September 2015 to January 2017): clients invited educational experts and architect to lead the team of architectural programming, with the result of a complete design proposal including all of initiation conditions, a function program and renovation feasibility study.

Competition phase (February 2017 to July 2017): the client in collaboration with the Turin Architects Association held the competition bidding and took less than six months to select the first winning team based on each team's design development drawings.

Design Development phase (August 2017 to May 2018): after announcing the winner, the client, programmers, the winner architect of BDR Bureau, and technical consultants refined the design and drew construction drawings; programmers organized simulation experiments to test the programming concept and modify the design proposal.

Construction and delivery phase (June 2018 to September 2019): The construction schedule was strictly controlled as the school needed to resume in the fall semester one year later.

3) Pingyao Film Palace

The Pingyao Film Palace is a project with extremely limited time that initiated formally in March 2017, and was delivered in October the same year, while architectural programming started earlier to make preparation as much as possible.

Pre-design phase (November 2016 to December 2016): architects with technical experts collected information, select suitable site and study the feasibility in the pre-design phase; the clients provided the requirements of the film festival.

Design phase (January 2017 to February 2017): architects did schematic design based on previous researches and further verified the feasibility of the design proposal.

Construction drawing phase (March 2017 to June 2017): architects drew construction drawings and refine the design preparing for construction phase.

Construction phase (July 2017 to October 2017): the project started construction phase and the opening ceremony of the first film festival was on October 19, 2017.

4) School of Future Design of BNU

The School of Future Design of BNU initiated the pre-design phase in October 2018, and delivered the south part in November 2019, with the completion of the north part in May, 2021 due to update requirements and modifications on design.

Pre-design phase (October 2018 to January 2019): architects provided programming consultation to the client, studying the future using pattern and renovation feasibility of existing buildings.

Design phase (February 2019 to April 2019): architects designed the spatial pattern and adjusted the function program in the process.

Construction drawing phase (May 2019 to September 2019): architects drew the construction drawings and obtained the approval of construction in September 2019.

Construction phase (September 2019 to May 2021): the project started construction phase and the south part was delivered in November 2019, while the north part was completed in May 2021 due to modified requirements by the client.

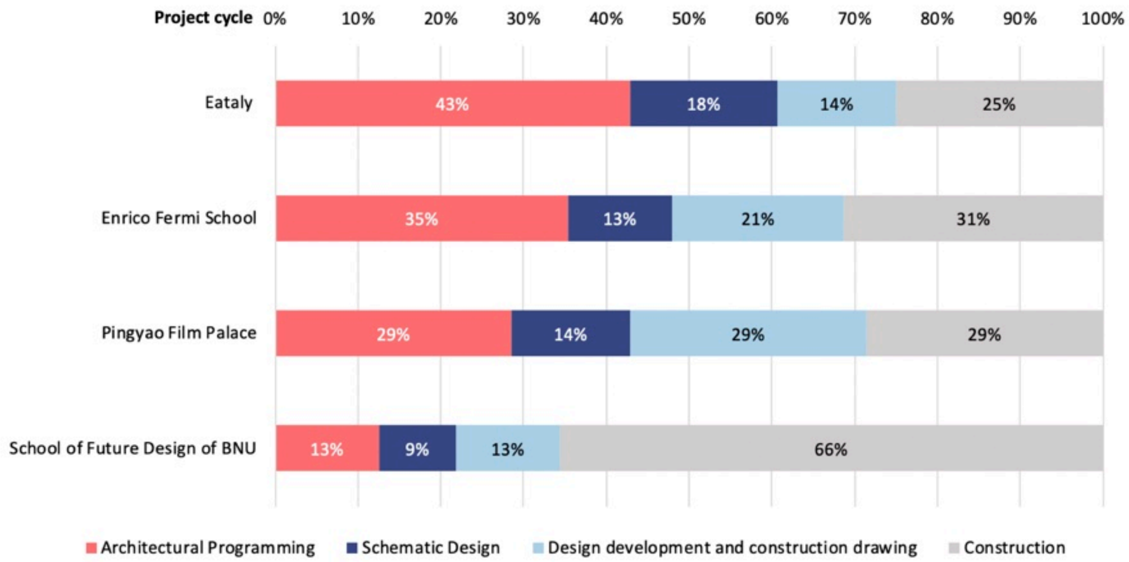


Figure 3.16 Time distribution in project cycle of four cases

Figure 3.16 compares the time distribution in project cycle of four cases. The pre-design phase in four cases lasts longer than the design phase and even no shorter than the phase of design development and construction drawing in all four cases. Among them, Eataly Lingotto and Enrico Fermi School distribute most time in the architectural programming phase.

There are two reasons behind this result. First, the initiation of renovation projects always accompanies with land transfer, property transfer, modification and approval of urban planning, building diagnosis and many other issues, which cost much time of negotiation and approval, with huge uncertainty and considerable possibility of change. Second, the architectural programming should be carried out simultaneously to collect complex and uncertain information, analyze the conditions and support the decision. Therefore, the architectural programming in the pre-design phase of renovation projects is likely to last longer than common projects. For example, Eataly Lingotto has undergone two acquisitions before the renovation with land and property transfer, a research of function orientation, an approval of the variant of urban planning, and a bidding process of investors and operators in the pre-design phase.

Besides, it is shown that a sufficient time distributed to the pre-design phase for researches can reduce significantly the time spent in the design phase and have better control over construction phase. In Enrico Fermi School and Pingyao Film Palace, programming teams identifies scientific function programs and clear design strategies which shorten the duration of design phases.

3.2.4.2 Architectural programming in the pre-design phase of four cases

As for the process regarding architectural programming in the pre-design phase, these four cases follow similar steps and vary in detail as seen in the following Table 3.5. We classified the contents and tasks of the pre-design phase into five categories of goal setting, information collecting, function identification and enhancement, feasibility studying, and design proposal generating. Comparison consists of similarity and difference analysis.

Table 3.5 Comparison of the pre-design phase of four cases

Pre-design phase		Eataly Lingotto Torino	Enrico Fermi School	Pingyao Film Palace	School of Future Design of BNU
Duration time		More than 24 months	17 months	4 months	4 months
Percentage of project cycle		43%	35%	29%	13%
Goal setting	Main goal	Conserve the factory and food and wine culture	Enhance the quality of pedagogy and facility	Deliver on time in an extremely limited time	Enhance the space quality
	Assembling programming team	Architects take the role by chance	Client delegates architects and experts, with a working group of users	Client delegates architects	Client delegates architects
Information collection	Urban information	• Industry composition • Public space, and streets • Relationship with the surrounding buildings	• Future development of the surrounding area • Corporation between school and community	• Historic districts • Influence of the new function on the area	• Organization of the university campus • Public space and traffic
	Building diagnosis	In the pre-design phase	In the pre-design phase	At the same time of schematic design	At the same time of schematic design
	User information and using pattern	• Discuss with operators about future sales and marketing	• Questionnaire, interviews and observation of existing and future users; • Discussing future pedagogic pattern	• Discussing using pattern with the organizers of film festival and operators	• Discussing using patterns with future users
	Case study	Compare with traditional retail cases	Investigation on site other outstanding school cases	Analyze of other cases of international film festivals	Analyze similar cases of global school of design

Pre-design phase		Eataly Lingotto Torino	Enrico Fermi School	Pingyao Film Palace	School of Future Design of BNU
Function identification	Function transformation	Functions with the theme of food and wine		Requirements of international film festival	
	Function enhancement		Requirements for innovative pedagogy		Requirements for innovative design education
	Developing function program	Architects discuss with operators	Architects and education expert study pedagogic potentials with the help of users' group	Architects adjust the function program of film festival based on existing conditions	Architects discuss with clients and users, and revise the function list provided by clients
Feasibility study and program evaluation	Space-function suitability evaluation	Sketches Demolition and conservation analysis	Function list Demolition and potential addition layout	Sketches Suitability evaluation for the theatre function	Sketches Function sectors or groups arrangement
	Considering other limitations	Building codes Preservation demands of building heritage	Limited floor area Building codes	Height limits and minimum intervention of historic districts Extremely limited time	Limit delivery time and changing requirements
Design proposal generation	Adjusting the interface with urban spaces	Change the main entrance and the function of public space	Change the main entrance and adjust the public space	Identify the entrance and main road of the park; redesign the public space	Adjust the interface with the main street and redesign the public space
	Design problems	Theme place for the brand Negative surroundings	Expand classrooms New pedagogic pattern	Two large theaters Iconic place for festival	Activate spaces for design Separate building clusters
	Programming strategies	• Use courtyard space as the theme place for retail • Change the main	• Pedagogic clusters inserted into existing spaces • Outdoor addition of	• Construct an outdoor 1500-seat theater • Construct new 250- seat cinema hall	• Connecting all the roofs and create roof exhibition spaces • Add glass roof for

Pre-design phase	Eataly Lingotto Torino	Enrico Fermi School	Pingyao Film Palace	School of Future Design of BNU
	entrance and renovate negative outdoor spaces • Partially demolished and insert new function boxes	terraces for classrooms • Change the entrance and transform negative outdoor spaces	• Make the most of height difference of the terrain	courtyard to create atrium • Use height difference to create outdoor displays
Optimization	Negotiations	Experiment with users		Update requirements

Similarities in the working steps include:

1) General working process: as we can see in the table, all four cases follow the general working process of architectural programming as **cognizing** the existing conditions, **analyzing** the problems, making **decisions** and providing **solutions** in the end. The cognizing process is to investigate and collect information from urban, building and user perspectives. Especially for the building level, programmers should collect information about building diagnosis as a foundation for all the following decision-making process. The analyzing process, corresponding to program conception in traditional architectural programming process, now pay additional attention to identity new function for reuse projects and enhance the function program to meet update requirements. As for the third process of making decisions and providing solutions, all of four cases have identified the design problems and find possible solutions as guidelines for later design phases.

2) Generating design proposal by programmers instead of clients

As an example, the design proposal of Enrico Fermi School is very detailed and contains nine chapters: project objectives, architecture and education, analysis of the current state of the Fermi School, shared design of the pedagogical concept and renovation feasibility study, analysis of the current structural energy of the existing building, design purpose and functional programming, budget and technical requirements, reference building codes and list of attachments. Chapter 6, "Design Purpose and Functional Programming", describes the functional layout of the existing building, the design guidelines, the requirements of each functional module and connections between them, and explains the use of the functional list in the annexes (Torino Fa Scuola, 2016c). The interior space is divided into 11 functional modules, such as public service space, sports arena, dining space, library and classrooms. Each functional module is subdivided into detailed spaces. For example, the public service spaces contain entrance hall, atrium, communication room, copy room, etc. The author has sorted out the design requirements for each functional space, categorizing them into seven areas: area, contents, performance, characteristics, connection with other spaces, equipment requirements, and flexibility.

The project provides a functional space list tool (Figure 3.17) that allows calculating and adjusting area proportion, and possibilities of adding new spaces. The architect can use this tool to quickly understand the functional needs of the school and calculate the feasibility and affordability of his or her proposal.

Programma funzionale - richieste concorsuali					Programma funzionale - progetto				
N.	Denominazione ambiente	Qta.	sup.	sup. totale	Qta.	sup.	sup. totale	bilancio	variazione
			m²	m²		m²	m²	+ / -	%
SUPERFICIE INTERNA (netta)									
1	**Paesaggio di apprendimento - spazi comuni e di servizio**								
1.1	Atrio d'ingresso / Atrio	1	450.00	450.00	0	0.00	0.00	-450.00	-100.00%
1.2	Bidelleria	1	35.00	35.00	0	0.00	0.00	-35.00	-100.00%
1.3	Locale fotocopiatrice	1	10.00	10.00	0	0.00	0.00	-10.00	-100.00%
	eventuale spazio aggiuntivo				0	0.00	0.00		
	tot. escluso spazio aggiuntivo			495.00			0.00	-495.00	-100.00%
	tot. compreso spazio aggiuntivo			495.00			0.00	-495.00	-100.00%
	spazio di distribuzione						0.00		
1	**Totale**						**0.00**		
2	**Palestra - laboratorio del movimento**								
2.1	Palestra	1	316.00	316.00	0	0.00	0.00	-316.00	-100.00%
2.2	Ballatoio (Galleria esistente)	1	76.00	76.00	0	0.00	0.00	-76.00	-100.00%
2.3	Deposito palestra	1	22.00	22.00	0	0.00	0.00	-22.00	-100.00%
2.4, 2.5	Servizi Palestra	1	120.00	120.00	0	0.00	0.00	-120.00	-100.00%
2.6	Spogliatoio insegnante	1	12.00	12.00	0	0.00	0.00	-12.00	-100.00%
2.7	Sala visita medica	1	12.00	12.00	0	0.00	0.00	-12.00	-100.00%
	eventuale spazio aggiuntivo				0	0.00	0.00		
	tot. escluso spazio aggiuntivo			558.00			0.00	-558.00	-100.00%
	tot. compreso spazio aggiuntivo			558.00			0.00	-558.00	-100.00%
	spazio di distribuzione						0.00		
2	**Totale**						**0.00**		

Figure 3.17 Functional program list and calculation tool (Torino Fa Scuola, n.d.)

Differences in the working process include:

1) Diagnosis before or with architectural programming: Architectural diagnosis is preferable, because the architect's experience is not always accurate, and it is also difficult to find out the potential problems under the surface, which may bring trouble to the subsequent construction. Building diagnosis should better be conducted in advance, because the architect's experience may not always be accurate, and it is also difficult to find the potential problems under the surface, which may bring trouble to the subsequent construction.

2) Optimization after generating design proposal: as architectural programming is not only in the pre-design phase, but can also extend to design and even construction phase, the optimization process of architectural programming is a meaning full step to ensure the success of a project. Among the four cases, the Enrico Fermi School project is the only one applying complete revising and optimizing procedure of architectural programming. The programming team led by architectural and educational experts prepared the programming of the design development phase, added experiment equipment during the bidding process. After the winning team was announced, they carried out surveys, experiments, etc., and cooperated with the clients and BDR Bureau

Office to deepen and revise the program. The purpose was to verify the feasibility of the preliminary teaching model, improve the space organization and area allocation, refine the design requirements to the level of equipment and furniture, collect opinions on the program, and ensure the coherence between the preliminary programming study and the final design practice.

The programming team simulated the new clusters and teaching schedule, and applied user questionnaire research and on-site observation to record the use of the space and to identify problems. The working group was reorganized, with faculties and parent representatives, and students became the objectives of the research. Teachers distributed questionnaires containing five-level scales and open questions to students, recorded the use of each space in the form of photos, audio and video recordings, and key members of the programming team conducted data collection and analysis, etc. (Figure 3.18).

Figure 3.18 Experiment, revise of proposals and design © Torino Fa Scuola

Upper Left: students are evaluating the design scheme; Upper Right: interviews with users; Below: notes of users’ opinions and advice on the design scheme

The results of the experiment found that students liked the new teaching schedule and clusters, and were interested in the outdoor teaching space. Low-saturation interior colors such as beige and gray-green were preferred over colorful interior design(黄也桐 et al., 2022). The programming team corrected and added parts of the preliminary programming, for example, the teachers and students preferred to integrate the library and multi-function room into a large open space (Figure 3.19). The designers built a new façade with a steel frame structure to increase the area of outdoor teaching space and to provide shading (Figure 3.20). The design development phase still continues the multi-stakeholder decision-making, fully respecting the needs of users and operators, and making decisions based on scientific experimental results rather than the client's ideas. In addition, the programming team played a good coordination role among multiple stakeholders, including the clients, users and architects, and avoided inconsistent opinions and subjective decisions leading to repeated revisions of the design scheme.

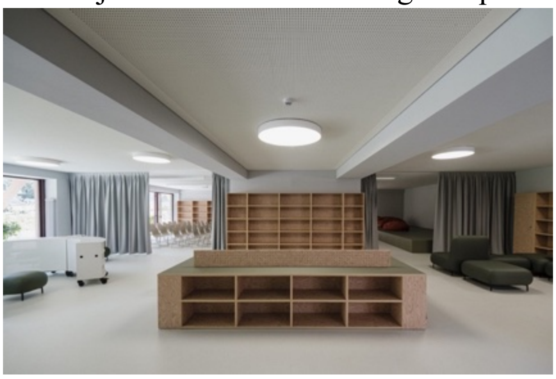


Figure 3.19 Flexible large open space ©Torino Fa Scuola

Figure 3.20 Outdoor terrace with steel structure ©Torino Fa Scuola

3.2.5 Decision-making mechanism in the pre-design phase of renovation projects

The role of the Programmers is always to collect information, analyze conditions and provide suggestions and program to facilitate major stakeholders to make decisions. Due to multiple stakeholders participating in renovation projects, and their various values and benefits, the decision-making process is not easy and inevitably accompanied with many conflicts, negotiation and balance. This section analyzes the decision-making mechanism in the pre-design phase of the four cases, in order to uncover different roles of stakeholders and better cooperation modes for the process of architectural programming.

1) Composition of architectural programming working group

The role of architects: architects always play the key role of architectural programming group. It could be the same architect responsible for both proposals and design, when the project period is short or there is no deliberate programming phase. It could also be separate architects doing the two tasks separately. The architect is the main planner when the project is tight or there is no deliberate planning phase: the owner is an important source of input most of the time, but is sometimes involved in planning as well. Separating programming and design, with a dedicated programming team responsible for pre-design phase, can help the clients clarify design goals and design problems, and negotiate among multiple stakeholders that include public interest in particular. At the same time, this pattern helps architects focus more on proposing solutions to problems and conceptualizing architectural design solutions with a clear problem-oriented proposal, without consuming too much time and energy on multi-stakeholder communication.

Multidisciplinary cooperation: the architectural programming group don't have all the professional knowledge about every function, thus they need to cooperate with experts from different fields. The programming team should preferably have multi-disciplinary experts and scholars, or hire professional consultants, whose role is to study the use patterns and technical conditions, so that 1) the future use patterns can be studied in advance as comprehensive as possible, thus extending the life cycle of the building and maximizing the improvement of renovation; 2) can better front-load the design problems and design conditions, minimizing the probability of confrontation and repeated revisions.

Technological cooperators before programming: there are some technological tasks that could be outsourced and better finished before starting the architectural programming procedure for renovation projects. They include building diagnosis, structure condition analysis, geological, geotechnical and seismic report, energetic pre-audit, etc. The technological reports are important evidence for decision-making of architectural programming group.

Users included: in the case of uncertainty about future use patterns, the programming group should better include representatives of all types of future users, who may or may not be owners. Users can participate in the experiments organized by the core programming staff, or they can express their own ideas about future use patterns. If the future users are also users of the existing space, they can point out problems in the use of the existing space and make suggestions for its renovation.

2) Influence of governmental involvement

Different forms of government participation: the government mainly represents public benefits considering the fiscal balance, participating in the renovation projects from several perspectives, including 1) proposes certain functional requirements, especially for public use; 2) supervise the protection of architectural values through any administration of heritage conservation and reuse; 3) implement policy compensation for renovation through some incentives; 4) approve modification in regional urban programming; 5) involve in the renovation investment.

Pros and cons of governmental involvement: architects of all the four cases admit that government participation would be beneficial to the legitimate review process; to a certain extent, it represents the public interest of the renovation and protects the value of the building itself from being destroyed, thus balancing the economic, social and environmental interests. Disadvantages include the complexity of considering government demands in the functional program; it is still unknown how to deal with government-possessed projects after the negotiated period with temporary operators, and thus existing risks of vacancy or underutilization; the possibility of stricter construction cycle appear often in projects involved the governments, which to a certain extent would probably compress the programming and design phase.

3) Decision power of each role and cooperation modes

The success of projects depends on a close cooperation among multiple stakeholders, which stems from a clear division of responsibilities, and is a guarantee for the success of the project. The government is responsible for supervision, communication and coordination between multiple bureau and agencies, without interfering too much in the detailed analysis of architectural programming and design; the clients, or investors can delegate project leader to manage the project, responsible for target setting, schedule and cost control, and should better give sufficient trust to the architectural programming team and professional experts. The original users, residents in the community can also participate in the whole architectural programming process, whose opinions should be fully respected by the programmers, and be one of foundations for finding problems, identifying requirements and improving the building performance.

Taking Enrico Fermi School as an example, the municipality, the investor, the school board, the programming team, representatives of students, teachers and parents, the architect and the community are all involved in the different stages of decision-making.

The government is the commissioning party, supervising the process by the municipal educational bureau and construction department, and the national-level agencies are responsible for coordinating between the various levels and sectors[12] without interfering too much in the architectural programming and design of the project. The two foundations are the investors in the project, with the Agnelli Foundation being responsible for the overall management of the project, hiring and assembling the programming team, the technical consultants, etc., and giving them sufficient trust and rights in working process(Torino Fa Scuola, 2016a). The principal and the school board, as well as a working group of students, parents and staff, were involved in the planning process. The planning team worked closely with the task force to draft the renovation proposal; the investor organized a design competition and the winner was selected as the architect (Aimo, 2017). The project fully respects the needs and opinions of users and actively engages the public. The planning team acted as an information hub for decision making, explored the future needs and renovation potential of the existing buildings based on scientific research methods, coordinated the interests and demands of various parties, and avoided subjective decisions that would have led to repeated revisions of the design (Figure 3.21).

[12] Participating institutions at the national level include the Piedmont Regional Education Office (l'Ufficio Scolastico Regionale), which is part of the Ministry of Education and is responsible for coordinating school instruction, providing training, etc.; and the Struttura di Missione, previously established by decree of the Prime Minister to promote the renovation of educational buildings, which is responsible for coordinating between the various departments and other public institutions involved in renovation work. This body is responsible for coordinating between the various departments and other public institutions involved in the renovation work.

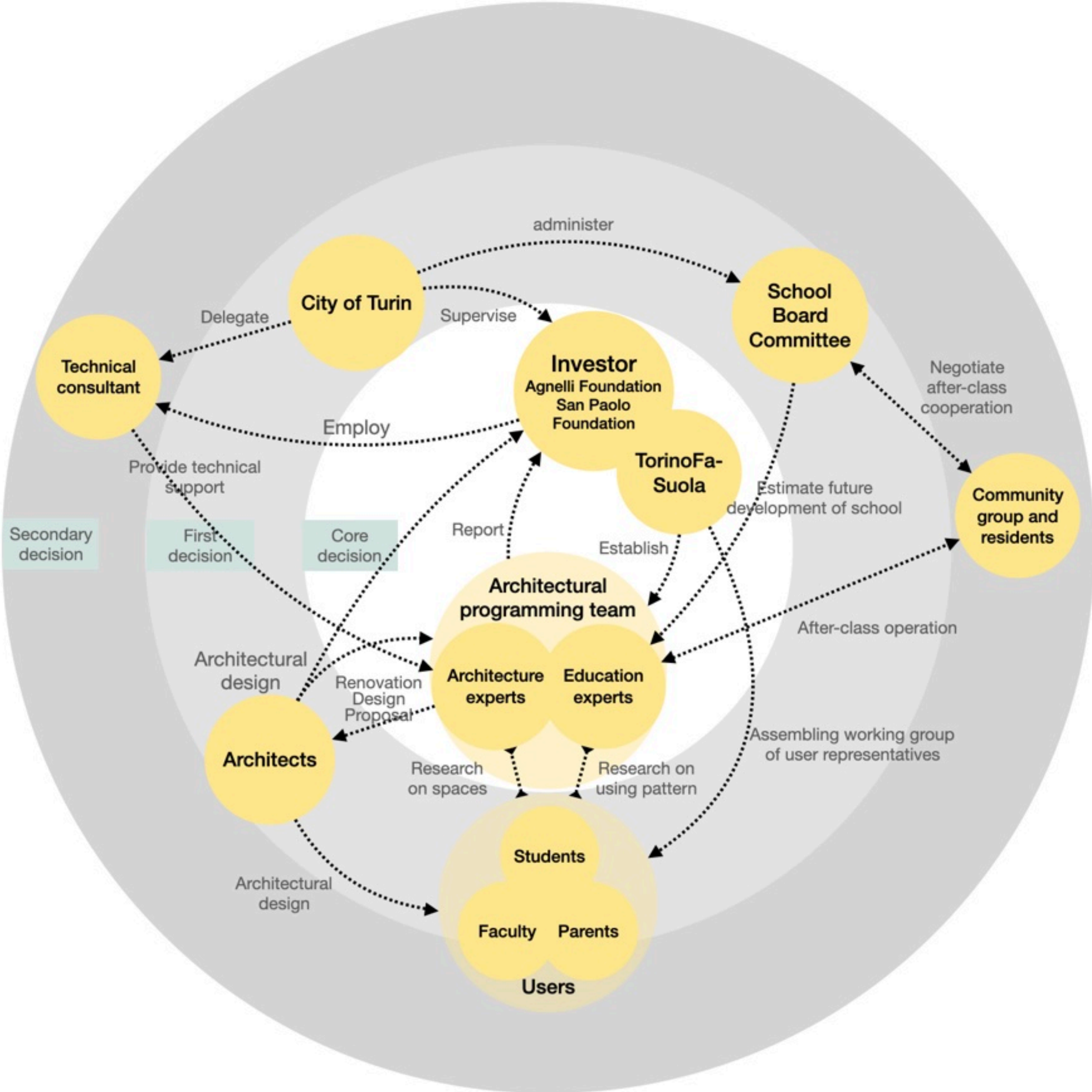


Figure 3.21 Multi-stakeholders mapping of Enrico Fermi School

3.3 Discussion: how architectural programming influence the renovation design?

The previous section discusses the process and contents of the pre-design phases, and this section will analyze the influence of architectural programming on the design and discuss the significant role it plays in the design outcome. We will analyze the influence from three perspectives regarding architectural design: planning and urban design, architectural design, and interior and landscape design.

3.3.1 Planning and urban design

New construction projects usually have clarified initiation conditions including urban planning and urban design for the target site. On the contrary, those for renovation projects are uncertain sometimes and require programmers to conduct researches and facilitate clients to reset these initiation conditions to be approved by the municipal urban planning bureau. In detail, architectural programming can affect the urban issues from two aspects: the first one is to propose the land use transformation and function orientation of the site; the second one is to modify the site plan of the existing building to be adapted to the present surrounding environment and reconnect the existing building with adjacent building as well as urban spaces.

1) Proposal of the land use transformation and function orientation of the site

In Eataly Lingotto project, the first owner did not rush to decide the new function for the building, but first asked the architect to explore the feasibility of the renovation based on the building's history, spatial characteristics and urban environment. After defining the concept of "food and wine" and the function of the complex as a public service, the architects proposed a function orientation for the factory and adjacent sites with transformation of the land use in the early pre-design phase based on the general concept and the value of each part (Figure 3.22). The vermouth factory is oriented to be a theme park of food and wine, with a new developed commercial complex on the western site adjacent to the factory. The other plot to the north side of the factory, the Pastificio Italiano, a 4-storey white frame building that was bought by the Carpano company as a pasta factory, is attended to be a hotel considering the upcoming 2006 Turin Winter Olympic Games whose venue locates nearby across from the railways. The Broni site on the north side was designed to be a residential building.

The municipalities approved the changes to the master plan as a urban renewal district and gave some guidelines for the use as Eataly, including: 1) the building should be open to the public and provide adequate public services; 2) the characteristics of the factory should be preserved; 3) there should be a museum to present the history of the Carpano vermouth; 4) there should be a multi-functional hall for events and meetings for public use. This new master plan for the sites was approved to be a huge success afterwards. Eataly resulted in a most popular restaurant and commercial building in the district; The Pastificio Italiano was later bought by the international Spanish hotel brand AC Hotel and converted into a hotel, and the Broni site later sold for a good-quality residential development. All the outcomes prove that the architects' judgment in the pre-design phase was appropriate and rational.

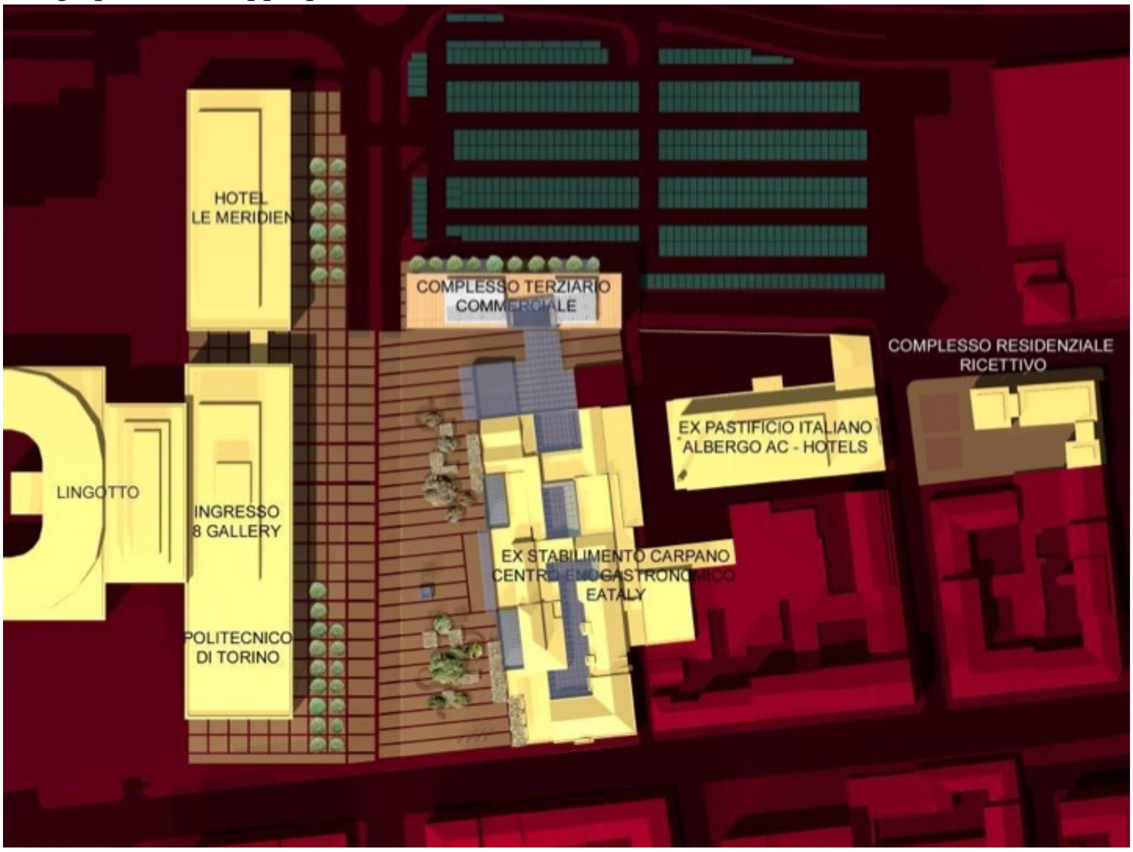


Figure 3.22 Function orientation for the site proposed by architects © Negozio Blu Architetti Associati

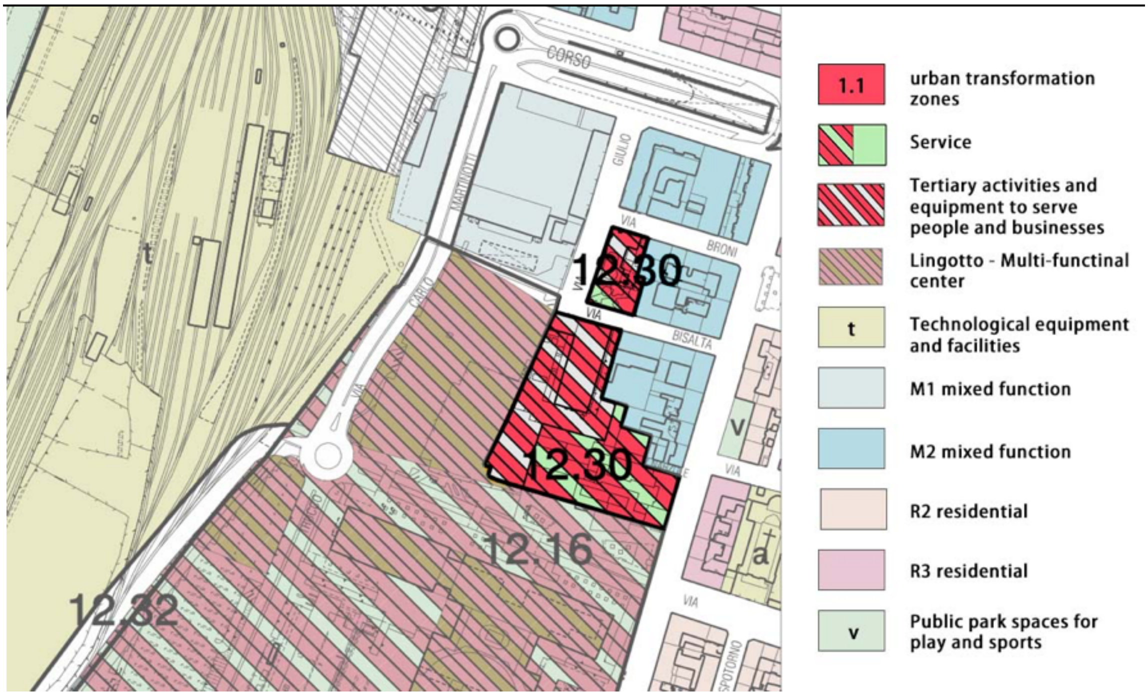


Figure 3.23 Urban planning variants to the municipal master plan (From City of Turin, translated by author)

2) Modifications of the site plan of the existing building

Apart from the function orientation proposed by architects in Eataly Lingotto project, they also redesigned the site plan including the entrance to the building, the main facade, and the adjacent outdoor spaces, parking lot, etc. The original entrance to the factory was located on the Via Nizza on the east side, which is relatively small and not historically significant; the north side of the factory was adjacent to other buildings, and the west and south sides were parking lots facing respectively the railroad and the Lingotto Fiat. If we look at the building itself, it would be wise to position the entrance facing the city road. However, considering that the renovated Lingotto attracted a large number of people and the parking lot between the two buildings was too negative (Colombino and Vanolo, 2017), the architects suggested changing the entrance to face the south side of the Lingotto to attract citizens; the public space between the two buildings becomes a friendly and open plaza, activating the urban interface and improving the quality of the overall environment, so that the two buildings and the surrounding area could achieve a win-win results (Figure 3.24).

Figure 3.24 Entrance and public space of Eataly Lingotto

Left: before renovation © Negozio Blu Architetti Associati; Right: after renovation (photo by author)

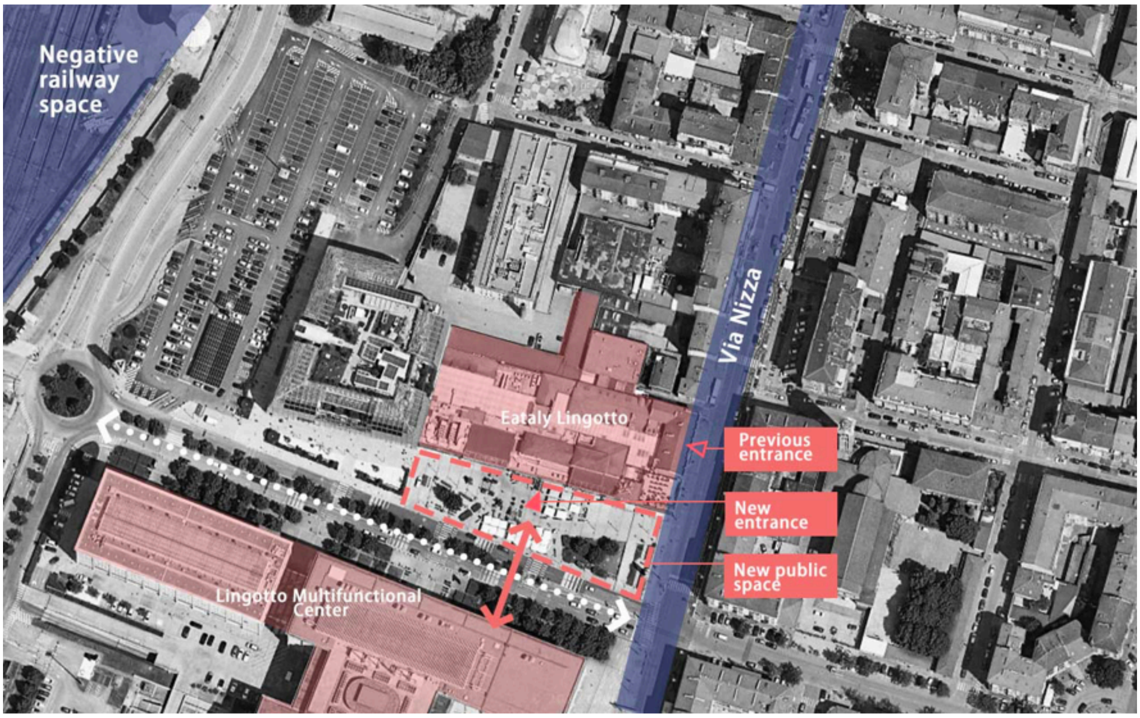


Figure 3.25 Modifications of the site plan of Eataly Lingotto

3.3.2 Architectural design

Architectural programming is to define the problem, and architectural design is to solve the problem, which is the relationship between analysis and synthesis, and requires abstract and concrete thinking respectively (William M. Peña, 2012). Architectural programming can affect the architectural design from many aspects. Here in renovation projects, three prominent tasks or influence of architectural programming on architectural design are analyzed as follows.

1) Analyze the building value and predict demolition and retainment

As for Eataly Lingotto project, In the first phase, the architects analyzed information of the interior spaces and found that the they were different and complex due to the superimposed effect of various historical periods, and had a uniform industrial atmosphere, which was very different from the homogeneous, uniform and self-contained spaces of the Lingotto factory to the south. The architects wanted to preserve the characteristics of the existing building, so they analyzed the value and condition of each part individually, and clearly marked the tendency of demolition and retainment, as well as the possible addition parts, not only for a certain building space, but also for the roof, façade and other architectural elements and components on the plan, elevation and photos (Figure 3.26 and Figure 3.27). For example, the roof of the west courtyard marked yellow was recommended for demolition; the façade with the iconic yellow columns and red brick walls of the Carpano factory, as well as the wine tanks, were marked green and recommended for retainment.

Figure 3.26 Plan analysis draft in Eataly © Negozio Blu Architetti Associati

Figure 3.27 Analysis draft of retained elements in Eataly © Negozio Blu Architetti Associati

Besides, the southwest corner in the existing building was partially destroyed by a bomb in 1943 during World War II and rebuilt in the 1950s in a slightly different style. The architects recommended demolishing this portion of the building in consideration of the access of large machinery for later construction. This judgment prepared for the government's later request to input a conference hall and an exhibition hall, and the architects placed two transparent boxes facing the public plaza on the south side on the basis of the demolition, expressing both the scale and nature of the functions and the difference between the old and new parts in the elevation.

2) Enhance function program and adjust spatial pattern

The spatial conception of new construction projects usually involves analyzing the flows, layouts, and deciding the contents of each space according to the requirements and external conditions(庄惟敏, 2016 [105]). Renovation projects are different, with a plan layout based on the existing spatial order and the new requirements. Eataly, as the investor and operator, wanted to have a main thematic space that accommodated the functions of selling and dining, but its experience was limited to the large flat homogeneous spaces that are efficiently organized in traditional supermarkets. The architects found the existing spaces were seemingly fragmented but with an inherent order. It was an opportunity to provide a diverse thematic food and beverage experience that would distinguish the brand from other retail spaces. The strategy was to link two courtyards to create a main street, with a glass roof that connected the various functions on both sides; the main street space is arranged with a number of "islands" of different food ingredients to create a special market space (Figure 3.28). Besides, a central, south-facing brewing hall with seven cylindrical tanks of 5-to-9-meter height for the production of vermouth is with high historic value, and thus is transformed to be the lobby of the retail space, in order to attract customers and impress them from the entrance. This concept guided the subsequent architectural and interior design, and the main street became a thematic space for the Eataly brand, attracting a large number of customers.

Figure 3.28 Ground floor plan of Eataly Lingotto

3) Verify the feasibility of new functions to the existing spaces

Renovation projects with target functions may have difficult requirements to satisfy considering the existing spaces. Therefore, programmers and architects should first verify the feasibility of new functions, which is to identify suitable spaces to contain the new requirements. In Pingyao Film Palace project, due to the requirement of holding an international film festival, the renovation projects must include a 1500-seat theater, a 250 to 500-seat cinema hall and several video halls. It should be verified the feasibility to contain all of these functions on site in the pre-design phase, otherwise architects would do a lot of drawings in the schematic design to test potential solutions, which would waste much time and many resources. This process will be introduced in the chapter 6.

Besides, the architectural programming can also predict potential problems and difficulties faced in design phase, which is especially important to the renovation projects. Since renovation projects should deal with the deficiency of the building codes of different ages and the conflicts between the update requirements and outdated spaces, programmers should indicate the legal norms, codes, standard and so on from the first beginning, and predict the possible solutions of design phase. In Enrico Fermi school project, the programming team collect and organize all the relative norms and standards involving procedure rules of construction, construction standards, demolishment standards, acoustics, energy, fire safety, structure, seismic risks, etc(Torino Fa Scuola, 2016c).

3.3.3 Interior and landscape design

Interior and landscape design sometimes are not main tasks of architects in common construction projects. But in renovation projects, architects should integrate them with renovation design, in order to reconnect the building outside and inside. And the best way to implement an integrative strategy is to define the problem and provide solutions in architectural programming in the pre-design phase.

1) Interior design

At the level of interior design, the architects continued to follow the concept of preserving the characteristics of the building, combining them and requirements of different agricultural products, and creating the atmosphere of each thematic space with human scale design and new furniture. For example, the stalls in the main street space were built with iron, wood and tents in the iconic red, yellow and white colors of the Carpano factory to create a bazaar atmosphere; wood was used to decorate the bread and pizza space, marble was used to decorate the fish and meat space, and white wooden shelves were a symbol of the old-time grocery store (Figure 3.29 and Figure 3.30). In addition, the integrated design of the architecture and the interior facilitated the architects to reconcile the contradictions between different spaces of the existing building and the multiple norms of commercial, restaurant and office.

In Enrico Fermi school project, the programming team distributes questionnaire among students and interview them to investigate the preference of the interior style. The results find that students prefer low-saturation interior colors such as beige and gray-green over bright color, which are usually used in educational buildings. As seen in the Figure 3.31 and Figure 3.32, architects finally choose these colors instead of bright colors of stereotypes, creating an atmosphere of comfort and nature.

Figure 3.29 Interior of Eataly

Figure 3.30 Stalls in the main street space of Eataly

Figure 3.31 Multi-function spaces ©Simone Bossi

Figure 3.32 Corridor space © Torino Fa Scuola

2) Landscape design

Landscape design of the renovation usually has close relationship with the urban spaces, and can regenerate the site from a larger scope. In Eataly, the urban pedestrian plaza on the south side had an area of 3,080 m2. The architects wanted to create places for people to stay and read in the open outdoor space, continuing the concept of indoor islands, and adding two outdoor resting islands with paving, benches and shrubs to define the boundary and separate them from the plaza. The paving of the plaza is designed as a continuous concrete strip perpendicular to the Eataly and Lingotto to emphasize the connection and access between the two buildings (Figure 3.34).

In the School of Future Design of BNU, the north part of existing buildings has a huge difference of ground level with the road crossing site, which is a negative space on site that should be coped with from the beginning (Figure 3.35). Architects in the pre-design phase has identified a strategy to transform the negative spaces to an active public space with limited intervention on the terrain. The final design result uses triangular vegetation terraces along the road to accommodate to different activities and to connect both sides of the road (Figure 3.36).

Figure 3.33 Plaza outside Eataly © Negozio Blu Architetti

Figure 3.34 Paving of plaza outside Eataly © Negozio Blu Architetti

Figure 3.35 Difference of ground level in School of Future Design of BNU ©THAD

Figure 3.36 Landscape strategy of School of Future Design of BNU ©THAD

The text above introduce the role of architectural programming plays in the project design from three perspectives. But the essential role of architectural programming is always to identify the problems for design to fine solutions. We take Enrico Fermi school project as a conclusion for this section since it is the only one project with separate architectural programming and design phase, and also different programmers and architects. Here, architectural programming has a strong binding effect on the design, and the design task statement is straight to the point of the problem, and the functional area is reasonably allocated, so the architect can quickly capture the problem, and the design scheme has a high degree of adaptation to the needs of the owner and users, and the scheme is less modified after winning the bid. The architects can quickly capture the problem, and the design is more suitable to the needs of the owners and users[13]. This also avoids the phenomenon that the owner and architects repeatedly revised the programming later due to unclear and unreasonable requirements in the early stage, which wasted a lot of time and human resources. Figure 3.37 shows the gradual deepening process between the architectural programming results and the final design proposal from four aspects: urban interface, functional program, building entity, and outdoor landscape, which illustrates that the final answer to the real problems can be found only through a scientific and reasonable method and progressive research from factual analysis, problem definition, programming concept to comprehensive problem-solving strategy.

[13] Refer to the author’s interview with the leading architect - Simona Della Rocca on January 8,2021.

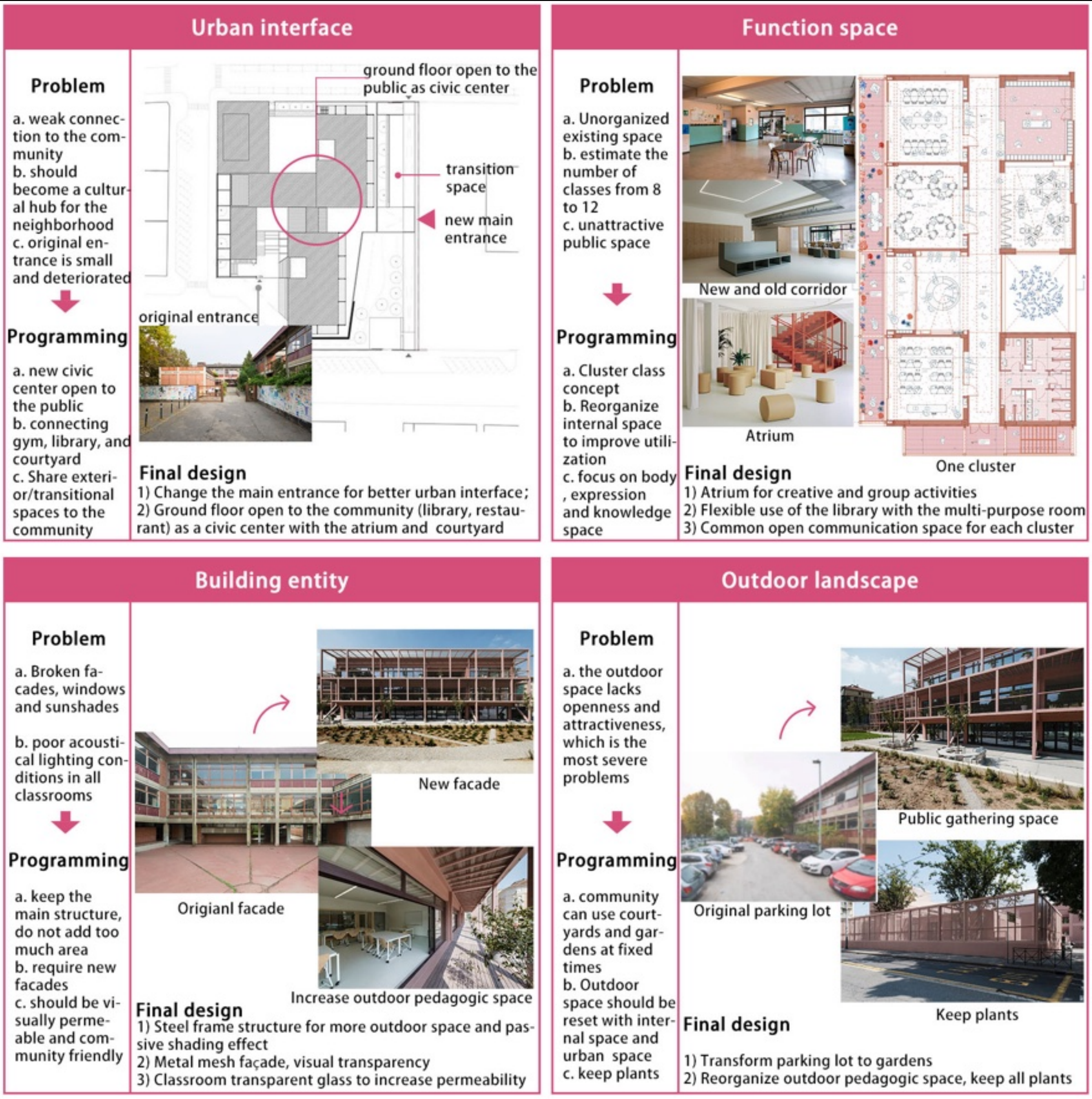


Figure 3.37 Analysis of the engagement of renovation architectural programming with the final design

3.4 Generation of architectural programming process for existing building renovation

This section is intended to propose a universal framework of architectural programming procedures for renovation of existing buildings, based on previous research from both theoretical and practical perspectives. The framework includes 5 steps, which include setting goals and establishing the programming team, collecting information, identifying function and conceiving program, pre-evaluating the architectural program, and finally generating the design proposal. After that, it clarifies the focus of this research among the process, which will be developed further in the following chapters. At last, this section discusses the relationship of the architectural programming process in renovation projects with the architect responsibility system that are implemented in China nowadays.

3.4.1 Proposal of architectural programming process for existing building renovation

1) Goal setting and programming team establishment

Setting a rational and clear goal is the basis for subsequent programming steps. The goal indicates the owner's intention to renovate and can inspire the architect's design. Objectives are derived from the starting point of the renovation, the owner's values, etc. The goal setting in architectural programming of new construction building is on the basis of definite initiation conditions with certain function orientation, while renovation projects, especially those with functional transformation, may not have clear orientation or function programs, so it is necessary to first clarify the nature of the project, the organization of decision makers, the basic conditions, and so on.

The main tasks in this phase include 1) establishing an architectural programming team, 2) identifying values in this project, 3) clarifying different responsibilities of decision makers, and finally, 4) setting main goals of the project. Clients can first delegate the leader of the architectural programming team and invite relevant experts of different professions. The composition of the programming team has a significant impact on the programming outcome. Currently, due to the lack of clear payment regulations and relevant norms and standards, the service of architectural programming is mostly provided by architects of the design phase, which results in some blending and overlapping of the programming and design processes. However, the Enrico Fermi school project proves that the separation of architectural programming and design, and an interdisciplinary team of programming play significant the role in the success of the project.

After delegating the programming team, programmers then can identify the organization structure of the client, all of stakeholders and different responsibility of each decision maker. Next, programmers should identify the values of clients and other significant stakeholders, and facilitate decision makers to select the most important goals of the projects. The goals can be to improve business conditions, performance enhancement, energy-saving renovation, etc., and to initially clarify building costs, construction methods, etc., to provide a basis for the subsequent steps. Different from new construction projects, it can be necessary for the architectural programming of renovation projects to include representatives of the original users of the existing building into the programming team in certain cases. The programmers thus could better identify problems and define requirements.

2) Information collection

Information, or facts include site conditions, social and human conditions, market conditions, and the building's relevance to the urban environment. Unlike new construction projects, information gathering for renovation projects focuses on the assessment of the current condition of existing buildings, or building diagnosis. The building diagnosis includes assessment of the aging condition of the building, value assessment, original user satisfaction survey, assessment of the building's energy consumption, and verification of the building and its site against existing codes. The renovation programming with the main goal of improving economic efficiency also involves operational diagnosis (Matsumura, 2019). In addition, renewal and renovation projects are often closely related to urban planning such as urban renewal and preservation demands of historic district. In recent years, more and more researches and practices are studying the renewal and renovation strategies of existing buildings from the city, with theoretical bases including urban catalyst theory, scene city theory, and historic urban landscape theory (Davis, 2009 ;Pezzetti, 2019). Therefore, in addition to the information on the current situation of existing buildings, it is also necessary to collect urban information and conduct urban condition analysis to understand the location of buildings in the built environment and their connections.

3) Function identification and program conception

In traditional process of architectural programming for common projects, after collecting relevant information, programmers should analyze the data and conceive a preliminary programming concept, including the strategies for spatial pattern and organization, financial scheme, technical scheme and so on. However, in renovation projects without definite initiation conditions and function orientation, there is an additional step which should be conducted before programming conception, that is function identification research for function-transformation renovation projects. The function identification should consider both limited conditions and multi-valued goals to make a comprehensive decision. It not only involves architectural design, but also land use and building type regarding urban planning.

Apart from function transforming project, many of renovation projects could remain the original function, but enhance the functional program to satisfy the updated requirements. Identifying using requirement and future user pattern requires corporation of programmers with future users or operators, and even the consultancy of interdisciplinary experts. The programming team can also invite interdisciplinary experts to join the team according to different building typologies to make the building brief more scientific and feasible.

After the analysis of the previous stages, the owner's objectives and needs are further clarified, such as function-space relationships, building plan efficiency, building quality, capital budget and construction period. The programming team should balance all the requirements and limitations among the potential programs, and draft a basic function program for conceiving and developing the whole program for renovation projects considering perspectives of finance, technologies, spatial organization and so on.

4) Pre-evaluation of architectural program

The pre-evaluation is a step to assess and refine the program before generating the final design proposal (梁思思, 2006 [24];Peña, 2012 [256]). In the traditional construction projects, it involves verification of all the regulations, budgets, technical feasibility, etc. However, due to the existing building in renovation project, there is an additional and significant step to evaluate the **suitability of the function program with the existing spaces** to test the feasibility of the program.

The suitability evaluation in pre-evaluation is to study the feasibility of potential new building functions and new spatial pattern, after drafting the new function program and before generating final design proposal. The purpose is to fully assess the renovation potential of existing buildings, and to modify and improve the program. Kumlin pointed out that the architectural programming of renewal projects should analyze the possibility of later use and prompt all disciplines to agree on the design and technology, including such issues as total area, structural load capacity, compliance of new functions with codes, and new traffic flow organization (Kumlin, 1995). Especially in projects with complex conditions such as the renovation of historical buildings and the need for comprehensive consideration of multidimensional values, the pre-valuation is conducive to fully recognize and respect the historical characteristic elements of the building and conducting compatibility tests compared to the owner's renovation goals in order to clarify the most appropriate use functions, scale, spatial patterns, etc. (Pyburn, 2017).

5) Design proposal generation and optimization

After testing the suitability and feasibility of the program, programmers can generate the design proposal and write reports. In the design proposal, programmers should state the main goal and value of the project, the conditions of site and existing buildings, the major problems that should be solved by design, the function program that should be satisfied for the most part, the flexibility, the limitations and conditions including energy, structure, soil and seismic conditions, budget and technical requirements, norms and building codes, and so forth. Specifically, the functional program should point out the floor area and design requirements of each room in each functional zone, including the usage pattern, performance requirement, characteristics, connection with other spaces, equipment requirements. In particular, renovation programming should clarify the range of flexibility of each room's floor area based on the previous feasibility study.

Programmers can also provide some programming concepts and strategies to guide the design. It should be clear that the programming concept is different from the design concept in that the programming concept is abstractly instructed, while the design concept is a concrete formal operation (William M. Peña, 2012). The programming concept and design concept are also different, as the programming concept is the abstract logic of functional space, morphogenetic logic, etc., while the design concept is implemented into the concrete generation of shape and space, and the use of materials. The programming concept includes spatial, economic and technical concepts, and the implementation process needs to consider the economic, technical and time programming characteristics of the renewal and renovation project different from the new project.

In addition, the design proposal is not always the final version that cannot be modified at all. An elaborated design proposal could ensure a problem-oriented design, while it would never be perfect to forecast all the problems and requirements. Therefore, optimization of the program and design proposal play a significant role in the whole working process. It would enhance the understanding of different stakeholders and users, and improve the final design at the same time. It is recognized that the architectural programming process is for the pre-design phase and provides clarified problems for the schematic design. In fact, architectural programming can provide continuous information for both schematic and design development phases. The aim of the second phase of programming is to evaluate and optimize the functional program in the design proposal, according to the feedbacks of architects or future users on the initial proposal. This process may be carried out simultaneously with the architect's schematic design, in the form of joint meeting, experiments in the existing building, and so forth.

3.4.2 Comparison of traditional and proposed architectural programming process

The previous section proposes the process and framework of architectural programming in renovation projects. This research attempts to improve the traditional architectural programming framework for renovation projects, rather than establish a new framework or process. The improved framework supplements three parts and replenishes new contents, in order to provide guidelines for renovation projects. Therefore, the research will not study each step, but focus on these three missing parts in traditional framework as below, which will be presented in detail in Chapter 4, 5 and 6.

Figure 3.38 compares the traditional and proposed architectural programming processes. The difference exists in three steps: information collection, program conception, and program evaluation. Figure 3.39 further presents the detailed framework and process of architectural programming for renovation projects throughout the project cycle. This research focuses on these three different steps and is intended to refine or supplement the traditional process with new contents and methods, including renovation information collection, function identification and suitability evaluation of function and spaces, which will be introduced in detail in Chapter 4, 5 and 6.

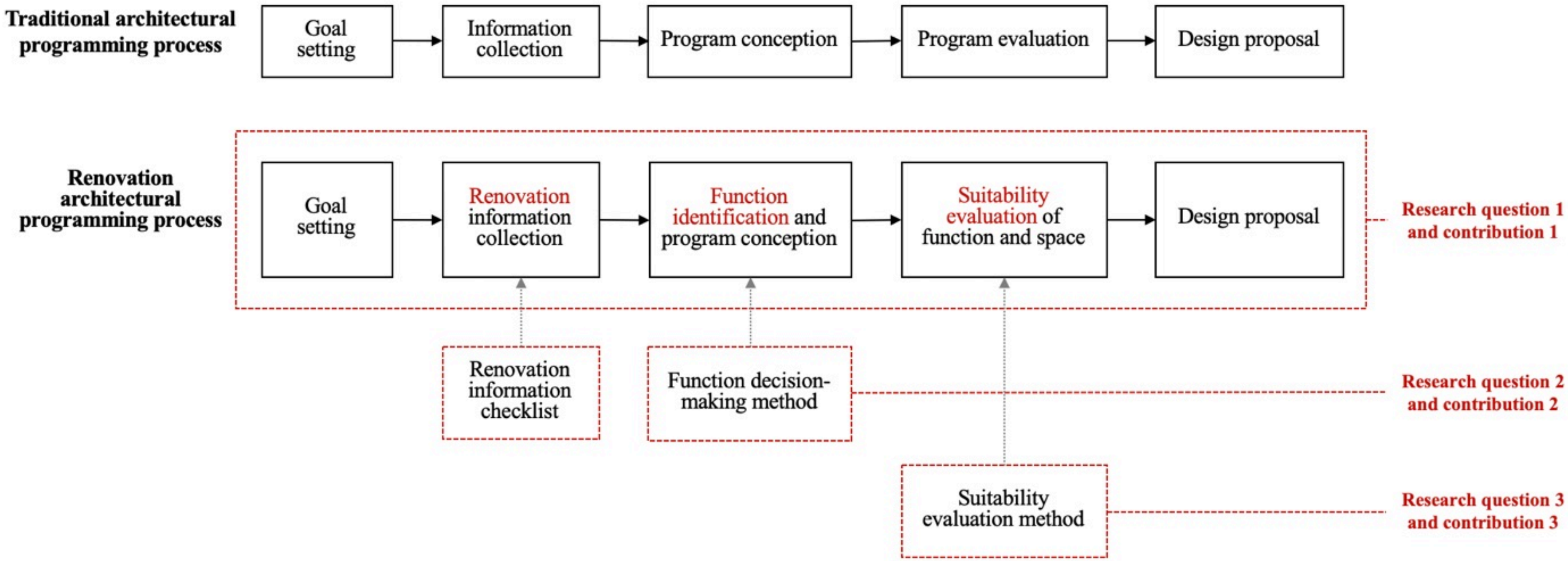


Figure 3.38 Comparison of processes of traditional architectural programming and enhanced renovation architectural programming

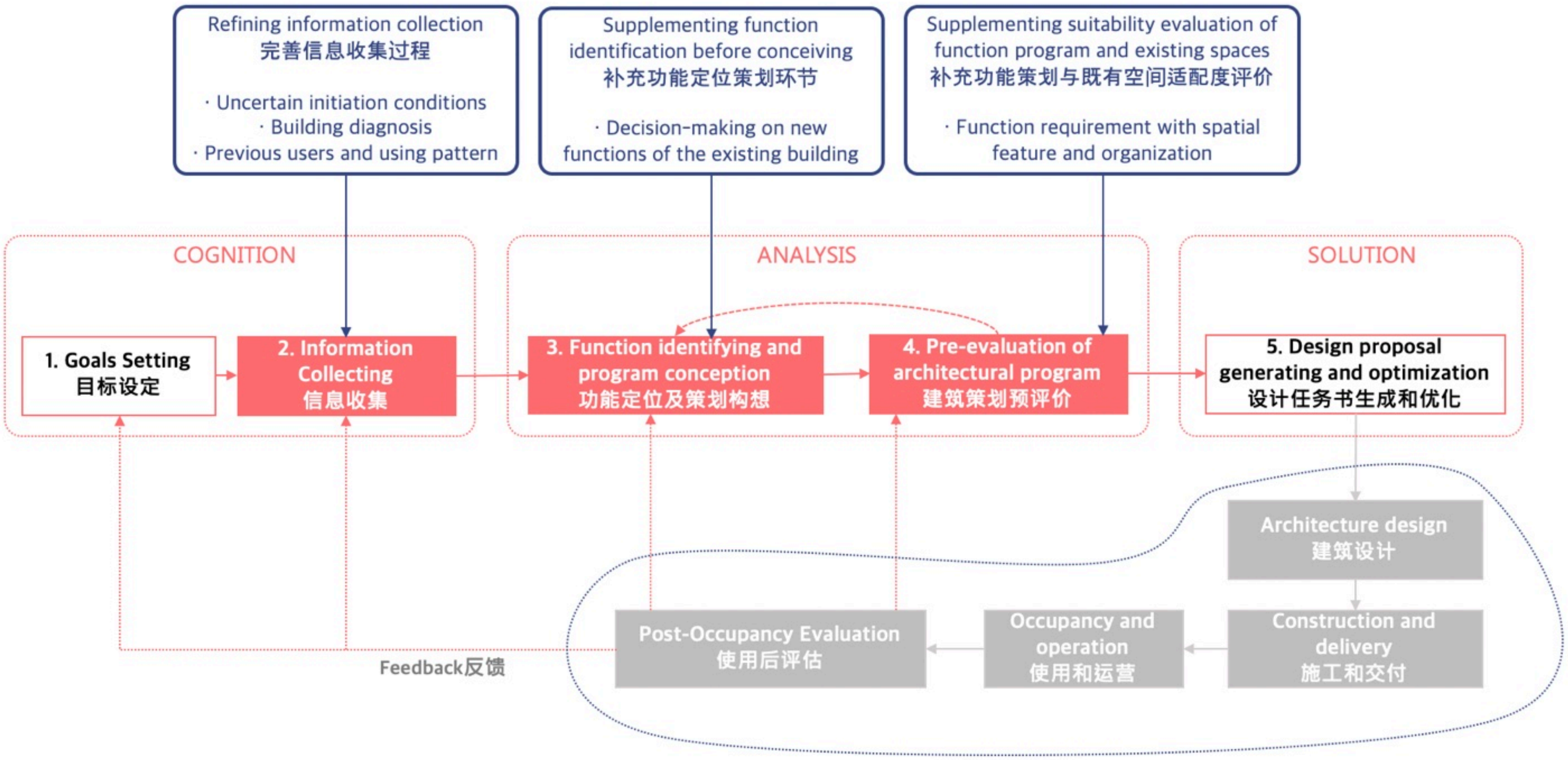


Figure 3.39 Framework of architectural programming in renovation projects and the focus of this research

1) Refining information collection in renovation projects

Information collection is the basis of all the decisions and conception. In renovation projects, the urban planning and project initiation conditions are always undetermined, with much complexity and more limitations. Besides, the existing building is a significant part which is not considered in new construction projects. The diagnosis of existing building and surrounding environment is the cornerstone of all the programs and decision-making process. The experience and advice from previous users should also be considered for enhancing the building performance which occur hardly in new construction projects.

In Enrico Fermi school project, programmers collect various kinds of information from the first beginning including building diagnosis, user experience, future estimation of the community, similar cases and so on. They investigate the previous using experience and explore the update and even future using patterns. Architects and educationist study the existing pedagogical pattern, international experience, and conducted experiments with the students and staff. In contrast to the previous idea of arranging classes in close proximity to each other, the school wanted to provide students with a sense of identity and belonging over the three years, and to promote vertical communication and support between the grades. The preliminary research report gives a preliminary idea of the school's functional clusters (Figure 3.40), which became the core concept of the functional program and design brief afterwards.

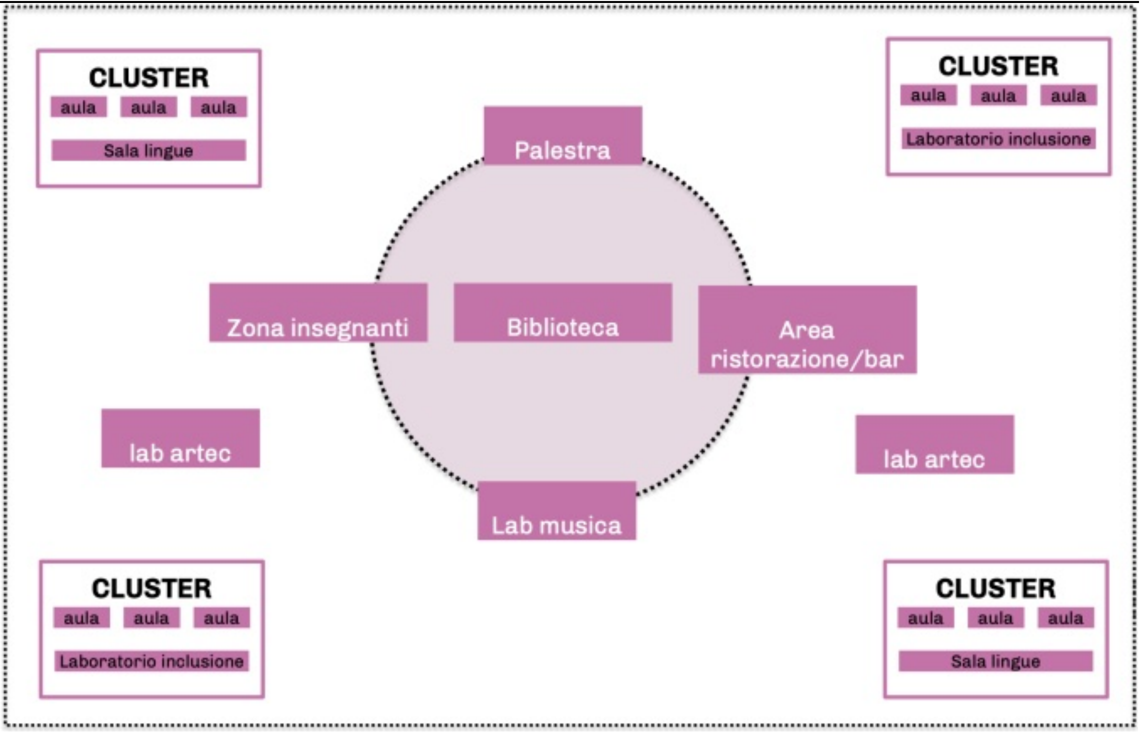


Figure 3.40 Preliminary functional program and usage pattern of Enrico Fermi School (Torino Fa Scuola, 2016b)

2) Supplementing function identification before conceiving program

The function identification with even enhancement is another additional task in the architectural programming of the renovation projects. This step is an exclusive step in renovation projects since new construction projects have definite function orientation in the project initiation and approval. It should consider the orientation in master planning and sectoral planning of urban renewal, as well as the local market, the potential users and customers, and the potential of the existing building itself.

In the example of Eataly Lingotto project, due to change of clients, the municipality does not have a clear idea which function would be best for the existing building (Figure 3.41). At that moment, the architects took the role of programmers, analyzed the existing spaces and the external urban environment, explored the possibility of reusing the building through sketches without a design proposal. At the architectural level, the architects were intended to preserve the spatial character of the building to reflect the forms of industrial architecture at the beginning of the century; at the urban level, they expected the renovation project to enrich the space and image of the city, and to preserve the memory of the city's food industry tradition by using the association of the vermouth with the sense of taste (Figure 3.42). The architects first proposed a function as a museum showcasing the culture of food and wine in the Piedmont region, but also explored a mixed-use building with exhibitions, commercial activities, dining and entertainment, and cultural facilities. However, the core concept of the reuse had been the theme of "food and wine", even if the functions and the design proposal were not defined.

Figure 3.41 Original building of Eataly Lingotto ©Filippo Gallino

Figure 3.42 Carpano vermouth factory in Turin from www.carpano.com

3) Supplementing suitability evaluation of function program and existing space in pre-evaluation

Suitability evaluation of the function program and existing spaces is also a unique step following function identification in renovation projects, which is necessary to test the feasibility of the function program based on the cornerstone of the existing building. The suitability evaluation should assess the rationality and risks of the program, test if the existing spaces have the ability to contain all the functions and if the function organization is matching with the spatial patter.

In Pingyao Film Palace project, programmers first check the suitability of the primary function of a 1500-seat theater with the existing site. The considerations include the technical limitations and requirements of the theater function, as well as the restrictions demanding by the preservation of the historic districts. Figure 3.43 shows the four potential strategies proposed by architects in the pre-design phase. Based on the verification of the feasibility of this site to be capable of holding the functions of a film festival, this project starts to apply for the initiation and approval and begins the design phase afterwards.

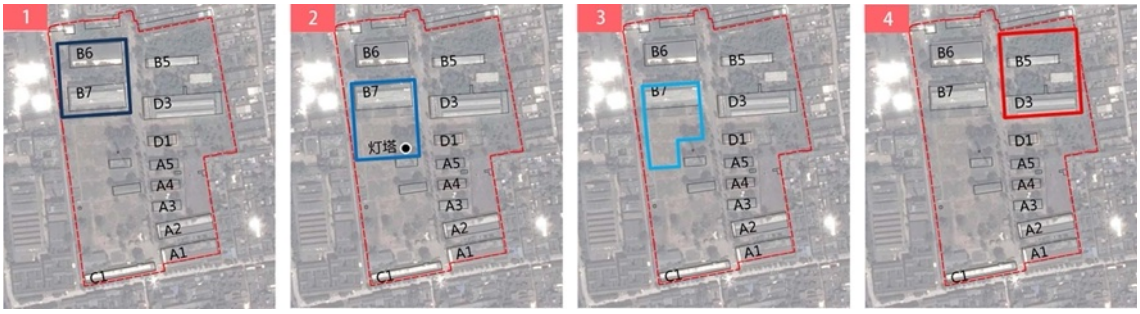


Figure 3.43 Four strategies in suitability evaluation of primary function in Pingyao Film Palace

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3.4.3 Discussion: process with architect responsibility system

On June 8, 2020, the Ministry of Housing and Construction issued a reply letter on agreeing to the pilot architect responsibility system in Beijing; on December 3 of the same year, the Beijing Municipal Commission of Programming and Natural Resources issued the Guidance on the Pilot Architect responsibility System in Beijing (Draft for Comments). This guidance stipulates that the basic services of the architect responsibility system include all or part of the six phases of planning and urban design, programming and consultation, architectural design, bidding and procurement, contract management, operation and maintenance, and other additional services [1]. Among them, architectural design is a traditional architect's business, while urban planning and programming consultation are in the early stage of the project, which is an important phase to connect architectural design and urban planning, to identify objectives and problems, and to clarify requirements, which is the basis of subsequent design. However, most of the existing researches focus on the relationship between responsibility and rights, as well as project management in the architects' responsibility system [2,3], but less on the mode and method of architects' participation in the preliminary programming and consultation. Besides, it lacks reference of practical cases.

Figure 3.44 compares the conventional design process with architect responsibility system processes in both new construction projects and renovation projects. With reference to the scope of services listed in the Beijing architects' responsibility system draft, table 1 compares the services in traditional EPC and Eataly projects. The traditional project process is that the client determines the reuse functions, and give the design proposal to the architects without architectural programming. Besides, due to the lack of consideration for operation, the project would be managed by another operation team after delivery, which results in inappropriate functions and poor management. In this project, the architect's role has been expanded in both time and space dimensions. In terms of time dimension, the architects have been involved from the beginning of the project, and went through architectural programming, design and construction process, and even extended to the post-operation and expansion stage. The direct benefit of this model is that it enables the logical continuation of the project before and after, ensures the consistency of the design concept, and integrates research, design, construction, operation and maintenance, thus saving the time and communication costs arising from team handover or work changes. In the spatial dimension, the architects involved in all levels of urban planning, architecture and interior to consider the regeneration of the building and the surrounding urban environment from macro to micro perspectives. Instead of following the traditional macro to micro logic, the architects start from the existing buildings, then up to the planning and urban design, and down to the landscape and interior design. The urban planning, landscape and interior design will in turn influence the architecture design, forming a circular and interactive relationship between these three levels.

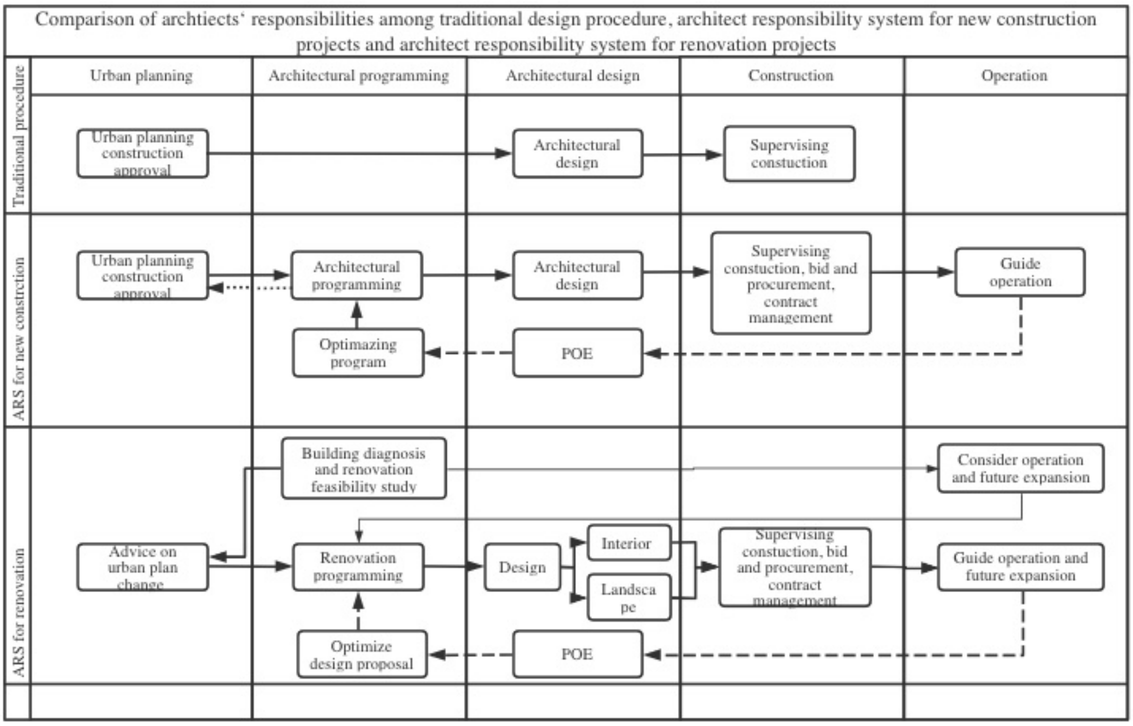

Figure 3.44 traditional design process, responsibility system process of new construction and renovation

1) The architect responsibility system is an important guarantee for the smooth implementation of renovation projects: the success of the Eataly verifies the rationality of the partnership model and the architect's responsibility described above. Even though it is an inadvertent decision, the whole process of consulting services provided by the architect was an important guarantee for the successful result. For such a highly complex and comprehensive project as building renovation, the architect responsibility system and the whole process consulting mode are conducive to fully understanding the value of

existing buildings, scientifically and rationally deciding the reuse functions, and improving the completion of the project.

(2) Architects should provide consulting services based on the architectural programming theory: the whole-process consulting and the architect responsibility system expand the service scope of architects and put forward higher requirements for them; renovation is different from new construction. It is difficult for architects to solve problems from traditional design theories, so they could combine architectural programming theories and methods to identify the design problems, requirements and constraints, to explore the renovation feasibility and potentials, translating them into structure and spaces. To draft the design proposals, architects should consider functional requirements, spatial elements and operation modes, deducting the main concepts to guide the subsequent design and construction.

3) Multiple decision makers such as government, investors, architects and operators should work closely together to consider both building renovation and urban renewal at the same time: the government should conduct sufficient researches with urban planners and architects on the detailed urban planning and design associated with the renovation project to allow for the urban-zone transformation; based on the opinions of planning and architecture experts, make rational decisions on land use transformation, building functions, volume ratio and closely connect with the subsequent architecture design and operation phases, so that new functions can serve communities and cities, improving the quality of public spaces and reviving the existing buildings and urban areas.

3.5 Conclusion

This chapter establishes a holistic framework of renovation programming improved from classic architectural programming process, based on characteristics summarized in the previous chapter, with both theoretical and practical researches on the pre-design phase of renovation projects.

The conclusions in this chapter are as below:

1) **Comparative research on functional renovation cases in Italy and China**. Based on the joint PhD program of Italy and China, the research conducts deep comparative analysis on four functional renovation cases in the two countries. It studies the process of architectural programming, and decision-making mechanism in these four

cases, and then discusses the effect of architectural programming on the design outcomes from three aspects. All of the four cases verify the significant role which architectural programming plays in the whole project cycle to facilitate decision and guide design under multiple values, stakeholders and many restrictions.

2) **Structure the architectural programming framework in existing building renovation**. Traditional process of architectural programming consists of five steps as goal setting, information collection, program conception, program evaluation and generation of the design proposal. Through literature review and practices in Italy and China, as well as distinguishing features of architectural programming in the last chapter, it proposes a framework of architectural programming in existing building renovation, which extends the universal architectural programming theory into renovation projects.

3) **Identify three supplements to be studied in the framework of renovation programming**. This chapter identifies renovation information collection, function identification and suitability evaluation of function and space as three issues to be supplemented respectively to three steps of the universal architectural programing framework, which are information collection, program conception and program evaluation. The architectural programing framework for new construction projects lack discussion on these three issues, which are studied in the next three chapters.

This chapter presents not only the structure of the architectural programming framework for renovation, but also the organization of rest parts of the thesis. The enhanced architectural programming framework facilitates to achieve a scientific and rational pre-design phase in renovation projects.

CHAPTER 4 Information collection in renovation projects

The previous chapter examined the architectural programming process for the renovation of existing buildings and identified three major deficiencies of traditional architectural programming for universal new construction projects in dealing with the renovation projects. This chapter will address the first one, the information gathering process of architectural programming for renovation projects.

This chapter first reviews the information collection in existing architectural programming theories. Next, it analyzes the characteristics of information gathering in renovation projects and establish a framework for this collection following three scale of physical space: urban, building, and user. In the section of each scale, it further classifies the information into 3 categories to analyze the necessary and general information and facts that influence the architectural programming of renovation projects. At last, it introduces a case study underway from the perspective of information gathering and how it influences the decision-making among multiple stakeholders.

This chapter will answer the following questions:

1) What are the characteristics of information collection in renovation projects?

2) What information should be collected in the renovation projects of urban existing buildings and the checklist?

3) How do programmers organize the large amount of information and is there any priority of information that influence the decision-making afterwards?

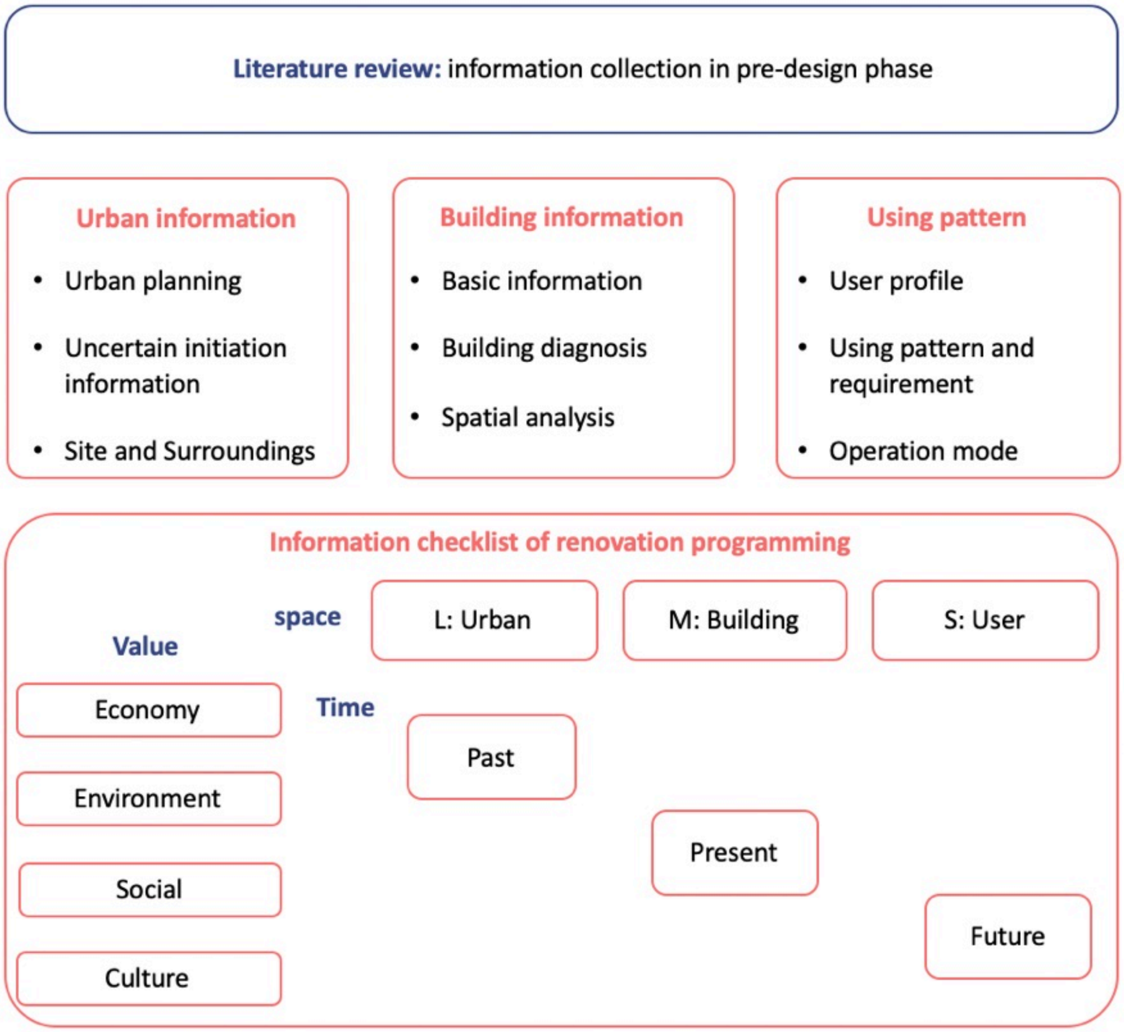

Figure 4.1 Framework of Chapter 4

4.1 Literature review: information collection

Information, "is processed, organized and structured data. It provides context for data and enables decision making process"(2021). There are several principles in information collecting and management that can be applied to many kinds of fields. One of the most well-known principle in optimum arrangement of information is the MECE principle, to collect information mutually exclusive and collectively exhaustive.

Essentially, architectural programming is a decision-making process, and its theory is based on the framework of collecting and analyzing information, and making decisions, whose many aspects receive the influence of information management and decision-making theory.

To collect information carefully and effectively can decrease the uncertainty of the problem or circumstance, and thus achieve to a rational process for decision-making (Citroen, 2011). In architectural programming theories, information is also called as facts or data by some theorist and researchers, which can be the cornerstone of the architectural programming. Information in architectural programming theory indicates the objective conditions and status quo that are related to the subject of the project and point to clear design issues, etc. Since one construction project involves various kinds of information and knowledge, it is significant to provide a relatively comprehensive checklist for programmers, architects, clients to collect information before making rational decisions. Research on information collection in the pre-design phase can be beneficial to avoid omission of key information leading to wrong decisions.

This section reviews three aspects of information gathering in architectural programming theory based on literature review： kinds of information, sources of information, and limitations of existing research adapted for renovation project.

4.1.1 Information collection in traditional architectural programming

A scientific and rational classification of information collection is the basis for information management. Researchers of architectural programming have provided several frames and checklists of information collection from different logics and perspectives as reviewed below.

• **By architectural dimensions**: Peña proposes a framework to analyze problems from 4 perspectives: function, form, economy and time and classifies all the factors into this four aspects which will be used as design considerations afterwards(William M. Peña, 2012 [18]). The information index matrix takes the 4 elements as the vertical axis, while put 5 steps of architectural programming on the horizontal axis, which are goals, facts, concepts, needs and problem. All the information thus is classified into these 20 grids (Figure 4.2).

	Goals	Facts	Concepts	Needs	Problem
Function People Activities Relationships	Mission Maximum Number Individual Identity Interaction/Privacy Hierarchy of Values Prime Activities Security Progression Segregation Encounters Transportation/Parking Efficiency Priority of Relationships	Statistical Data Area Parameters Personnel Forecasts User Characteristics Community Characteristics Organizational Structure Value of Potential Loss Time-Motion Studies Traffic Analysis Behavioral Patterns Space Adequacy Type/Intensity Physically Challenged Guidelines	Service Grouping People Grouping Activity Grouping Priority Hierarchy Security Controls Sequential Flow Separated Flow Mixed Flow Functional Relationships Communications	Area Requirements by organization by space type by time by location Parking Requirements Outdoor Space Requirements Functional Alternatives	Unique and important performance requirements that will shape building design
Form Site Environment Quality	Bias on Site Elements Environmental Response Efficient Land Use Community Relations Community and Ecosystem Improvements Physical Comfort Life Safety Social/Psychological Environments Individuality Wayfinding Projected Image Client Expectations Sustainability	Site Analysis Soils Analysis FAR and GAC Climate Analysis Code Survey Surroundings Psychological Implications Point of Reference/Entry Cost/Square Feet Building or Layout Efficiency Equipment Costs Area per Unit Sustainability Analysis	Enhancements Special Foundations Density Environmental Controls Safety Neighbors Officing Concepts: On-Premise and Off-Premise Orientation Accessibility Character Quality Control Reduce/Reuse/Recycle	Site Developmental Costs Environmental Influences on Costs Building Cost/SF Building Overall Efficiency Factor Building System Design Criteria Green Building Rating System	Major form and sustainability considerations that will affect building design
Economy Initial Budget Operating Costs Life-Cycle Costs	Extent of Funds Cost-Effectiveness Maximum Return Return on Investment Minimization of Operating Costs Maintenance and Operating Costs Reduction of Life-Cycle Costs	Cost Parameters Maximum Budget Time-Use Factors Market Analysis Energy Source Costs Activities and Climate Factors Economic Data	Cost Control Efficient Allocation Multifunction/Versatility Merchandising Energy Conservation Cost Reduction	Budget Estimate Analysis Balance Budget Cash-Flow Analysis Energy Budget Operating Costs Life-Cycle Costs	Attitude toward the initial budget, and its influence on the fabric and geometry of the building
Time Past Present Future	Historic Preservation Static/Dynamic Activities Change Growth Occupancy Date Availability of Funds	Significance Space Parameters Activities Projections Escalation Factors	Adaptability Tolerance Convertibility Expansibility Linear/Concurrent Scheduling Phasing	Escalation Time Schedule Time/Cost Schedule	Implications of change/growth on long-range performance

Figure 4.2 Information index matrix of William Peña's architectural programming(William M. Peña, 2012 [26-27])

• **By the value of information**: Hershberger's architectural programming methods are based on the value theory with 8 main values considered: human, environmental, cultural, technological, temporal, economic, aesthetic and safety. He proposes a programming matrix (Figure 4.3) following these 8 values and goals, facts, needs, ideas on the other dimension. As for the facts or design considerations, Hershberger classified them into 5 categories including human, environmental, cultural, technical, and other aspects (Hershberger, 1999 [376-377]). The human aspects indicate the features, behavior, activities of the users and the organization of the target user company. Environmental aspect includes all the facts about the construction site and the climate in that zone. Cultural facts encompass the tradition of the community, the regional laws, codes, and ordinances. Technical information indicates the physical and technical part of the facility and equipment, as well as requirement on materials and furniture. Other considerations include the image and signage of the form, safety, accessibility, colors, and information about budget and cost, time limit, etc. (Hershberger, 1999 [378-381]).

Values	Goals	Facts	Needs	Ideas
Human				
Environmental				
Cultural				
Technological				
Temporal				
Economic				
Aesthetic				
Safety				

Figure 4.3 Value-Based Programming Matrix. credit to Hershberger Figure 5-15(Hershberger, 1999 [217])

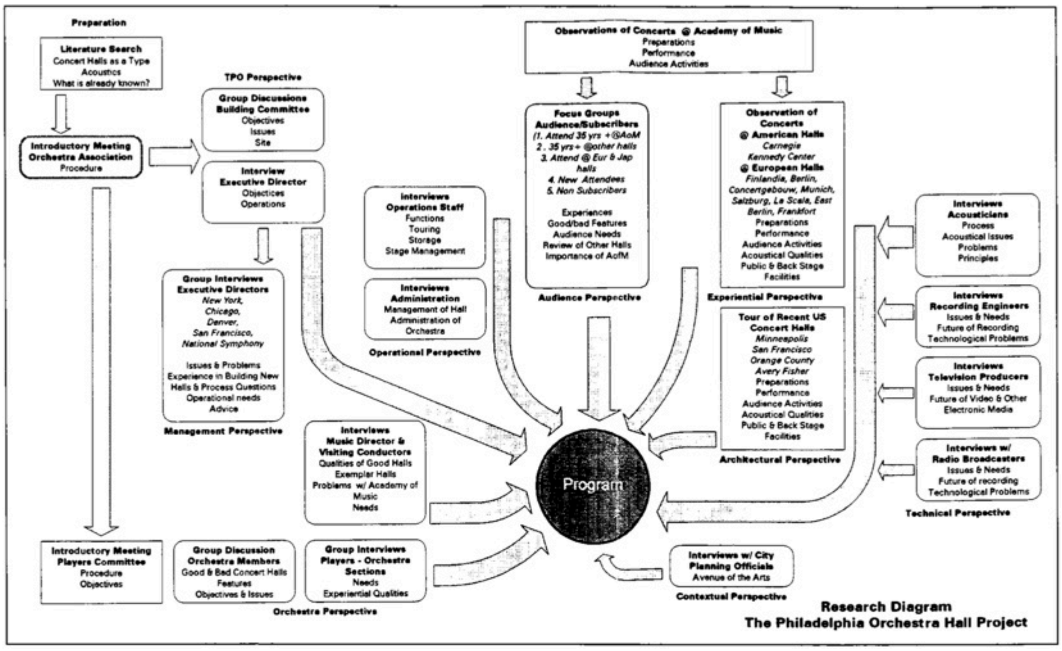

Figure 4.4 Orchestra Hall: Research Diagram

Credit: Walter Moleski, 1995. The Philadelphia Orchestra Hall Project. Permission: ERG/Environmental Research Group

• **By internal and external of the subject**: take the building as an object, classify the information as the internal and external of the physical space. This classification is also the most commonly used framework in design specification of construction projects, because it conforms to the basic logic of how people perceive spaces. Zhuang Weimin, on the other hand, divides planning information into two categories: internal information and external information. Zhuang(庄 惟 敏 , 2016) classifies the information for architectural programming into two categories: external and internal architectural construction conditions. External architectural construction conditions compass the social, cultural and territorial aspects of the site, and the relations to the surrounding area. Internal counterpart includes the features and demands of the users, and the functional requirement (Table 4.1).

Table 4.1 External and internal architectural construction conditions in architectural programming (author conclude from (庄惟敏, 2016)

Categories of conditions	Aspects	Examples
External conditions	Social	economy structure and business value population composition local living style outdoor public spaces dynamic estimation on future users
	Cultural	regional culture feature and evolvement regional building style and features influence on the neighborhoods social conventions
	Territorial	geography, geology and hydrography energy, sunlight, and orientation
Internal conditions	Users	categories using patterns and scopes behavior and mental characteristics subjective preference
	Functional requirements	case study on identical building type POE on similar cases future using requirements

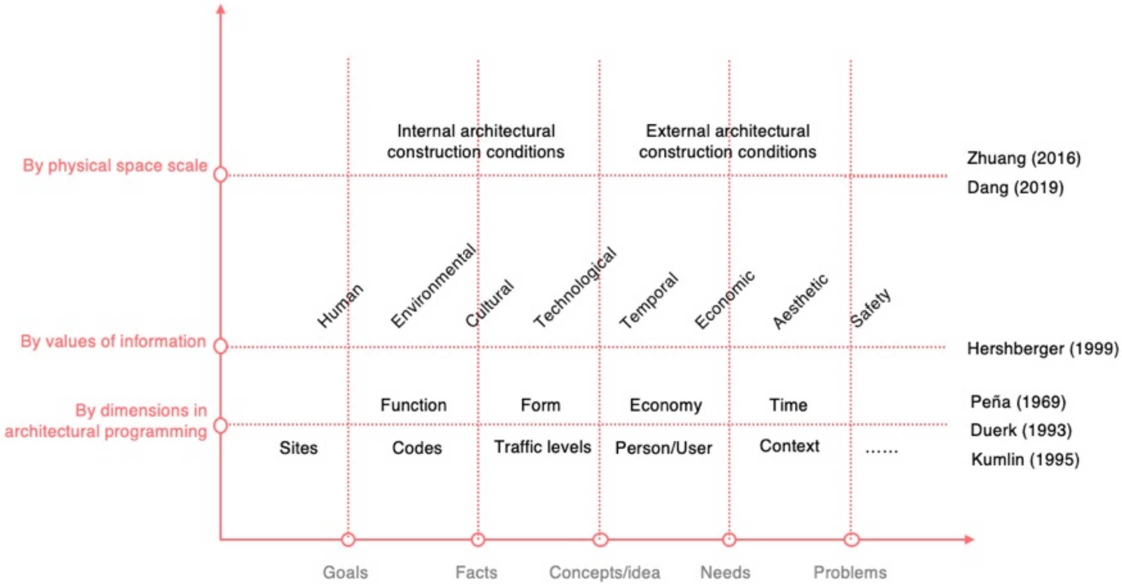

Figure 4.5 Different frameworks to collect information in traditional architectural programming theory

• Risk of overwhelming information

Clear and scientific classification is the basis of success on collecting information for making rational decisions. Nevertheless, the information is dynamic and endlessly collecting, there is also a risk for gathering too much information to manage and analyze. Duerk (1993) points out that sweeping information will overwhelm the decision-makers and programmers, thus proposing an issue-based structure for information classification. In her methodology, facts are categorized in site, user and context (Figure 4.6). All of the facts could be analyzed in different issues and sub-issues (Figure 4.7), in order to identify goals, requirements and concepts through the lens of values in a specific project. Besides, the programmers should set priority on the issues for a certain project, which is based on different judgement of values in the project.

SITE
CLIMATE
- Degree days
- Precipitation
- Solar exposure
- Wind speed and direction

CODES
- Building
- Zoning

SITE CONDITIONS
- City services/transit
- Geology
- Hydrology
- Noise
- Odors
- Site features (rocks, flora, fauna, streams, etc.)
- Soil-bearing capacity
- Topography
- Utilities
- Views to and from site

TRAFFIC LEVELS
- Bicycles
- Pedestrians
- Vehicles

PERSON/USER
ACTIVITY ANALYSIS
AGE GROUP
ANTHROPOMETRICS
DISABILITY
ENVIRONMENTAL HISTORY
NUMBERS OF PEOPLE/ GROUPINGS
- Organizational structure

PERCEPTUAL ABILITIES
PERSONALITY
ROLES
RULES
VALUES

CONTEXT
CULTURAL
DEMOGRAPHIC
ECONOMIC
ETHICAL
ETHNIC
HISTORICAL
POLITICAL
SOCIAL

Figure 4.6 Duerk' s fact check list (Duerk, 1993 [75])

AUDIBILITY
- Behavior Settings

CIRCULATION
- Information
- Material
- Parking
- Pedestrians
- Vehicles

COMFORT
- Physical
- Psychological

CONVENIENCE
DURABILITY
ECONOMY
- Elegant means
- Phasing
- Quality

ENERGY EFFICIENCY
ENVIRONMENTAL IMPACT
FLEXIBILITY
- Adaptability
- Choice/variety
- Expansion/contraction
- Multi-use

IMAGE
- Identity
- Message
- Ordering/proportion
- Status/hierarchy
- Symbolism

INTERACTION
- Group participation
- Social

LEGIBILITY
- Layering
- Orientation
- Plan recognition
- Sequence

MAINTENANCE
MOOD/AMBIENCE
- Attitude
- Emotional response
- Spirit of place

OLFACTORY
PERSONALIZATION
- Group
- Individual

PRIVACY
- Group
- Individual

RESOURCE MANAGEMENT
SAFETY
- Accidents
- Hazards

SECURITY
- Assault
- Robbery
- Unauthorized access/entry
- Vandalism

TERRITORY
- Group
- Individual

VISIBILITY

Figure 4.7 Duerk' s Issue Check list (Duerk, 1993 [72-73])

4.1.2 Limitation of existing research

From the above reviews, on the one hand, traditional checklists of information collection for architectural programming is applicable to universal construction projects and not specifically for existing building renovation projects; on the other hand, information collection for renovation projects is also mainly for existing buildings themselves, lacking a comprehensive list based on objectives of architectural programming, especially the specific information affecting functional programming.

For example, universal construction projects often have definite urban planning regulations and ordinances, while the pre-design phase of existing building renovation and reuse projects often involves the adjustment of land use, property lines, utilities and other conditions due to functional transformation, investment compensation, integration of the surrounding environment, etc. Historic buildings have case-by-case regulations, and thus cannot gather information directly according to the general conditions. Therefore, the collection and analysis of facts in the renovation of existing buildings is more complex and flexible, and ask for a detailed research on the specific checklist.

In addition, the types of information to be collected are complicated and variable. For example, information on using needs will change at any time with the change of the client, key stakeholders, investment and budgets, etc.; the requirements of users can also change over time after the project has been suspended for a period of time due to external factors. These situations are common in public projects with government's participation. The purpose of information collection is to make better decisions, and it is often the critical information that really affects the decisions. Information gathering can take up resources such as human and material resources, and in the case of ongoing comprehensive information gathering, it can be a drain on limited programming resources. Therefore, the programming team needs to select the variable information and definite facts, different degrees of importance, to identify and collect critical information, and to judge and pre-process variable information in order to achieve the purpose of collecting information efficiently and assisting architectural programming decisions.

Since this study focuses on the architectural programming of existing building renovation projects that distinguishes them from general universal projects, this chapter focuses on the types of information collection and the key factors that influence functional programming. The methods of information collection are partially presented in the context, but are not the key research objects of this chapter.

4.2 Index matrix of information collection

Section 4.1 reviews information collection in the architectural programming. This section will develop the specific information collection matrix for renovation projects based on the review and limitation before. Based on the classification applied in China corresponding with the common logic in design specification, the framework follows the logic of macro-medium-micro levels of physical spaces. On top of that, it will absorb the advantage of value-based programming methods and pay more attention to the priority and significance of information to adjust to the features of renovation projects and to avoid the situation of overwhelming data for better decision-making process (Figure 4.8).

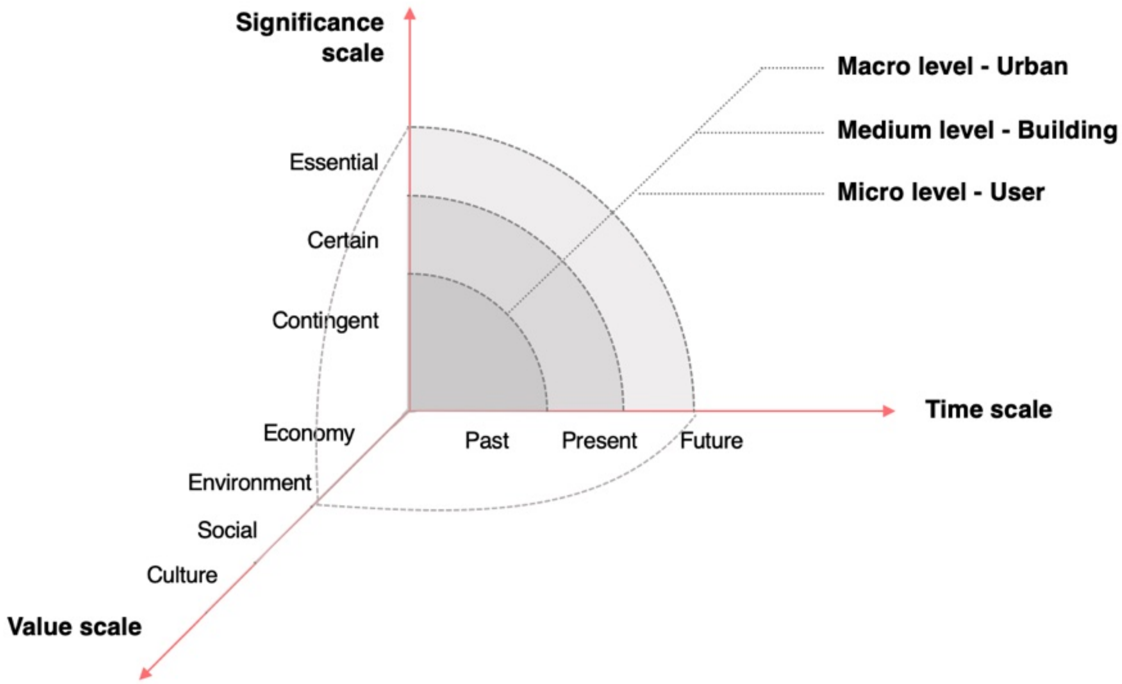

Figure 4.8 Information collection matrix for architectural programming of renovation projects

4.2.1 Characteristics of information collection in renovation architectural programming

• **Uncertainty of urban planning and project initiation conditions**: the architectural programming and design of traditional new construction projects are based on the approval of project initiation documents (项目立项), and therefore have definite initiation conditions. However, in renovation projects with functional transformation or upgrade, the client may not be able to provide the design proposal. The function program, form and whether to conduct the secondary land development are all open questions. Upon the implementation of "Multiple Planning Integration (多规合一)" [14] in the

14 Multiple Planning Integration is to integrate multiple spatial plans such as the planning for main functional

Territorial Spatial Planning System (国土空间规划体系) and probe into sectoral planning of urban renewal (城市更新专项规划) in China, the urban planning conditions of the renovation project may be uncertain and need to be re-evaluated and planned. Therefore, the information collection of architectural programming in renovation projects is facing more uncertainties, more extensive requirement, so as to prepare for the project initiation and revision of urban regulatory plans.

• **Increase in the number of limitations**: In the past, new projects had clear urban planning conditions, project orientation, in need of collecting information on the external conditions of the urban environment, site information, internal conditions such as user demand information, etc., in order to analyze, clarify design considerations, find design strategies, and modify or generate design proposals. However, in renovation projects, existing buildings are the basis for architectural programming, which itself is a very big constraint for the design. The existing buildings and sites are significant resources of information. The structure, space, foundation, etc. of the existing building are all constraints to the renovation design, and some factors even directly determine whether the design strategy works or not, rather than whether it is good or bad. In addition, for renovation projects with function enhancement or transformation, it is necessary to extensively collect information on urban planning and related policies that affect function transformation when making decisions on new functions. If the information is not collected from all aspects, or there is no comprehensive, in-depth and detailed understanding of the current situation of existing buildings and sites, it is likely to result in the blind spots of design schemes, and problems of schemes not anticipating construction problems, and conflicts between schemes and actual construction conditions, which will bring potential risks to subsequent construction phase and time management.

• **Expansion on collected time:** traditional architectural programming generally does not emphasize the chronological nature of information collection. The focus is on the historical context of the site and the current and future use needs of the owner. However, the renovation project itself has a temporal meaning of "renewal". From the definition of "renovation", we can see that renovation means enhancement, change, before and after, and is a continuous process. Therefore, it is important to collect information from the **past,**

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zones, land use planning, urban planning in a unified plan of Territorial Spatial Planning.6

present and future. For the past, the information includes the historical context of the site, the evolution of the surrounding urban environment, the historical background of the existing building and all the modifications up to now, the original designer of the existing building, all the information of the original design, etc. For the present, the information includes the current status of the surrounding urban physical and human environment, the current use of the existing buildings, etc. For the future, since renewal itself means extending the life of the building and is an ongoing process, it is also necessary to speculate about the future, to allow renewal to address the current needs while leaving a redundant amount for future space use to meet future requirement.

• **Complexity and continuity**: because of the large time span and many restrictions of the information to be collected for the renovation project, it inevitably brings the complexity of information collection. This is reflected in the lack of information types and unknown information channels. For example, the design drawings and related background information of existing buildings may be missing; the current status of existing buildings cannot correspond to the original design drawings due to several changes along the history, and thus requires new surveying and mapping of the site. In addition to the complexity of information collection, the time phase of information collection is also different from that of traditional new construction projects. According to the author's interviews with a number of architects, many projects have not yet undergone architectural diagnosis and actual site survey, and the architects have already stepped in to begin architectural programming and even schematic design. It is very common for architectural programming to precede or coincide with site surveys and architectural diagnosis. This also means that there is a constant influx of information, a longer timeline for information gathering, and a need for the programming team to continuously collect and update information.

Based on the information gathering characteristics of architectural programming for renovation projects, the previous information architecture may no longer be fully used. In particular, the combination of complexity and uncertainty is not conducive to the work of programmers or architects, and information omission or overload is likely to occur. Therefore, it is necessary to refine a framework for information collection for renovation architectural programming based on the original information collection framework and for the information collection characteristics of renovation projects.

4.2.2 Spatial scale: urban-building-user

According to the physical spatial scale of the built environment as a dimension, the information to be collected can be divided into three levels: urban, building and user. In the classical architectural programming theory, information collection can be divided into external and internal information. The external information focuses on the information of the urban plan, the site and the surrounding environment. Internal information generally contains information on spatial patterns, user behavior patterns, needs, etc. However, for the existing building renovation project, the existing building itself is an important information condition and its spatial pattern already exists, so the programming team needs to organize various professional and technical personnel to collect information and research and analyze it, and extract it from the internal information separately. At the same time, there are original users in existing building renovation projects, who have first-hand feelings and experiences of the existing building; future use demands also need to be explored based on the current status of existing spaces. Therefore, in this study, the internal information encompasses the building unit and the individual use level, as two types of information alongside with the urban information. A spatial information hierarchy is established with the physical spatial scale of the built environment as the dimension.

The **urban scale information** is further divided into three categories: urban planning, uncertain initiation conditions, and site and surroundings. Since the existing building renovation projects are often uncertain about the project initiation conditions, and it is also possible to re-establish the sectoral plan of urban renewal within "multi-planning integration", the urban scale information should be collected and analyzed separately from the site and surroundings. Therefore, this study will supplement the external information collection in the classical architectural programming theory with urban planning conditions, policies, potential project initiation conditions, physical site information, surrounding environment, etc.

The **building scale information** consists of three types of information: basic information, building diagnosis and spatial cognition. Among them, the basic technical information includes architectural design drawings, current state survey drawings, evolution history of existing buildings, etc. Building diagnostic information includes building audit information, survey on geology, building structure, energy consumption, aging and loss of building elements and materials, building equipment, site photos, etc.

Spatial cognition mainly includes use function program and space list of the existing building, all types of flows, spatial scale characteristics, etc.

The **user scale information** also contains three types of information: user profiles, using pattern and requirement, and operation mode, which mainly focus on the user features, daily behavior pattern, using mode, opinion of target users, predictable future growth, as well as the operation and investment information.

The advantages of the physical space scale of information collection in renovation programming are: clear hierarchy, corresponding with the general project logic of planning and design, urban design and architectural design, convenient to corporation with interdisciplinary professionals, as well as the division of tasks. It is beneficial to the practical operation of information collection, and is applicable to most existing building renovation projects.

4.2.3 Values scale

The United Nations has positioned three dimensions of sustainable development goals: economic, social, and environmental. For a construction project, the benefits should be integrated. Hershberger has developed a multi-value-oriented theory of architectural programming, grouping programming elements into eight value categories: human, environmental, cultural, technological, temporal, economic, aesthetic, and safety.

The renovation of existing buildings is an important part of urban renewal. China has included urban renewal in the 14th Five-Year Plan (2021), emphasizing that urban renewal is a comprehensive process, which inevitably involves economic, social, environmental, quality of life, urban space quality and other aspects of renewal and improvement. At the same time, urban regeneration involves the interests of multiple parties, and the interests of each party are no longer limited to economic benefits, but are more concerned about social welfare, citizens' rights and interests, green dual carbon, historical heritage, cultural promotion and other comprehensive benefits, and even the ethical values of space, including humanism, justice and governance (秦红岭, 2021 ;赵峥 and 王炳文, 2021).

In order to balance the interests of multiple parties and maximize the comprehensive benefits of multiple values, it is necessary to make full consideration in the architectural programming process, so the information collection, which is the basic part of architectural programming, should also consciously collect and analyze information from the multi-stakeholder perspective and multiple value orientation.

The information classification with value-oriented dimension includes economic, social, environmental, and cultural. Among them, the information of economic value includes investment budget, renovation cost, market analysis, investment and operation, etc. The information of social value includes employment population, surrounding community welfare, surrounding community participation, etc. The information of environmental value includes energy saving and emission reduction policy support, energy consumption status, green building standards, etc. Information of cultural value includes historical heritage, regional cultural value, etc. The characteristics of information collection according to the value-oriented dimension are: taking the value of sustainable development and the national urban development strategy guidelines as the guide to ensure the correct direction of existing building renovation projects in urban renewal; focusing on the participation of multiple subjects and the balance of multiple interests from the information collection process, and preparing objective and comprehensive factual materials for subsequent information analysis and decision-making of multiple subjects. Of course, some information and facts may meet multiple value orientations, so they may be labeled with multiple value tags, and the information in each value category may be duplicated. However, the purpose of this division is not to collect information without overlap, but to add a multiple value reference system based on the original physical and spatial scale classification, so as to lay the foundation for the subsequent value-oriented decision-making process and balanced decision-making of multiple interests.

4.2.4 Time scale: past-present-future

The time scale can divide the collected information into three layers: past, present, and future. Since the original construction phase of an existing building renovation project belongs to the past, a large amount of historical information exists, including the design drawings from the initial construction, the historical development of the existing building, and the location of the existing building in the historical memory of the local community. Much of the information collected belongs to the present moment, and the existing information is collected to assess the current state of affairs, identify existing problems with the site and the building, and develop a concept for renovation programming. However, architectural programming also requires anticipating future use, especially for adaptive buildings, and especially for reuse projects with functional transformation, where the changes to the building itself and its surroundings can be significant.

In addition to collecting present factors, it is also necessary to predict future use, leaving room for future use needs; in addition, it is also necessary to collect some of the information to predict the impact of the building renewal on the surrounding area, to compare strategies and verify the superiority of the options chosen during the architectural programming and evaluation phase; thirdly, assessing the future impact of the renovation on the building and its surroundings during the architectural programming phase can also lay the foundation for post-use evaluation, which facilitates Third, evaluating the future impact of the renovation on the building and its surroundings during the architectural programming stage can also provide a basis for post-use evaluation and facilitate the evaluation of the renovation after delivery. The collection of future information requires the use of analogical reasoning. This means collecting cases with similar characteristics and predicting the impact of this project on the surrounding city through the data of changes before and after the case renovation.

The characteristics of information collection according to the time dimension are: it helps to sort out the historical changes, current problems and future needs clearly, and facilitates the planning team to obtain a clear time perception. Also, classifying the information by temporal coordinates helps to extract information that remains unchanged and continues to change: facts that remain unchanged such as historical changes in buildings and the evolution of the neighborhood's historical environment; information that may continue to change and needs to be continuously collected and updated over time, such as information on future user categories, future population growth projections for the surrounding community, future operating entities and investment teams, in order to remind the a architectural programming team to focus on a targeted continuous updating of some information.

4.2.5 Significance scale: constant and variables

Due to the uncertainty of initiation conditions in renovation projects, the information collection is always a dynamic process. It is necessary to clarify “constant” - essential and unalterable facts, and “variables” – uncertain and contingent conditions(苏腾飞, 2022). Only by having key information and update the contingent information in time can we make the rational decisions and generate effective architectural programming solutions and design strategies. The judgement of which genre the information belongs to depends case by case, but the research would briefly analyze some common situations and provide reference for programmers in future real projects.

1) Essential information: the essential information is the facts of most significance that has decisive power on the design schemes. Below are some of such kind of facts, which will be discussed more in the following sections.

• Land use of urban planning, transformation scope of permissible building functions, property right division, conditions of land leasing; these facts directly affect the feasibility of the project and the approval of project initiation.

• Current building codes: are certain for a relatively long period of time with exception of codes changed in the project cycle. These factors, especially the fire protection codes and structural safety standards, are necessary for the approval of the construction drawings and construction, which decides the feasibility of the renovation design.

Necessary information does not mean that it cannot be changed at all, it just means the highest priority for resolution. The project cannot be designed and constructed without these issues being resolved.

2) Certain information: there are some constant factors in the renovation project, which can be identified at the first time, in order to set up the basis for the programming and design later.

• Physical information of the site: the physical spatial information about the site is certain for a period of time, such as geography, geology, orientation, sunlight and acoustics, landscape, etc.

• Conditions of the existing building: this kind of information involves building diagnosis report, the historic information of the building, and the spatial feature of the existing building.

Certain information can be identified first, and is also of great significance because these facts are the basis for identifying essential information such as potential land use, whether to satisfy the current building codes, and the potential of the functional and spatial transformation.

3) Contingent information: the contingent information includes undecided facts and conditions that require continuous attention, or certain conditions that may change because of other external factors.

• Stakeholders and budget: renovation projects, especially the public projects with participation of many kinds of stakeholders, have the possibility of stakeholder changing and budget changing, due to the transition term of leaders and annual fiscal finance.

• Surrounding environment: the surrounding environment is changing constantly, thus the regeneration of the neighborhoods and communities also require the latest data and facts in the aspects of population, economy, social and cultural factors.

• Using pattern and requirement: the using requirement is changing overtime due to change of organization structure, corporation of users, upgrade technologies, and other subjective factors.

Contingent information are the facts in need of update by the programming team or the client. The programming scheme and design proposal should always follow this kind of information to date in order to make appropriate decisions.

4.3 Macro level: urban information

The position of architectural programming in the whole process of construction project is located after urban planning and the approval of project initiation, and before architectural design (Figure 1.5). Architectural programming for common construction projects, like new construction projects also collect urban contexts related to the site， including site analysis, surroundings (William M. Peña, 2012), regional, local and site considerations(Hershberger, 1999 ;庄惟敏, 2016), etc. But renovation projects are not only about gathering this kind of information, they are also about identifying problems with existing buildings and the surrounding urban environment, and seeking to enhance the buildings and their surrounding communities. As mentioned in section 1.2, multiple purposes of renovation projects always include stimulating the urban vitality and regenerating both the existing building and the surrounding area, especially under the background of urban renewal nowadays.

However, according to the previous analysis, the existing building renovation projects in urban renewal are different from the previous new construction projects in planning conditions: rather than just following the general urban plan and regulatory plan, the client needs the architectural programming team to intervene before the initiation of the project, so the traditional information collection of urban plan and regulations is no longer fully applicable, and the project initiation conditions may be missing. This section will analyze the information of urban planning dimension in the renovation programming classified into urban planning, site and initiation conditions, and surroundings.

The urban planning information checklist is improved from previous researches, supplemented with relevant information regarding urban renewal planning, and specific urban renewal information in all kinds of normal planning and policies. The information of site and surroundings is also summarized based on literature review. The uncertain initiation conditions, which only occurs in renovation, are proposed by the author, and are classified into several kinds.

4.3.1 Urban planning information

Before the establishment of the Ministry of Natural Resources in 2018, the urban planning system implemented in China included main functional area planning, land use planning, urban and rural planning, environmental protection planning, etc.(史育龙, 2008). Due to the problems of conflicting multiple planning types and difficulties in coordinating various departments, the Ministry of Natural Resources was formally established in 2018 and then issued a set of policies to clarify the future implementation of "five levels and three types"[15] of territorial spatial planning system (国土空间规划体系), which integrates the main functional area planning, land use planning, urban and rural planning and other spatial planning into a unified territorial spatial planning system, and realizes "multiple planning integration", including three levels of master planning (总体规划), detailed planning (详细规划) and relevant sectoral planning (专项规划)(新华社, 2022). In 2020, the Ministry of Natural Resources issued the "Guidelines for the Preparation of Municipal Territorial Spatial Master Plans (for Trial Implementation)", which proposed to "clarify the key areas and mechanisms for implementing urban organic renewal ...... systematically divide spatial units of urban renewal, focus on mending shortcomings and strengthening weaknesses, optimize functional structure and development intensity, inherit history and culture, improve urban quality and vitality, avoid major demolition and construction, and protect public interests" (The Ministry of

15 Five levels refer to the planning level, divided into national, provincial, municipal, county and township levels; three types refer to the planning type, divided into three types of planning: master plan, detailed plan and relevant sectoral plan. Detailed planning, including regulatory detailed plan and detailed construction planning, specifying specific land use and development intensity, etc., is generally prepared at the municipal and county level and below.

Natural Resources, 2020), which clarifies the significance of urban renewal spatial units in the national territorial spatial planning. Although China is currently in the transition stage between these two planning systems, urban renewal unit planning is also still being explored, which poses certain difficulties for this study. This study is mainly based on the territorial spatial planning system, focusing on the information required to be collected for the project, and classifying the urban planning information affecting the renovation of existing buildings based on the general plan, detailed plan, sectoral plan, related plans and guidelines of urban renewal, etc.

- **Master planning (总体规划)**: A general plan is a general arrangement for the spatial and temporal development and protection of land space in a certain area, emphasizing comprehensiveness. The main object of this research is the urban existing buildings, which are mainly guided by general plan of municipal level[16]. The effective planning information contained in the general plan includes: regional development and protection within the municipal area, regional main function orientation, land use planning and orientation, population structrue, economic development, transportation planning, etc. Collecting information from the general plan can understand orientation of the future development and policy of the region, which has a direct impact on the new functions of the existing buildings or building clusters on a macro level.
- **Detailed planning (详细规划) :** Emphasizing on implementation, the detailed plan regulates the land use and development intensity of the specific site plot, which is the legal basis for planning and construction approval of the project. Detailed planning is generally divided into detailed regulatory planning and detailed construction planning, containing information such as plot ratio, restricted height, boundary line of land (用地红线), nature of the building, area requirements for each function. Existing building renovation projects are accompanied by functional transformation or enhancement, and their land use and construction indexes are bound to conflict with the original detailed planning, which results in urban renewal unit planning.
- **Sectoral planning (专项规划):** refers to the special arrangement of spatial development and protection utilization in a specific area (watershed) and specific field to

[16] The master plan includes the pattern of territorial spatial development and protection, the orientation of the main functions of the region, three control lines of the integrated layout of ecological, agricultural, urban and other functional spatial boundaries, and the delineation of the boundaries of various spatial entities.

reflect specific functions, emphasizing specialization. Sectoral planning involving the transformation of existing buildings mainly includes the protection planning of historic and cultural districts, and the protection of cultural relics, etc. In addition, Shanghai, Guangzhou, Shenzhen and other cities currently use urban renewal planning as a kind of sectoral planning in the territorial spatial planning system.

• **Urban renewal planning (城市更新规划):** current urban renewal planning in China is still in the exploration and is contained in two levels: detailed planning and sectoral planning (陈群弟, 2021). Cities like Shenzhen, in addition to formulating sectoral plans for urban renewal, also supplement another urban renewal unit plans between these two levels (深圳市人民代表大会常务委员会, 2021). In November 2021, the Ministry of Housing and Urban-Rural Development announced the first batch of 21 pilot cities for urban renewal, exploring the development of urban renewal planning and annual implementation plans by each city, encouraging the issue of local regulations and rules, and exploration of the supporting system and policies of urban renewal (General Office of the Ministry of Housing and Urban-rural Development, 2021)。

China has not yet established a mature mechanism for sectoral plans of urban renewal. There are two main positions of urban renewal plans in the territorial spatial planning system. The first is planning overlay, where urban renewal plays a control role for urban renewal areas in the form of sectoral planning, in parallel with the overall territorial spatial planning and detailed planning, such as Shenzhen, Guangzhou, Shanghai, etc. (杨慧祎, 2021). Taking Shenzhen as an example, on the basis of the sectoral plan urban renewal issued by the government, the development and construction units (referred to market entities below) chosen by the property owners themselves are responsible for declaring the unit scheme of urban renewal[17] (城市更新单元计划) and drafting unit plan of urban renewal (城市更新单元规划) (深圳市人民代表大会常务委员会, 2021)。The second is planning integration, where urban renewal areas are treated as a spatial type for differentiated control and integrated into the general plan and detailed plan. For example, Beijing has implemented an urban renewal system, which is based on "general plan - sectoral plan – community regulatory plan - action plan"; Chengdu has drafted a sectoral plan for organic renewal in the central district, and the first implementation plans for

17 An urban renewal unit can include one or more urban renewal projects.

renewal units, integrating them into the municipal detailed plan.

In Shenzhen, the content of urban renewal planning includes the scope of renewal, the subject of declaration, the renewal willingness of the property possessor, renewal orientation, use of public land, and the validity period, etc. Among them, the orientation of renewal should be determined in accordance with the dominant function of the land use in municipal general plans. The content of unit plan of urban renewal includes 1) target and orientation, renewal mode, land use, development and construction indicators, road and transportation, municipal engineering, urban design, balance of interests; 2) construction requirements of public service facilities; 3) innovative industrial buildings, public housing and other supporting requirements; 4) the scope and area of public land transferred to the government without compensation, including mandatory content of the unit leading function, development intensity, and public service facilities which shall not be modified within two years.

• **Industrial planning (产业规划):** Industrial planning is a plan for local industrial positioning, industrial structure, industrial chain, spatial layout, supporting policies, etc., combined with the advantageous resources and strategic positioning of a certain place. It is different from new construction projects that have established project positioning conditions. Renovation building planning may require finding industrial positioning for existing buildings. This situation often occurs in the reuse of industrial sites in China, where a large number of existing industrial relics are owned by the local government or state-owned enterprises, but have been left idle for a long time due to problems such as lack of clarity on new industries or investment attractiveness. Introducing new industries into existing buildings can, on the one hand, promote local industrial upgrading and, on the other hand, make the most of the existing buildings, reduce investment costs and shorten pre-construction time to a certain extent.

In Beijing, for example, the "Beijing 14th Five-Year Plan" defines one of the four industries of "Beijing Smart" as an intelligent network-connected vehicle(北京市人民政府, 2021). In October 2021, Li Auto Beijing Green Intelligent Manufacturing Base was located in Shunyi District, the project uses the former Hyundai One Factory to build an intelligent manufacturing plant for pure electric passenger cars, with a total area of 270,000 square meters for renovation and expansion, and a 60% usage rate along(曹政 王可心, 2021). Thanks to the support of industrial planning, this project has maximized the existing stock of factory resources. The Municipal Development and Reform

Commission coordinated with the Municipal Planning and Natural Resources Commission, the Municipal Housing and Urban-Rural Development Commission, the Municipal Bureau of Cultural Heritage and other departments to cooperate fully, speeding up the approval process, saving about 110 working days compared with the conventional process, completing the confirmation of the area of suspected cultural heritage remains in the shortest possible time, and finally compressing the entire excavation work to about 20 days (Figure 4.9).

Figure 4.9 Beijing green intelligent manufacturing base of Li Auto
(https://auto.ifeng.com/c/8AO2LLIn3S1)

Industrial planning not only facilitates the approval process of renewal and transformation projects, but also facilitates the investment and operation of transformation projects. The industrial planning policy involves incentive policies for enterprises in related industries, including financial support, subsidized funding, achievement awards, rent subsidies, enterprise loan guarantee subsidies, etc. These measures will attract a large number of related enterprises to move in and form a cluster effect, which is convenient for the renovation project to attract investment in advance and implement subsequent operation and use.

• **Supporting policy(政策支持)**: as China's urban renewal is still at the stage of sub-regional experimental exploration, the relevant regulatory system is not fully established, and existing building renovation projects rely heavily on local policies to guide them. In particular, the reuse projects of functional conversion involve land policy, industrial guidance, control regulation adjustment, etc., which have not yet formed a complete and transparent process and clear division of responsibilities, so they strongly rely on local government and policy support. Policy support is divided into two types: function-oriented and project-oriented.

1) Function-oriented: clarify the function of the renovated building and support for post-renovation operation and use. For example, on June 24, 2021, the General Office of the State Council issued "Opinions on Accelerating the Development of Guaranteed Rental Housing", which clarifies that non-residential stock houses such as idle and inefficiently utilized commercial offices, hotels, factory buildings, warehouses, scientific research and education are allowed to be converted into guaranteed rental housing under certain conditions. The opinions stipulate that such projects can simplify the approval process, receive central subsidy funding support, apply preferential tax policies such as VAT and property tax on housing leases, exempt from urban infrastructure support fees, and implement civilian water, electricity and gas prices.

2) Project-oriented: policy support for the renovation project itself, without limiting the function. For example, the Shenzhen Municipal Bureau of Planning and Natural Resources released on June 6, 2019, "Several Measures on Deepening Urban Renewal Work for High-Quality Urban Development", in which several incentives for urban renewal are clarified in three aspects: the number of years of completion of existing buildings, policy incentives, and plot ratio incentives. First, the relaxation of the annual limit. Renewal and transformation direction for the general industrial land (M1) demolition and reconstruction of urban renewal projects to relax the building completion period to December 31, 2009. The second is to increase the policy incentives for comprehensive improvement of old industries. In addition to the original policy allowing the addition of elevators, corridors, stairs, distribution rooms and other auxiliary utilities with an area not exceeding 15% of the current building area, it also proposes to increase R&D office and commercial support through space optimization without increasing the building area, and authorizes the district government to formulate incentives in various aspects such as simplification of procedures, functional optimization and financial subsidies. Third, support industrial land to increase the volume ratio. For industrial land that has signed a land use right transfer contract or has been registered for real estate and in accordance with the relevant provisions, the original land use can be maintained unchanged, the comprehensive use of additions, alterations, expansions and other means

to improve the plot ratio.

• **Design criteria of specific area (政府颁布的特定地区设计准则)**: even for existing buildings that are not cultural preservation buildings or historical buildings, if they are located in historical and cultural districts, their renovation needs to comply with the design guidelines for historical districts. For example, in the post-use assessment project for the renovation of courtyards in Beijing's Shichahai Historical and Cultural Preservation Area, most of the courtyards were renovated for cultural and commercial functions such as bed and breakfasts and restaurants, in order to revitalize the stock of existing courtyard buildings that do not have historical and cultural value. In the renovation design, it is necessary to refer to the requirements of both the *Design Guidelines for the Protection and Renewal of the Style of Beijing's Historical and Cultural Neighborhoods* and the *Urban Design Guidelines for the Finishing of Beijing's Xicheng Neighborhoods*, which stipulate content including site layout, spatial form, use of materials, parking lots and other restrictions(黄也桐 and 庄惟敏, 2021).

4.3.2 Uncertain initiation conditions

Unlike new construction projects, existing building renovation projects have likely not yet acquired project initiation and approval (项目立项) in the preliminary architectural programming phase. If it is a project with unchanged functions, most of the conditions are fixed and the planning conditions do not change much. However, if it is a renovation project with a functional transformation, its planning conditions may change significantly. This kind of uncertainty exist in all aspects: functional identification, various kinds of approvals involving urban planning and construction, renovation policies, budgets, etc. (柴培根 and 周凯, 2020). The uncertainty of the project orientation (项目定位) is also a distinctive feature that makes renovation projects different from new construction projects.

Based on the interviews with architects in Section 2.5, architects involved in renovation projects may face the following situations in the pre-design stage.

• The client has the ownership of the existing building and the start-up capital, and does not know what the existing building can be used for;

• The client has the start-up capital to upgrade the property, but does not have a comprehensive and clear understanding of the problems of the existing building;

• The client only has a general goal such as "good" renovation, but does not know what specific aspects of good renovation are, or only has a single general goal such as improving economic efficiency, but has not yet formed systematic and comprehensive multiple goals, and does not have detailed and operational plans.

• The client has a clear goal, but has not formed complete demand, and there is no corresponding design proposal for reference;

• The client has clear ideas about functional transformation, but is not sure whether it can meet the demands of urban planning;

• The client has strong constraints, such as project delivery time or strict budget.

Considering the situations above, programmers needs to gather basic project information as follows.

The motivation for the renovation: for what reason did the project initiate the renovation plan, and what objective or subjective factors prevent it from being reconstructed? Are there any conflicts with the existing urban regulatory plan?

Reasons for renovation instead of reconstruction: sorting out the factors for inability to reconstruct actually clarifies the inevitable conditions for renovation. The reasons include: 1) the project cycle is too short to achieve reconstruction; 2) the cost budget is limited and cannot cover all the costs required for new construction, and renovation is relatively better to control the cost; 3) the current control regulatory plan demands on decreasing the floor area ratio of the existing building; 4) existing buildings have historical value with prohibition of demolishment. Some other factors result in the transformation more appropriate than new construction, such as policy support, high social or cultural values, period restrictions on land use, etc.

The goals of the renovation: the client with a lot of preliminary and initiative information of the project, usually has an intuitive perception of the general goals of the project, such as enhancement of the spatial quality and increase on revenues; however, only one general objective is risky. First, projects often involve multiple stakeholders, it is very important to fully consider the needs of each stakeholder to develop a design brief; second, only maximizing the overall benefits is often the key to the success of a project; for example, opening public space and increasing green spaces can maximize social, environmental and economic benefits at the same time; third, various objectives can mutually promote or constrain each other, and the priority of the objectives needs to be determined for later decision making.

Financial source: does the project have definite funding source, such as fiscal appropriation, private equity, or other potential investment? What is the identified available budget?

Conditions of land leasing (土地出让条件)：the function transformed project may involve land leasing with certain demands. For example, Block 16 on Pingyang road in Yangpu District, Shanghai is an uncompleted commercial building project. Everbright Asset Investment (EBA), a Non-performing asset management company purchased this property and intended to transform it into an office building for renting. The conditions of the land leasing include a possessing property of 30000 m2 high-end star hotel.(苏腾飞, 2022)

Property rights: if the property rights are separated due to previous deals, only part of the building may be renovated. At present, functional conversion projects in China are mainly factories, because the property rights of factories are usually clearer, which makes for transfer of land and building property. The author once organized a post-occupancy evaluation of a "coexist-courtyard (共生院)" renovation project in Beijing's Shichahai Historical and Cultural Protection Zone. The developer, a state-owned financing platform company, only have part of the property right which is transformed to be a homestay, coexisting with residents in the rest part of the courtyard (黄也桐 and 庄惟敏, 2021).

Stakeholders and decision makers: stakeholders in the project consist of the property owner, investor, user, operator, municipalities, etc. It should be clarified the form of participation of each party and its relevant benefits and values. One of the challenges in the multi-stakeholder projects is the conflict and comprise of different benefits with the purpose of maximizing the whole profit. It should be noticed that stakeholders are not always the decision makers, who have different decision power and interest in a project.

Time constraints: for general renovation projects, there is a close relationship between renovation cycle time constraints and return on investment, and it is important to control the delivery time in order to maximize returns. However, under certain specific conditions, the project cycle may be subject to other strict constraints and largely affect the overall architectural programming and design strategy. These include 1) renovation triggered by mega-events, which must be completed and delivered in time for the event, such as the Olympics, Expositions, etc.; 2) renovation strongly dependent on policy support, the policy period passed that is unable to obtain sufficient policy support or subsidies; 3) future users is same as the original ones, commonly in public services such as schools, libraries, etc., or company-owned offices. The renovation cycle will affect the normal use of the target users and thus affect the normal operation. It is necessary to consider the balance between the additional costs incurred and the revenues. These constraints will greatly affect the renovation programming and should be clarified at the beginning, with strong factors such as the timing of events as the primary goal.

In the case of unclear functional conversion, it may also be necessary to conduct market analysis, explore possible target client, or the supporting resources and market scarcity within a certain range of the area where the building is located.

4.3.3 Site and surroundings

Apart from the uncertain initiations about the site and project above, information collection about the site is similar to new construction projects. The difference lies in the surrounding information. Since the existing building has served the neighborhoods and established relations with surroundings for some time, it may have important cultural and social values to the local community and be a part of residents' living memories. In addition, renovation projects under the urban renewal background always carry out the goal of regenerating the surrounding neighborhood and communities, which has higher demands on the stimulating effect of the programming and design from a comprehensive perspective.

Information of the site are basically the same as the information collection in traditional architectural programming theory, including transportation and traffic, landscapes, design styles of surrounding buildings; hydro-geographical characteristics such as rivers, lakes, water channels; local climate, geological conditions, etc. (**Error! Reference source not found.**).

Table 4.2 Information checklist for site and surroundings

Category	Sub-category	Items
Geography & geology	geography	• Height difference inside the site • Slope on site
	geology	• Geotechnical information on site • Aseismic demands on site • Special geology element • Local climate information
	hydrology	• Volume, orientation, and quality of river, stream, ditches on site or nearby

Category	Sub-category	Items
		• Water supply and drainage system on site
Sunlight and acoustics	sunlight and over-shading analysis	• Orientation of the site • Over-shading analysis between the site and surrounding buildings
	acoustics	• Noise analysis around the site • Acoustic demands on site
Landscape	plants	• Area covered by plants on site • Protected trees and plants on site • Suitable plants cultivated in the region
	surrounding resources	• Landscape in the neighborhood: park, river bank, nature preservation area, etc.
Social	facilities	• Service facilities nearby • Safety in the neighborhoods • Functional deficiency in the community
	people	• Employment status in the community • Local living habits • Communication and interpersonal relationships in the community
Human & Culture	population	• Population composition and structure in the community: gender, age, education, income, occupation, religion, race, etc. • Future trends of population
	cultural resources nearby	• Historic and cultural background • Traditions and customs • Important culture facilities nearby
Aesthetic	local aesthetic feature	• Style, facades, height of surrounding buildings
Transportation	on site	• Streets and roads embracing or crossing the site • Pedestrian flow analysis and potential entrances and exits
	surrounding traffic	• Main roads and expressways nearby • Transportation infrastructure nearby: metros, bus stations, trains, etc. • Common traffic conditions nearby
Economic	market value	• Land value in the neighborhoods • Rental prices of offices, houses, etc. nearby • Market prospect
Technical	parking	• Existing parking capacity and opening hours • Parking lots nearby

Category	Sub-category	Items
	construction	• Construction limits
View	visuality	• Views from different angles seen from the site • Views from different angles seen to the site

4.4 Medium level: building information

The renovation of existing buildings is different from the creation of space and form in new construction projects, which requires secondary creation based on the original characteristics of the space. Modern architecture puts forward the slogan "form follows function" to oppose the fact that this practice is still the mainstream architectural creation process in today's architectural projects, and traditional new projects are designed according to the proposed functional design mission statement. However, the existing building space restricts the arbitrary development of function, especially the existing space with historical and cultural value, and the main idea of renewal and renovation is to preserve the spatial characteristics.

The internal information of classical architectural programming collects the functional spatial patterns of the same type of buildings. For the reasons stated in section 4.2.2, this study splits the internal information collection into architectural and individual dimensions for elaboration. This section specifies the architectural dimension, which is divided into basic information, building diagnostic information, and spatial cognitive information.

The basic information and information of space analysis are refined based on previous researches, specified by the author with information regarding existing building and renovation. The building diagnosis information is summarized from literature review of building failure and diagnosis, but it is first time to be organized in the context of architectural programming framework.

4.4.1 Basic information: technical and historical

The basic information of the renovation project at the level of the building unit includes technical information and historical background information. **Technical information** includes the following categories.

• **Architectural drawings**: the renovation project requires not only the initial design drawings, but also the construction acceptance drawings (施工验收图纸) to obtain the most compatible drawings with the current situations. The architectural drawings can be obtained from the property owner, the local archives or the municipalities, etc. In the case that architectural drawings are lost, or there are modifications with no record of the drawings, the client or the programming team should hire professional experts to conduct on-site surveying and mapping to generate accurate drawings of the current condition in the pre-design phase. This is more common in reuse projects of historical building.

• **Function-space list (功能面积列表)**: based on the architectural drawings and user interviews, the floor area and quantity of each functional space are recorded and corresponds to each floor lay-out. Figure 4.10 shows the function-space list of the existing building spaces in the architectural programming of the Enrico Fermi school project.

PIANO SEMINTERRATO							
Scuola media statale "E. Fermi"							**972,00**
00.01	palestra	piano seminterrato	1	6,55	310,00		
00.02	deposito attrezzi	piano seminterrato	1	3,00	22,00		
00.03	spogliatoio	piano seminterrato	1	3,00	25,00		
00.04	wc	piano seminterrato	1	3,00	26,00		
00.05	spogliatoio	piano seminterrato	1	3,00	26,00		
00.06	wc	piano seminterrato	1	3,00	26,00		
00.07	sala medica	piano seminterrato	1	3,00	18,00		
00.08	disimpegno	piano seminterrato	1	3,00	7,00		
00.09	disimpegno	piano seminterrato	1	3,00	66,00		
00.10	atrio	piano seminterrato	1	3,00	44,00		
00.11	disimpegno	piano seminterrato	1	2,40	106,00		
00.12	ex laboratorio	piano seminterrato	1	2,40	48,00		
00.13	sala polifunzionale	piano seminterrato	1	2,40	109,00		
00.14	ex laboratorio	piano seminterrato	1	2,40	15,00		
00.15	wc	piano seminterrato	1	2,40	11,00		
00.16	wc hp	piano seminterrato	1	2,40	7,00		
00.17	ex laboratorio	piano seminterrato	1	2,40	48,00		
00.18	ex laboratorio	piano seminterrato	1	2,40	47,00		
00.19	disimpegno	piano seminterrato	1	2,40	8,00		
00.20	vano tecnico	piano seminterrato	1	2,40	3,00		
Spazio Anziani							**331,00**
00.21	spazio anziani 1	piano seminterrato	1	2,40	30,00		
00.22	spazio anziani 2	piano seminterrato	1	2,40	49,00		
00.23	spazio anziani 3	piano seminterrato	1	2,40	54,00		
00.24	spazio anziani 4	piano seminterrato	1	2,40	48,00		
00.25	spazio anziani 5	piano seminterrato	1	2,40	48,00		
00.26	spazio anziani 6	piano seminterrato	1	2,40	53,00		
00.27	locale preparazione cibi	piano seminterrato	1	2,40	8,00		
00.28	wc	piano seminterrato	1	2,40	12,00		
00.29	locale di servizio	piano seminterrato	1	2,40	13,00		
00.30	wc hp	piano seminterrato	1	2,40	5,00		
00.31	wc	piano seminterrato	1	2,40	11,00		
							1.303,00

SPAZI ESTERNI							
Piano seminterrato							**3.617,00**
E.01	area verde	piano seminterrato	1	-	10,00		
E.02	area verde	piano seminterrato	1	-	68,00		
E.03	zona pavimentata	piano seminterrato	1	-	167,00		
E.04	portico	piano seminterrato	1	-	224,00		
E.05	cortile	piano seminterrato	1	-	394,00		
E.06	terrapieno	piano seminterrato	1	-	85,00		
E.07	terrapieno	piano seminterrato	1	-	70,00		
E.08	zona pavimentata	piano seminterrato	1	-	106,00		
E.09	zona pavimentata	piano seminterrato	1	-	44,00		
E.10	area verde	piano seminterrato	1	-	56,00		
E.11	zona pavimentata	piano seminterrato	1	-	55,00		
E.12	zona pavimentata	piano seminterrato	1	-	131,00		
E.13	area verde	piano seminterrato	1	-	24,00		
E.14	area verde	piano seminterrato	1	-	29,00		
E.15	anfiteatro	piano seminterrato	1	-	131,00		
E.16	terrazza	piano seminterrato	1	-	35,00		
E.17	area verde	piano seminterrato	1	-	389,00		
E.18	ingresso pavimentato	piano seminterrato	1	-	19,00		
E.19	area verde	piano seminterrato	1	-	167,00		
E.20	area verde	piano seminterrato	1	-	33,00		
E.21	zona pavimentata	piano seminterrato	1	-	67,00		
E.22	area verde	piano seminterrato	1	-	24,00		
E.23	parcheggio	piano seminterrato	1	-	1.289,00		

Figure 4.10 Space list of Enrico Fermi School © Torino Fa Scuola

• **Building codes**: two types of information need to be collected on building codes, the past and the present. The past is the building codes used when the building was constructed, which can be combined with the building diagnostic information in the next section to get a comprehensive picture of the current status of existing buildings. The present information includes the current general codes and the building codes of the target building types. Generic codes include fire codes, seismic codes, etc. The building codes of the target building types can be compared with the information in the subsequent building diagnostics to analyze the possibility of functional transformation and enhancement of existing buildings. Gaps in building codes are an important factor limiting the functional range of building reuse.

Safety is the first issue to be considered in the renovation of existing buildings, so fire codes and structural seismic codes are the first to be verified. The architects interviewed in chapter 2 reported that these two codes are also the most troublesome aspects in renovation. Structural reinforcement can cost much more than the original budget. For example, in the Torino Esposizioni project, an additional investment of 3 million Euros was needed to meet the current structural seismic code for Pavilion 2, and it is the most significant reason to cause indefinite delay of construction.

Two main strategies to deal with this kind of problems are the "case-by-case" review of the project or the issuance of a special building code for renovating existing buildings. Taking the fire code as an example. Fire codes are one of the most prominent issues in the renovation projects, because they are limited by the structure and spaces of buildings and the scale of outdoor spaces, it is difficult to solve the problems of fire prevention space for stairs, corridors, and building groups, which are common problems in the renovation of historic districts, historic buildings and industrial heritage. This kind of uncertainty is the main obstacle for programming and design. The fire protection design of renovation projects should consider the requirements of safety, technical rationality and feasibility, and engineering economy. Current possible responses include:

1) Municipalities prepare design guidelines respectively for renovating existing buildings. Beijing issued the "Fire Protection Design Guidelines for Existing Building Renovation Projects in Beijing (for Trial Implementation)" (《北京市既有建筑改造工程消防设计指南（试行）》) in 2021, proposing 42 loose design requirements in 3 dimensions: maintaining the status quo, meeting original standards, and performance compensation (Beijing Municipal Commission of Planning and Natural Resources, 2021a). The implementation of this design guideline encourages retrofitting projects, reduces the cumbersome process and the burden of governmental affairs brought about by "case-by-case" process, and avoid to a certain degree the problems that existing buildings can only be demolished and rebuilt due to difficulties in meeting current fire codes, or lack of legal basis after renovation.

2) compensation by other means, the planning bureau organized by the expert

demonstration will be approved. For example, Jingdezhen took the historic district as a renewal demonstration area and issued *Jingdezhen Tao Yangli Jianguo porcelain factory and the Royal kiln factory area around the building fire design guidelines* (景德镇陶阳里建国瓷厂及御窑厂片区周边建筑消防设计指引), which provided regulations for the provisions of the group division, the size limit of the building volumes, a variety of fire escape paths, addition of automatic sprinkler system in all the buildings that cannot meet the regulations above, addition of automatic fire alarm system and other devices, in order to promote the fire protection design in industrial heritage reuse projects(张杰 et al., 2021b).

3) Apply to the department examining and approving the fire protection design to carry out an expert meeting of special fire protection design for a certain project.

• **Historical information** shows the background and evolution of the existing building, which results in a better understanding of purposes, reasons and meaning of the current situations, and its contributions to urban development and the relations to the urban history and memory. Historical information includes the following categories.

• **Phases division:** programmers should first clarify the phases or the timeline of the evolution history of the existing building or building cluster. Table 4.3 shows the evolution history of Pingyao Diesel Engine Factory.

• **Detailed recordings for each phase:** for each time of modifications, addition, expansion or demolishment, information includes the client, architects, users, operators at that time, as well as the construction drawings, site photos, or even news, reports, textual recordings, etc (Figure 4.11).

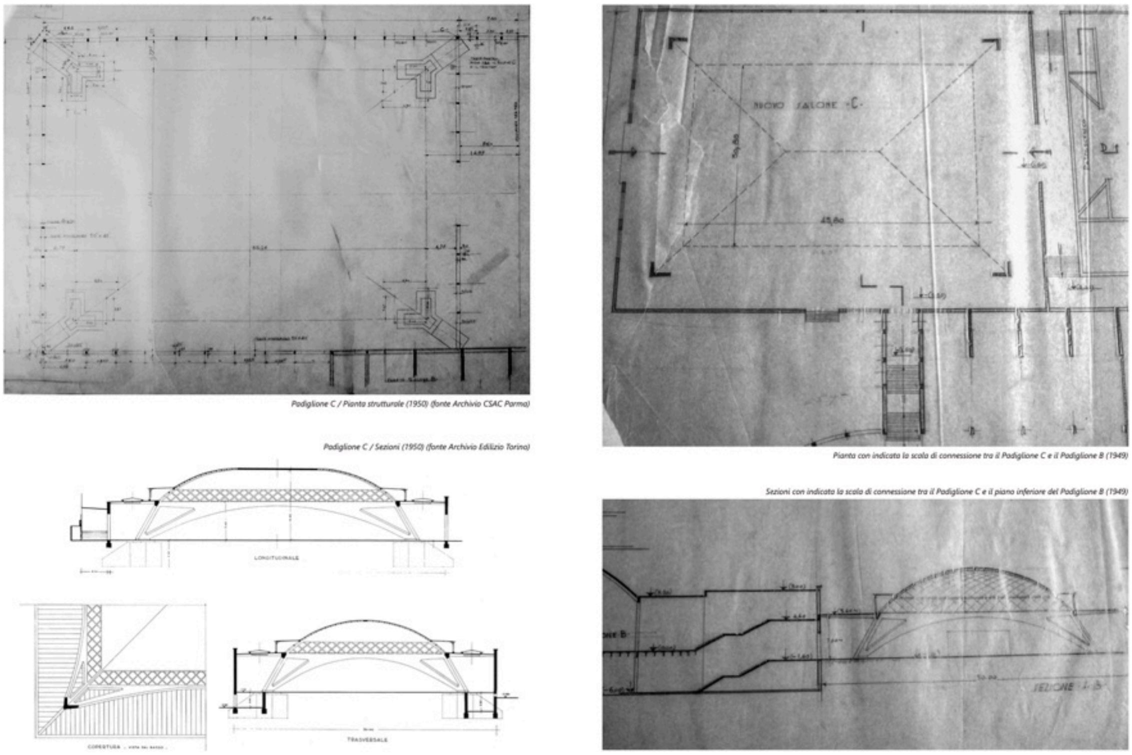


Figure 4.11 Materials in the evolution history of Exhibition hall C of Torino Esposizioni © Masterplan_PoliTo

Table 4.3 History of Pingyao Diesel Engine Factory

Year	Factory	Activities/events	Modifications on buildings
1920	Establishment of Juxing steel factory		
1948	Factory was renamed as Jinzhong Diesel Engine Factory		
1970	Factory construction project		Built diesel engine factory building, covering 71,951 square meters, with cotton weaving factory covering a total of 150 acres
1994.6	Jinzhong Diesel Engine Factory was closed and Jinzhong Machinery Manufacturing Company was formed		
2001		The first Pingyao International Photography Exhibition	

Year	Factory	Activities/events	Modifications on buildings
		opened in September	
2002		Using old factories and warehouses as exhibition space for a major photography exhibition	
2004	Bankruptcy of Jinzhong Machinery Manufacturing Company		
2005		The 5th Pingyao International Photography Exhibition	first transformed to be the main venue for the photography exhibition: dismantle the machinery and equipment
2010		The 10th Pingyao International Photography Exhibition	Second renovation of diesel engine factory
2012		The 12th Pingyao International Photography Exhibition	Third renovation to satisfy expanded requirement of the photography exhibition
2016.12		Pingyao Film Exhibition Co., Ltd. was established with Jia Zhangke as legal representative	
2017		The 1st Pingyao International Film Festival on October 28, as the fifth state-approved international film festival	Renovation on 4 factories completed from July-October
2018		The 1st Pingyao International Sculpture Festival	The Film Palace won the WA China Architecture Award "City Contribution Award";
2019			Addition of catering and other service facilities

4.4.2 Building diagnosis

Building diagnosis, or building diagnostics, is to assess building status, to identify technical defects resulting in building failures, high energy assumption and other problems. The **purposes** of building diagnosis could be for building maintenance, renovation, energy retrofit, safety considerations, asset appraisal, etc. The **narrow scope of contents** of building diagnosis aim at assessing physical state of building deterioration to cope with or prevent building failures(Ransom, 2002), while the **broader scope** encompass building energy audit, and even evaluation of indoor environment quality(Jaggs and Palmer, 2000 ;Caccavelli and Gugerli, 2002); some researchers also take up functional obsolescence in building diagnosis to measure the degree of satisfaction to the user needs(Caccavelli and Gugerli, 2002). The traditional **objects** of building diagnosis are always for the technical assessment of deterioration, which involves structure, material and component, foundation, floors, walls, claddings and coating, doors and windows, roofs, other equipment and services such as drainage, HVAC, electricity and lighting, etc. While the **broader range of objects** include energy consumption, using pattern and user needs. Douglas and Ransom (2013) list categories of building failures for diagnostic analysis from the perspective of physical and performance aspects (Table 4.4).

Table 4.4 Typical categories of building failure (Douglas and Ransom, 2013 [10])

Failure type	*Example*
Aesthetic failure	Crazing or shrinkage cracking of concrete or render Flaking and peeling of paintwork Bossing and spalling of render Staining and soiling of finishes Chipped, dented or lipped floor/wall/ceiling finishes and veneer finishes to doors
Functional failure	Misalignment of building components such as doors and windows not operating properly Leaks in elements such as roofs, walls and floors Sagging of floors
Failure of materials	Chemical (e.g. sulphate) attack of rendering, mortar or brick Fungal attack of timber Corrosion of metals
System failure of components and elements	Carbonation of concrete, leading to corrosion of reinforcement and subsequent cracking and spalling of concrete members Debonding and bubbling of membrane from substrate owing to moisture or incompatibility
Structural failure	Subsidence (a downward movement of a building caused by below-ground factors – such as desiccation of clay soil) Settlement (a downward movement of a building caused by above-ground factors – such as overloading)
Non-structural failure	Delamination of roof tiles and slates Cracking and debonding of plaster or rendering Blistering and peeling of paint coatings Tenting, debonding and bubbling of floor coverings
Reversible failure	Jamming of doors and windows as a result of moisture intake by these components – usually in winter; in the summer the wood dries out and the windows and doors become unstuck
Irreversible failure	Chemical reactions such as sulphate attack on mortar or rendering Excessive distortion in beam/slab, column or wall owing to structural movement

The **people** and group who conduct building diagnosis should have expertise and professional experience in testing in order for accredited test reports(Kwan and Ng, 2015). Since this research focuses on architectural programming and the potential readers are programmers, architects and even clients, **it will not explain detailed methods or technologies** of building diagnosis. Instead, it will draw a comprehensive picture for understanding and **provide the process and information checklist** for information collection in the pre-design phase, so as the architectural programming group or clients can have a better understanding about how to organize this process, what facts they need, and who they should hire or consult.

No matter the narrow or broad working scope of building diagnosis, the **process** usually consists of three steps: 1) a general and overall visual inspection; 2) a more detailed condition assessment; 3) further examination of problems in the second step and draft test reports. The next sections will introduce the process step by step and identify the information list, professionals, and feasible methods respectively.

• Step 1 – Visual inspection

The **purpose** of visual inspection is to observe the building conditions and identify some provident problems and points of detailed examination. It provides a general and panoramic view of the existing conditions, so the inspection doesn't utilize professional **tools** or equipment, but with all kinds of human senses and simple tools such as tape measure, infrared distance meter, etc. The **people** conduct visual inspection can be architects, structural engineers with expertise, clients and principal users. In this stage, programmers already have the materials in the initial preparation phase, including construction design drawings, test records during construction, alterations during construction, construction acceptance report, etc. The **checklist** of visual inspection is shown as in the Table 4.5 below. This kind of on-site investigations can obtain literal and photographic records.

• Step 2 – Detailed assessment

The **purpose** of detailed assessment is to further investigate the problems on the basis of the results in the first step. It will position precisely the abnormal locations in the building components to trace the internal defects(Douglas and Ransom, 2013). The **people** conduct detailed assessment should possess professional knowledge that can be hired by clients or the technicians from the municipalities. Table X presents the **checklist** of detailed assessment. The **method** in this phase should combine destructive and non-destructive testing methods and use samples to test each part of the building. The techniques and **tools** in assessing deterioration of building diagnosis including infra-red thermography, ultrasound, radar, vibration, lasers, etc (Wikipedia). The **outcomes** of this step are a group of reports focusing on different professions and a draft report for building diagnosis.

• Step 3 – Examination and reports

The **purpose** of examination is to re-examine the problems found in step 1 and tested in step 2, and to refine the building diagnosis reports. The **people** that conduct examination and write final reports are programmers, architects and technical consultants. The **checklist** is listed in the following table. The method and technologies in this step could be destructive testing methods. The outcome in this step is the final **report** consisting of objectives of the assessment, investigation procedures, assessment methods, results and important conclusions, recommendations and a plan to carry out remedial actions.

Table 4.5 Process of building diagnosis

	Visual inspection	Detailed assessment	Examination and reports
Purpose	• observe the building conditions • identify provident problems detailed examination	• further investigate the problems	• re-examine the problems found in step 1 and tested in step 2 • refine the building diagnosis reports
People	architects, structural engineers, clients and principal users	experts	programmers, architects and technical consultants
Tools	• Visual observations with notebook • Olfactory – smells • Aural – sound by tapping the structure, pipes, etc • Tactile – surface and materials • Taste – drink water • simple tools such as tape measure	• infra-red thermography • ultrasound • radar • vibration • lasers, etc	• destructive testing methods
Outcome	• literal and photographic records	• a group of reports focusing on different professions • a draft report for building diagnosis	• final report of building diagnosis

This study will not do further research on building diagnosis, but focus on the information which programmers should collect from the final report. Through review the diagnostic information of the cases in chapter 2 and 3 with literature review, the table below shows the general information index for building diagnosis.

Table 4.6 Information index of building diagnosis

Category	Sub-category	Contents
Surveying and drawings (测绘资料)	Horizontal surveying	• layout and positioning of foundations and each floor • surveying drawings and photos of each structural element • indications of dimensions and materials
	Vertical surveying	• elevation surveying and drawings • section surveying and drawings • indications of dimensions and materials
	Details	• surveying drawings of typical detail • indications of dimensions and materials
	3D scanning	• 3D scanning models of existing site and surroundings • 3D scanning models of existing buildings
Structural diagnosis	Investigations	• archives • onsite investigations • Load testing report • Material testing report
	Analysis of current state	• geology and foundation analysis • static analysis of elements each floor and part • seismic analysis
Energy audit	Current state	• investigation on heated area and insulation of all types of elements • calculation and analysis of energy consuming and thermal losses
	Upgrade potential	• target energy codes and standards • advice on architectural design and element upgrade
Geological, geotechnical	Geology	• geological and geomorphological features • lithostratigraphy

Category	Sub-category	Contents
and seismic report	Hydrography	• hydrographic and hydrogenic characteristics
	Seismic aspects	• seismic parameters • geotechnical characteristics
Site photos	Surroundings	• street view and the existing building from the street • every entrance
	Outdoor space	• street view and the existing building from the street • every entrance • outdoor space of each floor
	Interior space	• each room • inner public spaces • service space on each floor • details of elements, furniture, decorations and original usage

Extension of building diagnosis – urban health examination

In 2021, the Ministry of Natural Resources (MNR) issued the "Regulations for Urban Health Examination and Assessment of Territorial Spatial Planning", which will be implemented from June 18, 2021, taking the form of an annual health check and a five-year assessment to diagnose urban diseases. This system will become an important tool to promote the high-quality development of cities in China and improve the effectiveness of spatial planning implementation. The Regulations set up specific indicators for city physical examination and assessment in six dimensions: security, innovation, coordination, green, openness and sharing. Among them, 33 basic indicators, such as per capita annual water consumption, groundwater level, arable land retention, total construction land area, urban resident population density, etc., are mandatory for each city to choose when conducting physical examination and evaluation. There are also 89 recommended indicators that cities can choose to use according to their development stages and priority tasks. Around these indicators, cities can make horizontal comparisons with other cities and vertical comparisons with their own past to find gaps and shortcomings. The future research could combine building diagnosis with urban health examination to fulfill the scale of physical spaces and achieve integrated improvement for a better contribution in urban renewal.

Building diagnosis, on the one hand, can clarify the constraints of renovation; on the other hand, it can also clarify the gap with the current building standards as early as possible, and judge the technical difficulties and assess the renovation costs in advance. According to the project manager and architects interviewed in chapter 2, due to the limitation of the project cycle and uncertainty of the initial conditions, building diagnosis is generally carried out at the same time as the architectural programming or even later, so that architects project experience can visit the site to make a pre-judgment of the existing building, have a general understanding of the current situation, and collect the basic information; they can also clarify the challenges and risks for further testing by building diagnosis.

4.4.3 Spatial analysis

If building diagnosis is more about identifying the constraints of architectural design, spatial pattern analysis is the basis for finding design strategies and exploring potential of the spaces. The spatial pattern is based on the comprehensive and detailed information of the existing building in the previous step, including accurate construction drawings of the building, current use functions and a list of functional spaces. The purpose of spatial analysis is to **obtain the characteristics of each space unit, the internal flow of the building, and sort out the spatial relationships**, so as to prepare for the next stage of functional identification, program conception, and renovation feasibility study. This section only briefly introduces the relevant theories and methods, while the specific implementation is described in Chapter 6.

It has been a long history in the abstract description of spaces. Spaces first possess geometric characteristics, but the topological features more represent the essence the of spatial relations, which can be conceived by children first as proximity, separation, enclosure, and so on(Piaget and Inhelder, 1956). Researches on spatial relations, composition and configuration include several directions such as architectural composition, topological and numerical nature, spatial pattern language, etc. Studies of architectural composition regards the internal and external spaces, from and material of a building as some kind of independent unit generated by collection and arrangement, and the internal space of a building is divided and unified in sequence to form the inner structure of space by moving flows(Iwaoka, 2018). Inspired by semantics, it studies the space unit and various kinds of arrangement and relations including lay-out composition, space distribution, disposition and so on(王骏阳, 2021)。Research on topology of spaces inspired by mathematics and graph theory, extract the abstract features of spaces in a quantitative form. One of the most well-known theories of topological spatial analysis is **Space Syntax** (空间句法). Space syntax is a set of theories and quantitative methods for spatial analysis, proposed by Bill Hillier, Julienne Hanson, etc. in the last 70 era. Combined theory of topological geometry and theory of syntax, it provides a perspective to conceive the relations between spaces and social, cultural and economic behaviors (Hillier and Hanson, 1984 ;Hillier, 2007).

Considering the broadness and openness of application, this study chooses Space Syntax as a tool to conduct spatial analysis. Space syntax has been applied broadly in urban issues, as well as in post-occupancy evaluation of buildings to assess the results of architectural programming and design(庄惟敏 and 韩默, 2019). As for renovation projects, Space syntax can be used to uncover the existing problems such as renovation of Trafalgar Square in London; or to assess the improvement result of renovation based on the comparison between the before and after situations of spaces, traffic, social and economic aspects, etc.(Wang et al., 2017 ;王量量 and 张智欢, 2019); it can also compare and select renovation schemes from dimensions of efficiency, vitality, accessibility of rooms and public spaces, and the understandability of flows (黄海阳, 2015).

The input condition of space syntax to analyze spaces is the floor plan. The software DepthMapX of space syntax can generate convex map, axial map, and segment map for further analysis (Table 4.7). The preliminary spatial analysis includes accessibility, depth measure, integration pattern, choice pattern and other index to present the spaces from different perspectives. In the step of information collection, programmers can input the lay-out into the software, and obtain these three kinds of maps, to prepare for the following steps as shown in chapter 6.

Table 4.7 Preliminary mapping of existing building spaces

Types of map in space syntax	Definition
convex map	the least (minimal) set of fattest spaces that covers the system(Hillier and Hanson, 1984 [92])
axial map	a set of intersecting lines through all the spaces of the urban grid so that the grid is covered and all rings of circulation are completed(Hillier and Hanson, 1984 [91])

segment map	based on axial map, reduce over-articulated curves and to remove extraneous road traffic features(Turner, 2004 [26-27])

4.5 Micro level: user information

In the traditional universal architectural programming theory, the internal information includes the characteristics of the future users, their behavior patterns and their functional requirements. The study of user behavior patterns is also part of the architectural programming. However, in existing building renovation projects, user behavior is not only related to the activity but also to the existing building. Therefore, studying the existing behavior patterns of users is also a way to find out the problems of using existing buildings. Using pattern study is aimed to investigate the original usage in the existing building and uncover the problems and requirements according to the study. It usually involves the original and future users, the operators and even the citizens. The user information is summarized and organized from literature review and previous researches in architectural programming theory, with addition of practical experience from architects and clients interviewed, and that from the author’s practice.

4.5.1 User profile

The user is the one that use the spaces and conduct activities in the building; in reverse, the building serves the user. Therefore, the architectural design needs to match the characteristics of the user and meet the needs of the target user. The first thing to be studied in the internal information collection of architectural programming is the feature of users. Traditional architectural programming for new projects only needs to consider future users, and if a renovated building is planned for functional transformation, its user characteristics are generally similar to those of architectural programming for new projects, including age, gender, social class, preference, intellectual ability from aspects of physical, social, emotional, and intellectual ability from aspects of physical, social, emotional, and intellectual(Peña, 2012)。The difference is that the new function is uncertain, and therefore the future users may not be fully identified. Programmers should first gather general information following a research framework, and then conduct the feasibility study with other conditions. In addition, if the main function of the renovated building is retained but only partially upgraded, the future users may also be the original users of the existing building, so it is necessary to analyze their features, collect and record their feelings and opinions about the use of the existing spaces, which will be introduced in detail in the next section.

Jingdezhen Grain Depot renovation project in which the author participated, is a project of complete functional transformation, and the client tends to create a multi-functional cultural center for art performance, and commission the programming and design team to conduct a study on the future target users. Based on the general function and requirement, the programming team researched on five types of users including scientists, artists, entrepreneurs, performers, tourists, summarize their representative behavior characteristics from user types, user profile, representative characters and scenarios (Table 4.8 & Figure 4.12).

Table 4.8 Research framework for user profile

User classification	Classified by age, occupation, activities, etc.		
User profile	Basic feature	Social feature	Age, gender, region, education, occupation, marital status, housing and vehicles
		Living habits	Sports, leisure, travel, food and living, shopping, games, sports, culture
	Behavior pattern	Social behavior	Interaction unit, number, type, form
		Consume behavior	Consumption amount, times, frequency, etc.
		Activity	Behavior for a specific activity
	Attitude feature	Cultural preferences, visual preferences	
Requirement	Needs of all types of users	Functional needs	
		Psychological needs	
Organization structure	Administrative structure		
	Task or activity distribution/ collaboration structure		
	Specialization of work		

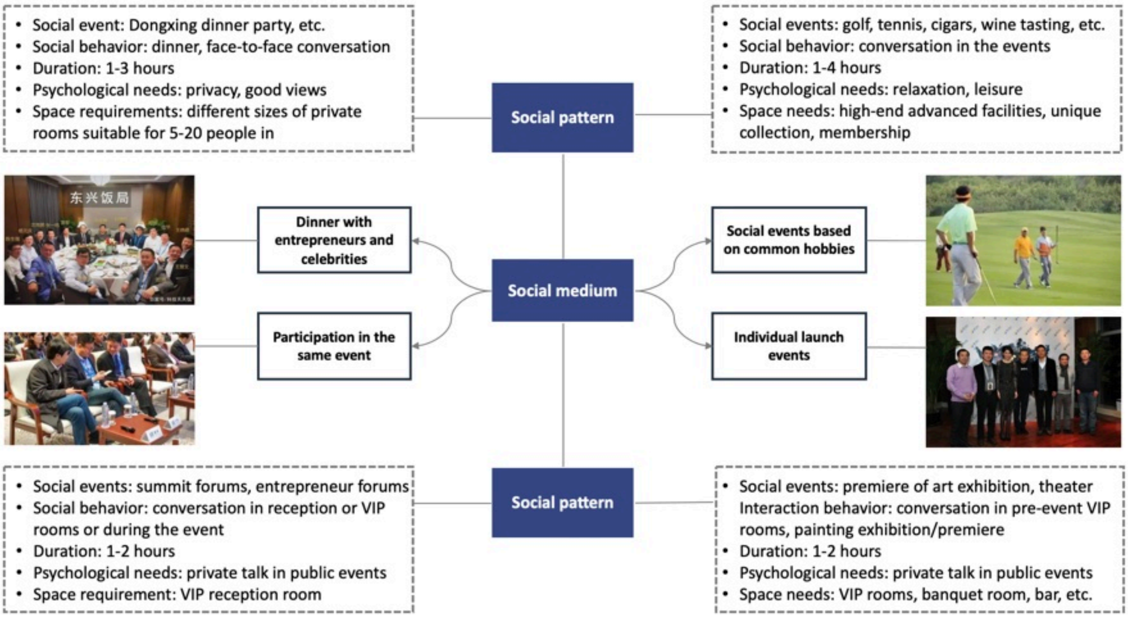


Figure 4.12 User characteristics and potential using scenes of Jingdezhen grain depot renovation project

Table 4.9 User profile and behavior analysis of Jingdezhen grain depot renovation project

Basic feature	Social feature	Scientist: average age-73, gender ratio 94:6 Artist: wide range of age, gender ratio 7:3 Entrepreneur: average age-56, gender ratio 7:3		
	Living habits	high-end activities and living habits; preference for sports like swimming, golf, etc.		
Behavior pattern	Performance type	Small art performance	Private exhibition	Theatre
	Social behavior	1 person	2 persons/companions	more than 3 people, families
		2 pl: private conversation, 3-10 pl: Small table >10 pl: large table	Private communication space in partition	Open communication space
	Social distance	Close: 1-1.5m	Division distance: 5-10m	parent-child activities >200m2
	Travel mode	Pick up, self-drive		
Requirement feature	Attitude feature	Private, high-end, privileged	Customized enjoyment	Warmth and harmony
	Functional needs	Banquet room, bar, book/art	Beauty spa, culture and art	Indoor children's playground, outdoor

	display, outdoor courtyard, swimming pool, wine collection area, tea room	exhibition, gym, yoga room, jumping gym, SPA, squash room	beach playground
Psychological needs	Private meeting, unique views	Private and comfortable	Close to nature, joy of scenery

4.5.2 Using pattern and requirement

Function requirements and using patterns are closely linked. Function requirements refer to what types of functions are needed, the capacity of each type, and the refined requirements, etc. They are usually presented as function program lists in the design proposal, with information including function names, number of rooms, floor area, number of users, and facility requirements. These clear parameters are partly derived from the direct requirements of the owner, and partly from the conclusions of the programming team based on the analysis of the using pattern information. Using pattern information is the information about the organization of users, the number of people, the kind of activities they need to perform, and other events, and can be obtained through a variety of techniques such as interviews, research, and observation. The using pattern study is the key for the programming team to analyze the functional requirements and generate the function program.

The owner sometimes provides a design proposal, but due to the lack of the architect's expertise and experience in space and functions, this design proposal often does not reflect true requirements of the client. The information obtained from the owner about the user organization, number of people, activities and other using patterns needs to be translated into architectural language by the architect, such as the size, scale, proportion and flow organization of the rooms. By studying the behavioral activities of the future users clearly, the architectural programmers or architects can compile a list of corresponding functional requirements based on the analysis of the correlation between behavior and space, prepare for the subsequent renovation feasibility study, and finally generate a design proposal.

For the study of user behavior patterns, the architectural programming of renovation projects differs little from that of new construction projects. For example, in a renovation project with functional transformation, the original users may no longer be the future users, and the functional needs and users are new. However, in the case of renovation projects where the main function remains unchanged and will be upgraded, the original use pattern is retained to a certain extent and the original users are likely to be the future users. Based on the existing building and original users, the sources of information are richer, and therefore the information gathering and contents are slightly different. Regardless of the type of renovation project, the programmer needs to refine the owner's needs and determine whether, or to what extent, the existing building can meet the owner's current missing use requirement. The following are two case studies that illustrate the process of collecting information on use patterns for each of these two types of projects.

1) Function-enhancement project

In Enrico Fermi School project, educational experts and a work group of faculties, students, and parents collaborated to complete the research on the current state of use and the future requirements, with consultants from the municipalities and educational counsellors. External groups and associations who wanted to use campus buildings after school also participated in some of the discussions. The research methodology was based on three steps: listening, seeing, and doing (Torino Fa Scuola, 2016b). The first step, "Listen," involved initiating meetings, visiting schools, listening to needs, and presenting innovative schools worldwide by educational experts. The second step, "See", was to visit the most advanced schools in southern Italy and to summarize their spatial atmosphere, furniture and materials. The third step, "Doing", was to conduct a series of workshops to study the behavior of students, staff and other users, and their future expectations, to brainstorm on the daily teaching schedule, use of the core spaces (Figure 4.13 and Figure 4.14), and to study the relationship between various parts of the existing building and the use of teaching space.

Figure 4.13 Brainstorm by Programmers © Torino Fa Scuola

Figure 4.14 Interview with users by programmers © Torino Fa Scuola

2）Function-transformation project

Take Pingyao Film Palace as an example. The indicators of some building spaces are clear, for example, a cinema hall for 500 people, whose area indicators can be deduced from the experience of per capita area of the cinema design, and the net height requirements of the space can be deduced from the slope height of the auditorium and the view range. However, in order to truly understand the details of users, it is still necessary to carefully consider the usage scenario and explore the space potential. In the preliminary planning, the architects and the owner discussed in detail the various aspects and usage scenarios of the festival, including the clear use requirements of movie viewing and forum, as well as the red carpet and movie premiere, which are special feature of the festival with huge popularity[18]. The architects analyzed the flow of the red-carpet entrance, the photo-shooting pattern and media working station. Based on the previously information about topographical height difference, they thought about the element of stairs at the intersection of the main venue and the main axis of the park to meet the demand for the red carpet, which later became one of the iconic punching points of the park (Figure 4.15). This kind of function rarely appears in the design brief, but it is very important and requires the architect to explore the functional needs of users by studying using patterns and scenarios.

18 Sourced from the interview with architect Ren F on September 1st, 2021.

Figure 4.15 Big stairs of Pingyao Film Palace

(https://www.pyiffestival.com/guanYuJuBanDi.html#102)

4.5.3 Operation mode

Renovation projects may bring about a change in the user groups or the operation mode: the type of user cluster may change, and the range of the user may expand or contract; the operator may change, and the number of participators may increase or decrease. Renovation projects cannot regenerate the existing building without the continuous operation and promotion. The content of operation involves commercial activities, investment, promotion and publicity, asset management, property management, etc. Without virtuous operation, even the excellent renovation design will not be sustainable, and may cause the risk of secondary decay and vacancy(刘岩, 2017). In reality, there are many wonderful renovation cases where the lack of post-operational management causes the existing buildings to remain decayed or difficult to be used according to the programming scheme. For example, Doreen Heng Liu, the lead designer of NODE Architects, once said that some of their renovation projects often face the dilemma of demolition a few years after the completion. In the Pingshan Riverfront Sewage Treatment factory project, they designed an open roof as a viewing platform to the public, but the platform was soon closed due to operational management reasons[19]。

The solution to such problems is to invite the post-operation team to participate in the discussion at the early stage of architectural programming, to achieve a consensus with the owner, investor and other multi-stakeholders, and to incorporate the demand and mode of post-operation into the drafting of the design proposal, so as to ensure that the architectural programming, design and using pattern are consistent after the completion of the project, and to realize the sustainable development. The following are two examples in China and Italy to illustrate the consideration of operation mode in renovation architectural programming.

In the renovation project of Enrico Fermi School in Turin, one of the goals is to create a cultural center for the neighborhood, and the school committee plan to open part of spaces to the community, to provide more cultural and educational functions for residents, and to increase social welfare while improving the occupation efficiency of the facilities. Therefore, during the pre-design stage, the client and programming team invite representatives of community and cultural institutions to discuss the cooperation mode, including the sharing area, use functions, and opening hours. The study of the operational mode also directly influenced the development of the architectural programming and design strategy. The programming team develop a three-level spatial strategy of open-transition-inward, considering the private nature of the school classroom and the openness to the community. In the open zones, the outdoor space orients friendly to the street, adding outdoor green landscape and parking spaces; in the transition level, the shared mix-used spaces, such as multi-functional hall and library, are with much flexibility, and are located on the second floor, while other teaching areas that will not be open are placed on the second and third floors, making the spatial pattern match the operation pattern.

Jingdezhen Taoxichuan and Hedong Old Town industrial heritage development project apply DIBO (Design-Investment-Build-Operation) model (Figure 4.16), consider the investment and later operation from the beginning of the pre-design phase. Under the concept of scene creation and operation content, design team and the operation team jointly lead the whole process of design and construction. The operation mode is considered even in the preparation of controlled regulatory plan, including exploration of

[19] Sourced from the interview with architect Doreen Heng Liu on February 4, 2021.

the cultural IP, organization of investment campaign, and establishment of a product line with the theme of local culture. and during the opening of a comprehensive investment. The programming and operation team develop operation Key Performance Indicator (KPI) from environmental, cultural, social and economic perspectives through the pre-and-post construction(张杰 et al., 2021a).

Table 4.10 summarizes the research contents of the operation modes in the pre-design phase of renovation projects, including social organizations, business operation, cultural operation and property management. In real projects, the programming team should often consider and seek resources comprehensively from the four perspectives and organize multiple operation modes together to increase the sustainability and vitality of the renovation projects after delivery.

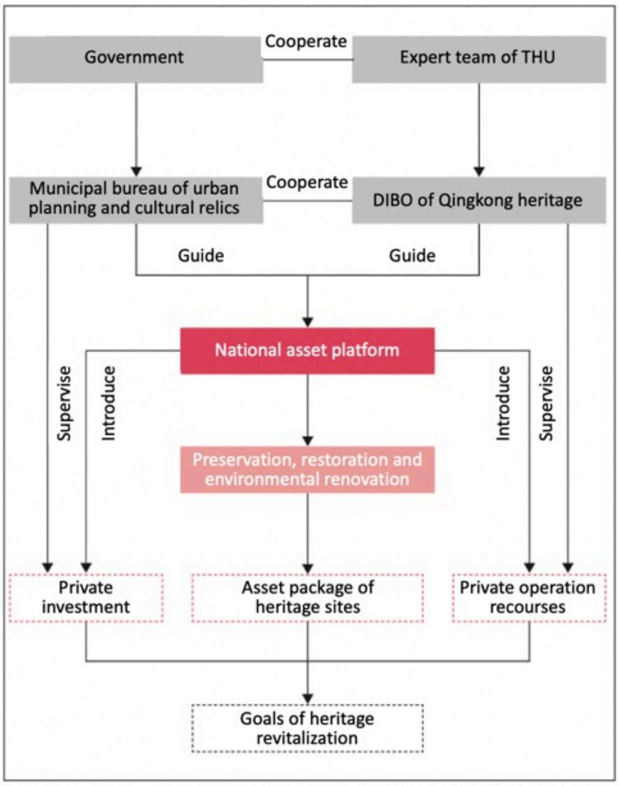


Figure 4.16 Working pattern for Jingdezhen "DIBO Plan (张杰 et al., 2021a)

Table 4.10 Research contents of the operation mode

Type of operation	Content	Details
Social organizations	Composition of operators and time distribution	Organize the group of operators of different types

	Different operation scenes	Consider all kinds of using patterns
	Coordination between bureau	Construction engineering, communication engineering, municipal engineering, etc.
Business operation	Potential investors	Attractiveness to investment
	Anchor store and brands	Connect with anchor store and brands even in the pre-design phase to attract more investors
Cultural operation	Incubation of local cultural IP brand	Brand planning and cultivation, product orientation, business orientation
	Scenes of brand campaigns and events	Conceive various scenes in future operation in advance that can affect design
Property management	Security, cleaning, intelligent operation	Requirement from the property management participators

4.6 Case study: Torino Esposizioni renovation project

This case study in Italy - Torino Esposizioni project - is reviewed through the lens of information collection index in this chapter to verify the effectiveness of the framework. The reasons for selecting this case are: 1) the case is an adaptive reuse project with complex conditions; 2) the case is an ongoing project in pre-design phase and thus is required to continue to collect information; 3) this project has commissioned an architectural programming team leading the pre-design phase, with whom the author has interviewed.

4.6.1 Introduction

4.6.1.1 Background

Torino Esposizioni is the former exhibition building cluster designed by a famous Italian architect and engineer Luigi Nervi, and now is the property of City of Turin. In 2006, it was renovated for the Winter Olympics as a skating venue, but has been partially vacant after that. It is a building cluster of 5 exhibition halls: Padiglione 1, 2, 3A, 3B and 5, located in Valentino Park in Turin, adjacent to the Po River on the east (Figure 4.17). This project has undergone a long process for being transformed since 2014. In 2015, the City of Turin organized an international competition for transformation on Torino Esposizioni won by team of architect Rafael Moneo. However, due to transition term of the municipality, budget cuts, upgrade of buildings codes and regulations, and many other reasons, the initiations for the project changed a lot so that the client had to return to the pre-design phase and think about the functional program again.

The Politecnico di Torino, who is the main stakeholder, a future user and an operator for existing buildings, has delegated Masterplan team of the Politecnico to take the lead in the pre-design research since the beginning of the project in 2014. The campus of Politecnico di Torino is now separated into several parts in Turin and the existing spaces cannot meet the pedagogic needs. Therefore, the Politecnico is intended to reuse the Torino Esposizioni to substitute the Lingotto teaching spaces which is now used by Department of Architecture, in order to integrate the campus and create a cultural center in Valentino Park (Figure 4.20).

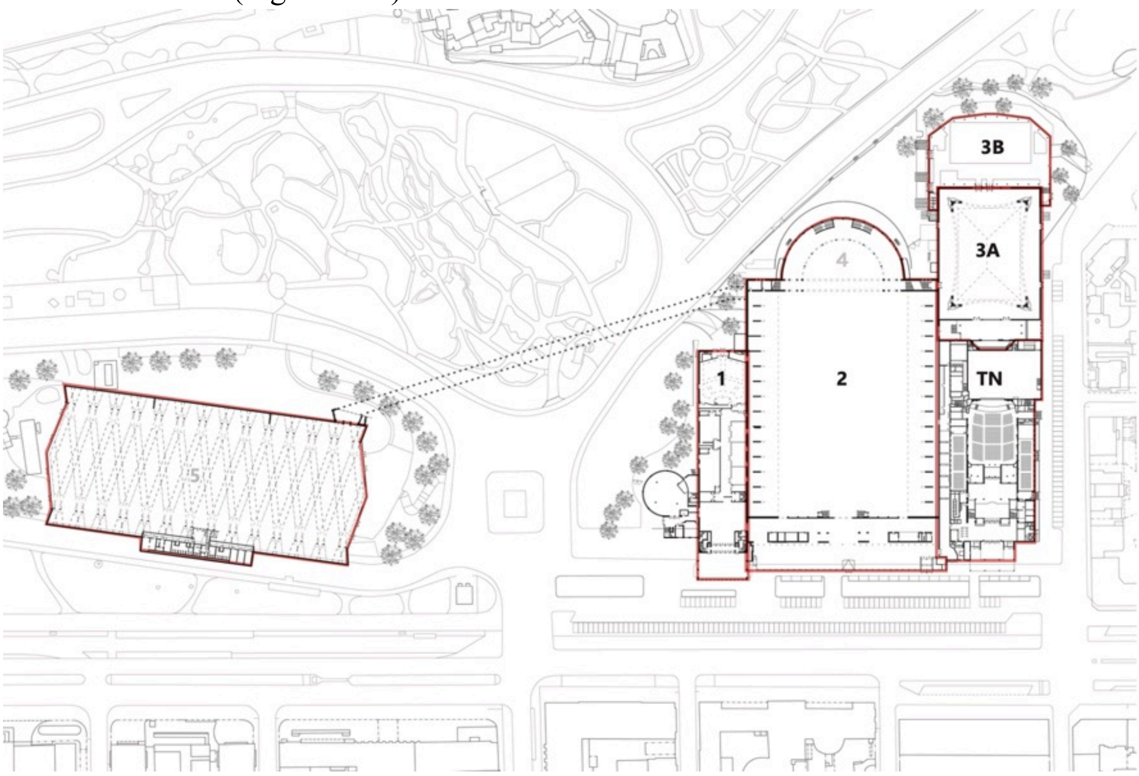


Figure 4.17 Existing buildings of Torino Esposizioni © Masterplan_PoliTo

Figure 4.18 Exhibition hall - 2 (1970) © Masterplan_PoliTo

Figure 4.19 Exhibition hall - 3A © Masterplan_PoliTo

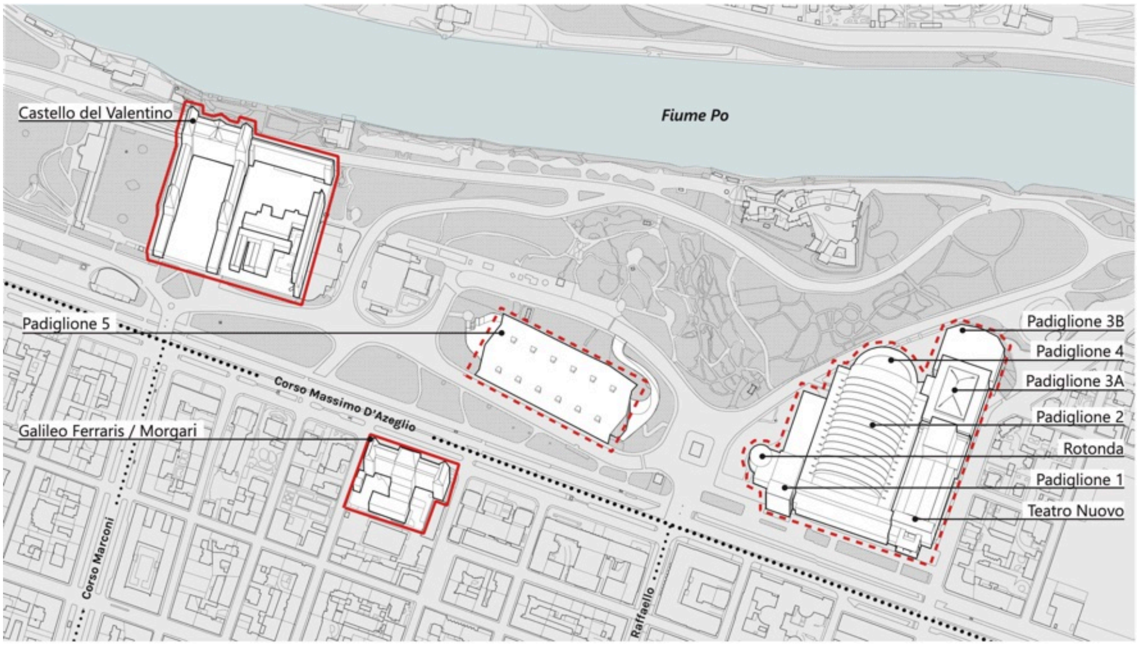


Figure 4.20 Torino Esposizioni in the master plan of Politecnico di Torino © Masterplan_PoliTo

4.6.1.2 Stakeholder analysis

Before collecting information and conditions for the projects, it should first analyze the stakeholders as the foundation for later steps. Since the project is a public building renovation, the stakeholder relationship is much more complex than that in a private project. In this project, there are a group of decision-makers categorized in three main organizations:

- City of Turin: City of Turin possessed the real-estate property and thus takes the main responsibility of deciding the future use of each building. However, different roles in City of Turin could also have distinguishing opinions and controversy on the future use considering their representation of departments. In detail, the mayor should consider the whole improvement and the balance of different benefits; the councilor (assessore in Italian) of culture departments prefer to use the main part of building as the new public library of Turin to promote cultural benefits of citizens; The technical manager prefer use of PoliTo's new classrooms or temporary exhibition space because he should choose the option that brings maximized feasibility, taking account of financial budget, modification of regulatory urban planning (Piano regolatore generale communale, PRGC in Italian), adaptability to new building codes, and so on.

• Politecnico di Torino (PoliTo): PoliTo is more like a tenderer than a real stakeholder because it is seeking the opportunity to expand their teaching area and to integrate the present fragmented campus. The rector takes the main responsibility of making decisions; the vice rector for planning, the board of directors (Consiglio di Amministrazione, CDA in Italian) have also much power in decision-making on the new campus.

• Superintendence (Soprintendenza per i Beni Architettonici e Paesaggistici): this is the department that regulates the historic building and heritages. Since Torino Esposizioni is a masterpiece designed by Architect Luigi Nervi, its historical and architectural values should be conserved. However, the values and the degree of conservation is relatively abstract and subject, compared with the building codes or budget, so architectural programmers or designers should also respect the regulations of Superintendence, and discuss with them about the degree of intervention and strategies.

Despite the main decision makers in this project, there are also other stakeholders and users related to the decision (Figure 4.21), whose requirements and benefits should be satisfied and balanced. Besides, another issue would also hamper the decision-making process, which are the different terms of election. For example, the term of the rector is 6 year, while the CDA changes their committee each 3 years, and the technical manager of the City of Turin is a tenure position. The differentiation of terms severely hinder achieving consensus and thus impede the promotion of a project.

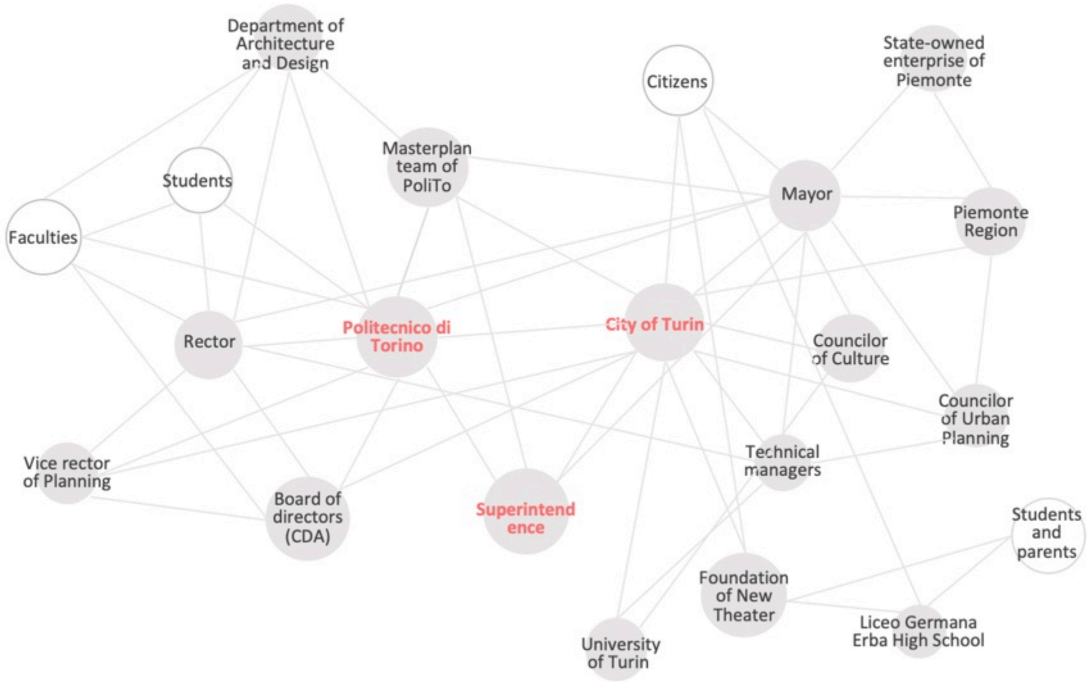


Figure 4.21 Stakeholder analysis of Torino Esposizioni project

This section will review the information collected by Masterplan team of PoliTo, to critically comment on the results through the lens of information collection index of architectural programming in renovation projects.

4.6.2 Information collection analysis

The following analysis will check the information through the index framework and critically reflect the facts and conditions with the purpose of identifying the design problems and strategies.

1. Urban information

1) Urban planning: Piano Regolatore Generale Comunale (PRGC) (Figure 4.22), protection regulations demanded by Cultural and Environmental Heritage, hydrogeomorphic information and demands by PRGC, acoustic zoning plan, sectoral planning rules-protection area planning of the Po river belt (Figure 4.23), regional landscape plan, and parking plan.

2) Initiation conditions: masterplan and property lines; financial budget of Politecnico and the municipalities with uncertainty; clear property rights of City of Turin; stakeholders including urban planning department, department of culture and education, library service, department of cultural and environmental heritage of the municipality,

and committee board of Politecnico; Goals and benefits of different stakeholders.

3) Site and surroundings: masterplan of the building cluster, existing parking capacity and parking lots nearby, site photos of views from and to the streets. The student team of design course conducted a factor mapping to analyze the site and surroundings.

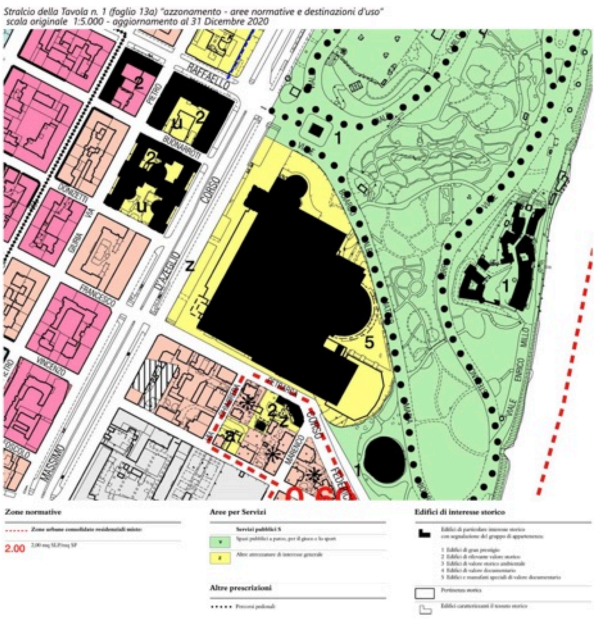


Figure 4.22 Municipal General Regulatory Plan (PRGC) of the site ©Masterplan_PoliTo

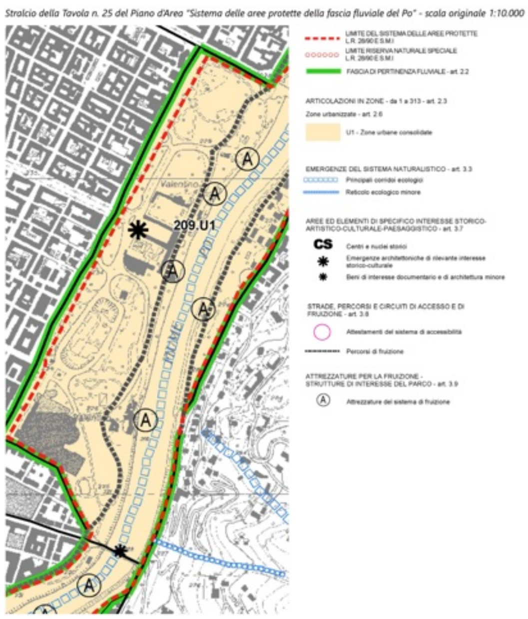


Figure 4.23 Sectoral plan of protected areas of the Po river belt ©Masterplan_PoliTo

2. Building information

1) basic information and history:

History information-since Torino Esposizioni are historic building group, programmers review its evolution history since 1937, from a palace of fashion to an exhibition center of Turin, with three additions and expansions of Hall C, Hall B, and Basement Pavilion, and the renovation in 2009. The materials include technical drawings, renderings, design model and site photos of each phase. Basic information-technical drawings of the building, and site photos in current situations from different perspectives,

2) Building diagnosis: structure analysis, using 3D scanning technologies to obtain the current status of existing buildings, experimental investigations on structures through ultrasonic technologies.

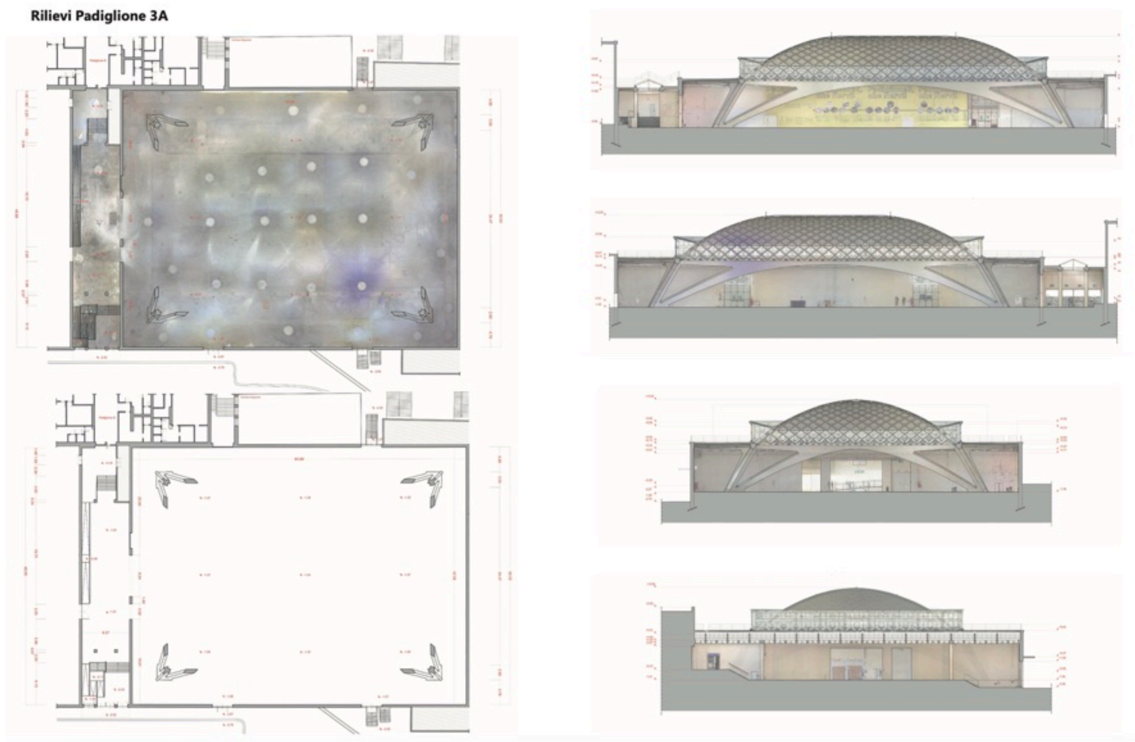


Figure 4.24 3D scanning of existing buildings © Masterplan_PoliTo

3) Spatial analysis: the programming team summarize all the scenarios of reusing part of the building cluster with potential area distribution (Figure 4.25) to analyze the spatial potential of reuse.

SCENARIO		AREA DI INTERESSE	PUNTI DI FORZA	PUNTI DI DEBOLEZZA	Didattica (mq)	Lab. modelli (mq)	Aula studio (mq)	Bar / relax (mq)	Uffici / Amministr. (mq)	Servizi / Connett. (mq)	Semplicità procedurale	TOT S.L. (mq)
Pad. 5	A		· Grandi spazi condivisi / vicinanza a sede storica. · QE quasi pienamente soddisfatto.	· Spazi interrati. · Gravi costi di adeguamento strutturale.	4.930	1.450	645	250	400	11.070		18.740
T.N. - Pad. 3A - Pad. 3B	B		· QE pienamente soddisfatto. · *Promenade architecturale* · Rispetto dell'esistente. · Costi inferiori.		5.620	1.400	800	300	2.050	5.700		15.870
Pad. 3A - Pad. 3B Via P. Giuria	C		· Edificio nuovo con standard attuali.	· QE non soddisfatto. · Dispersione degli spazi.	5.190	1.400	200			5.250		12.040
Pad. 3A - Pad. 3B (ricostruzione 3b)	D		· Campus compatto. · Rinnovamento della parte di minor pregio del complesso. · QE quasi soddisfatto.	· Aumento del volume verso il parco.	4.722	1.400	200			3.128		9.450
Pad. 4 - Pad. 3A - Pad. 3B	E1		· Rispetto degli edifici storici.	· Intersezioni tra flussi e funzioni. · Dislivelli. Impianto strutturale. · QE non soddisfatto. · Potenziali criticità su altezze padiglione 3b.	4.700	1.400	570			4.880		11.550
Pad. 4 - Pad. 3A - Pad. 3B	E2		· QE quasi soddisfatto. · Valorizzazione di spazi secondari del complesso.	· Modifica del padiglione storico di Nervi. · Potenziali criticità su altezze padiglione 3b.	5.820	1.520	200			4.000		11.550
Pad. 1 - Pad. 3A - Pad. 3B	F1		· QE quasi soddisfatto. · Poche criticità. · Rispetto delle parti storiche.	· Separazione tra le parti del complesso.	4.640	1.400	200			4.420		10.660
Pad. 1 - Pad. 3A - Pad. 3B (2 piani)	F2		· QE pienamente soddisfatto. · Rispetto delle parti storiche.	· Potenziali criticità su altezze padiglione 3b.	5.200	1.400	600	200	200	5.140		12.740

Figure 4.25 Programming schemes for reusing the Torino Esposizioni © Masterplan_PoliTo

3. User information

1) user profile: the main users are students and teachers from PoliTo, citizens reading in the civic library, the programmers don't conduct detailed analysis on the user profiles.

2) using pattern and requirement:

Using requirement: estimate the number of students will boost to 40000 according to the strategic plan of 2018-2024. The problem the school is now facing is the conflict between the future increase in enrollment and the limited classroom space, so the most important need for the owner is to anticipate a reasonable amount of classroom space and classroom types. Due to the unique nature of this renovation project and the uncertainty of the target building for renovation, the architectural programming is different from both a new construction project where the new floor area can be determined entirely based on demand, and a general renovation project where the needed area is calculated to match into the existing building. This project requires a dynamically changing tool to compare the match between demand and existing buildings in multiple scenarios.

The programming team designed a tool to estimate the size and number of classrooms. The idea of the building programming is to 1) predict the demand gap; 2) sort out the available space in several existing buildings; 3) dynamically match the two demand and the situation, and coordinate multiple scenarios to show the matching results based on different demand and existing building conditions (Figure 4.26). The number of students corresponding to the current classes, the projected future student growth of 1.2 times, the required classrooms; the current school classroom capacity estimate - the number of classes to be held must be 70% of the classroom capacity; whether to retain the Lingotto campus, respectively, corresponding to the number of classrooms to be filled.

3) Operation pattern: case study of Maquette hall of Department of Architecture and the Built Environment in Delft, function program, sizes, relationships and features of rooms and spaces; different operation potentials between Politecnico, City of Turin and other cultural organizations.

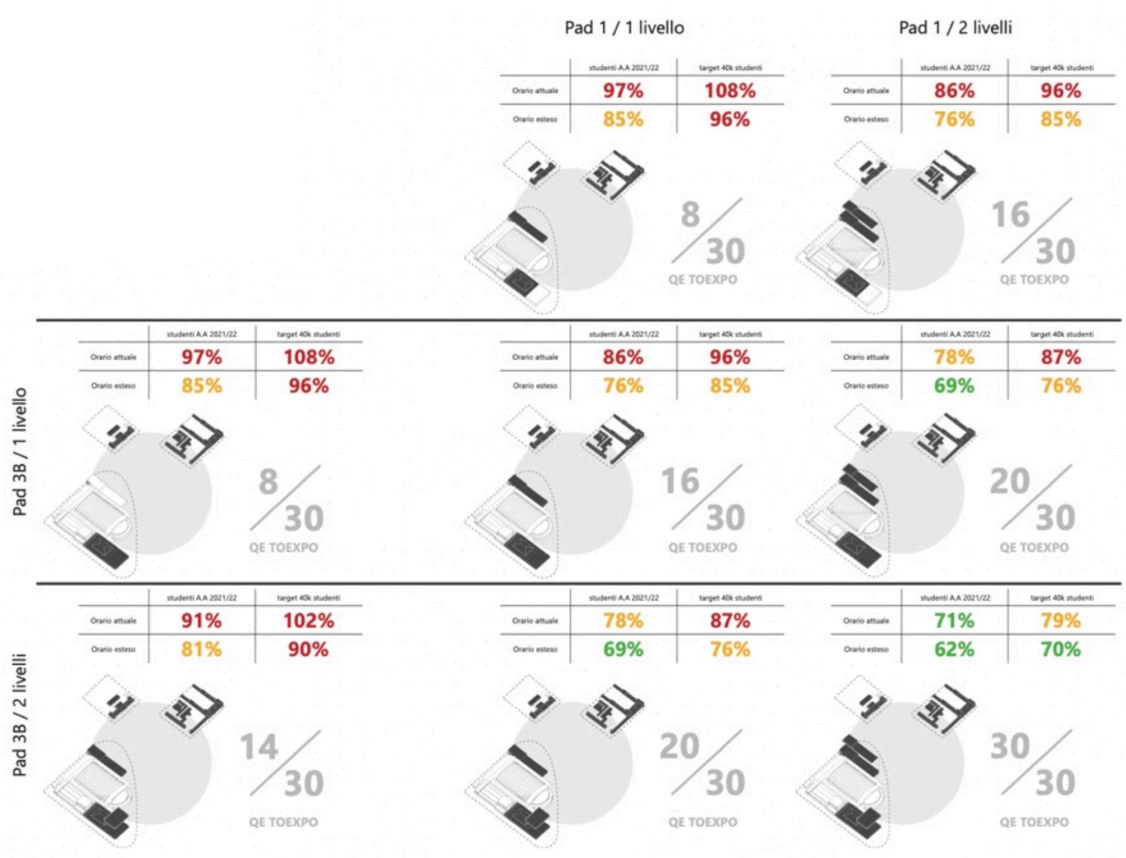


Figure 4.26 Multiple scenarios of matching demands and existing building conditions ©Masterplan_PoliTo

4.6.3 Critical comment

4.6.3.1 Significant information in index matrix

This project has been initiated since 2014, but it is still in discussion and decision-making process now. Many conditions have changed, and the program changes as well. In this project with **high uncertainty**, to classify and evaluate the information is significant to cope with the **inconstancy** and to avoid overloading information. This section discusses the information collection in highly contingent renovation projects, and some coping strategies of programmers in the re-design phase.

Using the information index matrix, it is clear for programming team to allocate resources and time in collecting information, such as the essential information which should be identified first, and contingent information which requires continuing collection and instant update (Figure 4.27). Below is significant information with great influence on the architectural programming.

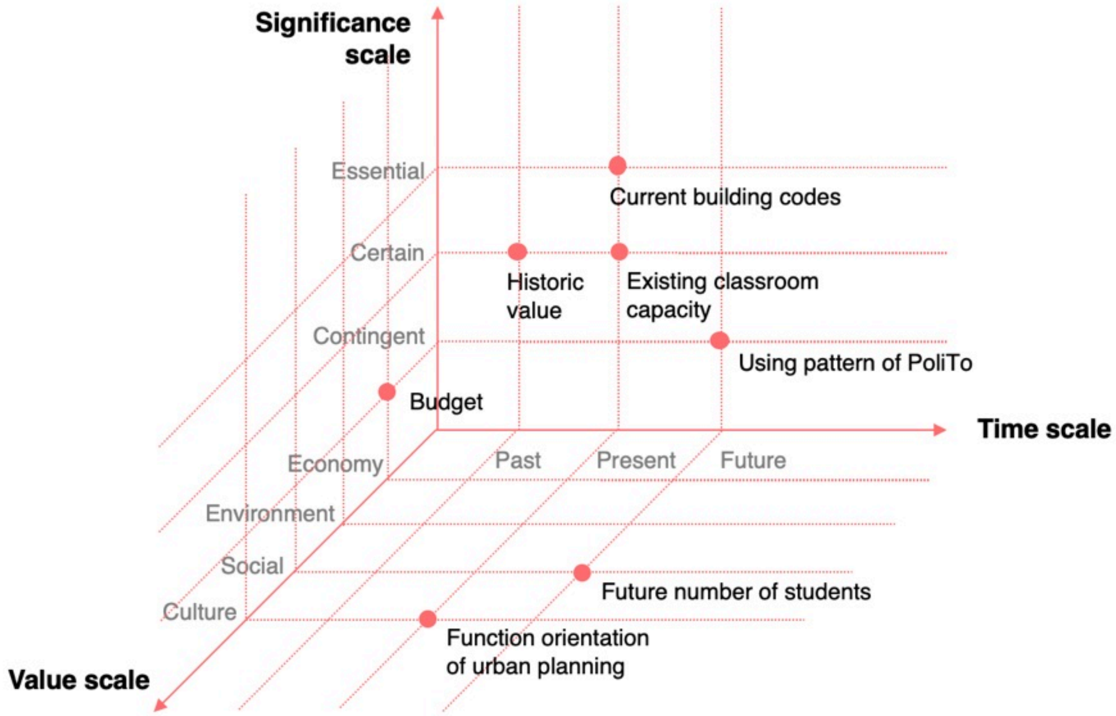


Figure 4.27 Application of information index matrix in Torino Esposizioni

• Building codes (present, essential): the current building codes are essential condition affecting and should be verified from the beginning. It is the change of structural safety code in 2018 that totally changes the direction of the project, because the higher standard increases largely the cost which cannot be afforded by the investors, which weakens technical and economic feasibilities. Padiglione 5 has thus been excluded from the potential existing buildings for renovation.

• Historic value (past, certain): the past information of existing buildings is definite, and it is significant to preserve the historic value of the building as a masterpiece of Pier Luigi Nervi. axis, façade and maintain the space distribution

• Budget (economic, contingent): budgets are contingent information since it has changed several times in the past eight years due to the annual governmental financial budget and term transition in different stakeholders every four or five years. The relationship of cost and budget has great influence on function use, space distribution and phase construction.

• Future number of students (social, future): since the Politecnico would like to transform the existing buildings to teaching spaces, the estimation of number of students is necessary information for proposing using requirement and negotiating with City of

Turin on allocation of spaces.

• Existing classroom capacity (present, certain): apart from future number of students, the current classroom capacity is definite information should be check first. Only by calculating the difference of future requirement and current capacity can programmers identify the required floor area.

• Using pattern of PoliTo (future, contingent): the using pattern of Department of Architecture and Design of PoliTo includes activities, users, required functions, space types and so on, which are contingent according to innovative technologies, pedagogic methods, laboratories, etc. Therefore, the programmers should always update this kind of information with the department in the function program.

In conclusion, applying the information index matrix with value, time and significance scales, programmers have a better understanding of the priority and strategy when collecting information including: *essential* information to be collected first, *contingent* information to be tracked constantly, *certain* information to be collected once; *future* information requiring estimation, *past* information requiring archives and reference, and *cultural and social* information related to public benefits.

4.6.3.2 Constraints and potentials

The information collected can either constrain or facilitate the programming strategies and design scheme. Figure 4.28 shows the interaction between significant information and programming issues. Due to the uncertainty, complexity, and inconstancy of the project conditions, it is difficult to solve the controversy and balance benefits among multiple stakeholders. The programming team thus plays a necessary and significant role in moving things forward by identifying design problems, core concepts and guidelines for design.

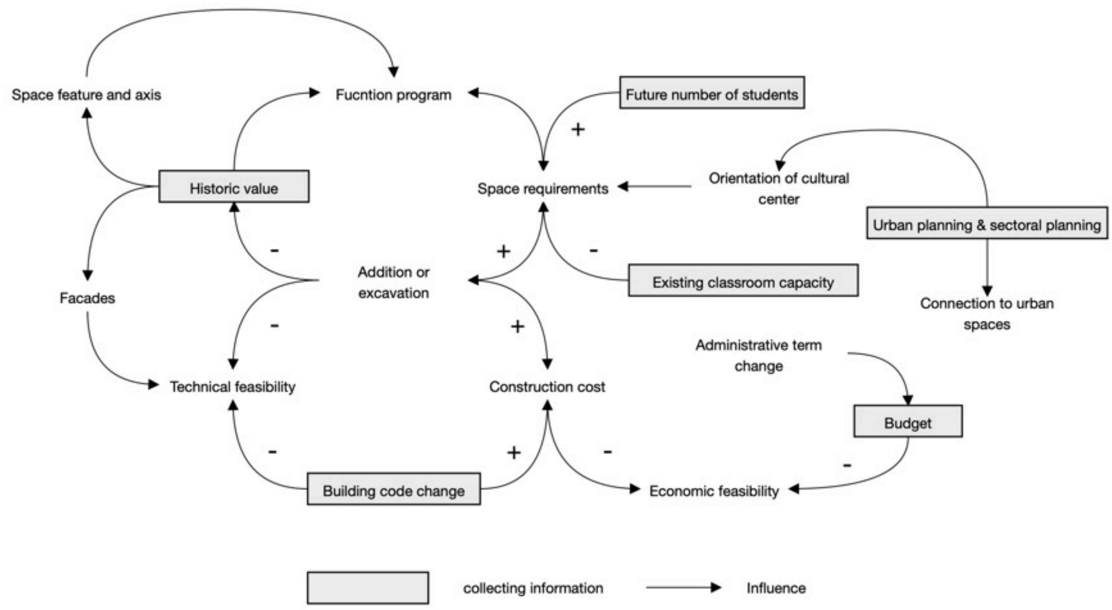


Figure 4.28 Renovation information and relevant influence

In this project, there are by chance two paths to promote the programming work. The first is the Masterplan team of PoliTo, which is the programming team to research on design proposal and to negotiate among stakeholders. The other complementary path is a design course to explore the potentials of the project. In 2020, the department of architecture and design of the Politecnico started a design course with the theme of Torino Esposizioni renovation. Six teachers led by Giovanni Durbiano and Caterina Barioglio[20] guided 15 teams of 42 students to design for the whole five exhibition halls of Torino Esposizioni with flexible conditions. Below are analysis and comments for these two paths in the pre-design phase of the renovation project.

- Identify program concepts and design strategies by the programming team

The design proposal given by the client is always unclear or mismatch to their real requirements or expectations. It would be disastrous to ask most of the clients how many rooms and how much space they need because they are only users but not architects. On the contrary, architectural programmers should uncover the daily activities and operation manner of the clients and groups, such as how many people share a room or should be gathered to conduct a certain activity.

[20] Teachers are Giovanni Durbiano, Isabella Maria Lami, Enrico Fabrizio, Caterina Barioglio, Jacopo Toniolo, Maria Ferrara.

In this project, the programming team first It then calculates t

Based on all the certain and essential information, the Masterplan team as the programmer identified four design strategies or guidelines for the architects in the following design phase.

Set axis: emphasize the original horizontal and vertical axes of the building to preserve its historic features, and use the original entrances and exits to strengthen the connection with the outdoor environment;

Open the facades: in the historic information collected before, the renderings of Nervi's original design showed that the first design scheme had many glass windows on the façade, but they gradually disappeared over time. Therefore, the programming team wanted to add more entrances and open the facades to get more lighting and pay tribute to the original design.

Partially addition: after estimating the demand for classroom space, the programming team suggested partial addition of the second floor to the existing building to meet the future requirement of teaching spaces.

Maintain large space for flexible use: considering the historic and architectural value of the elaborated structure, the future use should be flexible and maintain the whole large space.

In the Torino Esposizioni project, the programmers only provide a rendering of the main space and an axonometric drawing as a "preliminary design". The rendering is intended to show the flexibility and wideness of the spaces; the axonometric drawing articulates the axis in order to better connect with the outside park, and shows the opening on facades as the main strategy to tribute to the original facade design by architect Luigi Nervi and conserve the architectural value (Figure 4.29).

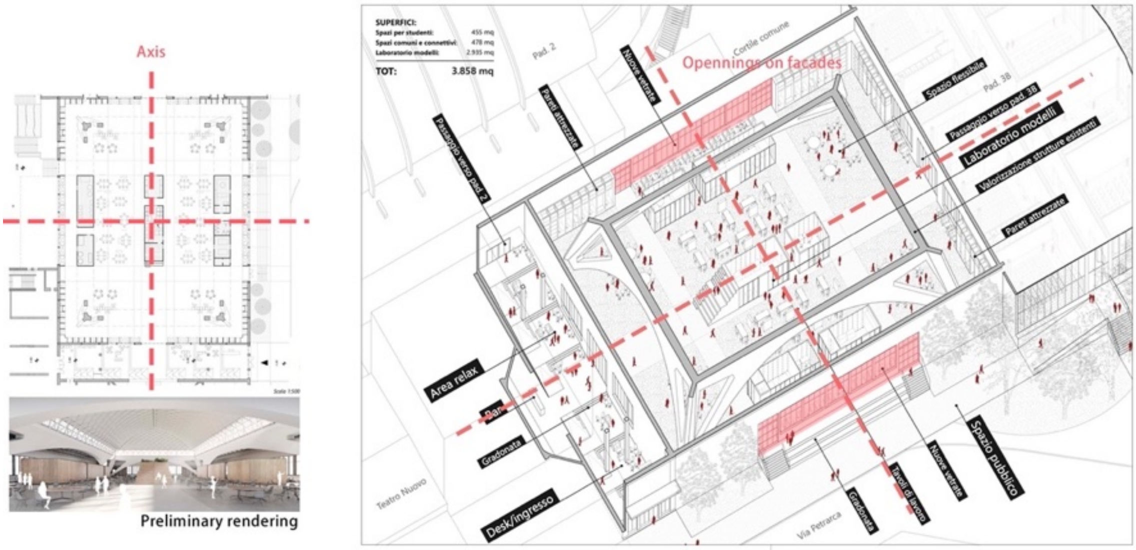


Figure 4.29 One of the hypotheses to present the programming concept

Modified from ©Masterplan_PoliTo

- Propose multiple design schemes for exploration and comparison by architects

Apart from the programming work of Masterplan team, students of the design course propose 14 design schemes for the reuse project considering conflicting interests of different stakeholders with more flexible conditions.

Unlike other common design courses with clear goals and tasks, this project has a relatively open question for everyone, with an uncertain and diverse design goals. Before designing the project, teachers guided the students to position themselves in a value coordinate system with introversion - extroversion axis and matching and transversal axis.

The final results of design teams are distinguishing in strategies based on the initially identified goals and values. Three teams propose a phased transformation scheme for renovating Esposizioni gradually, in particular one building each time. The other three teams focus on transforming exhibition hall 3B as an urban plaza to connect more with outer spaces. Three teams paying more attention to reconnecting the exhibition hall with urban spaces from a broader perspective, thus they consider all the buildings as a whole in the design schemes. The rest of 2 teams choose expansion strategy and thus add new structure to the existing building.

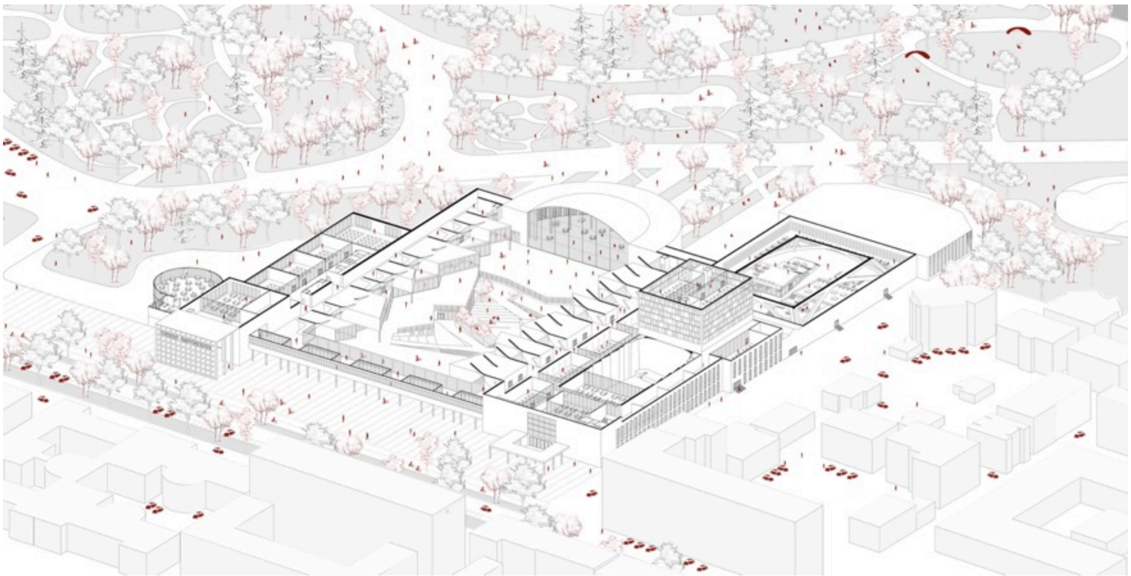


Figure 4.30 Group 6 design of Torino Esposizioni (from Caterina Barioglio)

- Comparison of the two paths

The programming team selects essential conditions and proposed the general design guidelines to preserve the historic value and meet the basic requirement, in order to maximize the economic and technical feasibility. On the contrary, the design course explores potential design schemes by trial and error. It is shown that without many constraints, it can have numerous design schemes with various potentials. However, it is not feasible in real practice. In conclusion, the pre-design phase should identify the main design problems and set the strategies so that the project could be promoted even under the circumstance of changes and obstacles. The architectural programmers shouldn't provide a comprehensive design, but only plans, facades, or simple renderings could work, in order to clarify different arguments for the stakeholders.

4.7 Conclusion

This chapter introduces renovation information collection, the first part that should be supplemented to the traditional architectural programming framework, regarding the existing building, the surrounding urban contexts and the related users or operators. As the foundation of architectural programming, this step cognizes the existing building, identifies relevant current conditions and requirements for later analysis and decisions.

The conclusions in this chapter are as below:

1) **Identify the deficiency in the classic information collection of architectural programming**. Based on literature review of previous information collection, it first analyzes the logics and systems of collecting information in the pre-design phase, and then indicates deficiencies of existing researches in existing building diagnosis, uncertain initiation conditions for renovation, and information classification of priority and time s according to features of renovation projects.

2) **Structure the information index matrix for collection and retrieval**. Since the amount of information is enormous and collecting activity costs much time and resources, it is significant to collect information in a systematic way with efficiency. The research structures a basic information index based on the common logic of macro-medium-micro levels as urban, building and individual users. On top of that, it absorbs the advantage of value-based programming methods and features of renovation projects to have classifications of time, priority and significance, in order to avoid the situation of overwhelming data for better decision-making process.

3) **Provide checklist for collecting information**. Based on three levels of information collection, it provides detailed information checklist for the sub-levels. The urban information of macro level consists of urban planning, uncertain initiation conditions, and site and surroundings. The building information of medium level includes basic information, building diagnosis, and spatial analysis. The user information of micro level contains user profile, using pattern and requirement, and operation mode.

The information collection is always a dynamic and continuous process which requires not only data update, but also the balance between the amount of information and time and resources spent on it.

CHAPTER 5 Function identification of renovation projects

The previous chapter examined the first deficiency of traditional architectural programming in response to the existing building renovation, and this chapter will address the second shortcoming - the **decision making of functional identification** - based on the information collection on existing buildings.

As it shows in the chapter 3, there are basically two kinds of functional renovation for existing buildings: first, new functions substitute the original ones which are completely abolished; second, major parts of the facility remain the previous functions, while the function composition is updated and supplemented according to the new using requirements to enrich the utility. The main problem of reuse projects is the lack of in-depth analysis and arbitrary decisions on new functions; only a systematic and scientific decision-making approach can find the most appropriate functional strategy for reuse (Mısırlısoy and Günçe, 2016). The functional identification study discussed in this chapter is for existing buildings that are abandoned or unused, and demand considering new functions (Figure 5.1).

This chapter answers the following 3 questions:

1) What is the definition of function identification and its characteristics in renovation projects?

2) What is multiple criteria decision analysis (MCDA), how can it support the decision-making on new functions of existing buildings?

3) What is the procedure of identifying functions in architectural programming phase, and what tools can be implemented to obtain the results?

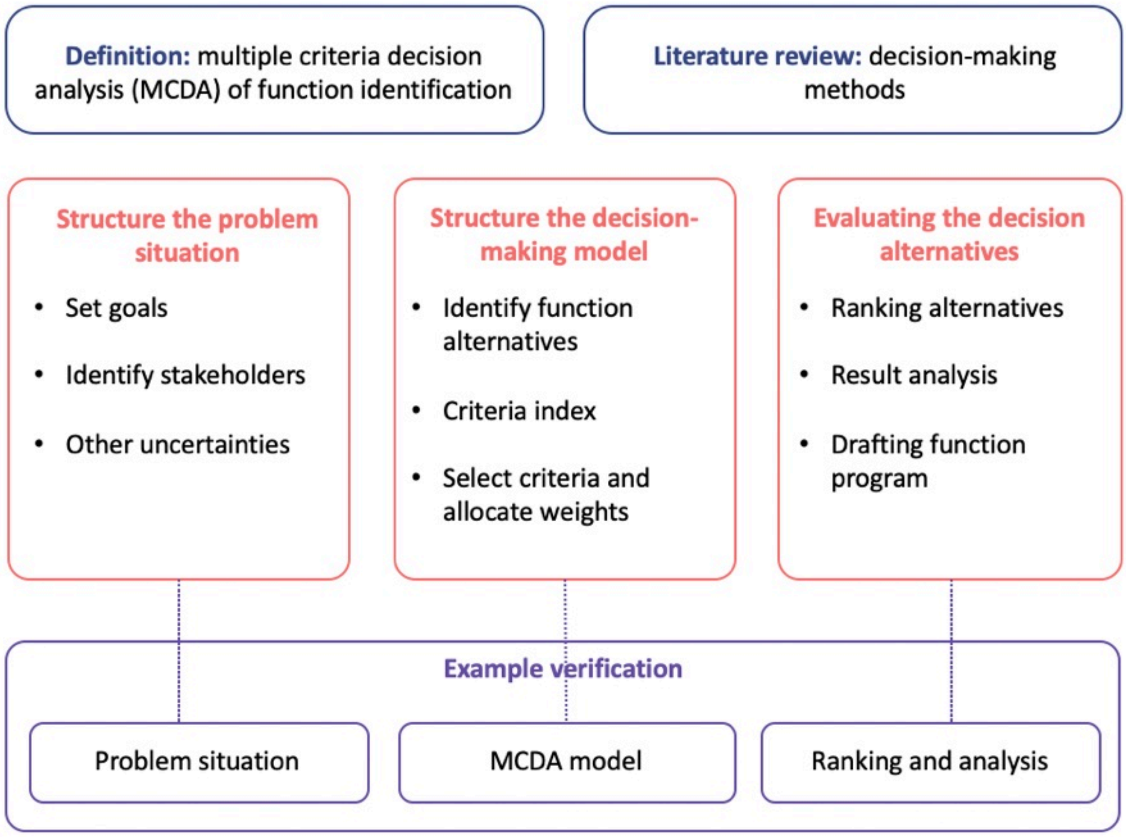


Figure 5.1 Framework of Chapter 5

5.1 Introduction of function identification in the renovation programming

5.1.1 Definition and content of function identification

As stated in section 2.2, there are various contents of functional renovation, but two main types of functional renovation are function transformation projects and function enhancement project. More specifically, it involves whether the nature of land use will be changed or not, and consequently the function of existing buildings will be transformed or enhanced. In traditional architecture design projects, the function of building has been determined in the approval of project initiation. The task of architectural programming hence is to develop the function program in the orientation of the determined function. However, in renovation projects, the detailed plan or sectoral plan for urban renewal may not come out or can be modified after further investigation of existing buildings. Architects or programmers have the opportunity to participate in the decision-making process to determine function for each single building, even in the modification of urban planning. These contents are not included in the traditional architectural programming and requires supplemented researches.

Reviewing the relevant literature, there are two similar concepts in real estate area. The first is Highest and Best Use (HBU). HBU principle in real estate valuation for the use of vacant land or updated or improved properties, which is defined by the Appraisal Institute as "a use function that is physically possible, properly supported, economically feasible It is defined by the Appraisal Institute as "a function of use that is physically possible, appropriately supported, economically feasible, and produces the highest value" (Appraisal Institute, 2008, p. 333). The highest and best use function must satisfy four principles: legal permissibility, technical possibility, economic viability, and maximization of value. The specific process includes three steps, property analysis, rights and constraints analysis, and market analysis. However, HBU focuses on land use but not on building functions. Another one is Most Probable Use(Graaskamp, 1992). In actual projects, developers choose a compromise reuse function based on past experience and actual financing and labor conditions to achieve sufficient profitability as well as safety. These two concepts similarly seek solutions mainly from the perspective of economy and profit maximization, that can’t completely deal with today’s problem in existing building renovation project (Thair, 1988).

The function identification in architectural programming of renovation projects can happen under three kinds of circumstances. As stated in section 4.3, the programming team may face uncertain project initiation conditions in the pre-design phase:

1) the sectoral plan of urban renewal has not been determined and the land use and transaction require further researches;

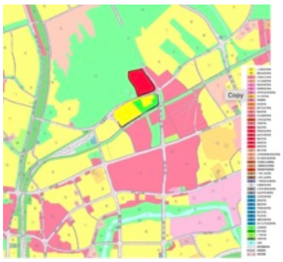
2) the sectoral plan of urban renewal is approved, determining the function orientation, indicators of developing intensity and other conditions, but the exact function of each existing building has not been decided;

3) the sectoral plan of urban renewal and the detailed plan of the site plot has been confirmed as sustaining the nature of land use and the existing building, but the enhancement of function program requires further study for the design proposal.

Correspondingly, the **first circumstance** involves complex considerations with urban planning and urban design depending on the regional policy and system of urban renewal and specific realities of the project. As mentioned in Chapter 3, Italy and China also have different situations for architectural programming participating in this phase: architects and programmers in Italy can participate in the urban planning stage for urban renewal in Italy where private land property applies and the single buildings serve the majority of the projects; while in China where building cluster serves the major type of renovation projects and top-down planning process with strong intervention are common, architect and programmers at present have less opportunity to participate in the planning phase. Therefore, the thesis will not research on this circumstance in detail. Instead, **the second situation** is more common in China nowadays with determined sectoral plan of urban planning and even urban design, requiring architects and programmers identifying specific functions for the single building. This chapter will **focus on this kind of situation** and provide possible solutions and methods for decision-making. **The third circumstance** involves drafting the design proposal considering the existing problems and new requirement of users. The process for drafting the function program can apply the methods in traditional architectural programming with facts and information collected as what Chapter 4 introduced. The question is to compromise between the function program and the existing spaces, which will be introduced in the Chapter 6. Table 5.1 summarizes these three circumstances. Above all, we stated the definition and content of function identification of architectural programming in renovation projects, which is further researched in this chapter.

Table 5.1 Definition of function identification in a renovation project

3 levels	Orientation in urban planning/urban design	Function identification of single buildings	Function program
Task	Identify function **orientation** for a district or a renovation unit	Identify the **main function** for each building	Develop the **function program** in detail
Content	• Determine the classification of urban land use for each plot; • Identify the plot 's development indicators	• Identify the functional composition of a building cluster • Modify the detailed plan of urban renewal	• Identify detailed functional composition and space distribution • Draft function list
Purpose	• To guide programming and design	• To modify urban planning and to develop function program	• To guide the architectural design

3 levels	Orientation in urban planning/urban design	Function identification of single buildings	Function program
Example			
New construc-tion	Determined	Determined in project initiation	Undetermined & developed in architectural programming
Renovatio n	Determined in sectoral plan of urban renewal	**Undetermined in pre-design phase**	Undetermined & developed in architectural programming

5.1.2 Characteristics of decision-making on function identification

Identifying new function for existing building renovation is a difficult decision involving complex conditions and multiple stakeholders. Many kinds of factors influence the decision on functions of the existing building in renovation projects, which are from diverse aspects and can either limit or encourage the choice of functions. Based on analysis of identifying function in practical renovation projects in the previous section, it summarizes some characteristics of this decision-making as below.

1) Multiple stakeholders participated: multiple goals and benefits are required by different stakeholders. The participation of multiple subjects in urban renewal is to coordinate the game of interests among social groups and maximize the fairness and justice in the process of redistribution of social resources (涂慧君 et al., 2019). Therefore, the participation of multiple stakeholders is a significant feature in decision-making on renovation function identification. However, different opinions of multiple stakeholders on deciding functions for the existing building are inevitably different. It is an important issue for the programming team how to negotiate among the stakeholders and balance their benefits.

2) Multiple values driven: multiple stakeholders necessarily represent different benefits and thus renovation projects are always driven by multiple values. The values drive the decision are from many aspects including social, economic, environmental, historic, aesthetic, technical, etc. In Chapter 4, information classified into value scale now can be extracted and applied into analysis on this problem (Table 5.2).

Table 5.2 Extract information collected to analyze multiple values influencing function identification

	Urban information	Building information	User information
Social			
Economic			
Environmental			
Historic			
Aesthetic			
Technical			

For example, in the case of urban public buildings of public interest, it is necessary to consider not only the economic profitability, but also the impact of the building on the city, its inhabitants and society. Therefore, the concept of alternative valuation has emerged, the most famous of which is the public interest value, which means that the new functions of an existing building should take care of the current and future development needs of the surrounding environment or community. In addition, if the existing building itself has a certain historical value and symbolic meaning, the new function of reuse should also preserve and pass on its traditional features and artistic value.

3) Basic conditions constrained: before selecting the best option, there are some basic conditions that constrain the choice of alternatives and identify the scope of feasibility options. These constraints can also be extracted from the information collected in the first step as introduced in Chapter 4. For example, land use is the previous orientation of industries and functions by urban planning and design that should comply with and could be moderately adjusted; the property rights are the owner of building property or the division of the ownership, deciding which parts of the building can be transformed as a whole or separated; the plot ratio limit and building codes; structure and height limitations, etc.

4) Optimal alternative selected: due to drivers of multiple values and constraints, the decision on identifying function for renovation should maximize the performance and total profit of the project. This feature demands on balancing among various benefits and making optimal decisions after careful consideration, compromise and negotiation. To achieve multiple goals, decision makers usually develop them into various criteria, which break up the goals in to detailed evaluation standards or effective paths to achieve them. Building up criteria is an important issue in decision making.

In conclusion, the decision-making on function identification calls for a method satisfying requirement of multiple goals and criteria, and can be implemented by analysts or programmers to support various stakeholders for compromise and negotiation to achieve the consensus on final decisions. Section 5.2 will introduce multiple criteria decision analysis (MCDA) in detail. Before this, we still need to clarify a premise of function identification, that is industry orientation and function distribution in renovation projects.

5.2 Multiple criteria decision analysis (MCDA) of function identification

5.2.1 Decision-making methods

5.2.1.1 Literature review of relevant decision-making methods

Generating and evaluating strategies are always central topics in renovation and re-use fields and are considered as complex decision problems due to multiple objectives, various dimensions, and different benefits of stakeholders. In terms of the new functions in reusing projects, multiple criteria decision analysis (MCDA) has been widely approved to be an effective method to cope with these problems (Wang and Zeng, 2010 ;Ferretti and Comino, 2015 ;Giuliani et al., 2018). A group of methods and techniques of MCDA have been applied to deciding reusing strategies for existing buildings in recent years. The most often used MCDA methods include Analytic Hierarchy Process (AHP) (Saaty, 1987 ;Ribera et al., 2019). This method breaks down the decision problem into criteria and sub-criteria to rank the strategies, assigns preference scores on alternatives and weights on criteria referring to ratio scales, and obtains the final ranking though hierarchical analysis algorithms. Analytic Network Process (ANP) are developed from AHP, organizing the criteria, sub-criteria and alternatives into a network structure rather than a hierarchy structure in order to present the interaction and dependence between these elements (Saaty 1996). ANP method has also been applied to selecting reusing strategies, combined with fuzzy Delphi method, a means of querying experts' opinions (Wang and Zeng, 2010). However, these two methods are found to have rank reversal problems and thus need to be corrected by other versions (Maleki and Zahir, 2013). Further research on this topic integrates these multi-criteria analysis tools with geographic information system, building multicriteria-spatial decision support systems (MC-SDSS) to highlight the potential opportunities for explorative uses (Oppio et al., 2015). Another applicable method is Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE). Based on pairwise comparison, this method could outrank a group of abandoned buildings with respect to different reuse scenarios, and thus benefit the legitimation process by identifying potential reusing functions (Bottero et al., 2019), while the robustness of the final results could be further developed. Table 5.3 shows previous researches on the decision making of reuse functions applying different MCDA approaches.

Table 5.3 Researches on identifying reuse-function applying MCDA methods

Authors	Year	Objectives of the evaluation	MCDA method
Lucia Della Spina	2021	Ranking adaptive reuse strategies	AHP + Discounted Cash Flow Analysis
Federica Ribera	2019	Identify the Highest and Best Use for historical buildings	AHP
Francesca Giuliani et al.	2018	Compare different reuse proposals and select the best one for Italian Silos	Delphi
Elzˇ bietaRadziszew ska-Zielina	2017	Consider the relationships between the selection criteria to select new use for historic buildings	Fuzzy modelling and structural analysis
Damla Mısırlısoy	2016	Provide a model with reviewed factors to propose reuse strategies	Case study Site surveys
Lucia Della Spina	2016	Identify the Highest and Best Use for historical buildings	AHP + Delphi
Dalia Abdelaziz Elsorady	2014	Assess the compatibility of new uses for heritage buildings	Semi-structured interviews
Wang & Zeng	2010	To rank different reuse alternatives (office, museum, hotel and shopping mall) for historical sites in Taiwan	AHP + Delphi

Architectural programmers provide services that facilitate clients, building owners, especially multi-stakeholders to make decisions on reuse functions for existing buildings, rather than directly choose the best function for them. Therefore, different from some researches to select the most appropriate reuse proposals (Giuliani et al., 2018), we address this decision as a **ranking problem** where the goal is to acquire a descending rank of proposed alternatives.

5.2.1.2 Selection of ELECTRE III method

ELECTRE (ELimination Et Choix Traduisant la REalité - ELimination and Choice Expressing the Reality) methods (Roy, 1968) has been applied to ranking problems successfully in many cases, and has been developed to many kinds of approaches to address different situations. Among them, ELECTRE III method (Ostanello, 1985) was developed from ELECTRE II and ELECTRE IV and was implemented by researchers(Ostanello, 1985 ;Roy, 1990 ;Leyva Lopez and González, 2003). The idea behind ELECTRE III is to compare pairs of alternatives on each criterion and aggregate all binary outranking relations to form a final ranking, based on several thresholds and parameters identified by decision makers. This method has been widely used for ranking problems such as site selection, system optimization, project evaluation, risk evaluation and so on in the field of energy, environment and pollution, transportation, etc. (Papadopoulos and Karagiannidis, 2008 ;Wu et al., 2016 ;Donais et al., 2019 ;Mahmoudi et al., 2021). This research applies ELECTRE III method in the context of lrenovation to address the ranking problem of new function alternatives. There are **three main advantages** of this approach to be selected:

• It is based on ordinal information which means the decision group could only rank the performance of alternatives on each criterion instead of searching and acquiring all the statistics from clients and quantifies the difference between preferences. For some uncertain problems, the input data can be both ordinal/qualitative and cardinal/quantitative.

• It allows stakeholders to have a hesitation or buffer space when evaluating the performance of each alternative on each criterion, rather than a defined score when applying other MCDA approaches such as AHP. It would be better to adapt to situations in renovation projects with many uncertain conditions.

• The weights in ELECTRE III methods can represent importance or voting power of the criterion and can be presented in a scenario according to distribution of decision makers, which benefits to comparing different distributions of weights to better understand the whole scenarios. While in other outranking methods like MACBETH (COSTA et al., 2012), weights depend on the ranges or the scale of attributes. And in AHP method, weights reflect the relative importance of the average performance on each criterion, depending on the alternatives and their performance(Saaty, 1987).

MCDA procedure is generally composed of 3 phases. The first phase is to structure the decision situation, the second one is to develop the MCDA model and the last phase is to evaluate alternatives, as shown in the Figure 5.2 (Franco and Montibeller, 2010). The subsequent section establishes the MCDA model to address the reuse function problems according to these 3 phases and verify the procedure and approach of ELECTRE III applying on a real case in China.

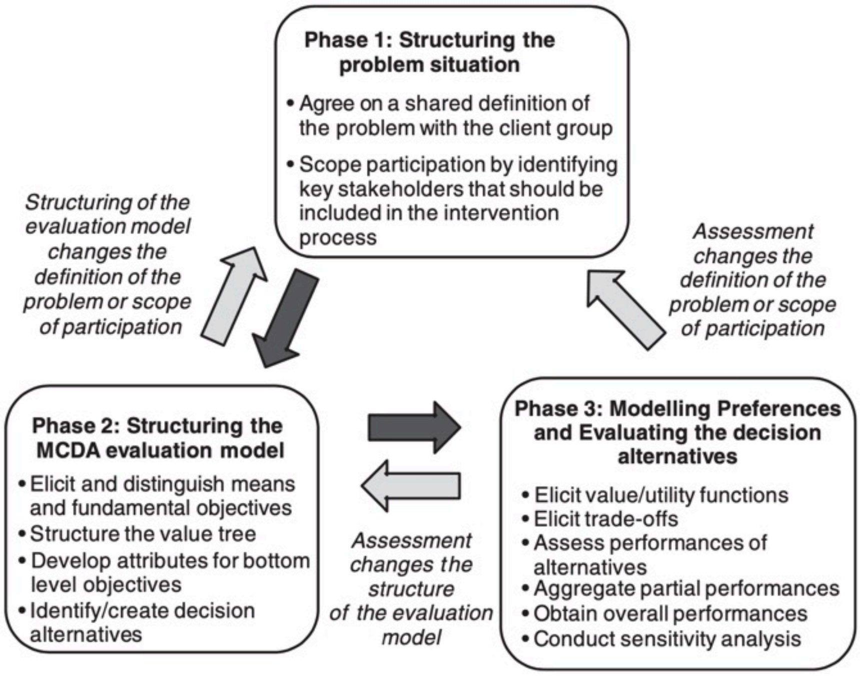


Figure 5.2 MCDA structuring framework (Franco and Montibeller, 2010) Figure 5

5.2.2 Establishment of MCDA process of function identification

Based on the introduction of decision-making methods for searching and ranking the best use of renovation projects in the last section, the research has identified general process of multiple criteria decision-making analysis on this problem, from structuring the problem situation, structuring the MCDA evaluation model, to select appropriate methods and tools for evaluating the decision alternatives. Considering the specific situation of the problem that this chapter focuses on, it requires further development of establishing the process through literature review and case studies, in order to support the decision-making of function identification in the pre-design phase. The process consists of 4 main steps as seen in the Figure 5.3.

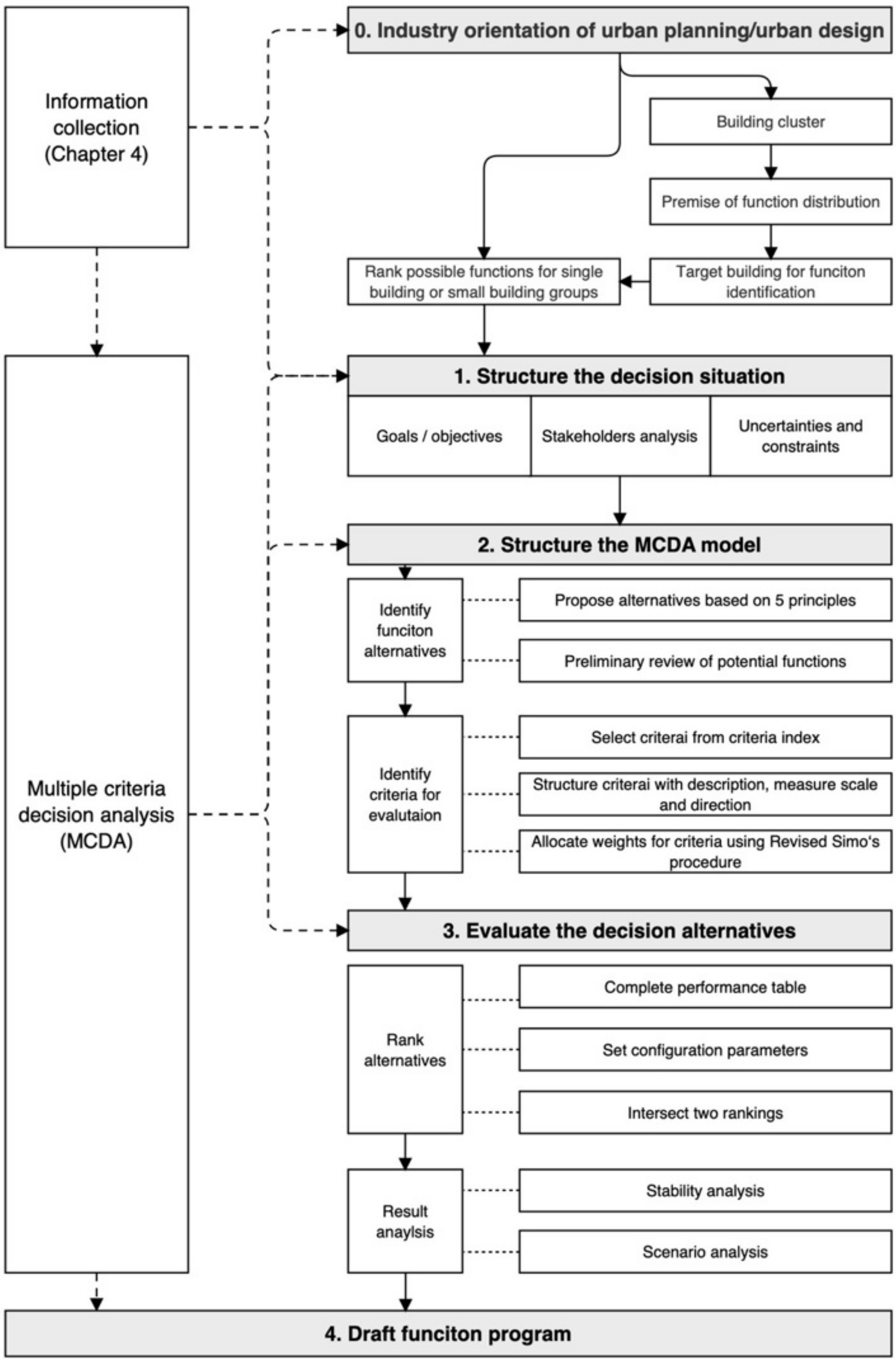


Figure 5.3 Framework of decision making on function identification of renovation projects

5.2.2.1 Structuring the decision situation

In order to build a feasible multiple criteria decision-making analysis model, the first step is to structure the decision situation from several perspectives, in order to achieve a comprehensive understanding of the problem through listing all the issues and concerns on the problem which decision makers should consider and pay attention to. Based on **information collection as introduced in Chapter 4**, the tasks for identifying the problem situation can be conducted by **retrieving and analyzing information**, including main goals of the project, multiple stakeholders, constants and variables, etc. It aims to establish a solid foundation for the decision making and assure full participation of different stakeholders.

There are also some tools and checklist provided by researchers to better understand the situation for later making decisions. French, S. et al (2009) proposed PESTEL principle and the 7S's respectively for obtaining external and internal issues. Belton and Stewart (2010) listed several checklists including Kiplings' six thinking men, Checkland's CATWOE, and SUECA. The issues discussed in those checklists embrace goals, stakeholders, organizations, values and expectations, relevant impacts of the decision and constraints, etc. Marttunen et al (2017) compared the support of different tools in the problem structuring phase to identify 6 main dimensions: the frame, stakeholders, objectives, criteria, alternatives and uncertainties. Brainstorming and cognitive maps also facilitate the group to conceive the panorama of the problem situation (Franco & Montibeller 2010). All of these methods above give a general picture of structuring the problem situation for multiple criteria decision, but don't specifically cope with problems in the architectural area, especially in the architectural programming situation of pre-design phase. Below are adapting guidelines in preparation of MCDA evaluation. Most of them are retrieved from information collection in the first phase, while are analyzed in order to adapted for identifying and evaluating functions of renovation projects.

- **Multiple stakeholders**

Since the research object is the partially or entirely public buildings which should consider public benefits, sustainability benefits, etc., rather than only financial feasibility, the stakeholders involved in this situation are more than just clients and investors. Generally, stakeholders consist of several categories: **the owner, the municipality, the investor, potential operators, relevant associations, experts and consultants, the municipality and the public**. As for partially or entirely public buildings, the owners could be the government, municipalities, state-owned or mix-ownership enterprises. The municipality always has the responsibility of supervision from many aspects including industry development, regulation, planning, technologies, and so on. The investors are private enterprises in most Italian cases, while in China investors in most renovation projects are state-owned financing platform companies. The main difference between renovation projects invested by state-owned financing platform companies with private projects is to consider the public benefits and externalities rather than only focus on the profit and revenue it could provide. Hence, the relevant associations and the public participation are significant to the decision-making results. Due to the importance of operation in the renovation projects, potential operators should also be invited to the pre-design phase. The early intervention of operators is beneficial to the implementation of programming and design in the final result (刘岩, 2017). For example, Eataly is both the investor and operator in Eataly project in Turin(Ambrosini, 2017). The relevant associations include departments of urban planning and housing in the municipalities, and other authorities concerning architecture preservation. Experts and consultant can give advice on the decisions as a third party. The community representatives, habitants, or potential users in the future should also state their requirements and expectations.

From the perspective of the power and the interest, all the stakeholders could be put into a four-quadrant coordinates (Figure 5.4). This graph could help analyze the relations and voting power of different stakeholders.

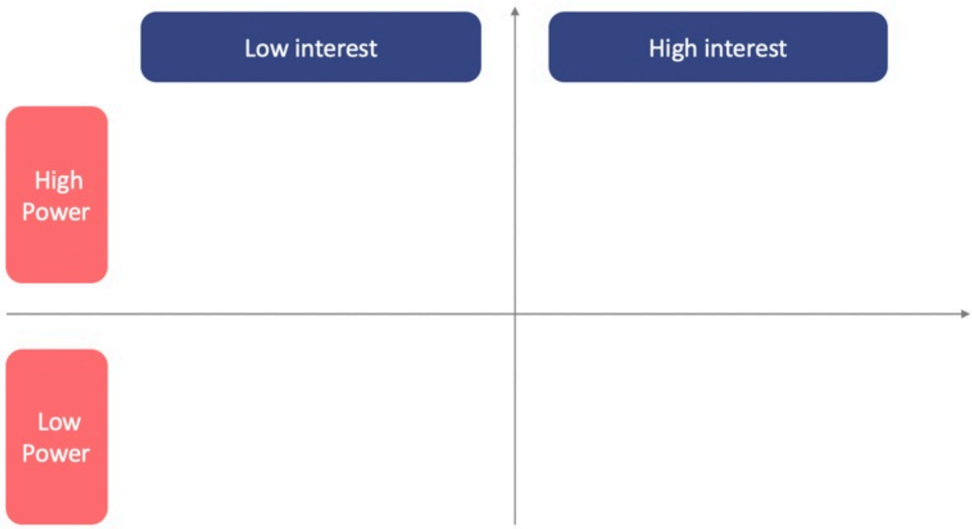


Figure 5.4 Four-quadrant coordinate for stakeholders

• Goals and values

As mentioned in Section 4.3.2, the stakeholders usually have general goals for the renovation project, but the programming team needs to identify different benefits and requirements of all stakeholders, and attempt to make balance among different benefits and values (Table 5.4).

Table 5.4 Value and benefit analysis of multi-stakeholders

	Value orientation and benefits					
	Social	Economic	Cultural	Environmental	Aesthetic	Technical
Stakeholder_1						
Stakeholder_2						
Stakeholder_3						
……						

• Uncertainties and constraints

As mentioned in Section 4.2.5, renovation projects always have lots of variable information and uncertainties, which requires continued information collection and update, as well as constant constraints which should be identified from the first beginning. In general, the first step of MCDA process also demands on identifying the uncertainties and constraints for later structuring the alternatives and criteria in the evaluation model. Besides, uncertainties, or variable conditions can be applied in the sensitivity analysis after acquiring the evaluation results, in order to obtain contingent plans for stakeholders to make the final decisions.

5.2.2.2 Structuring the MCDA model

After structuring the situation for the decision-making problem, the next step is to establish the multiple criteria decision analysis (MCDA) model, which can be broken into 2 parts: identifying function alternatives and selecting the criteria from the decision-tree.

• Identifying function alternatives: based on the principles of proposing function alternatives which will be clarified in the next section, the programmers should organize discussion meeting with principle stakeholders to brainstorm potential function schemes for future use of the renovation projects. The proposed function alternatives can be a building type, or a mixed function with one theme. After proposing such potential functions, the programming team should conduct a preliminarily study of the functions to verify the feasibility of the alternatives. The verification should consider both the market demands of the community or even the city, and also the capacity of the existing building space. The programmers will further describe the future use and possible operation modes of the verified alternatives as the reference for the later evaluation step.

• Selecting criteria: in the section 5.4, the researcher will propose a criteria index or decision tree which focuses on the decision problem of function identification and is based on multiple values. The programming team can select criteria from the index or add special item according to the certain project. The tasks include structure the criteria with detailed description, clarify the optimum direction of each criterion, such as maximizing, increasing or minimizing, decreasing, etc., and identify the measure scales as cardinal or ordinal, which could also be stated as quantitative or qualitative. Apart from select the criteria system, the team should also support the allocation of weight setting for each criterion.

5.2.2.3 Evaluating the decision alternatives

After structuring the MCDA model, it can be applied to evaluate the alternatives and obtain the ranking result to support stakeholders to make decisions. There are main two steps including ranking alternatives and drafting function program.

• Ranking alternatives: based on the structured MCDA model, the programming team should organize stakeholders to evaluate each alternative through the lens of those criteria. The first task is to score the performance of each alternative on each criterion to draw a performance table in ELECTRE III. Then it should identify the parameter configuration of MCDA model on the specific project to set the preference scale of pair comparison. After setting down all the performance and indicators, we use ELECTRE III methods to intersect descending and ascending distillations to achieve the final ranking of all alternative. The sensitivity analysis provides a ranking panorama with the variation of all the indicators. Section 5.5 will introduce this part in detail.

• Drafting function program: after multiple criteria decision-making analysis, the programming team obtain a preferred function alternative for the existing building. To draft the design proposal, the identified function should be first developed into a function program indicating the function and space list with consideration of flow, using mode, requirement of various kinds of users, etc. This part can refer to methods in traditional architectural programming theory regarding spatial conception and evaluation, which will be presented in section 5.6.4.

5.3 Identification of function alternatives

5.3.1 Principles of identifying function alternatives

Function alternatives here indicates the possible schemes of primary function for the building to be renovated. Researchers listed several constraints for identifying the alternatives. Wang & Zeng (2010) screened for a short list of reuse proposals based on site locations, building conditions, economy and maintenance, and each of them is a single function. Giuliani F, et al. (2018) identified 5 constraints for the reuse proposals: 1) the materials, technologies, and sufficient funding should be available; 2) it can be reversed to the original state; 3) the existing facility and new functions are compatible to preserve its value; 4) it should meet the interest of the community; 5) it must comply with urban regulations and building codes in terms of specific land uses. Based on these principles, the team proposed both single and combined functions for a real case focusing respectively on different stakeholders' benefits. Ribera et al (2019) listed technical, legal and budget constraints, and economic benefit to the community. Based on the reviews above and the interviews with Chinese government officers, experts and architects, this study concludes 5 constraints for identifying potential reuse functions.

• ***Compatible with existing building characteristics***: existing buildings contain the memory of the city and have architectural characteristics representing certain eras. New functions should maintain and extend this kind of values, and not damage the original state of buildings. Hence, the reuse proposals need to be compatible with the existing structure, facades, spaces and even materials.

• ***Economically feasible***: a fundamental principle of a project is economically feasible in terms of NPV and IRR. Generally, the renovation budget should be lower than that of the new construction. Although the kind of projects that we discuss possess a part of public priorities, the renovated building should be operated sustainably.

• ***Technically suitable***: technologies used in projects always have close relationships with the economic feasibility, which means that the choice of interfered technologies also decides the final cost. This principle demands that the spatial form of the new function should match the existing spatial composition. For example, the idle hotel has separated rooms with bathrooms, which is similar to the spaces of the nursing home facility, while factory buildings with large span structure and free plans are more difficult to add single room spaces. The budget for the hotel thus costs less than that of the factory.

• ***Provide public services or meet market demands***: reuse projects are expected to have a positive impact on its environment, serving the inhabitants or citizens both materially and spiritually, while the environment and people will react to the building, fully exploiting its use value and giving a new lease of life to the existing building. For example, in the Shichahai neighborhood of Beijing's Xicheng District, many bungalows with no historical value and intact structures have been transformed into community food stores or barber stores, providing a convenient living environment for residents in the historic district. To a certain extent, it can alleviate social problems, such as the serious problem of aging in the community, and the reuse function can consider community elderly care facilities, day care for the elderly, community canteens, etc. to improve the quality of life of the elderly in the community; in Italian cities, many communities, because of multi-racial coexistence, long and narrow streets, and inward-looking courtyards in the form of building space, have low street.

• ***Regenerate the community and urban spaces***: bring new vitality to the community, promote community revitalization, and increase the attractiveness of the community to residents and citizens in other areas of the city; this is reflected in the enrichment of public activities for community residents, the provision of more jobs, and the enhancement of the image of the community while also improving the economic value of the entire For example, the LocHal Library in the Netherlands has transformed an abandoned bus terminal into a multi-functional cultural center that includes a library, public offices, a technology incubator, and a lecture theater, which has attracted a large number of citizens and transformed the area from a lost urban space to a vibrant "urban living room" (Figure 5.5).

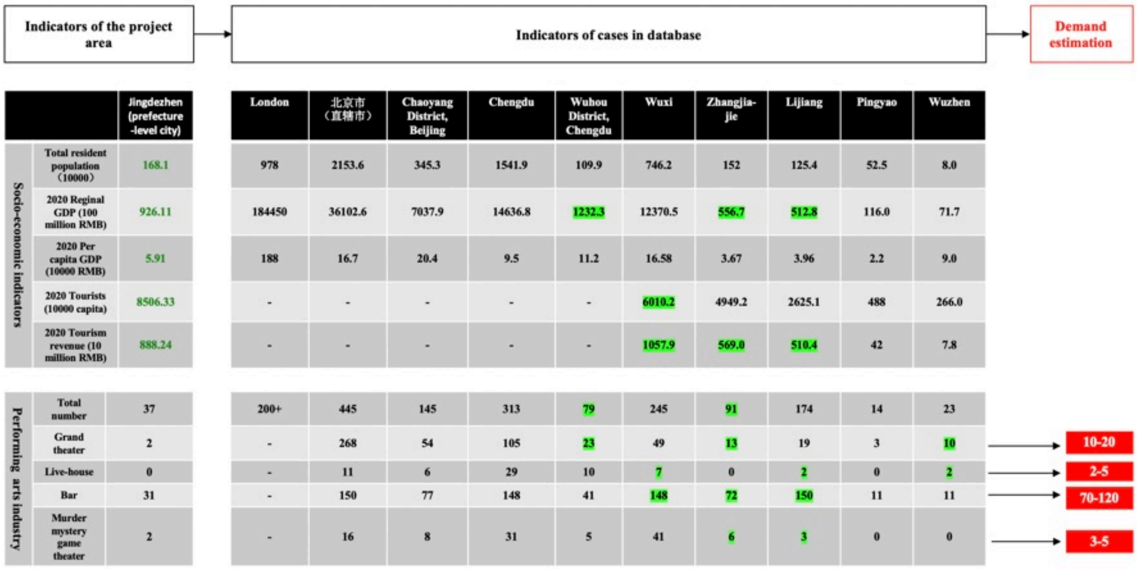
Figure 5.5 LocHal Library renovation project as an “urban living room” (photo by Stijn Bollaert)

These constraints above correlate with each other to a certain degree, and real projects may not satisfy all the principles, but rather focus on parts of them. Nowadays, reuse proposals tend to contains multiple functions in order to regenerate the existing building and its surrounding area. Therefore, alternatives could be generated based mainly on one or two constraints at the beginning. Then programmers analyze new functions or group some of them together as mixed-function proposals. Mixed functions can improve the service which the main function provides and increase the attractiveness of the facilities. The project thus can be transformed to an urban catalyst(Novy and Peters, 2013 ;Beck and Brooks, 2018).

5.3.2 Preliminary review of potential functions

The preliminary review of potential functions is an additional step to roughly check the feasibility of the alternatives before the evaluation of MCDA model. It avoids over flexibility of the alternative brainstorm and can help check the feasibility of the alternatives in advance. The preliminary review focuses on the **constraints and demands** of each alternative. Giuliani et al (2018) applies four of the five principles to propose alternatives to compare them qualitatively again before being evaluated by the MCDA model, which are feasibility, reversibility, compatibility, and social interest. Considering the consistency with information collection in Chapter 4, reviewing alternatives can also refer to two of the spatial scales, urban and building.

1) Urban scale: guiding by urban planning analysis can prevent the project orientation from being over-led by investors(张杰 et al., 2021a). From the urban scale, programmers can review the planning of industry development and check if the city or district can afford the function capacity. In other words, supply and demand should be matched to avoid resources wasting or shortage. Does the city or district that the building is located have the certain capacity demand on this kind of function? There are direct or indirect approaches to answer this question. Programmers can review the quantum of certain industries in development planning of municipalities. Meanwhile, programmers can compare the quantum of certain function facilities or visitor flows of similar cities or districts, or conduct a regression analysis with a set of data retrieving from other cities.



		Jingdezhen (prefecture -level city)	London	北京市（直辖市）	Chaoyang District, Beijing	Chengdu	Wuhou District, Chengdu	Wuxi	Zhangjia-jie	Lijiang	Pingyao	Wuzhen	Demand estimation
Socio-economic indicators	Total resident population（10000）	168.1	978	2153.6	345.3	1541.9	109.9	746.2	152	125.4	52.5	8.0	
	2020 Reginal GDP (100 million RMB)	926.11	184450	36102.6	7037.9	14636.8	1232.3	12370.5	556.7	512.8	116.0	71.7	
	2020 Per capita GDP (10000 RMB)	5.91	188	16.7	20.4	9.5	11.2	16.58	3.67	3.96	2.2	9.0	
	2020 Tourists (10000 capita)	8506.33	-	-	-	-	-	6010.2	4949.2	2625.1	488	266.0	
	2020 Tourism revenue (10 million RMB)	888.24	-	-	-	-	-	1057.9	569.0	510.4	42	7.8	
Performing arts industry	Total number	37	200+	445	145	313	79	245	91	174	14	23	
	Grand theater	2	-	268	54	105	23	49	13	19	3	10	10-20
	Live-house	0	-	11	6	29	10	7	0	2	0	2	2-5
	Bar	31	-	150	77	148	41	148	72	150	11	11	70-120
	Murder mystery game theater	2	-	16	8	31	5	41	6	3	0	0	3-5

Figure 5.6 Demand estimation of art performance industry in Jingdezhen, translated from © THAD

2) Building scale: since the potential functions will be translated into spatial language adapting to the existing building in the end, preliminary feasibility study can also review the existing conditions and constraints from the perspective of building scale. From the building scale, programmers mainly check the spatial suitability and technical feasibility such as the compatibility of building codes, especially fire protection codes and structural safety standards. Furthermore, programmers can analyze the necessity of modifying floors, facades and volumes, as well as the possibility of addition, connection with adjacent buildings, or expansion. The analysis can be presented in diagrams, or given scores in tables. For example, in Pingyao Film Palace, architects first examine the structure and spatial features to test the technical feasibility and compatibility. Taking D2 factory as an example, this building is comprised with two parallel truss structure of different net heights above the ground. Although it is the largest building on site, which is feasible for the floor area of the 1500-seat theater or 500-seat cinema hall, the two structures cannot be integrated to create a whole space. Besides, it costs much to meet the fire protection codes and structural safety standards to create a new theater. The final strategy is to insert several small video halls into one part of the space and leave the other part as open spaces for events and exhibitions (Figure 5.7). It not only respects the original feature of the space and structure, but also avoids the challenge of meeting the new building codes.

Figure 5.7 Functional feasibility of D2 factory of Pingyao Film Palace project. Left: before renovation; Right: after renovation.

5.4 Criteria selection of evaluating function alternatives

5.4.1 Criteria index developing

One of the distinguishing features of various MCDA model is the criteria selection, which reflects the **goals** of the projects and also the **value orientation** of the stakeholders. Since identifying the reuse function is a multi-criteria decision, the stakeholders should consider comprehensive and concise factors that influence the reuse decision. Some international development goals and relevant studies on reuse have identified or discussed those criteria or the classification of the incremental values.

In MCDA methods, criteria, or attributes are used to evaluate alternatives from comprehensive dimensions in order to satisfy all the benefits. In traditional decision-making theory, two kinds of approaches can help identify criteria, one is Top-down approach (Keeney 2007) that starts from values then develop the criterion hierarchy. The other is Bottom-up approach (Roy 2013) that analyzes and group the consequence first and then conclude criteria. Most of relevant studies used Top-down approach and have structured different sets of criteria based on major categories: economic, environmental, social, architectural or cultural(Wang and Zeng, 2010 ;Elsorady, 2014 ;Mısırlısoy and Günçe, 2016 ;Ribera et al., 2019). The contents of social, cultural and architectural values sometimes overlap but the idea behind them is to preserve architectural values and to benefit the community. Table 5.5 collects and analyzes all the possible criteria based on four categories of values that are able to assess the performance of alternatives. Many relevant researches which apply AHP methods develop decision trees after the previous step to have sub criteria or sub attributes for scoring. However, this study After defining the criteria, it needs to identify the measures, sometimes called attributes to assess how the alternatives satisfy each objective. The criteria and sub attributes should be specific and understandable to any participators (Keeney 2007).

Researcher have pointed out that criteria proposed in previous studies may be inconsistent due to different situations (Robles 2010). When the criteria and sub criteria are applied to case study, Giuliani et al(2018) supposed decision-makers could select out suitable criteria and eliminate those in lack of data or satisfying all alternatives. Therefore, building the criteria system should be specific to the project situation, and consider the feasibility of obtaining data, avoiding overloading tasks in the later evaluation process.

Table 5.5 Relevant researches on criteria that evaluate reusing proposals

Category	Criteria	Sub criteria	Relevant researches
Social	Community involvement	Public awareness	(Ribera et al 2019; Bullen & Love 2011; Wang & Zeng 2010)
	Employment		(Ribera et al 2019;)

Category	Criteria	Sub criteria	Relevant researches
Economic	Living quality	Public spaces; Green space; Sense of security	(Giuliani et al. 2018; Radziszewska-Zielina 2017)
	Cultural significance	Public perception; symbolic value; recognition of present being	(Elsorady 2014; Bullen & Love 2011)
	Financial sources/ investment/budget		(Giuliani et al. 2018; Wang & Zeng 2010)
	Market demand		(Bullen & Love 2011; Wang & Zeng 2010)
	Externalities to local economy		(Elsorady 2014; Bullen & Love 2011; Douglas 2006)
	Cost on future maintenance		(Giuliani et al. 2018; Wang & Zeng 2010)
Environmental	Sustainability	Sustainable design; life cycle assessment; recycling existing materials; energy efficiency	(Elsorady 2014; Bullen & Love 2011; Douglas 2006)
	Environmental Externalities to local community	Reduced use of green lands; Reduction of resource consumption	(Radziszewska-Zielina 2017; Elsorady 2014; Bullen & Love 2011; Wang & Zeng 2010; Douglas 2006)
Architectural	Historic/artistic value		(Robles 2010; Bullen & Love 2011; Wang & Zeng 2010; Mason 2002)
	Function utility		(Giuliani et al. 2018
	Compatibility/building codes	Invention degree;	(Ribera et al 2019; Giuliani et al. 2018; Bullen & Love 2011; Wang & Zeng 2010)
	Integrity	Acceptance of changes;	Elsorady 2014; Wang & Zeng 2010; Bronson & Jester 1997)
	Flexibility	Ability of adaptation; potential for adaptive reuse	(Latham 2016; Elsorady 2014; Bullen & Love 2011)
	Technological feasibility	Availability of materials;	(Bullen & Love 2011)

There are two limitations of the relevant researches. 1) *Lack of universality*: the values in criteria systems proposed in these researches focus on specific themes or projects and thus lack of universal classification adapting for common projects; 2) *lack of flexibility*: the category and description of criteria are so detailed that cannot adjusted and applied to other case. Considering these two deficiencies with the conclusion of relevant researches, this study attempts to provide a comprehensive criteria system based on comprehensive classification of values, a flexible list of criteria and sub-criteria to be chosen by the decision makers which can be adapted to specific situations of real cases, and notes of measure scale for each criterion.

Based on the literature review and value-based architecture programming theory (Hershberger, 1999 [73]), the research classified criteria into 6 value-based categories that basically cover renovation projects with function transformation: social, economic, environmental, cultural, aesthetic, and technical (Table 5.6). Criteria of architectural value mentioned in some references are broken up into cultural, aesthetic and technical categories. It clarifies different challenges or goals under each category for decision-makers locating the projects. Criteria and sub-criteria are developed according to those challenges. Labels of plus or minus indicates the direction of criteria to be evaluated, as maximizing and minimizing respectively. Measure scales include O for ordinal scale and C for cardinal scale, which will be introduced in the next section. The criteria can be supplemented according to specific situations. Based on such criteria index, programmers can support decision-makers to develop criteria system for certain projects.

Table 5.6 Criteria index for decision-making in renovation projects

Values	Challenge/goals	Criteria		Sub-criteria	Measure
Social	Community involvement and organization	Community building	+	Acceptability, awareness and integration of the community	O
			+	Attractiveness of the community	O
			+	Vitality and creativeness of the surrounding communities	O
		Employment	+	Net growth number of new jobs	C
	Living quality	Community safety	-	Criminal rate of the community	O
		Functional utility	+	Provision of public service	O
			+	Positive interaction with surrounding function facilities	O
			+	Area of public space	C
			-	Conflicts or competency with surrounding functions	O
			+	Contribution to parking area	C
		Comfort	-	Noise influence on the community	O
			+	Contribution to the traffic and accessibility	O
			+	Contribution to the local microclimate	O
Economic	Pursue for plenty budget and investment/ Sustainable operation	Potential profit	+	Internal rate of return (IRR)	C
			-	payback time	C
			+	Annual profitability	O/C
			+	Additional economic value to the land use	O/C
		Market demand	+	Attractiveness to potential investment	O
			+	Satisfy the market requirement of the surroundings	O

Values	Challenge/goals	Criteria		Sub-criteria	Measure
		Externalities to local economy	+	Profits from market demand	O/C
			+	Increase value in surrounding real estate market	O/C
			+	Contribution to the development of local tourism	O
			+	Promotion to the local industry development	O
			+	Attractiveness to developing supporting service	O
	Limited budget and indefinite cost	Cost	-	Construction cost	O/C
			-	Cost on future maintenance	O/C
		Policy support	+	Accessibility to subsidy	O/C
			+	Benefits of exemption	O/C
Environmental	Energy conservation and pollution reduction	Environmental sustainability	-	Energy consumption of life cycle	O/C
			-	Quantity of demolition and reconstruction	C
			+	Generate sustainable energy	C
			+	Reuse of existing materials and elements	C
	Environmental contributions and impact	Externalities to the surroundings	+	Contribution to the surrounding environmental quality	O
			+	Increase the vegetation coverage area	C
			-	Negative environmental impact on the surroundings	O
Cultural	Cultural significance to the city and citizen’s memory	Historic and artistic value	+	conservation of the historical value of the building	O
			+	conservation of the artistic value of the building	O
			+	integrity and authenticity	O
		Cultural significance	+	Preservation of cultural identity	O
			+	Increase public awareness of cultural values	O

Values	Challenge/goals	Criteria		Sub-criteria	Measure
Aesthetic	Special esthetic features or significant location	Conservation of aesthetic values	+	reservation of original materials and elements	O
			+	reservation of original decorations	O
		Symbolic value	+	Potential to increase the symbolic value of the building	O
Technical	Technical feasibility with engineering economy	Building codes*	-	Difference between conditions with target building codes	O
			+	Structure safety	O/C
		Compatibility	-	Degree of intervention and technical feasibility	O/C
			+	Similarity of potential spatial use with existing spaces	O/C
	Extend life cycle and adapt to future use	Flexibility	+	Accommodating different functions	O
			+	Adaptation to other functions	O

* For measure, O means ordinal scale, while C means cardinal scale;

* + means maximize or increase to obtain the optimum benefits, while – means minimize or decrease to achieve the goal.

5.4.2 Criteria selecting for the target project

As for selecting the criteria for the specific project, the programmer team can organize discussion with multiple stakeholders on selection of criteria with reference to the criteria index, in order to match the pre-setting goals and key benefits of stakeholders. This section will first introduce principles to choose criteria in the context of the project, and then explain how to set the measure scale of each criterion.

• Principles of selecting and refining criteria

There are five desirable principles to select objectives or criteria in MCDA models, that are unambiguous, comprehensive, direct, operational, and understandable(Keeney and Gregory, 2005).

Unambiguous – make clear descriptions reflecting the causality between the criterion and its consequence, and consider the situation of uncertainties.

Comprehensive – the level set for the criterion covers all the possible results corresponding to the goals, and the description of criterion better consider the value judgement appropriately.

Direct – the description of criteria should be directed to the consequences that can be compared with the goals; the setting level for the consequences of the criterion should also be clearly described.

Operational – the information date is accessible for scoring the criterion. It is better to collect a small set of easily-obtained data in detail than to collect rough data for a large set of criteria.

Understandable – criterion description should be lucid to any of decision makers, stakeholders and participators.

Besides these considerations, another significant issue is the number of the selected criteria. The number of goals and corresponding criteria should be smallest to appropriately reflect the kernel of the decision problems. Redundant criteria and information will distract the focus of the problems.

• Measure scale of criteria

For each sub-criterion, decision-makers should identify measure scales considering the accessible database and the nature of each criterion. First, it should clarify the direction of the scale, whether to maximize or increase this criterion or to minimize or decrease it in order to achieve the goal. Second, decision makers should identify whether it’s ordinal scale, meaning qualified scale, or cardinal scale, that is quantified. For ordinal scale, it should identify the scale of criterion level and define the meaning for each degree (Figure 5.8). For cardinal scale, it should be able to calculate the item and clarify the meaning of that number or calculation, with units such as kW/h, RMB per year, etc. Instead of clearly defined level scale, the quantitative criteria should be defined the feasible maximum and acceptable minimum in case that value trade-off is unbalanced (Franco and Montibeller, 2010).

Attribute level	Representative environmental impact
0	No impact
1	Impact to historical or archeological site of major significance; no aesthetic or biological impact
2	Major aesthetic impact or disruption of an endangered species habitat; no archeological or historical impact
3	Major aesthetic impact or disruption of an endangered species habitat, plus impact to historical or archeological site of major significance
4	Major aesthetic impact and disruption of an endangered species habitat, no archeological or historical impact
5	Major aesthetic impact and disruption of an endangered species habitat, plus impact to historical or archeological site of major significance

Figure 5.8 Ordinal scale of constructed criterion in MCDA model (Keeney, 2007 [120])

These scales also examine the applicability of the criteria to the assessment of different reuses proposals. The criteria and measurable scales composite the complete evaluation model for the decision-making problem.

5.4.3 Weight allocating of criteria

Due to different contribution of each criterion to the goals, decision makers should identify weights for each criterion to represent its significance. One of the most common used methods for ranking decision problems is Revised Simos’ procedure(Figueira and Roy, 2002). The idea of this kind of method is to arrange criterion cards in an ascending order and insert white cards between each pair of successive cards to distinguish the weights. For example, there are *n* cards of n criteria arranged in ascending order of importance, which are c1, c2, …, cn, and there are *m* white cards between two successive cards, c1 and c2. If m=0, c2 is one time important than c1; if m=1, c2 is 2 times important than c1. Two cards of the same importance should be overlapped together. All the weights are added up to 1, so it could calculate the weight of each criterion to satisfy the arrangement of the cards. DecSpace software online[21] is another professional weight setting tool including various methods for the corresponding decision problems. The following two figures are the working interfaces of a Revised Simos' procedure software and the counterpart in DecSpace software online.

After setting the weight of each criteria, the MCDA model is basically established. The next step is to apply the MCDA model on the alternatives and obtaining the final ranking of the potential functions for the renovation projects.

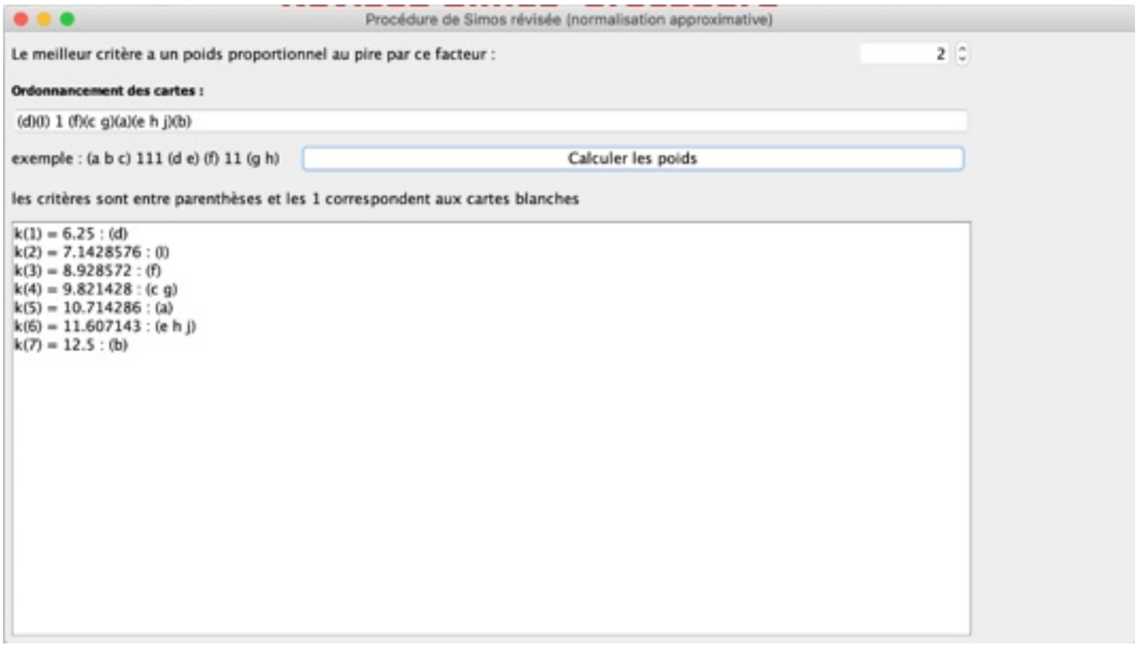


Figure 5.9 Revised Simos' procedure for weight setting

21 The software can be used at http://app.decspacedev.sysresearch.org/#/.

Figure 5.10 Application of DecSpace software to allocate weights

The **weights (k)** in ELECTRE methods describe the relative importance of each criterion under consideration. If the weight of criterion *j* is more than that of criterion *i*, then *j* has more voting power than *i* in deciding the outranking assertion. Therefore, the sum of all the weights should be 1. The stakeholders are supposed to reach a consensus on the weight distribution. Differently, weights in other MCDA ranking methods like MACBETH doesn't represent the voting power, to which should be paid attention.

5.5 Application of MCDA on function alternatives

After structuring the MCDA model, the programming team can apply it to alternatives and ranking them. This part first introduces the ranking process with application of ELECTRE III methods[22] as explained in the section 5.2, then provides the approach of sensitivity analysis based on the results. At last, it will roughly extend to the drafting of function program with literature review of universal architectural programming theory.

5.5.1 Ranking alternatives

Ranking proposed alternatives is a multi-criteria aggregation procedure applying ELECTRE III (Roy, 1990) according to their performance on each criterion. It needs 2 steps to conduct this ranking: determine the preference indicators and intersect two rankings to achieve the final result. After that, a sensitivity analysis could help discuss

[22] This research uses ELETRE-based softerware: MCDA-Ulaval, which was developed by the group led by Irène Abi-Zeid. https://mcda.fsa.ulaval.ca

the results.

1) **Determine preference indicators**

ELECTRE methods have four main indicators to depicts the preference situations between each pair of alternatives such as *a* and *b* (Figueira et al., 2010 [55-58]): "*I*" represents indifference, and *aIb* means *a* could outrank *b* and *b* could also outrank a; "*P*" represents strict preference, and *aPb* means *a* outranks *b* while *b* doesn't outrank *a*; "*Q*" means hesitation; "*R*" represents incomparability, and aRb means neither *a* outranks *b* (*aSb*) or *b* outranks *a* (*bSa*). If *a* outranks *b*, then the relations between them could include *aPb*, *aQb*, and *aIb*.

For a certain criterion *j*, there are two thresholds p_j and q_j, which mean preference threshold and indifference threshold, to describe different performance of alternatives *a* and *b* on this criterion. The value of φ_j shows the outranking relation between two alternatives on criterion *j* (Figure 5.11). As for all the criteria, they need to satisfy both two conditions to verify *a* outranks *b*: the first one is concordance, in which the majority of criteria should support *aSb*; the second one is non-discordance, in which none of criteria in the minority objects firmly to *aSb*. Partial concordance is used to assess the degree one criterion supports the assertion *aSb*. The overall concordance *C* is a weighted sum of all the concordance values for each criterion. If the value of *C(aSb)* is 1, it means all criteria supports a outranks b; if the value of *C(aSb)* is 0, it means none of criteria supports this assertion; and if the value of *C(aSb)* is between 0 and 1, it means parts of criteria supports *a* outranks *b*.

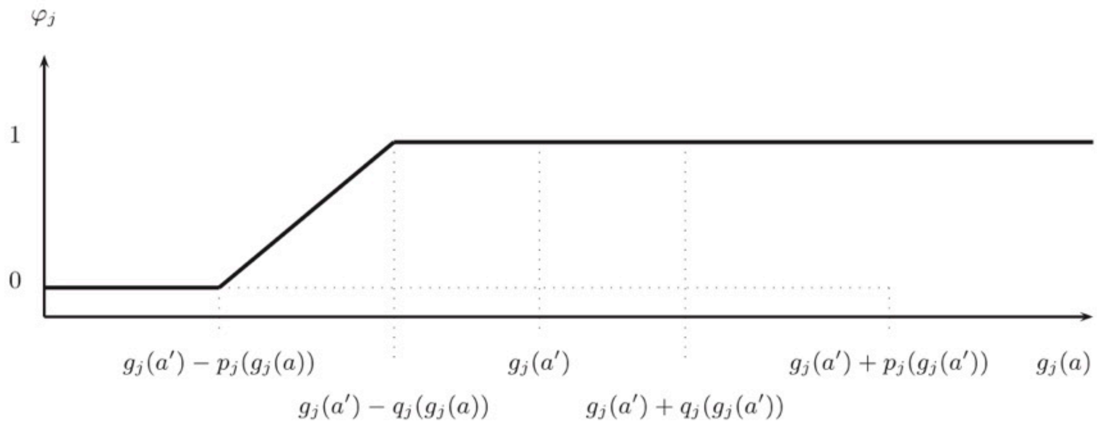


Figure 5.11 Variation of φ_j for a given $g_j(a')$ and variable $g_j(a)$ (Figueira et al., 2010 [57])

The discordance index $d_j(aSb)$ using veto threshold v_j is to describe the opposing power of a criterion *j* to the assertion *aSb* (Equation 1). The credibility index δ combines the overall concordance *C(aSb)* and discordance $d_j(aSb)$ together, measuring the overall support of criteria to the assertion *aSb*. If none of criteria oppose the assertion, $\delta(aSb)$ equals the overall concordance *C(aSb)*; while if criterion *j* strongly opposes the assertion that $d_j(aSb)$ is 1, then $\delta(aSb)$ equals 0.

$$d_j\left(a,a'\right) = \begin{cases} 1 & \text{if } g_j(a) - g_j\left(a'\right) < -v_j\left(g_j(a)\right), \\ \dfrac{g_j(a) - g_j\left(a'\right) + p_j\left(g_j(a)\right)}{p_j\left(g_j(a)\right) - v_j\left(g_j(a)\right)} & \text{if } -v_j\left(g_j(a)\right) \leqslant g_j(a) - g_j\left(a'\right) < -p_j\left(g_j(a)\right), \\ 0 & \text{if } g_j(a) - g_j\left(a'\right) \geqslant -p_j\left(g_j(a)\right). \end{cases}$$

Equation 5.1 Partial discordance indices (Figueira et al., 2010 [59])

The preference threshold p_j, the indifference threshold q_j, and the veto threshold v_j should be identified by all the stakeholders. The applying example is shown in Section 5.6.

2) Intersect two rankings

In ELETRE methods, decision-makers should intersect two rankings including descending and ascending distillations to achieve the final ranking(Figueira et al., 2016 [168-169]). The procedure of both the two partial pre-orders is to identify the best or worst alternative one by one to arrange all the criteria. If an alternative A outranks or equals to another alternative B in both two pre-orders, then the preference would be the same in the final order; if A outranks B in one order and is equivalent to b in another one, then A is preferred to B in the final ranking. If the preference is reverse in the two orders, then these two alternatives are recognized as incomparable in the final result. There are three relations in the outranking:

Preference between a pair of alternatives occur when one is preferred/outranks the other. It is marked in the graph with an arrow directed from the outranking alternative to the outranked one.

Incomparability between a pair of alternatives occurs when their ascending and descending distillation orders are in contradiction with each other. For incomparability relations between pairs of alternatives, no arrow is drawn between them in the graph.

Indifference between a pair of alternatives occurs when the cutting threshold (λ) of the credibility is not met in the distillation procedure and it cannot be stated that the credibility of one alternative outranking the other is higher than that related to opposite statement.

Figure 5.12 are an example for showing the ranking result. There are 10 alternatives from *A*, *B* to *I*, which are evaluated by 10 criteria (*C1, C2*, ……*C10*) with ELETRE III method. In the distillation graph (Figure 5.13) of ascending and descending orders, the horizontal and vertical coordinates show the ranks of each alternative in ascending and descending orders respectively. For example, the alternative *E* and *I* both ranks first in the ascending order, while alternative *E* outranks *I* in the descending order. Figure 5.14 shows the outranking matrix of each pair of alternatives. *P*, *I*, *R*, as said before, are representing preference, indifference and incomparability to indicate the relations of each two alternatives. *BP+A* means alternative *B* outranks *A* in both two preorders; *AIC* means *A* is equivalent to *C* in two preorders; *GRB* means *G* outranks *B* in the descending order while *B* outranks *G* in the ascending order so these two are incomparable.

The credibility σ quantifies the strength of the outranking statement between two alternatives with respect to the subset of criteria agreeing to the statement, weakened by the ones opposing that statement. The credibility value is calculated from the concordance and discordance indices and can be either equal to 1 (total concordance), between 0 and 1 (partial concordance), or equal to 0 (when one or more criteria use their veto power). Figure 5.15 shows the example of credibility analysis matrix.

Through intersecting the descending and ascending preorders, we obtain the final ranking order as the result (Figure 5.12). The arrows direct to the lower ranked alternatives. For example, *E* outranks *I*, and *I* outranks *F*. When two alternatives are at the same lever, they could be either incomparable if they are not put together or equivalent if they are in the same box. For example, *B* and *G* are incomparable, while *A* and *I* are equivalent. One thing that decision makers should pay attention to is that alternative *G* outranks *A* and *I*, while it is not necessarily preferred than alternative *D* or *H*, even *G* is positioned higher than the two alternatives.

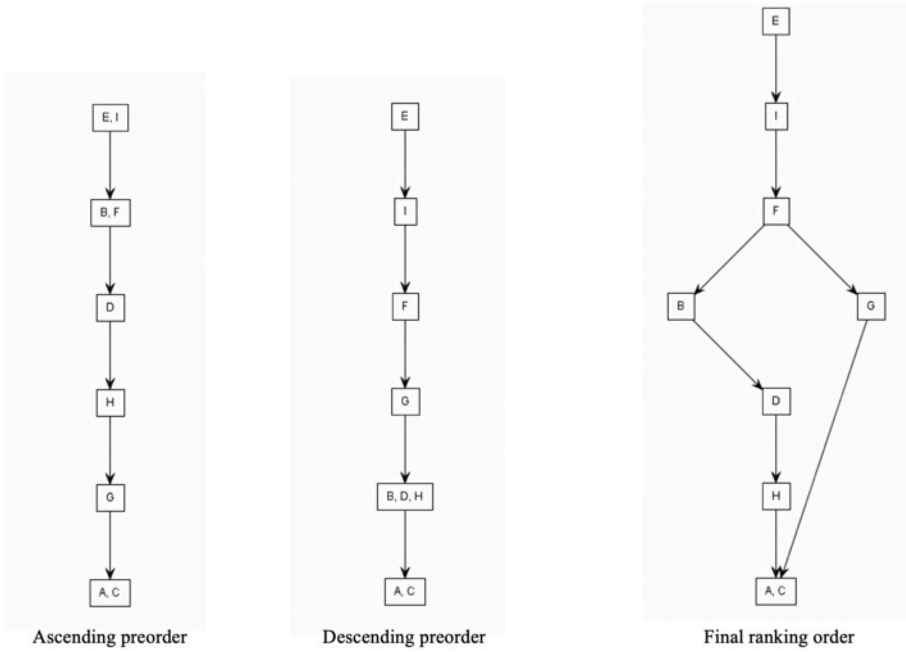


Figure 5.12 Example of ranking graphs

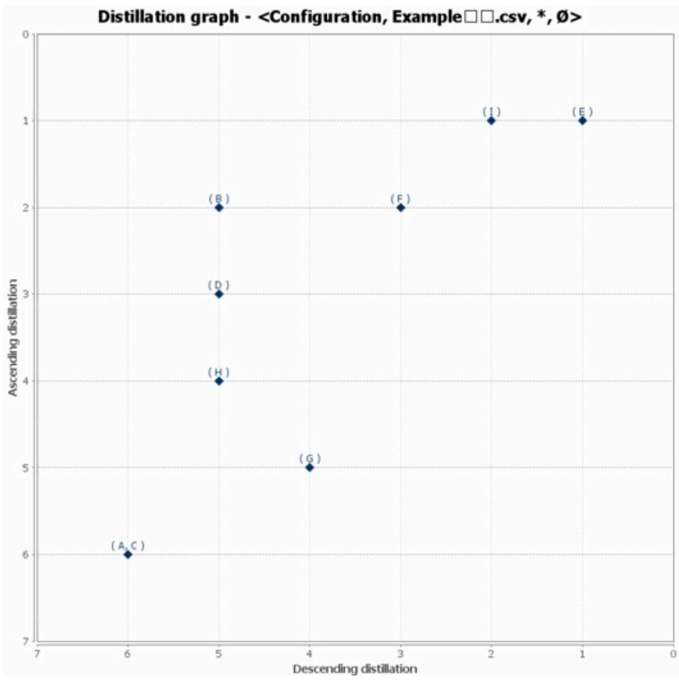


Figure 5.13 Example of distillation graph in ELECTRE III

[-]	A	B	C	D	E	F	G	H	I
A	I	P-	I	P-	P-	P-	P-	P-	P-
B	P+	I	P+	P+	P-	P-	R	P+	P-
C	I	P-	I	P-	P-	P-	P-	P-	P-
D	P+	P-	P+	I	P-	P-	R	P+	P-
E	P+	P+	P+	P+	I	P+	P+	P+	P+
F	P+	P+	P+	P+	P-	I	P+	P+	P-
G	P+	R	P+	R	P-	P-	I	R	P-
H	P+	P-	P+	P-	P-	P-	R	I	P-
I	P+	P+	P+	P+	P-	P+	P+	P+	I

Figure 5.14 Outranking matrix of each pair of alternatives

[-]	A	B	C	D	E	F	G	H	I
A	1.0000	0.3000	0.6000	0.6000	0.2000	0.3000	0.4000	0.6000	0.3000
B	0.8000	1.0000	0.7000	0.6000	0.4000	0.6000	0.7000	0.6000	0.4000
C	0.6000	0.4000	1.0000	0.6000	0.3000	0.4000	0.6000	0.5000	0.3000
D	0.6000	0.5000	0.8000	1.0000	0.3000	0.6000	0.6000	0.5000	0.5000
E	0.9000	0.6000	1.0000	0.8000	1.0000	0.6000	0.9000	1.0000	0.6000
F	0.7000	0.5000	0.8000	0.8000	0.4000	1.0000	0.8000	0.5000	0.6000
G	0.8000	0.5000	0.8000	0.5000	0.3000	0.4000	1.0000	0.5000	0.3000
H	0.9000	0.4000	0.7000	0.6000	0.2000	0.5000	0.7000	1.0000	0.2000
I	0.8000	0.7000	0.9000	0.8000	0.5000	0.8000	1.0000	0.8000	1.0000

Figure 5.15 Credibility index matrix of the example case

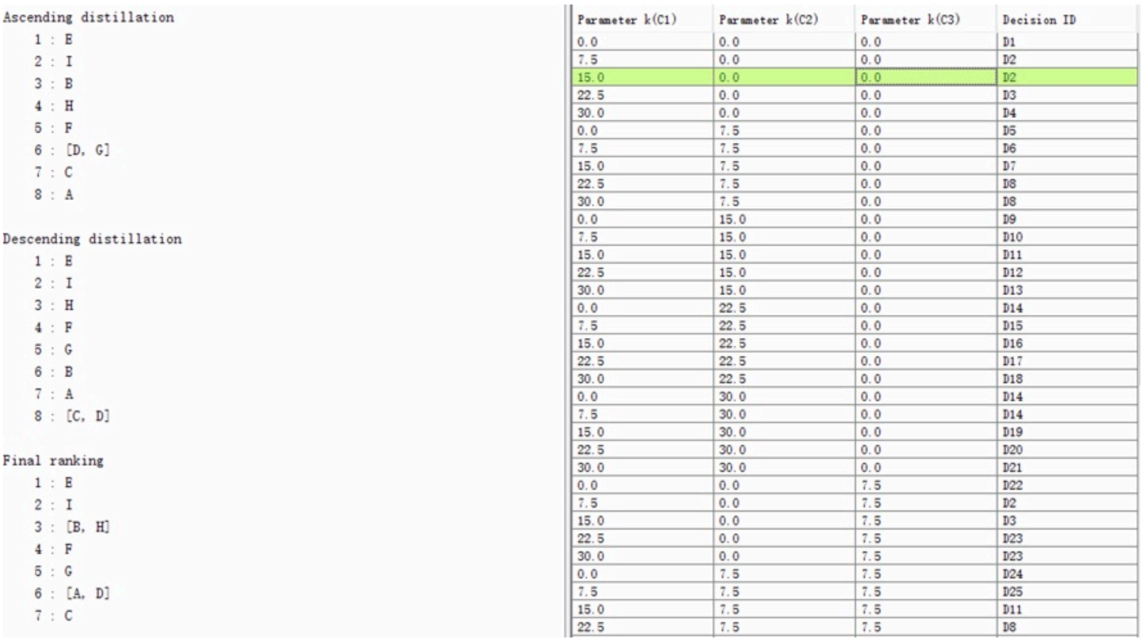
5.5.2 Result analysis

The final ranking is a recommendation for decision makers, but how will it make sense in practice? As explained before, one of the characteristics of the function identification problem is the uncertain initiation conditions of the renovation projects, which requires **contingent solutions** to cope with change. It is possible that a variation of one parameter in the MCDA model have huge impacts on the final results and thus analysts should analyze two issues of the final results: 1) different scenarios and how one variation of a parameter influence the results; 2) the robust of the results, recommending the clients that in which range of variations the final ranking remains stable (Figueira et al., 2016 [172]). These two requirements can be satisfied with scenario analysis and stability analysis, in order to better understand the final results and other possibilities according to variation of some parameters.

Scenario analysis could provide scenarios according to different distribution of weights of several criteria. The analyzed objects can either be one criterion or a certain ranking position. When initiation conditions of the projects change that weights should be re-allocated, analysts can use scenario analysis to analyze all possible rankings with various combination of weight. In the example problem, all ten criteria are allocated equally as 10% weights. Changing the weights of *C1*, *C2* and *C3* from 0 weight to 30% weight divided by 4 intervals will result in 125 different weight allocations. Figure 5.16 shows partially the allocation scenarios. The left part is the ranking results of scenario 3 (noted as *D2* since the result is the same as that of scenario 2) with 15% of weights allocating to criterion *C1*, eliminating criteria *C2* and *C3*, and equally weight to the rest of criteria. It is seen that alternative *D* and *G* both fall one position in the final ranking while alternative *A* rises inversely. Figure 5.17 shows all the possible rankings of alternative B with all weight combinations of criteria *C1* and *C3* weighted from 0 to 30%, and criterion *C3* weighted 7.5%. It is seen that alternative B is usually in the third to fifth position and most likely to be ranked fourth in the final ranking. Figure 5.18 shows the scenario for a certain position in the final ranking. In the same scenario analysis, we can see alternative E and I occupies nearly 90% of all the combinations to rank first in the final ranking, which can be suggested to the decision makers as two most likely functions no matter how weight allocation changes for criteria *C1*, *C2* and *C3* in a certain range.

Stability analysis is intended to find the boundaries of basic parameters where the final ranking remains unchanged. When decision-makers are not sure about the acceptability of the initial results or wonder the boundaries of the parameters, analysts can conduct stability analysis to offer suggestions. For the example problem, Table 5.7 shows the calculation result of acceptable range of three parameters *k*, *q* and *p* respectively for criterion *C1*, *C2* and *C3*. Since the ordinal criteria have clear preference threshold *p* the indifference threshold *q*, they will not have such stable ranges.

Besides, different from AHP and other multiple criteria decision-making methods that need scores for each pair comparison, ELECTRE III methods can easily change the number of criteria or alternatives selected to be evaluated, as well as the configurations and weights setting before. It is flexible for programmers and decision-makers to adjust the MCDA model anytime according to variable situations. Detailed application and analysis will be in the next section.



```
Ascending distillation
    1 : E
    2 : I
    3 : B
    4 : H
    5 : F
    6 : [D, G]
    7 : C
    8 : A

Descending distillation
    1 : E
    2 : I
    3 : H
    4 : F
    5 : G
    6 : B
    7 : A
    8 : [C, D]

Final ranking
    1 : E
    2 : I
    3 : [B, H]
    4 : F
    5 : G
    6 : [A, D]
    7 : C
```

Parameter k(C1)	Parameter k(C2)	Parameter k(C3)	Decision ID
0.0	0.0	0.0	D1
7.5	0.0	0.0	D2
15.0	0.0	0.0	D2
22.5	0.0	0.0	D3
30.0	0.0	0.0	D4
0.0	7.5	0.0	D5
7.5	7.5	0.0	D6
15.0	7.5	0.0	D7
22.5	7.5	0.0	D8
30.0	7.5	0.0	D8
0.0	15.0	0.0	D9
7.5	15.0	0.0	D10
15.0	15.0	0.0	D11
22.5	15.0	0.0	D12
30.0	15.0	0.0	D13
0.0	22.5	0.0	D14
7.5	22.5	0.0	D15
15.0	22.5	0.0	D16
22.5	22.5	0.0	D17
30.0	22.5	0.0	D18
0.0	30.0	0.0	D14
7.5	30.0	0.0	D14
15.0	30.0	0.0	D19
22.5	30.0	0.0	D20
30.0	30.0	0.0	D21
0.0	0.0	7.5	D22
7.5	0.0	7.5	D2
15.0	0.0	7.5	D3
22.5	0.0	7.5	D23
30.0	0.0	7.5	D23
0.0	7.5	7.5	D24
7.5	7.5	7.5	D25
15.0	7.5	7.5	D11
22.5	7.5	7.5	D8

Figure 5.16 Example of scenario analysis

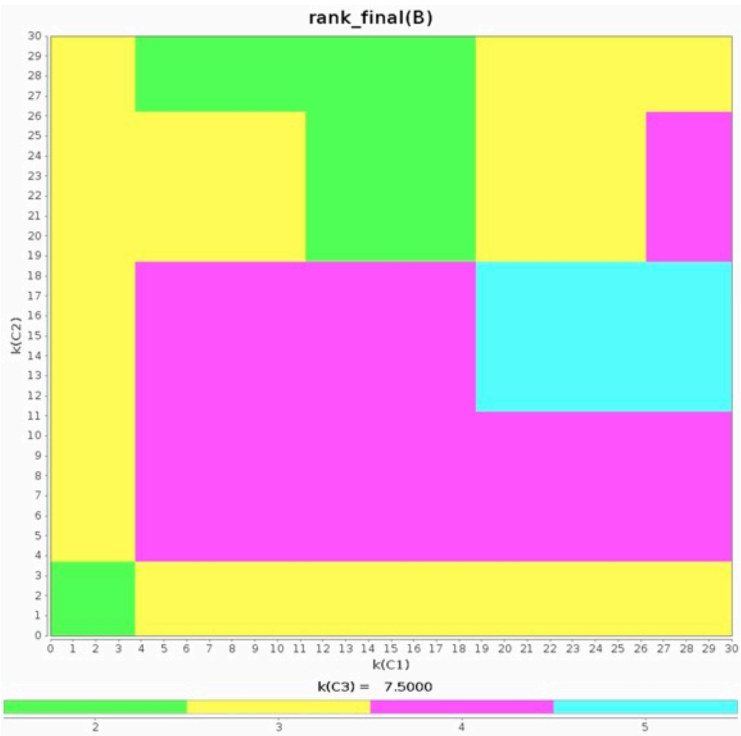


Figure 5.17 Example of scenario analysis on alternative *B* with various weight combinations of criteria *C1* and *C2* and stable weight of *C3*

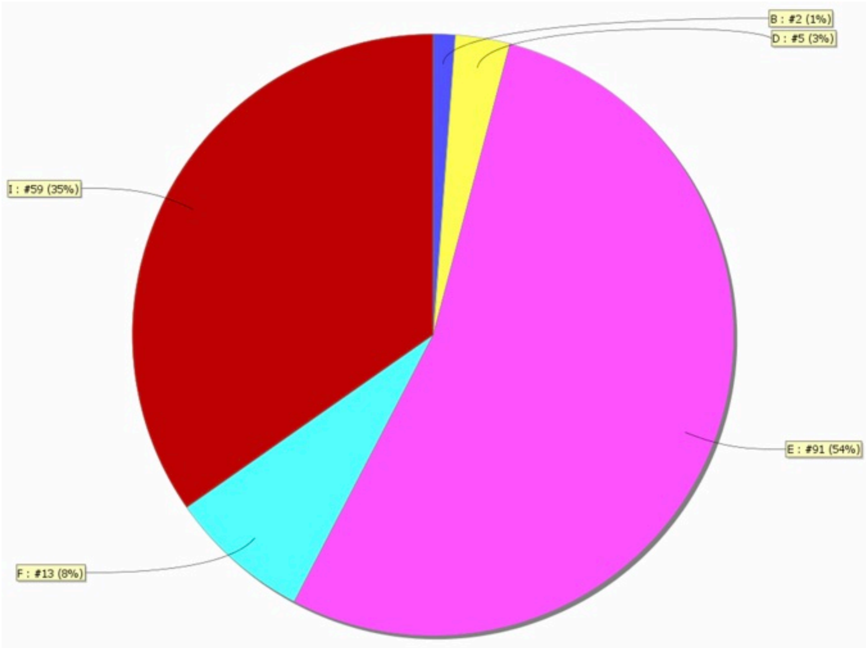


Figure 5.18 Example of scenario analysis on the first position in the final ranking

Table 5.7 Example of stability analysis of criteria

Criteria	Measure scale	k	q	p
C1	ordinal	[5.0591, 14.1283]	-	-
C2	cardinal	[7.3991, 12.2834]	[0,100]	[10,100]
C3	ordinal	[9.4562, 14.1283]	-	-

5.5.3 Extension: drafting function program

As for function-transformation renovation project, after identifying the primary function for the renovation of target buildings, it still requires further development of the function program with kinds of functions and required area size. For function-enhancement renovation project, whose primary function retains, it also has to develop the function program that satisfying the update requirement.

Developing function program is the one of the most significant part in traditional architectural programming theory as spatial conception (空间构想) or more specifically as spatial prediction (空间预测), which is intended to identify detailed content of the spaces, provide quantitative description of the spaces such as size, ration, height, etc., and specify the spatial relations, sequence and flows (苏实 and 庄惟敏, 2010 ;庄惟敏, 2016 [112]). Since the thesis focuses on supplementation of the traditional architectural programming theory, it will not explain this part in detail but introduce the ideas and programming references to draft the potential function program preparing for the final design proposal.

The development of function program includes 3 sources. 1) Cases study and literature review: study innovative cases of similar type and volume with update functions and reviews the literature focusing on the function program design of the target building type; programmers can also refer to the previous design proposal. 2) Experience of architects: programmers can interview with experienced architects or experts for the specific function to obtain the experience, or refer to the source book of architectural design. 3) Interviews with future users: sometimes the client or future users are aware of their requirement of detailed function spaces or have an idea of other expected cases; the programming team can interview them to obtain the direct response on the function program.

The programming team of BNU renovation project is intended to propose an enhancing function program to reuse the pedagogic building. They first study the spaces of department of design in top universities worldwide, then interview the future users for functional requirement on the future use, to generate a detailed functional groups and function program with common functions such as various kinds of classrooms, exhibition hall, laboratories and libraries, as well as special up-to date functions such as 3-D printing room, virtual reality laboratory, video and photograph room, etc. (Figure 5.19). Similarly, the programmers of Enrico Fermi school project conduct experiments and questionnaires to widely collect opinions from the users, with site visit to most advanced cases of pedagogic spaces. Based on existing spatial features, they improve the spatial organization and use a hierarchy diagram to present the function program of the school (Figure 5.20).

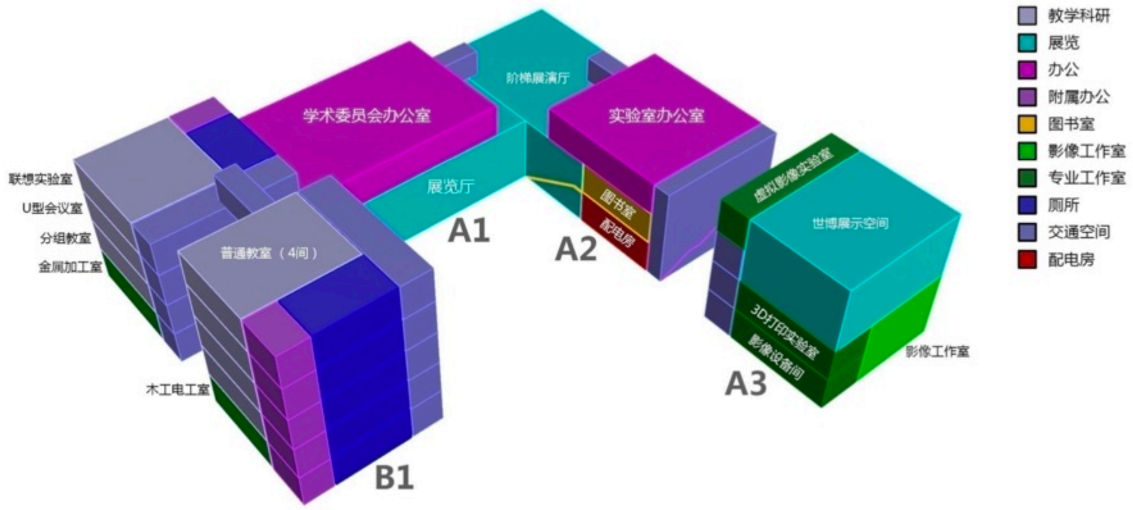


Figure 5.19 Function program of BNU renovation project ©THAD

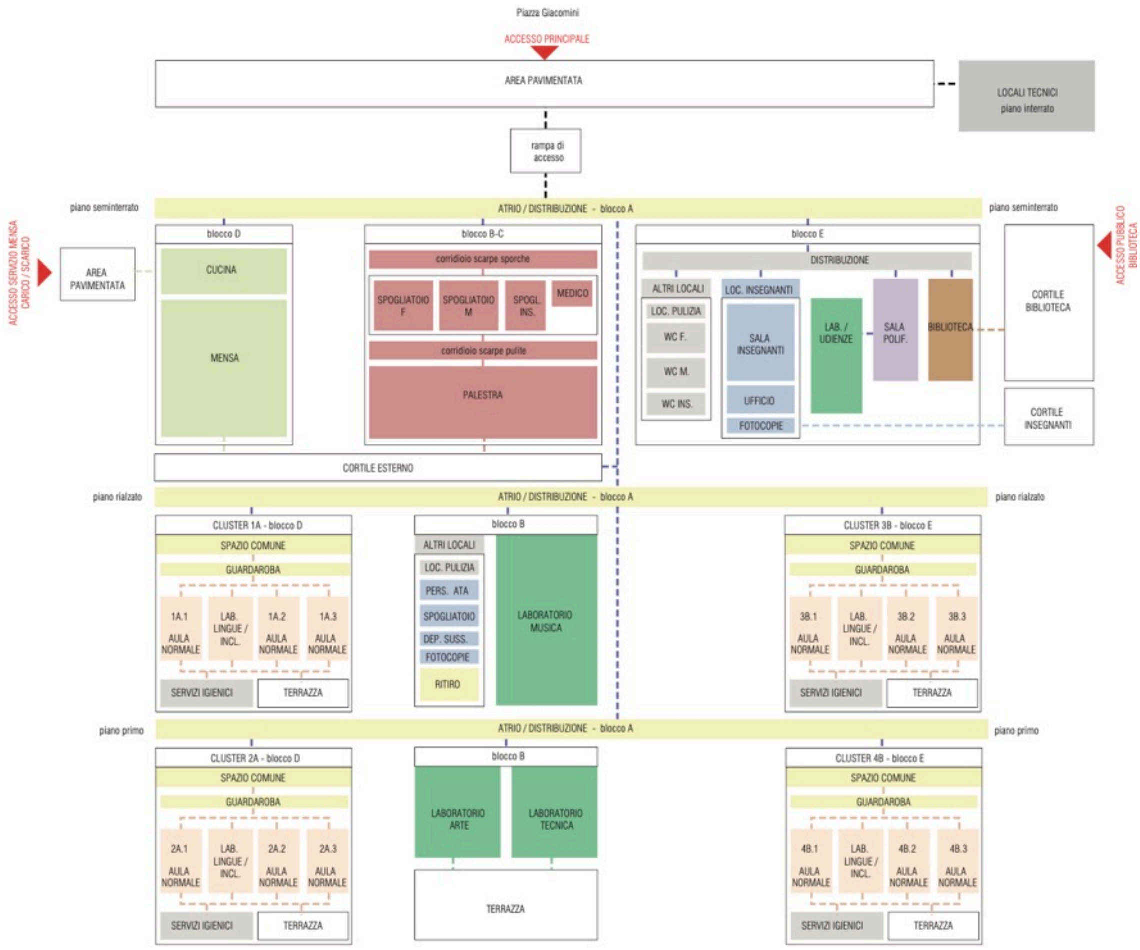


Figure 5.20 Functional program in the feasibility study of Enrico Fermi School, data resource from (Torino Fa Scuola, 2016c), ©MoDus Architects

5.6 Case study: Jingdezhen grain depot renovation project

This cases study is a practical project the author participates the whole pre-design phase from October 2021 to May 2022, collaborating with architects of Architecture Design & Research Institute of Tsinghua University. The project is undergone the design phase when this thesis is submitted. The result has been applied in the design scheme of the project, approved by the client, which can verify the research process and method to a certain degree.

The existing building clusters were designed in late 1990s and served as a state grain depot of Jingdezhen, the “Ceramic Capital of the World” in Jiangxi Province in the southeastern China. From the perspective of regional level, the site location has relative high development values since it is located on the north side to the district of Taoxichuan (陶溪川) Phase I project, which has achieved huge success in the reuse of industrial heritage and urban renewal[23], contributing a lot to tourism, one of the pillar industries in Jingdezhen. Based on the successful foundation of the Taoxichuan first phase, the municipality would like to expand the area of Taoxichuan towards both east and north side, to create a large developing area called DaTaoxichuan (大陶溪川), or Taoxichuan Phase II, with around 1.14 square kilometers (Figure 5.21). As for the site information, it borders Fenghuang Mountain (凤凰山) to the south, main axis road to the east, and is divided by Fengming road into two parts. The northern part consists of 5 factories, occupying plot area of about 47800 m^2 planned to be commercial land use with the theme of hotel, resort, guest house, etc. and other service facilities; while the southern part consists of the rest 11 buildings with plot area of over 80800 m^2 planned to be the second category of residential land use with service facilities (Figure 5.22).

Today, the property of existing building clusters is owned by Jingdezhen Ceramic Culture Tourism Development Co. LTD (景德镇陶瓷文化旅游发展有限公司), a state-owned financing platform company in Jingdezhen. From the perspective of building level, the previous state-owned grain depot is relatively important in the history of Jingdezhen and records the memory of the civic life. Besides, due to the transportation requirement,

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23 The first phase construction of industrial heritage reuse in Taoxichuan has been honored by over 80 awards of global, national and provincial levels including 2017 UNESCO Asia-Pacific Cultural Heritage Conservation Award and was recognized by the Ministry of Culture and Tourism as a national cultural industry demonstration park.

the grain depot is linked with a train platform and is crossed by rails. Therefore, there are many industrial features on site in Jingdezhen 20 years ago that should be preserved (Figure 5.23).

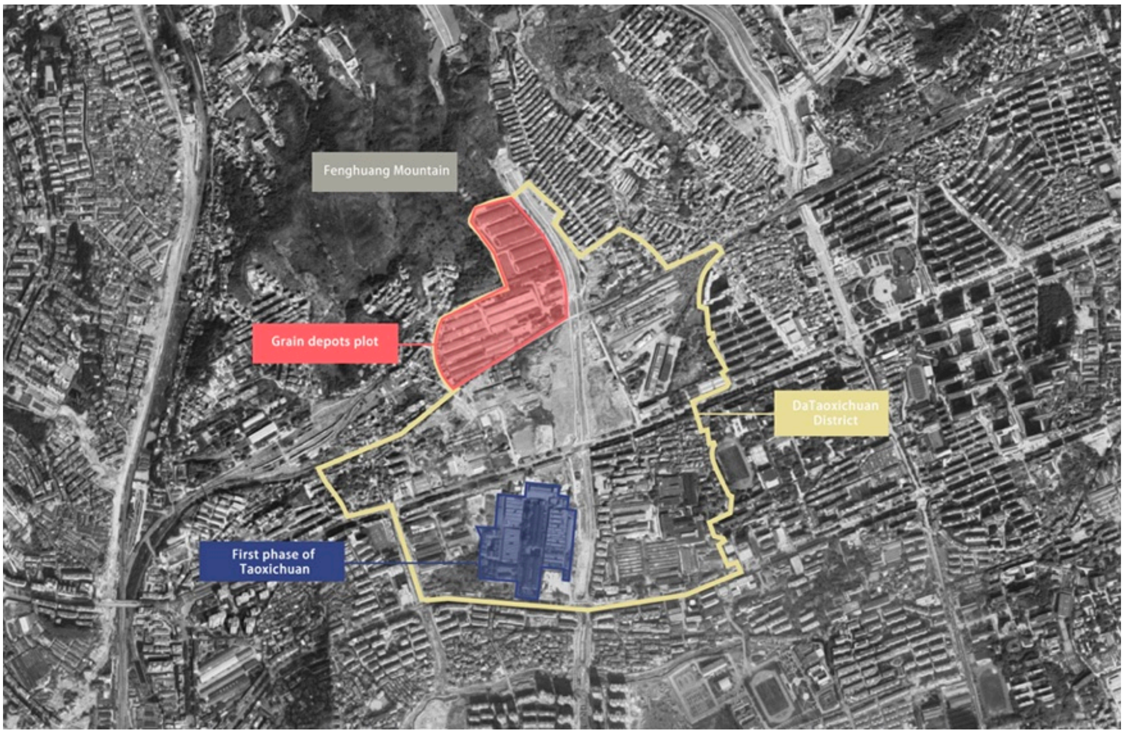


Figure 5.21 Location of the project

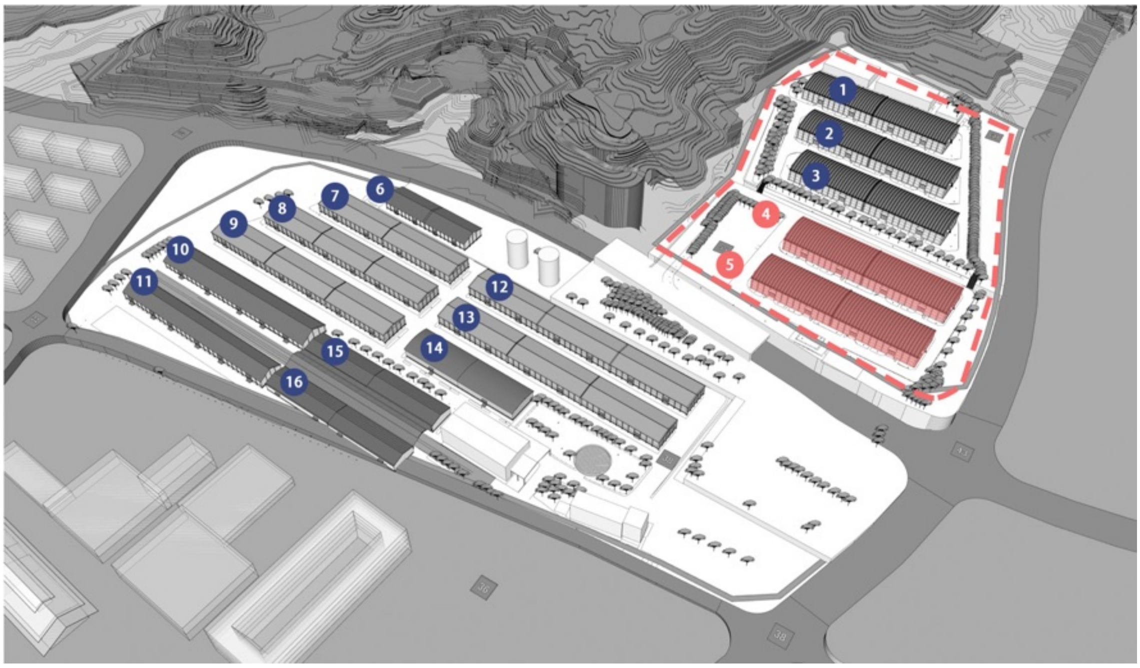


Figure 5.22 Existing building cluster of the Grain depot

Figure 5.23 Conditions of existing grain depots in the north plot ©THAD

This research project is intended to find suitable functions for the reuse of building No.4 and 5 in the north part, as marked in the Figure 5.22, which is a ranking decision problem among different functions. The reason to focus on these two depots will be explained in the next section. The clients invited the group of architects from the seventh branches of Architecture Design & Research Institute of Tsinghua University, to conduct architectural programming and design process for the site. The author participated the whole pre-design phase collaborating with the architectural programming group. Section 5.6 studies the case of function identification of building 4 and 5 applying the MCDA process and method as a part of the architectural programming process. To obtain the final ranking results to support stakeholders to make decisions, the architectural programming team should first identify the situation of the decision problem, then structure the evaluation model, and finally apple ELETRE III methods to rank the possible function alternatives.

5.6.1 Structuring the decision situation

5.6.1.1 Premise of function distribution on site

Before identify the goals and stakeholder to structure the decision situation, it should first clarify the premise of function distribution on the building cluster. According to the previous approved urban planning and design, the industries to be developed in Jingdezhen were oriented as four mixed industry functions, that are ceramic cultural industry, urban vitality service industry, education industry of ceramic culture, and urban recreation industry (Co. and Co., 2019). DaTaoxichuan district, as the most important district to drive the development of Jingdezhen, is oriented as four quadrants with four function orientations as well (Figure 5.24). The second quadrant, in which our project is located, is oriented as living, social communication and recreation spaces. Our site is thus identified with the theme of hotel, resort apartments, medium and high-class residential quarters, and recreation service facilities. Based on this functional orientation, the next step is to distribute such functions into the existing building cluster.

Figure 5.24 Orientation of four quadrants in DaTaoxichuan district

Figure 5.25 Urban planning scheme of urban structure, landscape corridor and road and traffic system ©THAD

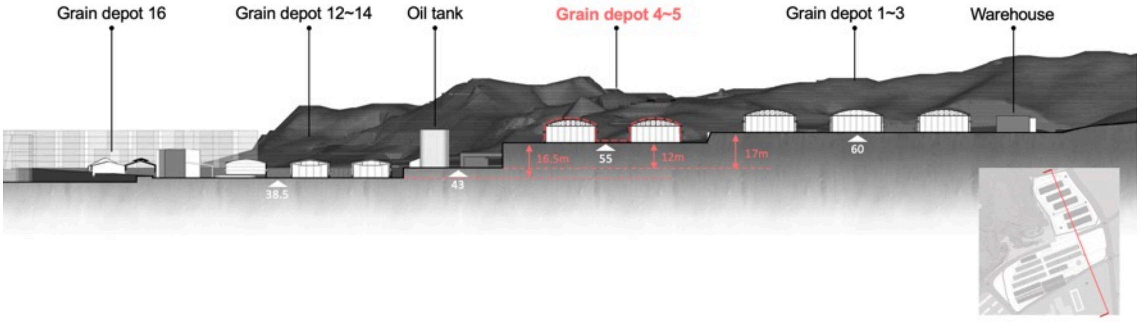


Figure 5.26 Height difference in the site from south to north

As mentioned in section 5.1.3, to distribute function should consider the limited factors and encouraging factors on site. There are there prominent factors and conditions here:

a. Urban planning premise: the previous urban planning and urban design identify the general structure of DaTaoxichuan (Figure 5.25). Apart from the road that crosses the site form west to east, a planned landscape corridor goes through it from south to north as well, which sets an axis for our site to connect with other southern plots, and split the southern part of the site into two parts. Furthermore, based on an overall consideration of the DaTaoxichuan site, one of the first vitality level knots is located on the end of the vertical axis, which will be a center point of our project.

b. Geography on site: one of the significant features of the site is the height difference between the south and north up to over 20 meters (Figure 5.26). This feature brings a kind of challenge to integrate the south and north plots, while brings a great opportunity of obtaining views and a sense of sacred from the north plot at the same time. Besides, the north plot and the south-west part of the south plot is adjacent to the Fenghuang Mountain to the west-north, and thus are closer to the nature and have more privacy than the south-east plot which is at the cross of urban main roads.

c. Resources: considering the renovation and reuse cultural heritage projects in Taoxichuan District, and the potential investment resources, the client has preference to transform the industrial park into a mixed-use community with the theme of art performance including drama, traditional Chinese opera, small concert and so on. But the client has no knowledge of the type and capacity of art performance.

d. Existing building: architects and programmers conduct preliminary research and site visit on the existing buildings. Based on the visual inspection, building structural diagnosis report and construction drawings, they make an initiative evaluation of the level of values to each building (Table 5.8). Figure 5.27 shows the model of the two target buildings. The number 1 to 5 buildings are grouped in the north site plot and possess a relative high value for preservation. The second group with high value is building 7, 8 and 9. It is possible to group similar and adjacent buildings into the same function group.

These factors above generate the final function distribution on site (Figure 5.28): the north-west part of the south plot will be residential spaces combined with art studios and lofts. The south-east part, located at the cross corner of the main roads, will be commercial facilities with some community service facilities. The north plot adjacent to the mountain will be a social and communication space for guests, visitors and citizens. The northern three buildings which has a relative higher degree of privacy and more sceneries will satisfy the land use requirement of hotel service such as hotel rooms, guest houses, resorts, etc. The southern two buildings will be a supporting facility consisting of social activities. But what kind of functions that best support the social spaces and intrigue the vitality of the site? It is the problem that should be identified later.

Table 5.8 Value analysis of existing buildings ©THAD

Existing building (No)	Structure and material	Width / diameter (m)	Height (m)	Preservation value
1-5, 14	Row frame structure + concrete arch roof frame	4	10.7	High
15, 16	Lattice structural system	6	7.7	High
7-9, 12, 13	Tensioned beam roof frame	4	10	High
6	Triangular timber roof frame	3.6	10	Low
10, 11	Triangular timber roof frame	4	10.8	Low
Oil tanks	Steel	13	22.2	High
Fire protection pool	Concrete	16.2	2.5	High

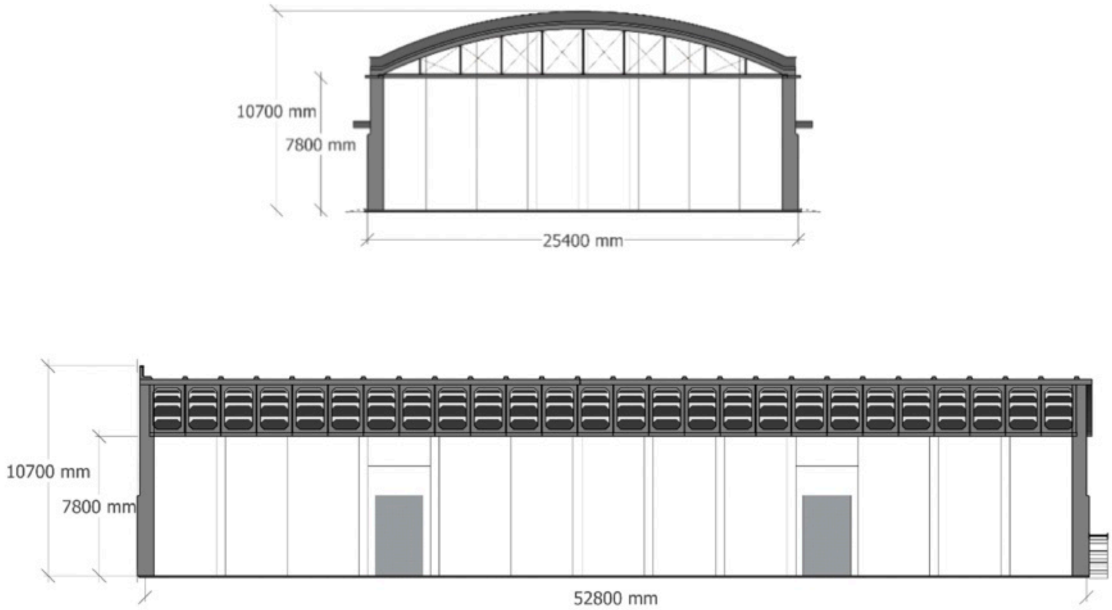


Figure 5.27 Sections of the target buildings ©THAD

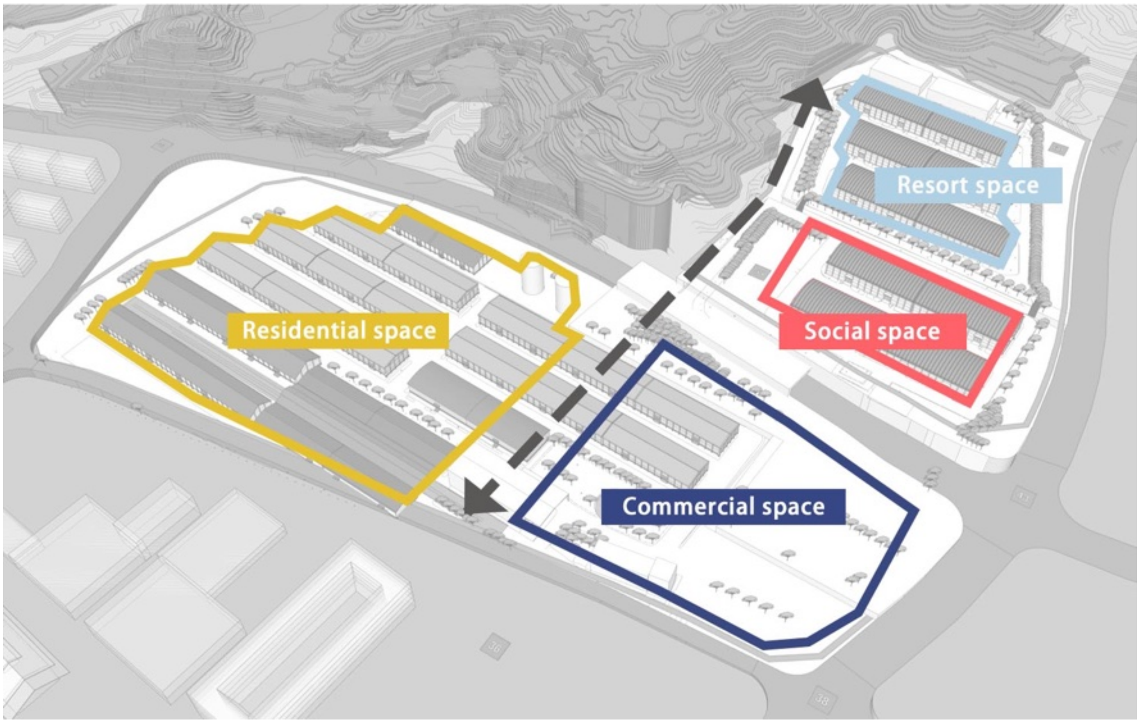


Figure 5.28 Function distribution of Jingdezhen grain depot renovation project

5.6.1.2 Goals and stakeholder analysis

1) Main goals

The problem is to identify the most suitable function for reuse of the buildings in the northern part of the site. More specifically, the problem of multiple criteria decision analysis is to **rank potential function alternatives for the two existing buildings** in the northern plot serving hotels and resorts of the adjacent three existing buildings. In detail, the stakeholders also clarify four main goals in the project from the very beginning: 1) the first is to stimulate social contact and communication based on the orientation of this site as social and living spaces in the DaTaoxichuan districts; 2) to create distinguishing spaces to attract visitors to stay in Taoxichuan for a while; 3) the third goal is to have good connections and interactions with other plots in the DaTaoxichuan districts; 4) the last one is to support creating a vibe of pilgrimage to arts in this site with the help of the geography and landscapes.

2) Multiple stakeholders and benefits

The stakeholders involved in the problem consist of the owner, the investor, the operator, and the public. The building is owned by the state-owned financing platform company, who would also be the major investor and operator for the building reuse. And the municipality is also a powerful stakeholder on the decision making. Besides, there are also some interested investor from different industries are invited to participate in the pre-design phase discussion. Some potential users and operators are also invited by the client representing different interests and benefits form the market and tourism promotion, which will be important for the later operation after project delivery. Since the site doesn't have original inhabitants, the government mainly considers the opinion of the municipality. Table 5.9 shows the stakeholders participated in the pre-design phase.

Table 5.9 Stakeholders analysis

Category	Stakeholders	Notes
1) Owner	Jingdezhen Ceramic Culture Tourism Development Co. LTD	a state-owned financing platform company that considers comprehensive benefits for the public
2) Municipality	Jingdezhen natural resources and planning bureau	Supervise the whole process to satisfy the regulation, balance the benefits
3) Investor	Jingdezhen Ceramic Culture Tourism Development Co. LTD;	the principal project manager and one of the investors
	Private sectors: real estate company; art and media company	Persons or companies interested in investing capital on the project
4) Operator and	Potential users	Potential visitors and users including

Category	Stakeholders	Notes
users		scientist, artist, entrepreneur, etc.
	Potential operators	Cultural media corporations, new media art industry, exhibition curatorial corporations
	News media and press	Participators in the future operation
5) Experts and consultants	Experts from urban planning	Give advice on industry development and function distribution in the restrict
	Experts from architecture	Give advice on design and operation modes
	Experts from ceramic archaeological research institute	Support research on cultural and historic values

The four-quadrant coordinate analysis (Figure 5.29) presents the interest level of different stakeholders and their power of impacts on the decision-making process. For example, the Jingdezhen Ceramic Culture Tourism Development Co. LTD, as the property owner, one of main investors and project managers, has the most power and interest among all the stakeholders; the potential investors and operators have less power but with high interest. The position is for better understanding of the whole picture and simulating the realistic situation.

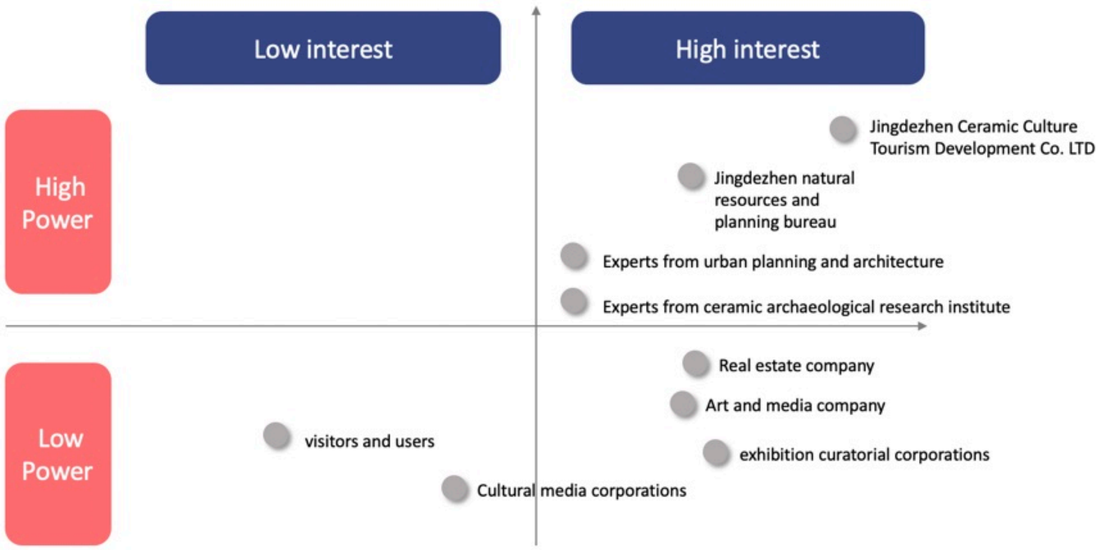


Figure 5.29 Diagram of stakeholders with respect to the levels of interest and power in the decision situation

5.6.2 Structuring the MCDA model

As introduced in the previous sections, structing the MCDA model is to identify alternatives, selecting criteria and allocating weights among stakeholders. Due to the pandemic situation and stakeholders being in different provinces, it is difficult to conduct face-to-face discussion meeting. The structuring process thus is based on text records of four online meetings with different stakeholders and other four meetings of the programming team in the pre-design phase.

5.6.2.1 Identifying alternatives

Based on basic information collected in the first step, 8 function alternatives are proposed based on the previous 5 principles as follows:

• *Exhibition center (Exh)*. an exhibition hall can display art pieces, hold academic, commercial or press conference, hold a banquet, etc. This function has highest flexibility of operation with open spaces, but the curatorial management plays an important role in the operation.

• *Live house and bar (Liv).* Corporations of art performance and new media have great interest in the project. Since the owner and experts suggest to create social and communication space, live house and bar can be a good choice which is popular now in other cities in China. It can be a small space for art performance such as live house, drama, stand-up comedy, as well as be transformed into banquet, party, press conference, etc.

• *Theme theater (The)*. Interested investors and operators also include art performance corporations, and theme theaters are a mature type in the tourism resort in China to attract tourists and family visitors, promoting local culture and customs at the same time.

• *Museum (Mus)*. Considering the existing museum of ceramics in Jingdezhen, this space can display other local traditional artifacts, or take the theme of art performance such as traditional Chinese opera accessible to the public.

• *Library and bookstore (Lib)*. Considering the large amount of residence in this project, one of the common supporting service facility of living community is a public library and bookstore. The public library can serve all range of age groups, and the relative bookstore with café can be an internet-famous site to attract visitors, which becomes a trend in China to take a snap at an internet-famous bookstore. Besides, Jingdezhen does not have library in this district at present, which has a certain degree of requirement for the cultural public service.

• *Community center (Com)*. Considering the large portion of the site would be mix-used living quarters and hotels, community center will be beneficial to the real estate investors, and can promote aggregation, integration, support, and provide services to the residents and visitors living here, including gym, library, meeting hall, sharing office and studios, etc.

• *Youth center (You).* Alternative of Youth center is generated based on the living residence and family visitors. The rest part of Taoxichuan are mainly intended for adults, but a large group of visitors can be families with children. This youth center provides activities for children and youth, with education of traditional culture and ceramic arts.

• *Sports center (Spo)*. Sports center is one of the potential functions proposed in the urban design scheme of this site. It provides various kinds of sports venues for the surrounding residence and living quarters in Jingdezhen. Since the south part of Taoxichuan first phase has been full of traditional culture and arts, the client would like to seek possibilities of motion and vitality in this plot.

To be mentioned, these alternatives represent the primary single function for the existing building, but will be composed of multiple functions, or even intersections in practice. For example, the community center will also contain youth center and sports center at the same time, but he primary and general function is a community center.

After identifying the alternatives, the programming team still need to conduct preliminary review of potential functions. Here is the example of the review for the alternative livehouse and bar. Programmers first analyze the market of livehouse and bar in other cities in China, and then collect information about the volume requirement of this function comparing with the existing building capacity. Below is a roughly analysis.

• Urban market demands: industry of livehouse and relevant entertainment activities is booming in China nowadays, especially in first-tire cities. Other small cities like Anyang, Xinxiang in Henan province, Zibo, Liaocheng, Linyi in Shandong province, also have at least one livehouse (Table 5.10). Many reports have forecasted a huge growth of domestic demand with booming growth of stand-up comedy in recent year, which became one of the most popular recreation among young people. Jingdezhen with tourism as a major industry, has a certain demand for offering such entertainment spaces for visitors.

• Building capacity: existing two depots have the same structure and size with floor area of 2700 m^2. For common livehouse facilities, the space has a certain flexibility with size and using people, possessing the ability to compatible with black-box theater, exhibition, press, party and so on. The floor area of livehouse ranges from 500 to 2000 square meters, which are quite carried in the target buildings (Table 5.11).

Table 5.10 Number of livehouse in cities in China

Number of livehouse	Cities as example
15	Beijing
11	Guangzhou
9	Shenzhen
8	Shanghai
3	Nanjing, Hefei, Changsha
2	Ningbo, Zhuhai, Kunming, Lanzhou
1	Chongqing, Tianjin, Xian, Wuhan, Chengdu, Zhengzhou, Fuzhou, Nanning, Jinan, Shijiazhuang; Nantong, Anyang, Xinxiang, Xiamen, Huaibei, Huangshan, Zibo, Liaocheng, Linyi

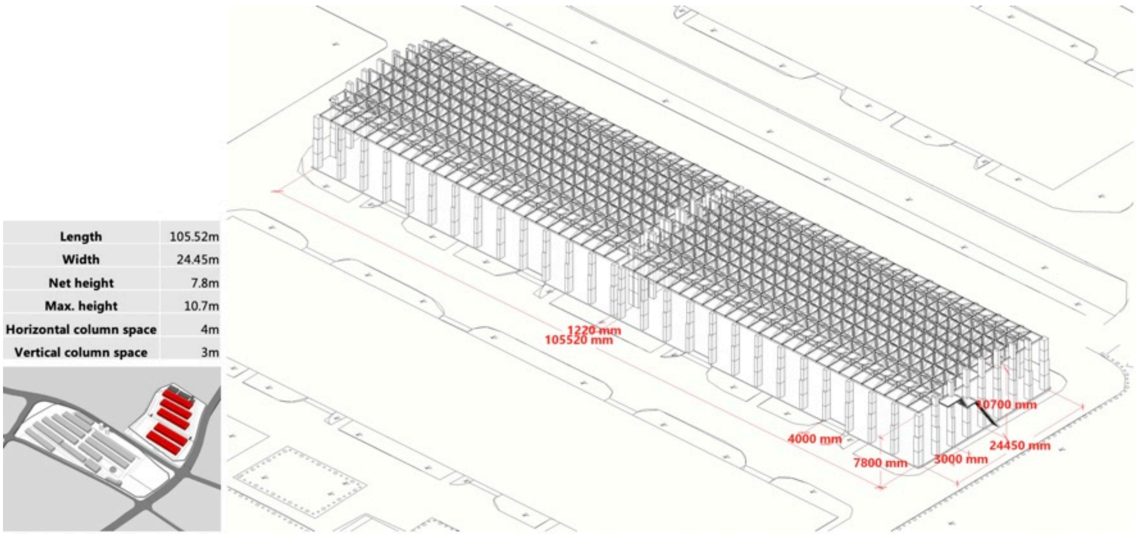


Figure 5.30 Structure and spatial feature of existing depots, translated from © THAD

Table 5.11 Capacity of similar cases

livehouse	City	Size (m2)	Capacity of people
School	Beijing	850	200-300
Yugongyishan	Beijing	850	500-700
DDC	Beijing	400-500	200

livehouse	City	Size (m2)	Capacity of people
MAO	Beijing	480	600
Damai 66	Beijing	1300	1600
Tango Live	Beijing	1500	1000
Hangaar2	Katwijk	2450	2500
Billboard Live	Tokyo	1500	300
Billboard Live	Osaka	800	250

5.6.2.2 Selecting criteria and allocating weights

Based on the goals proposed by the stakeholders and the criteria index introduced in the section 5.4.1, the programming team selects 15 criteria that both are of significance to major benefit and can be effective and measured based on open data. The criteria were then developed into measurable scales and identified whether each of them was ordinal or cardinal for the next ranking process.

1) Social

• A1-Vitality and creativeness of the surrounding communities (ordinal): four levels of extreme, strong, medium, and low stimulation and impacts on vitality and creativeness of the communities.

• A2-Net growth number of new jobs (cardinal): quantifies the number of new job positions which would be created within the building for each of the proposed alternatives.

• A3-Positive interaction with surrounding function facilities (ordinal): four levels of extreme, strong, medium, and low interaction with surrounding plots, focusing on the coordination and complementation of functions.

2) Economic

• B1-Annual profitability (ordinal): four levels of huge, high, medium, and low profit generated by the primary functions depending on the judgements of experienced investors.

• B2-Attractiveness to potential investment (ordinal): four levels of extreme, strong, medium, and low attractiveness to potential investors based on the interests, opinions and ideas of the investing stakeholders.

• B3-Contribution to the development of local tourism (ordinal): five levels of very strong, strong, medium, less, and least contributions to the development of local tourism based on previous case studies and opinions of the municipality.

• B4-Promotion to the local industry development (ordinal): four levels of extreme, strong, medium, and low promotion to the local industry development, depending on whether the function will develop a new industry or enhance the existing tourism and ceramic industry.

• B5-Increase value in surrounding real estate market (ordinal): three levels of strong, medium and low of the exceptional values added to the real estate market, depending on the value-added services to the living quality.

• B6-Construction cost (cardinal): estimated construction cost of each function per square meters (RMB/m^2), according to the building cost sheet of previous renovation projects.

3) Environmental

• C1- Energy consumption of life cycle (ordinal): three levels of huge, medium, and low energy consumption of a given alternative in the whole life cycle, according to open-access reports.

• C2- Contribution to the surrounding environmental quality (ordinal): three levels of strong, medium, and low promotion of new green areas and landscapes affiliated to the given alternative.

4) Cultural

• D1- Increase public awareness of cultural values (ordinal): four levels of strong, medium and low increasement of public awareness of cultural values, depending on the culture values and concepts given by the alternative to the public.

5) Aesthetic

E1- Reservation of original materials and elements (ordinal): three levels of high, medium and low reservation or retain of original materials and elements of the existing buildings that could be reused in the alternative function.

6) Technical

F1- Degree of intervention and technical feasibility (ordinal): four levels of strong, medium, less and least degree of intervention to the existing building including the structure adjustment, new openings, ect.

F2- Accommodating different functions (cardinal): number of possible usage scenes and modes or compatible functions in the alternative building.

The criteria, along with the type of scale of the associated attributes and the measurement unit have been summarized in the following Table 5.12.

Table 5.12 Criteria selection of Jingdezhen Grain Depot renovation project

Values	Criteria	Sub-criteria	No	Criteria constructed	Measurement unit
Social	Community building	Vitality and creativeness of the surrounding communities	A1	Maximize the vitality and creativeness of the surroundings	Ordinal scale
	Employment	Net growth number of new jobs	A2	Maximize the number of employees	Cardinal scale: count
	Functional utility	Positive interaction with surrounding function facilities	A3	Maximize the positive interaction with surrounding facilities	Ordinal scale
Economic	Potential profit	Annual profitability	B1	Maximize annual profit	Ordinal scale
	Market demand	Attractiveness to potential investment	B2	Maximize the attractiveness to potential investment	Ordinal scale
	Externalities to local community	Contribution to the development of local tourism	B3	Maximize the benefit to tourism	Ordinal scale
		Promotion to the local industry development	B4	Maximize the potential to develop industry for the local district	Ordinal scale
		Increase value in surrounding real estate market	B5	Maximize economic positive externalities: increase value in residential real estate	Ordinal scale
	Cost	Construction cost	B6	Minimize the cost of the intervention	Cardinal scale: Cost/floor area [RMB/m^2]
Environmental	Environmental sustainability	Energy consumption of life cycle	C1	Minimize quantity of energy consumption of life cycle	Ordinal scale
	Externalities to the surroundings	Contribution to the surrounding environmental quality	C2	Maximize the contribution to the central landscape corridor	Ordinal scale

Values	Criteria	Sub-criteria	No	Criteria constructed	Measurement unit
Cultural	Cultural significance	Increase public awareness of cultural values	D1	Maximize cultural value and symbolic features of traditional arts or local community	Ordinal scale
Aesthetic	Conservation of aesthetic values	Reservation of original materials and elements	E1	Maximize the quantity of retained materials and elements	Ordinal scale
Technical	Compatibility	Degree of intervention and technical feasibility	F1	Minimize the degree of intervention – openings, structural reinforcement	Ordinal scale
	Flexibility	Accommodating different functions	F2	Maximize the number of operation modes or usage scenarios that the alternative can accommodate	Cardinal scale: count

• Weight setting

The weight setting applies Revised Simos' procedure with DecSpace software online. As introduced in the previous section, the weight allocation can always be modified by decision makers and be discussed in the stability analysis and scenario analysis afterwards. Figure 5.31 is the preliminary weight allocation for each selected criterion in the case study and will be applied in the later MCDA model.

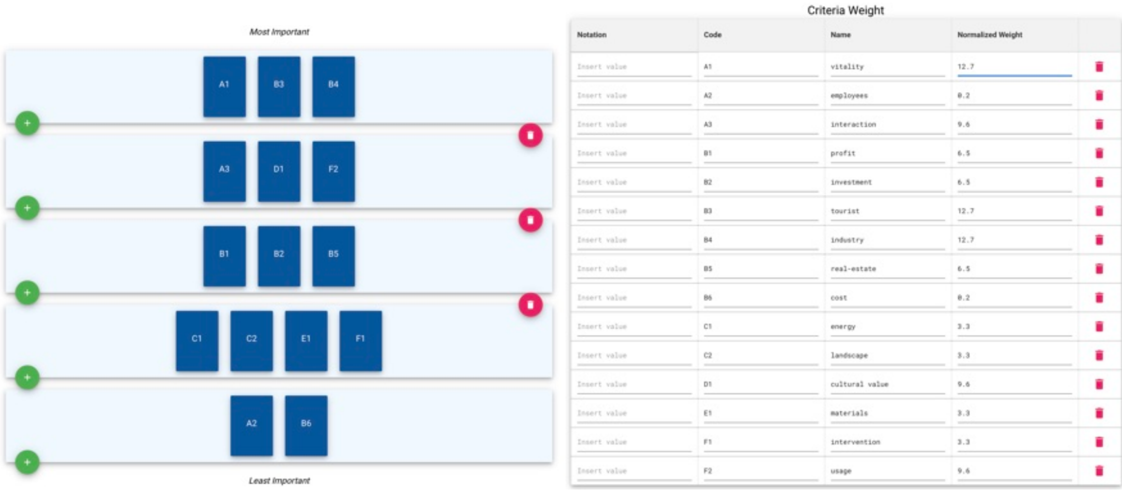


Figure 5.31 Weigh allocation in DecSpace

5.6.3 Evaluating the decision alternatives

Evaluating the decision alternatives should first apply the MCDA model to rank the alternatives, then conduct result analysis, and finally draft the function program based on the ranking results.

5.6.3.1 Ranking alternatives

Referring to the section 5.5.1, ranking alternatives should first complete the performance table based on the MCDA model structured, then determine preference indicators to draw the configuration table, and lastly intersect two distillations by ELECTRE III method to obtain the final ranking.

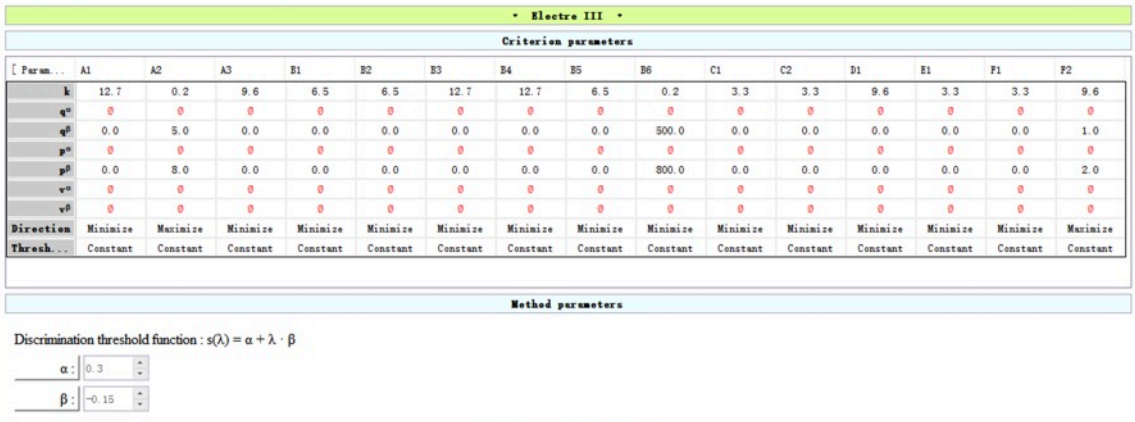
• Complete performance table: the performance of each alternative on each criterion is evaluated as Table 5.13 shows. According to the direction of each criterion as maximization or minimization, the L1 level in the ordinal criteria is the best one to facilitate the goal of the criterion. As for three cardinal criteria, data from previous cases and open-access data are the reference to the quantitative performance.

Table 5.13 Performance table of MCDA model in Jingdezhen Grain Depot project

	A1	A2	A3	B1	B2	B3	B4	B5	B6	C1	C2	D1	E1	F1	F2
Extent	3	10	3	3	3	4	3	2	4000	2	2	3	2	3	6
Exh	L2	20	L1	L2	L2	L2	L1	L3	4000	L3	L2	L2	L1	L1	3
The	L1	20	L3	L2	L2	L1	L2	L3	8000	L2	L3	L2	L3	L4	2
Mus	L2	10	L4	L2	L2	L1	L2	L3	6000	L1	L2	L1	L1	L3	2
Lib	L3	10	L2	L4	L4	L3	L3	L1	5000	L3	L1	L3	L2	L2	4
Com	L3	10	L3	L3	L4	L5	L4	L1	4500	L2	L1	L3	L2	L2	6
Liv	L1	15	L1	L2	L1	L3	L2	L2	6000	L3	L3	L2	L2	L3	2
Spo	L3	10	L3	L2	L3	L5	L4	L2	6000	L3	L1	L4	L2	L3	2
You	L4	15	L3	L1	L1	L4	L4	L1	5000	L2	L1	L4	L3	L2	6

• Determine preference indicators: in this step, the preference threshold (p), the indifference threshold (q) and the veto (v) are assigned to the cardinal criteria, which are A2- Maximize the number of employees, B6- Minimize the cost of the intervention, and F2- Maximize the number of operation modes or usage scenarios that the alternative can accommodate (Figure 5.32).

The preference threshold describes the absolute difference in the performance of an alternative with respect to a given criterion which would mark a preference, the indifference level marks the absolute difference under which hesitation occurs and the veto marks the preference difference above which a criterion is in strong opposition to the outranking. The p, q and v values proposed were defined considering the specific characteristics of the cardinal criterion under analysis. The weights of all criteria and the p, q, v thresholds of the cardinal criteria are summarized in the decision configuration table in ELECTRE III. The method parameters α, β remains the suggested numbers according to experience.



• Electre III •

Criterion parameters

[Param...	A1	A2	A3	B1	B2	B3	B4	B5	B6	C1	C2	D1	E1	F1	F2
k	12.7	0.2	9.6	6.5	6.5	12.7	12.7	6.5	0.2	3.3	3.3	9.6	3.3	3.3	9.6
q^{α}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
q^{β}	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	500.0	0.0	0.0	0.0	0.0	0.0	1.0
p^{α}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
p^{β}	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	800.0	0.0	0.0	0.0	0.0	0.0	2.0
v^{α}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v^{β}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Direction	Minimize	Maximize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Minimize	Maximize
Thresh...	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant

Method parameters

Discrimination threshold function : $s(\lambda) = \alpha + \lambda \cdot \beta$

α : 0.3

β : -0.15

Figure 5.32 Configuration setting of MCDA model in Jingdezhen Grain Depot project

• Intersect two rankings: once the decision configuration has been set, it is possible to validate the inserted parameters and execute the analysis to rank the alternatives. The Final Ranking graph is based on the combined data from the descending and the ascending distillations (Figure 5.33), which are shown in the Figure 5.34, discriminating indifference and incomparability. In the Final Ranking graph, the reciprocal relations between alternatives is plotted and arrows represent outranking relations.

According to the graphs, the most preferred alternative is *livehouse and bar*. The second-best alternative is the *exhibition hall*. The least preferred solution is the *sports center*. The outranking graph (Table 5.14) and the credibility index matrix (Table 5.15) plots a complex system of relations between alternatives, including relation of preference, incomparability, and indifference in detail. Alternative *livehouse and bar* is preferred or equivalent to all the rest of alternatives in both two preorders. The other two options ranking first in the ascending pre-order are *exhibition hall* and *museum*, while they ranked the second and the third respectively in the descending order. Therefore, *livehouse and bar* is the only one that ranks first in the final ranking. The *theme theater* is preferred to *museum* in descending pre-order, while *museum* is preferred to *theme theater* in ascending pre-order, so these two alternatives are incomparable in the final ranking, as their relation is labeled *R* in the outranking graph.

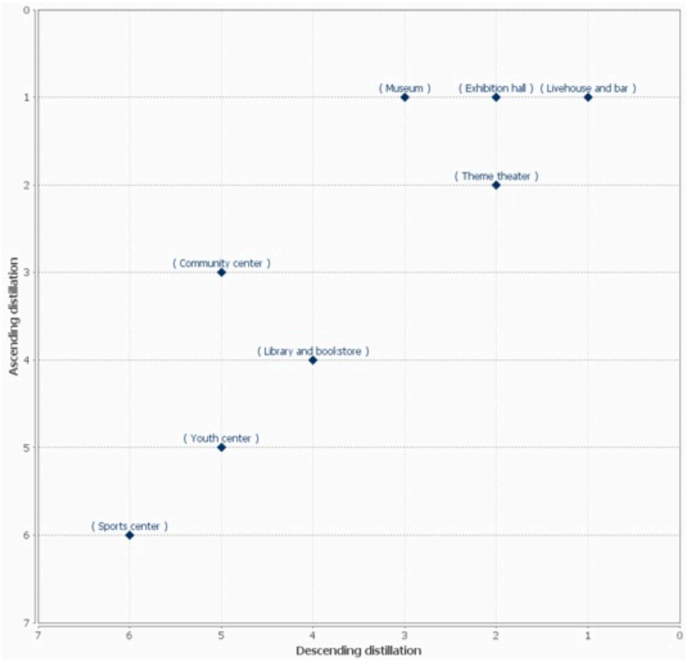


Figure 5.33 Distillation matrix of the final results

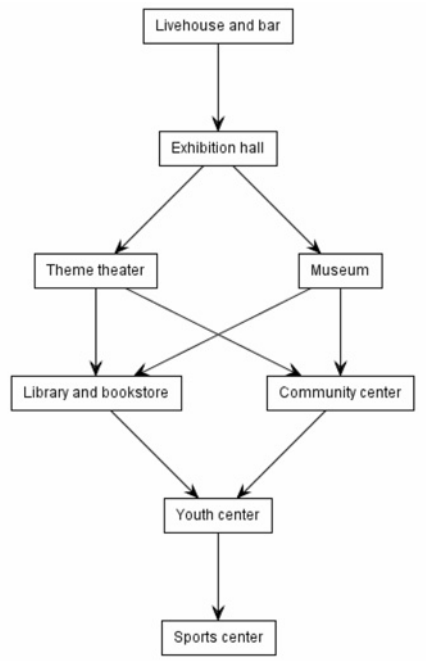


Figure 5.34 Final ranking of the function alternatives Grain depot

Table 5.14 Outranking of alternatives

	Exh	The	Mus	Lib	Com	Liv	Spo	You
Exh	I	P+	P+	P+	P+	P-	P+	P+
The	P-	I	R	P+	P+	P-	P+	P+
Mus	P-	R	I	P+	P+	P-	P+	P+
Lib	P-	P-	P-	I	R	P-	P+	P+
Com	P-	P-	P-	R	I	P-	P+	P+
Liv	P+	P+	P+	P+	P+	I	P+	P+
Spo	P-	P-	P-	P-	P-	P-	I	P-
You	P-	P-	P-	P-	P-	P-	P+	I

P+: outranks P-: outranked by R: incomparable I: indifferent

Table 5.15 Credibility index matrix

	Exh	The	Mus	Lib	Com	Liv	Spo	You
Exh	1	0.713	0.744	0.902	0.869	0.743	0.902	0.739
The	0.58	1	0.77	0.738	0.834	0.61	0.834	0.737
Mus	0.644	0.775	1	0.771	0.675	0.551	0.806	0.641
Lib	0.131	0.358	0.327	1	0.806	0.328	0.87	0.837

	Exh	The	Mus	Lib	Com	Liv	Spo	You
Com	0.133	0.391	0.327	0.65	1	0.201	0.87	0.743
Liv	0.645	0.84	0.678	0.867	0.834	1	0.967	0.769
Spo	0.196	0.423	0.392	0.454	0.675	0.266	1	0.61
You	0.263	0.523	0.457	0.394	0.648	0.298	0.84	1

5.6.3.2 Result analysis

Result analysis consists of scenario analysis and stability analysis. We first conduct a stability analysis to present the impacts of parameter variation on the results. As shown in the Table 5.16, we find the weight boundary of each criterion. As the stability of weight (k), there are some criteria with wide variable range that can have no influence on the existing result, such A2- Net growth number of new jobs, B3- Contribution to the development of local tourism, B4- Promotion to the local industry development, D1- Increase public awareness of cultural values. Oppositely, there are some criteria with narrow range of stability that decision-makers can pay attention to, such as B6- cost of the intervention, and C1- Energy consumption of life cycle.

Table 5.16 Stability analysis of Jingdezhen Grain depot project

Criteria	Measure scale	k	q^{β}	p^{β}
A1	ordinal	[10.1031, 16.3012]	-	-
A2	cardinal	[0.0000, 9.5989]	[0,8]	[5,10]
A3	ordinal	[4.3610, 10.6356]	-	-
B1	ordinal	[4.8031, 7.4593]	-	-
B2	ordinal	[3.0571, 7.4593]	-	-
B3	ordinal	[10.1031, 15.0167]	-	-
B4	ordinal	[10.1031, 15.0167]	-	-
B5	ordinal	[3.8001, 8.2309]	-	-
B6	cardinal	[0.0000, 1.2239]	[0,800]	[500,4000]
C1	ordinal	[1.5450, 4.5225]	-	-
C2	ordinal	[0.5071, 5.0929]	-	-
D1	ordinal	[6.9111, 18.5635]	-	-
E1	ordinal	[0.0000, 4.4077]	-	-
F1	ordinal	[0.3121, 4.2921]	-	-
F2	cardinal	[7.9593, 15.5685]	[0,2]	[1,4]

In order to cope with uncertainties in the project conditions and obtain parameters of the decision configuration, we also conduct scenario analysis. The uncertainties include the potential investors, the added-value of the service facility to the living quarters, the focus on cultural values or only comprehensive service, and preference on the degree of intervention. Therefore, we add parameters of four criteria into the configuration that stakeholders care about and may change later: weights of *B2- Attractiveness to potential investment*, *B5- Increase value in surrounding real estate market*, *D1- Increase public awareness of cultural values*, *F1- Degree of intervention and technical feasibility*. The minimum value of each criterion is 0.0 and the maximum value is 15.0, with 3 divisions of the interval that means the weights of each criterion in scenarios can be 0%, 5%, 10% or 15%. Weight of 0 means the stakeholders eliminate this criterion and 15% means they put it to the most important criterion since the biggest weight now is 12.7%. 256 different combinations are then generated including 204 final decisions after eliminating the same results with different combinations Figure 5.35). Taking the decision No.109 as an example, when weights of potential investors decrease to 0, and that of contribution to cultural values, value-added to real estate market and degree of intervention rise to 15, 10 and 15 respectively, the final ranking changes as *livehouse and bar* comes up to the first position with *exhibition hall*, while *museum* and *library and bookstore* comes to the second.

Ascending distillation
1 : [Exhibition hall, Museum, Livehouse and
2 : Library and bookstore
3 : [Community center, Youth center]
4 : Theme theater
5 : Sports center

Descending distillation
1 : [Exhibition hall, Livehouse and bar]
2 : Library and bookstore
3 : [Community center, Youth center]
4 : Museum
5 : [Theme theater, Sports center]

Final ranking
1 : [Exhibition hall, Livehouse and bar]
2 : [Museum, Library and bookstore]
3 : [Community center, Youth center]
4 : Theme theater
5 : Sports center

Median ranking
1 : [Exhibition hall, Livehouse and bar]
2 : Library and bookstore
3 : Museum
4 : [Community center, Youth center]
5 : Theme theater
6 : Sports center

Parameter k(B2)	Parameter k(B5)	Parameter k(D1)	Parameter k(F1)	Decision ID
15.0	15.0	0.0	15.0	D161
0.0	0.0	5.0	15.0	D162
5.0	0.0	5.0	15.0	D148
10.0	0.0	5.0	15.0	D163
15.0	0.0	5.0	15.0	D164
0.0	5.0	5.0	15.0	D165
5.0	5.0	5.0	15.0	D166
10.0	5.0	5.0	15.0	D167
15.0	5.0	5.0	15.0	D168
0.0	10.0	5.0	15.0	D169
5.0	10.0	5.0	15.0	D170
10.0	10.0	5.0	15.0	D171
15.0	10.0	5.0	15.0	D172
0.0	15.0	5.0	15.0	D173
5.0	15.0	5.0	15.0	D174
10.0	15.0	5.0	15.0	D175
15.0	15.0	5.0	15.0	D176
0.0	0.0	10.0	15.0	D177
5.0	0.0	10.0	15.0	D148
10.0	0.0	10.0	15.0	D178
15.0	0.0	10.0	15.0	D179
0.0	5.0	10.0	15.0	D165
5.0	5.0	10.0	15.0	D162
10.0	5.0	10.0	15.0	D180
15.0	5.0	10.0	15.0	D181
0.0	10.0	10.0	15.0	D182
5.0	10.0	10.0	15.0	D183
10.0	10.0	10.0	15.0	D184
15.0	10.0	10.0	15.0	D185
0.0	15.0	10.0	15.0	D186
5.0	15.0	10.0	15.0	D187
10.0	15.0	10.0	15.0	D188
15.0	15.0	10.0	15.0	D189
0.0	0.0	15.0	15.0	D190
5.0	0.0	15.0	15.0	D191
10.0	0.0	15.0	15.0	D192
15.0	0.0	15.0	15.0	D193
0.0	5.0	15.0	15.0	D194
5.0	5.0	15.0	15.0	D195
10.0	5.0	15.0	15.0	D196

Figure 5.35 Scenario analysis – 204 decisions of 256 combinations with weight variation of 4 criteria

The Figure 5.36 below shows the impacts that weights of *B2- Attractiveness to potential investment* and *B5- Increase value in surrounding real estate market* varies, have on the ranking of the alternative *museum*, with fixing weights of criteria D1 and F1 as 10% and 5% respectively. Museum would be second choice if more focus is put on the value added to the real estate market. Otherwise, mostly it ranks the third in the final rankings. It explains that this function has relative advantages on attractive to the real estate market. The Figure 5.37 presents the distribution of the first choice in the final rankings. With the variation weights of B2, B5, D1, and F1, the *exhibition hall* is the first choice for the most of the time, and the second potential choice can be *livehouse and bar for* 40% situations of all scenarios. Distribution of ranks of *community center* is shown in the Figure 5.38. The most possible rankings for this alternative are fourth and fifth, which occupies 60% of the decisions.

Both the stability analysis and scenario analysis would facilitate the developers or owners to better understand the final rankings and adapt their decisions according to the decision configuration analysis.

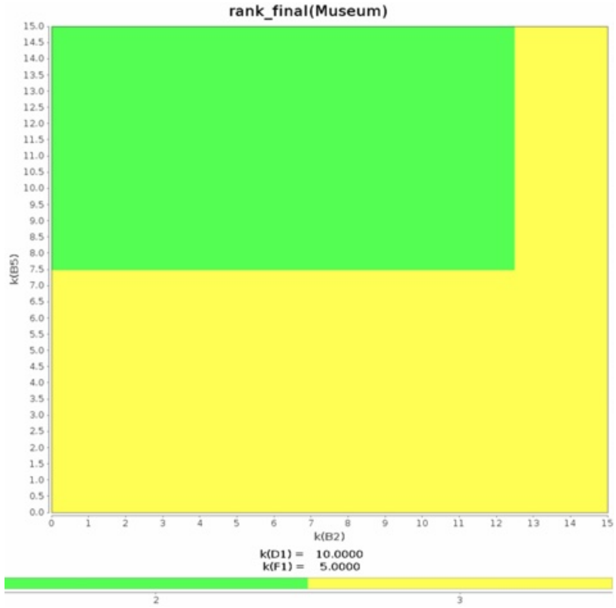


Figure 5.36 Scenario analysis of the final ranking of *museum* with weight variation of B2 and B5

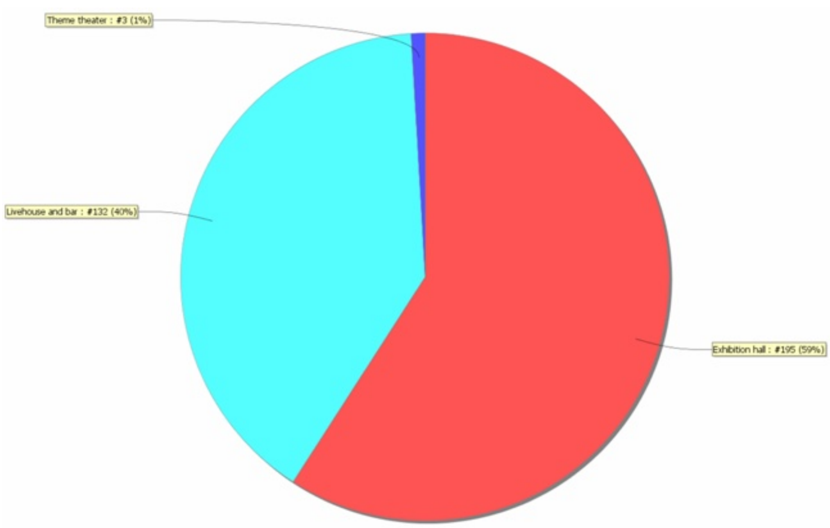


Figure 5.37 Scenario analysis of final ranking 1

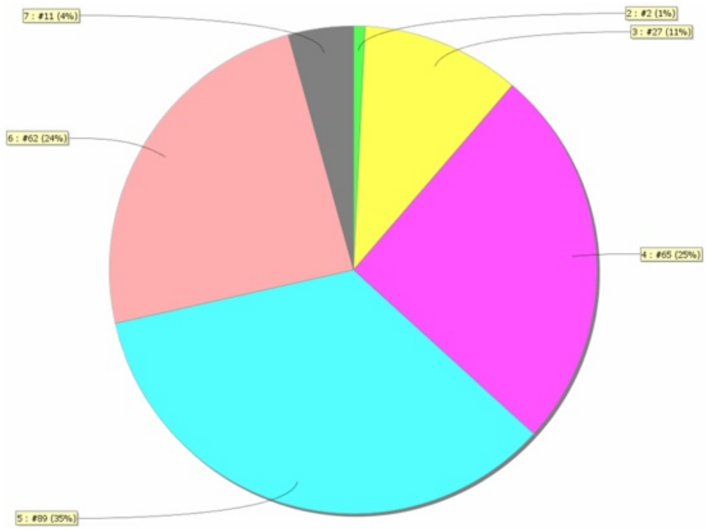


Figure 5.38 Scenario analysis of final ranking of *community center*

5.6.4 Drafting function program

The previous section identifies the most potential functions for the target existing buildings as *livehouse and bar* and *exhibition hall*. In the scenario analysis, *exhibition hall* even outranks the rest alternatives in more circumstances. Considering the variety and the total floor area of the existing factories, the programming team suggests functions of exhibition hall, livehouse, canteens and bar as mixed uses to create a **communication and cultural center** on site, which was agreed with the client in practice.

The next step is to develop the function programs. As mentioned in section 5.5.3, there are several approaches to develop the function program including cases study and literature review, experience of architects, interviews with future users and so on. In this case, the programming team analyzes the traditional function program of performance spaces especially the livehouse and black-box theater, and the combination with other functions such as exhibition, meetings, etc. Through case study and discussion, the programming team proposed an idea of flexibility of performance, exhibition and conference. It has three advantages: first, it matches the features of the factory's open space; second, it can accommodate various kinds of activities for multiple functions; Last, due to the second advantages, it is beneficial to the rental in the future.

The draft of function program is as Table 5.17 shows. Based on the draft function program, the programming team needs to evaluate the suitability between the possible function list with the existing spaces, and then adjust or optimize the function program to provide the final design proposal, which will be introduced in the Chapter 6.

Table 5.17 Drat function program of Jingdezhen grain depot renovation

No.		Function	Floor area	Notes
1		Stage of livehouse	540	
	1.1	Main stage 1	300	
	1.2	Technical room	80	2*40
	1.3	Property room	80	
	1.4	dimmer room	40	
	1.5	booth	40	2*20
2		Audience of livehouse	800	
	2.1	Spectator seat/house	550	
	2.2	Lobby	150	
	2.3	Ticket office	50	
	2.4	Cloak room	50	
3		Backstage of livehouse	700	
	3.1	Dressing room	100	2*50
	3.2	Clothing room	100	
	3.3	Green room	100	5*20
	3.4	Rehearsal room	200	2*50, 100
	3.5	Storage areas	200	2*100
4		Cultural	1650	
	4.1	Exhibition	500	
	4.2	Multi-media room	400	
	4.3	Classroom	150	50, 100
	4.4	Meeting room	600	2*50, 2*100, 300
5		Commercial	600	
	5.1	Café	100	
	5.2	Shops	50	
	5.3	Bar	100	
	5.4	Canteen	200	
	5.5	Kitchen	150	
6		Auxiliary	600	
	6.1	office	350	4*20,3*60,90
	6.2	rest rooms	100	2*50
	6.3	maintenance room	150	
7		Flow and other area	2400	

No.	Function	Floor area	Notes
	Total	7290	

5.7 Conclusion

This chapter proposes a framework to identify suitable reuse functions and rank all the alternatives to support decision makers based on multiple criteria decision analysis (MCDA) theory. This step is a supplement to the program conception after collecting renovation information, which is aimed at function transformation renovation projects.

The conclusions in this chapter are as below:

1) **Identify the definition and content of function identification architectural programming of function transformation projects**. It first analyzes the situation of function transformation renovation projects, and defines the contents of function identification, compared with similar concepts of Highest and Best Use and Most Probable Use. It then positions function identification between function orientation in urban planning and detailed function program in the next step. At last, it analyzes three characteristics of this decision-making problems, which are driven by multiple goals, participated by multiple stakeholders, and led by diverse values, for later proposing the solutions.

2) **Propose a multi-criteria decision-making process of function identification with multi-criteria and multi-stakeholder participation**. Based on the general framework of MCDA, the chapter adapt it to support the decision on new functions of the renovation buildings with three steps of structuring the decision situation, structuring the MCDA model, and evaluating the function alternatives.

3) **Provide operation guides for decision-making on new functions of existing buildings**. This chapter researches on operation guides for each step of the decision-making process. For structuring the decision situation, it analyzes goals, stakeholders, benefits, and uncertainties; for structuring the MCDA model, it provides principles for identifying function alternatives, and then provides a criteria index of function identification from social, economic, environmental, cultural, aesthetic and technical dimensions, as well as weight setting tools for criteria; for evaluating the function alternatives, the study selects ELECTRE III tools among MCDA methods due to three main advantages to facilitate ranking function alternatives. The final ranking result is analyzed by scenario analysis and stability analysis.

The framework and method have been verified on a case study that requires making reuse decision among several alternatives under multiple criteria. The structured multi-criteria decision-making process and method in this chapter can facilitate a transparent and rational decision-making for identifying the new function. Based on the identified function program developed in this chapter, the next chapter will introduce the suitability evaluation of it in order to test the feasibility, to adjust and modify the function program for the final design proposal.

CHAPTER 6 Suitability evaluation of function and space

After a comprehensive cognition of the existing building and identification of the functional requirements and usage patterns of the renovation, it is also necessary to analyze the suitability between the existing space and the potential functions before proposing the renovation brief. Otherwise, the new functions in the renovation proposal cannot be placed in the existing space, resulting in the architects being unable to meet the requirements of the function proposal when designing the plan and thus the function proposal and preliminary design would be repeatedly revised. Therefore, assessing the suitability of new functions and existing space in advance is an important part of renovation programming, and an important step that distinguishes renovation programming from new construction programming.

This chapter will analyze the definition and contents in terms of the suitability evaluation as a supplement in program evaluation in classic architectural programming process, and propose enhancing solutions based on the spatial analysis method in architectural programming theory to meet the demand for spatial function evaluation of existing building renovation programming.

This chapter answers the following three questions:

1) What is suitability evaluation of function and space?

2) What are the process and methods of suitability evaluation of function and space?

3) How does this evaluation process and method apply in the practical projects?

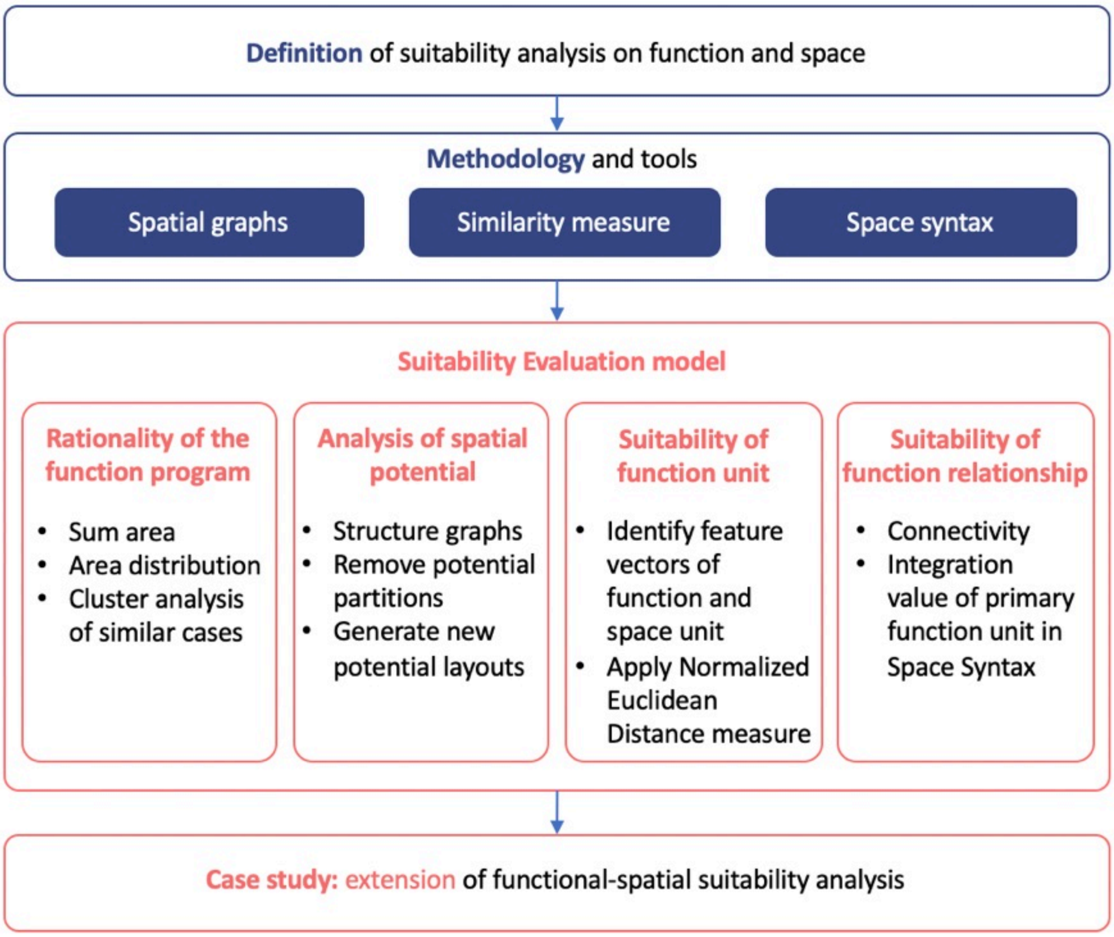


Figure 6.1 Framework of Chapter 6

6.1 Program evaluation in architectural programming

6.1.1 Program evaluation in traditional architectural programming

Program evaluation (策划评价), or Pre-evaluation (预评价) in architectural programming is evaluation of the results or products of the program, in order to assess the degree of excellence, or test the feasibility of the architectural program and adjust and modify the draft report(梁思思, 2006 [24];Peña, 2012 [256]). It can be a relatively independent step beside the traditional steps mentioned in section 3.1 to give feedback to each step in the programming process including information collection and conception of spaces and technologies, or can be one successive step after generating the program or concepting the program scheme (策划构想) before publishing the final design proposal, to offer feedbacks on the draft program (Duerk, 1993 ;屈张, 2019).

As for the contents of program evaluation or pre-evaluation, researchers have proposed different aspects for reference. Peña(2012 [257]) structures the same evaluation framework as that of programming from four aspects of function, form, economy and time. Kumlin(1995) provides a checklist of programming errors from three categories of general errors, documentation errors and cost errors. Liang(2006 [32]) assesses the program from the perspectives of users, building performance and equipment, and further classify 8 sub-categories for the pre-evaluation (Figure 6.2). Among them, functional requirement, spatial scale, form and organization are the contents related closely to the function program. Besides, another research focusing on the evaluation of the design proposal. Liu(2017) proposes a framework for design brief based on methods of systematic evaluation and risk assessment and text data mining techniques, evaluating design briefs from three aspects of spatial area list, text and images. The spatial area list, or function area list is the main part of function program and is assessed by sum area and area proportion checking.

For the approach of conducting pre-evaluation, some researchers propose assessment framework or checklist. Duerk(1993) suggests the participation of clients, architects, experts and project managers in the program evaluation process, and provides two kinds of working modes to assess the programming during each step, which are over-the-shoulder evaluation and client review meeting. Qu(2015) further develops the checklist into new projects of historic districts. Others provides applicable tools or techniques for programmers to conduct evaluation. Qu(2019) classified the trending researches on methods of pre-evaluation in architectural programming into 3 categories of two-dimension, three-dimension and four-dimension. The two-dimension methods give scores to different weighted aspects of the program, such as quality quotient graph proposed by Peña (Figure 6.3). The three-dimension methods applies computer-aided drawing techniques. Clayton (1998) develops the semantic modelling extension to interpret the architectural drawing language into semantic language understandable to computers. Huang (2015)applies space syntax techniques to pre-evaluate multiple programmatic schemes. This process can facilitate decision-making by assessing different concept design schemes or programs quantitatively (Figure 6.4). Researchers also attempt to apply builidng informaiton modeling (BIM) to manage the programming data in the life cycle adding the fourth dimension of time, but the database establishment is a prominent problem at present.

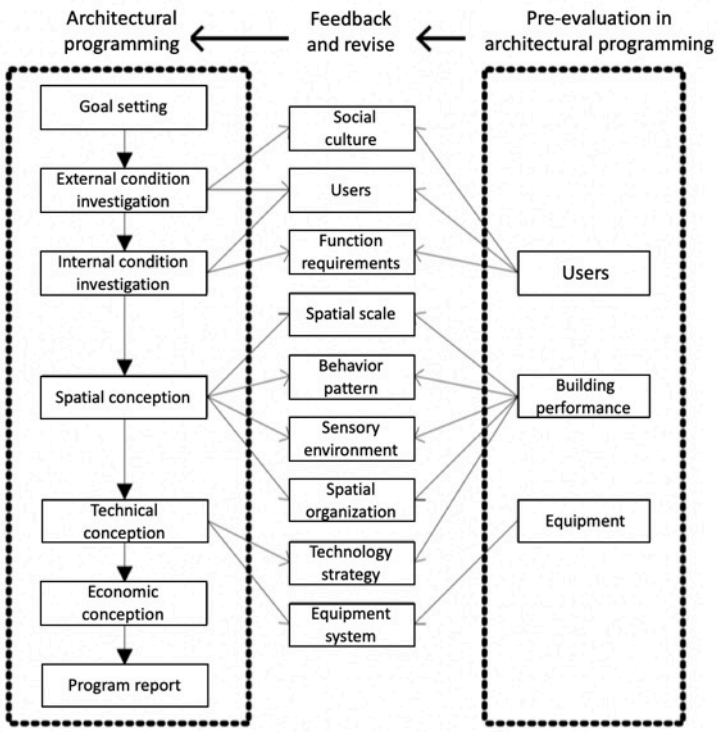


Figure 6.2 Contents of feedback in pre-evaluation step of architectural programming, translated from (梁思思, 2006 [33])

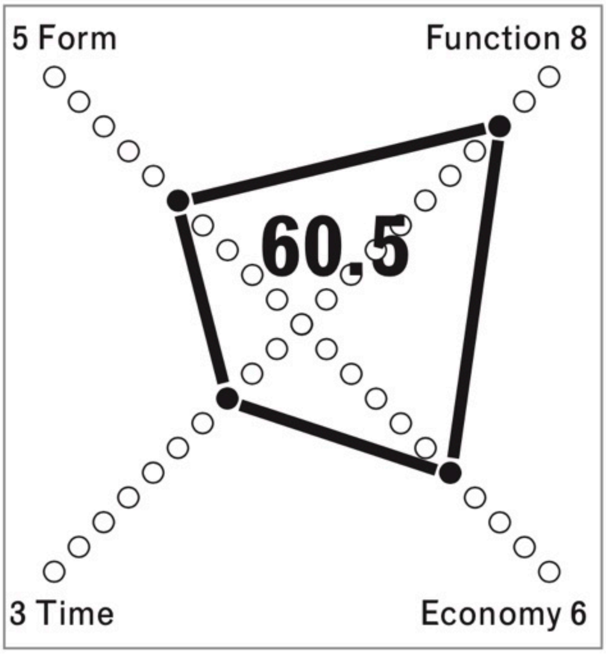


Figure 6.3 Graphic Analysis of Quality Quotient (Peña, 2012 [257])

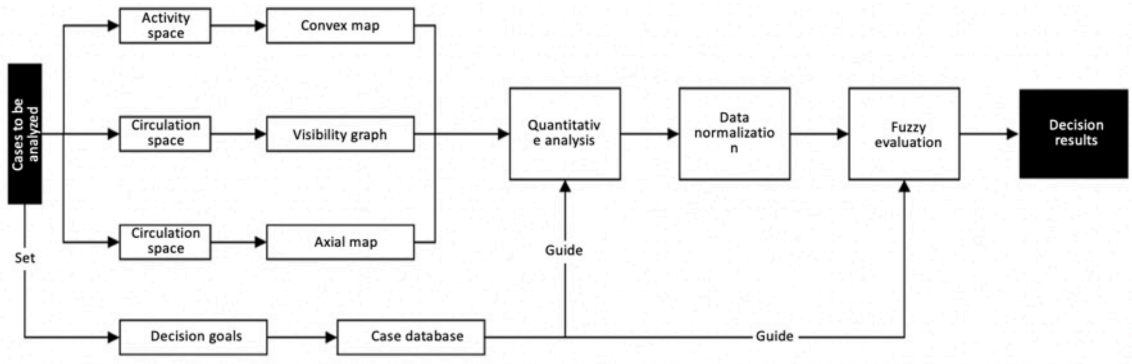


Figure 6.4 Working process of introducing space syntax into pre-evaluation of architectural programming, translated by author from (黄海阳, 2015 [7])

6.1.2 Requirement of program evaluation in architectural programming of renovation projects

The existing researches on program evaluation above are aimed at universal construction projects. Therefore, the question for this chapter is to identify pre-evaluation process for renovation project. And since this research focuses on function program in architectural programming of renovation projects, the study on program evaluation or pre-evaluation in architectural programming will also mainly discuss the assessment of function program. This section first discusses the limitations of existing researches and requirements of the program evaluation in architectural programming of renovation projects.

The existing researches of pre-evaluation focus on the program results or schemes under the project initiation conditions without the limitations of existing building. In contrast, all the program and design in renovation projects should be based on the existing building and spaces, which means the generated program should be feasible for the existing building. Therefore, programmers should not only test the feasibility of the program itself based on professional experience and case study, but also verify the suitability of the function program and existing spaces. The contents of suitability include capacity, size, spatial organization, technical conditions, and so on, which will be introduced in detail in the next section. The Evaluation of the suitability with existing building and spaces facilitates the adjustment of the function program and prevents architects from being hindered in later design process. Besides, researches for evaluating renovation concept design in the pre-design phase mainly compare the improvement of the renovation strategy to the existing spaces, but don't assess directly the feasibility and rationality of the function program.

Considering the theme of the thesis is the functional renovation, this chapter will focus on the pre-evaluation of the function program drafted in the last chapter, and analyse the suitability of the program with existing spaces. From the perspective of the whole process of the architectural programming, the suitability evaluation is an important part that should be supplemented to the program evaluation, as the step before generating the final design proposal.

6.2 Definition of suitability evaluation of function and space

This section is intended to identify the definition of suitability evaluation of function program and existing spaces before structuring the process and method in the next section. It first introduces the abstract forms to represent function program and building spaces, then clarifies the contents and purposes of the suitability evaluation.

6.2.1 Graph of spatial topology and functional program

Graphs, in the graph theory in mathematics, indicates a set of objects and the relationships among them. A graph is composed of two basic elements – a set of points and lines that connect them, which are called also called vertices and edges respectively in mathematical terms(Ore, 1963). The vertices can be in a diagrammatical form of circles or dots, and the edges can be lines or curves to join those points. As shown in the Figure 6.5, the letters and numbers all represents vertices connected by lines or curves, which are the simple forms of graph diagrams. Graphs are applied broadly as a data structure in various field such as social network or organizations analysis, chemistry, machine learning, etc (Rouvray, 1971 ;Boissevain, 1979). For example, in social networks, the nodes representing the units which could be a user, an individual or an entity, while the edges represents the relationships between those individuals (Akhtar and Ahamad, 2021).

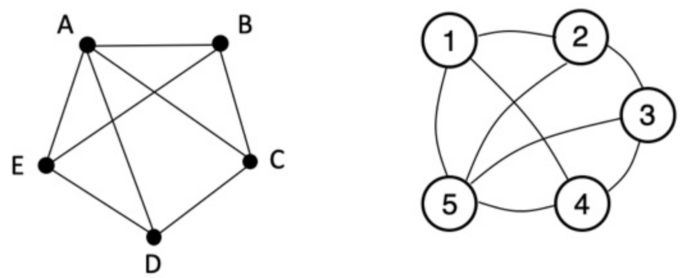


Figure 6.5 Graph diagrams

Scholars in the **field of architecture** has engaged the graph theory to analyze space design in interior and urban scale since early 1970s (Steadman, 1973 ;Dawes and Ostwald, 2013). Nowadays, graph is a common tool to present abstractly the functional program (Koutamanis, 2013) and the space. Space is the substantial entity of the architecture, and the physical carrier of all the function. Each space, or room in a building, can be considered as a unit, and the whole the building is composed of a collection of different units. There are many characteristics to define a space including width, length, height, materials, positions, etc. But the essence of spaces in the building is the location and connectivity relation of the collection of spaces units, which could be presented in the form of topology. In the field of architecture design, **bubble diagram**, an extension of graphs, has been a common tool for architects worldwide in the concept design (Figure 6.6). It is made up of a group of bubbles or boxes that represent different rooms and functions, with lines linking those units to express the connectivity between them ((Merrell et al., 2010)). The **graph can** show the floor plan in an abstract diagram, as well as the arrangement of functional rooms through the lens of topology, so that architects could focus on the essence of the arrangements without more considerations on detailed requirements of each room. At the same time, the bubble or box can be tagged different labels and colors to represent different rooms, and the size of the scope can indicate the relative size of the floor area of the room or space. And there are more types of lines such as dashes, dotted lines that express the adjacency or accessibility of each pair of rooms. In conclusion, no matter in which field, graph is always an effective tool to abstractly express individuals and their relationships.

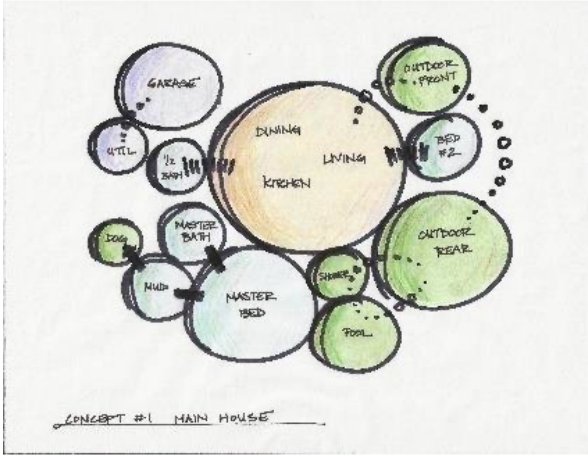


Figure 6.6 Typical Bubble Diagram (Tiwari, 2018)

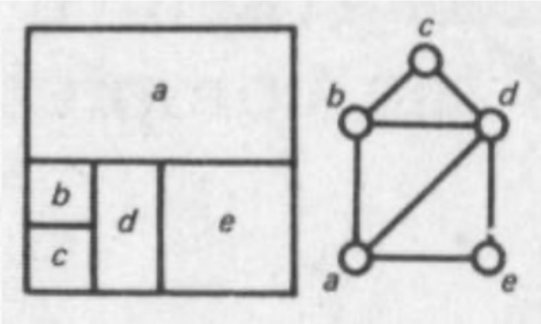


Figure 6.7 A plan and its corresponding adjacency graph (Steadman, 1973)

Corresponding to the abstract functional relationships, spatial topology is a substantial relationship existing in physical space, specifying the position of objects with reference to other objects. Architects applies topology diagrams in the design process to compare different room positions or room arrangement (Figure 6.7). The physical space is a container of abstract function. Therefore, as for a building with a collection of spaces, the functional relationships should have the same rules or patterns as that of spatial relations.

6.2.2 Matrix of functional relationships

Apart from the graph to represent abstractly the spatial topology and functional program, matrix is another common tool to show the functional relationships or function adjacency in architectural programming. Function is always one of the kernel considerations of architectural design and building projects, corresponding to utility or commodity in the three basic elements of building(Pollio and Morgan, 1960). Function relationship is a significant concept in architectural programming theory **intended for** analyzing the user needs, identifying the functional program and generating the design proposal. **Basically**, **it** draws a whole picture of all kinds of function required by clients, and represents the adjacency relationship among all of them. In **traditional architectural programming theory**, analyzing the functional relationship is intended to better identify the different user flows, the adjacency of different using requirements, the degree of communication between various user groups, etc (William M. Peña, 2012). As seen in the Figure 6.8, this **adjacency charts** are one of the simplest forms to show functional relationships in the format of table, to record one single function and its relationships with the rest of the functions, such as critical, desirable, accessible, and with no accessibility in the first row.

	Critical	Desirable	Accessible	None
A				
B	×			
C				×
D		×		
E				×
F			×	

Figure 6.8 Adjacency chart (Peña, 2012)

In traditional architectural programming theory, there is a one-way deduction from functional relationships to spatial relations, since the user requirements and function arrangement experience result in function program and functional relations, which then generate the possible space arrangements schemes and examines the design proposal. However, in reuse projects, there is an existing collection of space units and a corresponding spatial arrangement, which will impose impacts on the potential function program to a certain degree.

As mentioned in the 6.1.1, matrix is an important tool in architectural programming to analyze functional relationship, in order to identify function proximity required by different users and organize them in an optimal order(William M. Peña, 2012 [208-209]). The most used method is interaction matrix (Figure 6.9). In the interaction matrix of function adjacency analysis, programmers could define several types of proximity such as being adjacent, being on the same floor, being in the same building, etc. This method in architectural programming is often used in triangular forms.

There are several kinds of matrices that could manifest the functional relationship and further record users' opinions and expectations of using the facility. Figure 6.9 is such a simple **function matrix**, consisting of a function list column and a triangular matrix, are used to manifest different relationships between each of the two functions. The size of the dots indicates the type of adjacency: biggest one means adjacent rooms, middle one means rooms on the same floor, while the small dot means two rooms in the same building.

When the building has many different kinds of functions, such a large triangular matrix can clearly show the general view of function program. Figure 6.10 is the function adjacency matrix of Tsinghua Technology Park, drawn by the programmers in the pre-design phase. uses different kinds of pattern to represent the adjacency types, full grid meaning close connection, half-full grid vicinity, dot in the grid independency, blank grid loose connection. Applying the tools for analysis, programmers and clients can have a clear understanding of user requirements and the professional architectural experience of functional adjacency.

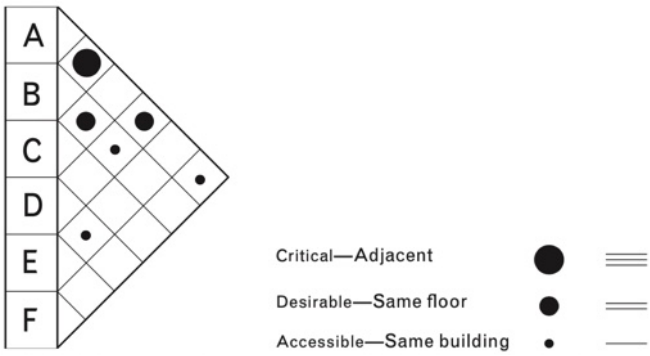


Figure 6.9 Example of interaction matrix and proximity definition (William M. Peña, 2012 [209])

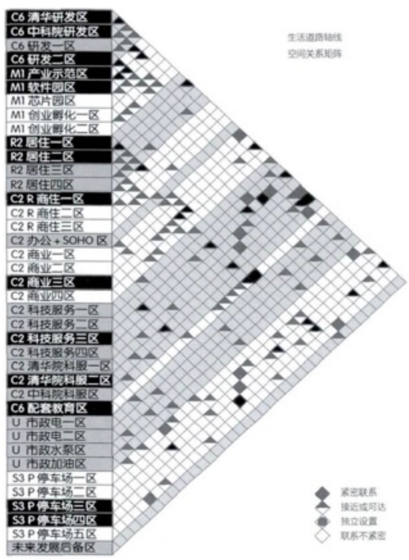


Figure 6.10 Function relationship matrix of Tsinghua Technology Park programming (Zhuang, 2016)

Another method to represent the relationship of functions is number, which could establish an algebraic matrix for calculation and research afterwards. This kind of matrices is in the form of rectangular. The values of numbers could show the strength of different functions or activities by pairs. The total score of one object can show the significance of one activity with the others(Koutamanis, 2013).

	A	*B*	*C*	*D*	*E*	*Total*
A		9	9	1	3	22
B	9		9	1	3	22
C	9	9		3	3	24
D	1	1	3		9	14
E	3	3	3	9		18

	A	*B*	*C*	*D*	*E*	*Total*
A		*9*	*9*	*1*	*3*	*22*
B			*9*	*1*	*3*	*22*
C				*3*	*3*	*24*
D					*9*	*14*
E						*18*

Figure 6.11 A relationship matrix for five activities (Koutamanis, 2013 [158])

6.2.3 Suitability evaluation for space-function relationships

Suitability evaluation, or suitability evaluation, is often used in the field of habitat research, land use and site selection, most common in GIS contexts (Dobson, 1979 ;Malczewski, 2006). Although it is usually seen in larger scale researches, the aim is still to propose the most suitable spatial pattern that satisfy some specific requirements (Collins et al., 2001).

Evaluating suitability is one of three components to the programming of a building renovation according to Kumlin (1995), in order to accommodate the existing building with programming, in terms of total area, structural load capacity, layout, code compliance, vertical traffic, interior clear height, entrances, etc.

In practice, suitability evaluation is always a necessary step in the pre-design or design phase, while being achieved mainly by repeatedly attempts in drawing drafts by architects based on accumulated practical experience[24]. The renovation of the Hinman Research Building at Georgia Tech required the owner to expand the use area by 560 square meters while preserving the character of the historic building. The programming team conducted a series of suitability studies, using a matrix to study the correspondence between the original function of the existing space and the user's demand, and finally clarified that only the existing building features truss structure can be used to support the

[24] Refer to the interviews with Architect Gustavo Ambrosini

building mezzanine, and the maximum increase of 150 square meters of usable area, so as to reach an agreement with the owner and reach a balance between the architectural value and the demand for use (Pyburn, 2017).

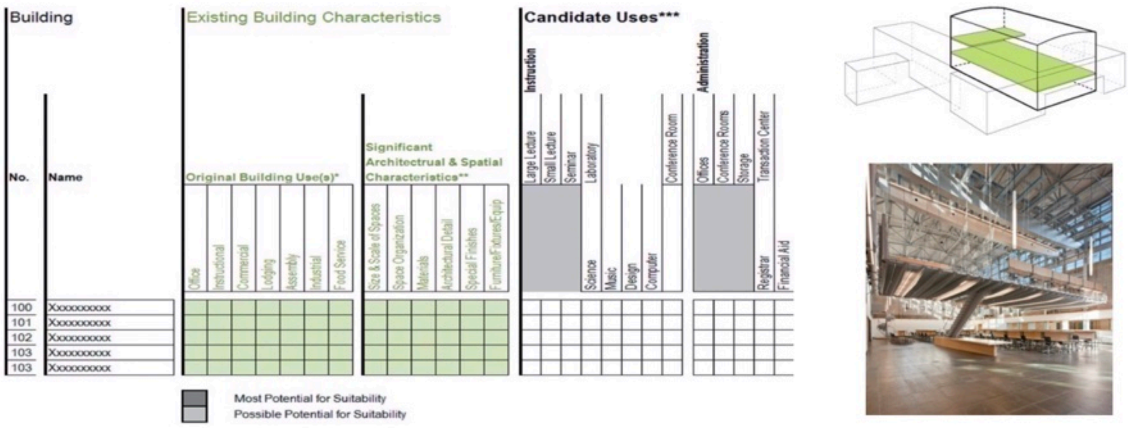


Figure 6.12 Renovation feasibility study of Hinman research building (Pyburn, 2017)

Besides, the new functional program probably to result in demolition and new additions in parts of the existing space (Figure 6.13). Suitability evaluation should also consider the structural modification of plan layout in order to make a balance between all of the limitations.

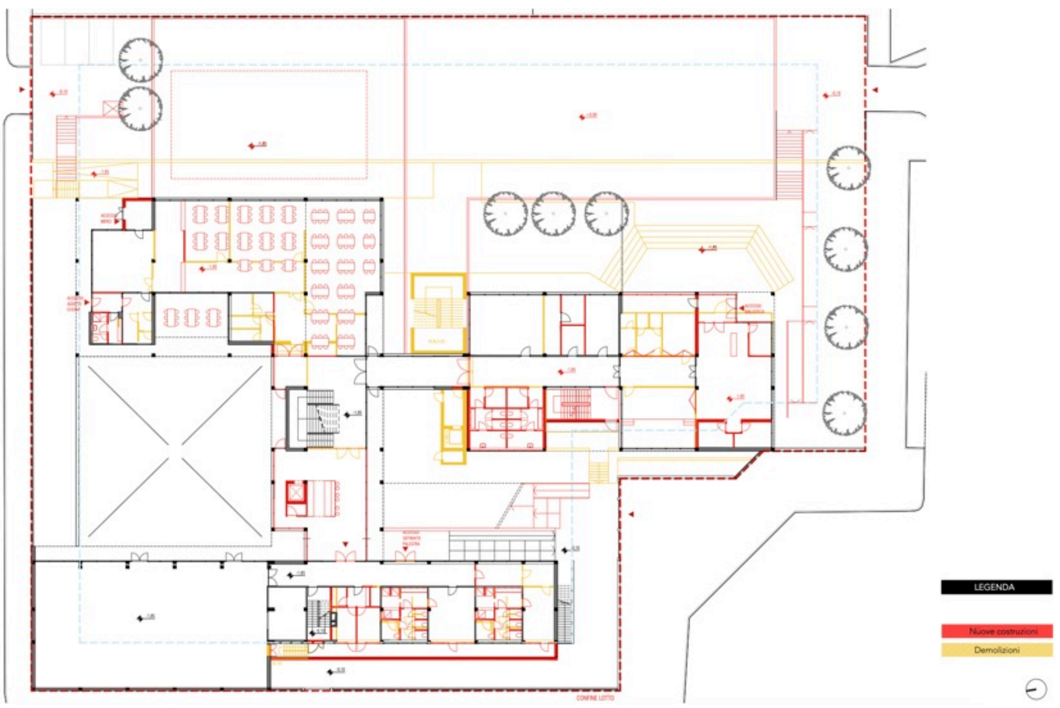


Figure 6.13 Suitable functional program in proposal of Enrico Fermi School © MoDus

Therefore, the suitability evaluation is an evaluation tool for the architectural programming and design afterwards. It is necessary for proposing the functional program in renovation brief, and it should also be conducted for the schematic design. In this chapter, we only focus on suitability evaluation in the pre-design phase, which means to verify the effectively of proposed functional program for the existing buildings.

Before conducting the functional spatial suitability evaluation, it is first necessary to clarify the known constraints. In Chapter 4, we have cognized the spatial characteristics and spatial relationships of existing buildings; in Chapter 5, the identification of new functions is explored, while a preliminary functional concept can be obtained based on traditional building programming theory. These are the two given conditions. Besides, the function program generated should be evaluated first for the rationality of the program itself, including the sum area check and the proportion of floor area distribution (刘佳凝, 2017).

For the relationship between function and space, two main conditions should be satisfied: 1) the **features of a single room** could meet the **requirement of one of the new functions**; 2) the **proximity requirements** between functions satisfy the arrangement **relationship of the existing spaces**. The first condition is from the perspective of units and thus a space unit could contain a function use at each time. The second condition is from an overall perspective of relationships and have a close connection with the user flow in the operation. The combination of these two conditions together contribute to the assessment framework of suitability evaluation for space and function relationships.

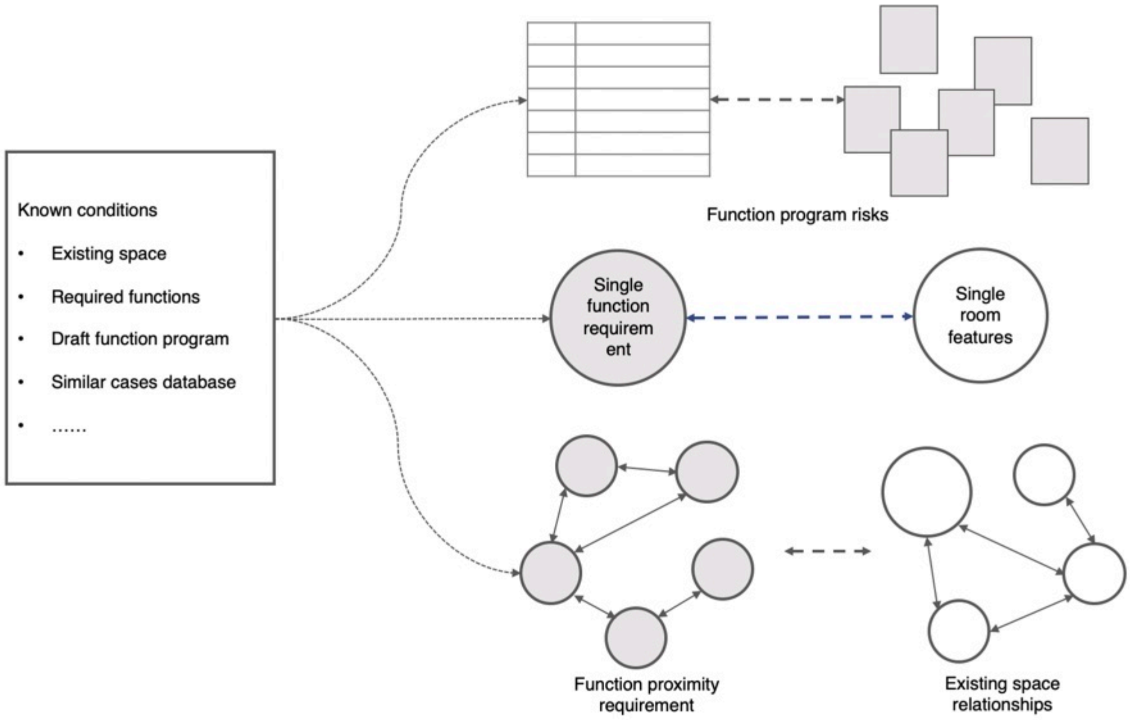


Figure 6.14 Contents of suitability evaluation in the program evaluation step

The purpose of evaluating suitability between the function program and existing spaces is to uncover problems of the draft version of function programs, and then warn the potential risks for adjustment and improvement of the function program, which will facilitate the rationality of the design proposal and avoid wasting resources. The following are the goals in this evaluation process.

1) *Rationality of the function program*: a. the sum of all functional sectors can be accommodated by the existing building, otherwise programmers should indicate the potential of expansion or demolition and warn the risks; b. the distribution of the floor area into each functional sector should be rational according to not only the user requirements, but also the previous experience or cases in order to obtain optimal plan efficiency and using performance.

2) *Feasibility of primary function*: the function unit comparison focuses on the satisfaction of the primary function of the renovation building, which includes the requirement of necessary space and certain area proportion, and the technical conditions.

3) *Feasibility of the function relationships*: a. the connectivity and adjacency of the primary function should be feasible in the existing spaces; b. the main flow in the building should be positioned if it is important and difficult to be modified, and programmers can

compare different spatial organization strategy.

6.2.4 Similarity measure

As mentioned in section 6.1.2, the **suitability evaluation** of the function program and space is based on two main aspects: 1) the features of a single room could meet the requirement of one of the new functions; 2) the proximity requirements between functions satisfy the arrangement relationship of the existing spaces. Therefore, it should discuss the method respectively for evaluating the suitability from these two perspectives. Because the function relationship and the space distribution both can be abstracted to topologic graphs, to evaluate suitability, is actually, to measure the similarity of nodes and edges in abstract graphs.

Similarity Measure, also called similarity function or similarity metric, is a function to evaluate quantitatively the similarity of two objects. It is broadly applied in data science to cope with many kinds of problems, such as classification tasks, clustering, filtering recommendation, scoring systems, pattern recognition and so on (Jarvis and Patrick, 1973 ;Lin et al., 2013 ;Bisandu et al., 2019). The most common principle in similarity measurement is to measure the distance between samples, while it is significant to choose the propriate methods for measuring distance because of the strong influence on the final results. Widely-used methods include Euclidean distance, Manhattan or taxicab distance, Cosine distance similarity, Pearson Correlation Coefficient, Jaccard Similarity and so on(Qian et al., 2004 ;Borg and Groenen, 2005). As for the field of architecture and urban planning, spatial similarity measure is a significant issue in map theory and Geographic Information System (GIS). Similarity search is also an important function in ArcGIS. This research will not introduce and compare these methods in detail, but choose the relatively better option based on the features of the problem we cope with.

Each function and each space have many characteristics, so it should first save these data appropriately, and then employ a function to comprehensively evaluate the similarity of these data sets. The single space with a group of characteristics or a single function with a set of requirements can be considered as a **feature vector**. A feature vector is a vector representing an object with many features, which is a significant concept in data science and machine learning (Lim et al., 2001 ;Baudat and Anouar, 2003). It could be presented in the form of linear algebra, or a vector in a 3D space called feature space (Figure 6.15). Each characteristic is a dimension of the vector, and the length and direction of the vector represents the comprehensive characteristics of an object. Therefore, any function unit and space unit can be abstracted into a feature vector with multiple dimensions of characteristics representing the area, length, width, height, and so on, in order for further comparison and evaluation.

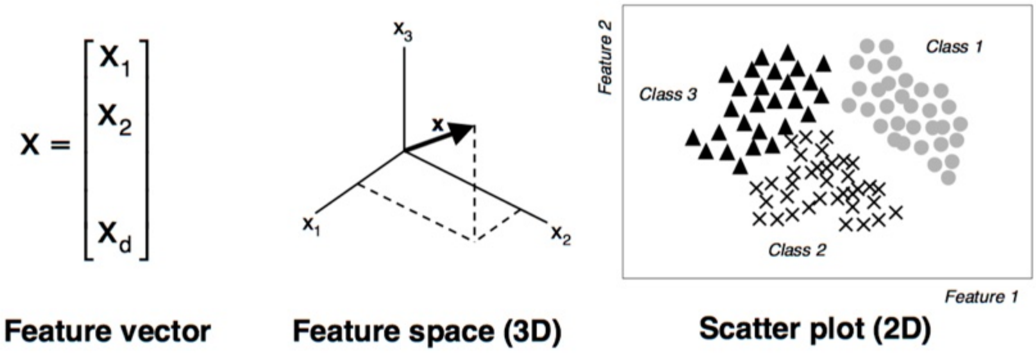


Figure 6.15 Forms of Feature Vector. Retrieved from Gutierrez-Osuna R. Introduction to Pattern Analysis (https://people.engr.tamu.edu/rgutier/lectures/iss/iss_l9.pdf)

In the following text, we introduce two classical similarity measures of cosine distance similarity and normalized Euclidean distance measure to deal with suitability evaluation involving function requirements and existing spaces.

1) Cosine similarity measure

Cosine similarity is the cosine value of the angle between two vectors in the space, which is not influenced by the magnitudes of the dimensions. The bigger the number is, the smaller the angle is, and the similar two feature vectors are. For example, the cosines similarity value of two vectors with the same direction is 1, while two totally opposite vectors have the cosine similarity value of -1. It is mainly applied in text comparison, natural language process, recommender system, ect(Qian et al., 2004 ;Li and Han, 2013).

A single room or space has many characteristics that should be considered by architects, such as dimensions of length, width and height, floor area, original function, structure, accessibility, etc. Correspondingly, a new function unit also has many features, such as dimension proportions, required height, estimated floor area, other function, structural or equipment requirements. Here are features considered in positioning a new function into a vacant space.

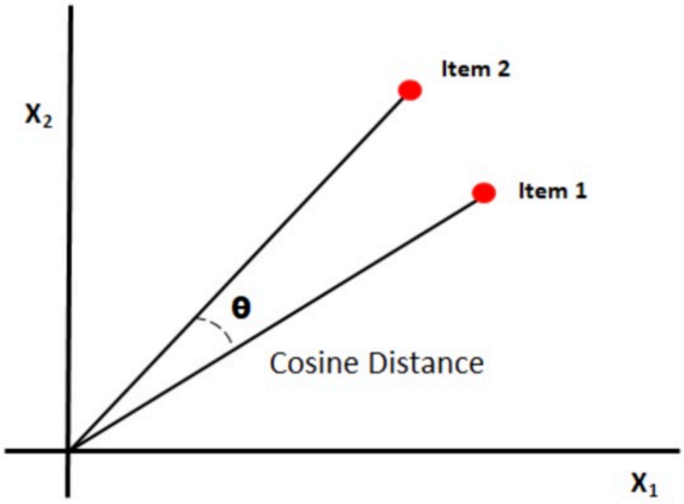


Figure 6.16 Cosine similarity between two vectors

$$sim\,(A,B) = \cos(\theta) = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2}\sqrt{\sum_{i=1}^{n} B_i^2}} \tag{6.1}$$

2) Normalized Euclidean Distance

Cosine similarity focus on the relative comparison of the feature vector from the perspectives of direction and proportion, but it cannot show the absolute difference of the objects. When evaluating of the similarity between function and space unit, it is important to search for that space that is most similar to the absolute area and size of the required function, rather than the proportion of the length and width. Therefore, we introduce the Normalized Euclidean Distance as most common approach to measure the absolute distance between features of function units and space units.

The Euclidean distance is the length of a line linking two points in Euclidean space, which can be applied to from one-dimension space to high-dimension space. In two-dimensional space, the length of the line linking points p and q is calculated through Pythagorean theorem (Figure 6.17). Equation 6.2 shows the deduction in n-dimensional space.

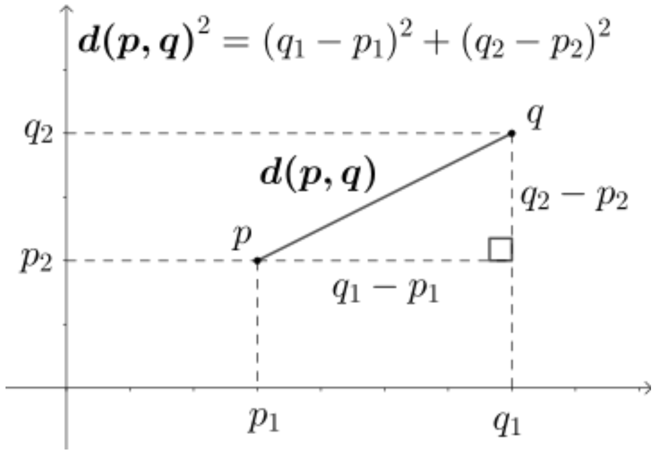


Figure 6.17 Euclidean distance in the two-dimension coordinate

$$D(p,q) = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2} \tag{6.2}$$

Section 6.3 further introduces the application of these two similarity measures in the suitability evaluation problems and section 6.4 provides two cases as examples to implement the process and approaches.

6.3 Suitability evaluation model establishing

This section introduces the framework and methods of the program evaluation in the architectural programing of renovation projects after obtaining a potential function program. Based on the previous work of our research group in the field of architectural programming and post-occupancy evaluation, the research will improve the process and methods of the pre-evaluation for renovation projects, which include mainly three steps. The first step is to add all the floor area up to check with the total area of the existing building and compare the area proportion with case study, in order to see if the existing capacity can hold the new function program, or if the existing building should be expanded with additional parts. The second step is to evaluate the suitability of the primary function unit and the spatial counterpart with cosine similarity measure. Before the matching work, we should first provide some flexible lay-outs to be evaluated, with the demolition of walls and partitions. The total unit score is added up from each weighted unit score. The third step is to evaluate the relationship similarity of functions and spaces. In this part, we will apply connection and integration index in space syntax to evaluate the function adjacency of the most significant function or area. The programming team will give the suggestions and warn the risks for refining the function program in the end.

6.3.1 Rationality of the function program

The first thing to check is whether the total floor area of the existing building can accommodate that of the function program. The first reason for this is that the function program is usually established from bottom to top including multiple levels and sub-levels which are composed of each function unit, and the area of each unit may be modified several times, resulting in some discrepancies between the total floor areas. The second is that renovation can be achieved by expansion, addition, and partially demolition, which may change the total area of the existing building. To calculate the difference value can help programmers evaluate the potential for expansion or demolition as well.

In the evaluation of design proposal for new construction projects, programmers can compare the total floor area of the function program with the area in planning permit for urban construction, and the early waning line for the discrepancy is 3% (刘佳凝, 2017 [126]). As for renovation projects, if there is already the planning permit for urban construction and the target building occupies all the area, programmers can still apply this approach to check the feasibility of the function program. If the architectural programming is conducted earlier than acquirement of planning permit for urban construction, or if the target buildings are only part of the whole site, which means there is no definite preference for the total floor area, then this evaluation should refer to the floor area of the existing building and indicate the potential for expansion, demolition or adjust the function program.

The Figure 6.18 below shows the coding for checking the total floor area[25]. Programmers should first input the total area of the target existing buildings, than input the drafted function program table composed of different levels or groups such as a1, a2, ……an, and the sub-level of function unit such as a11, a12……, a1i for the a1 level. The software then calculates the total area of each level and the discrepancy between the total area of the existing building and that of the function program.

[25] This code is developed based on the previous codes by Liu J.

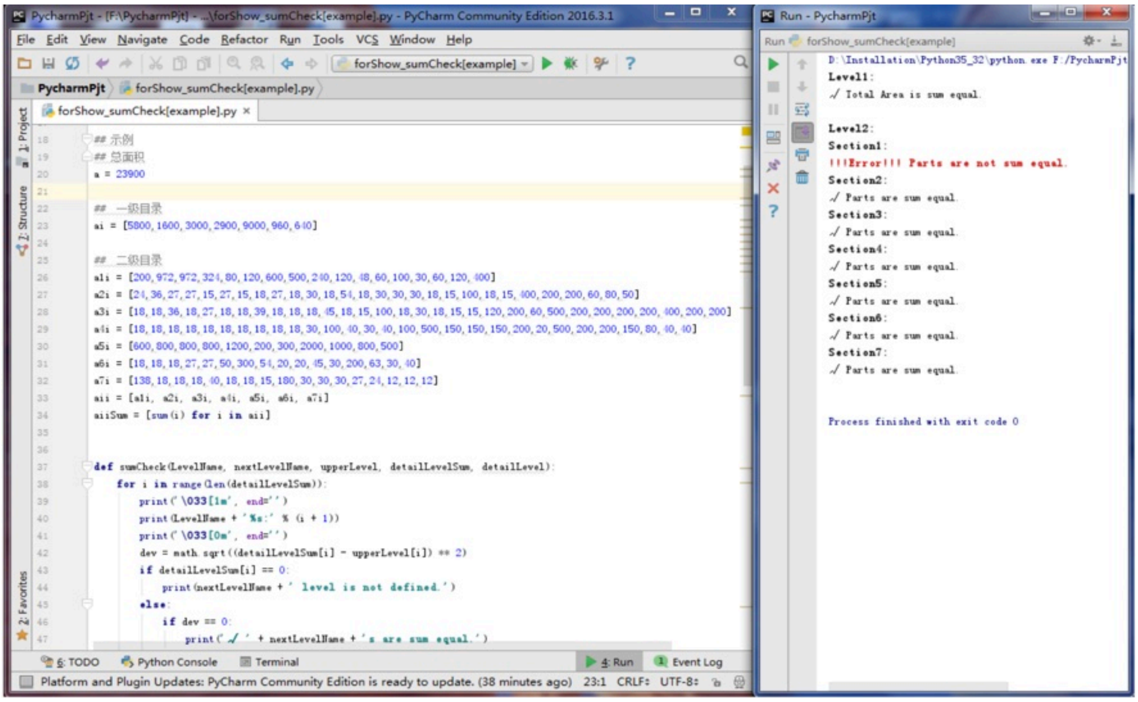


Figure 6.18 Sum area check in the programming interface (刘佳凝, 2017 [126])

The second part is to test the proportion of area distribution in the function program. Buildings of the same building type are similar in function area distribution, which can be further classified into categories(刘佳凝, 2017 [127]). Parallel coordinates and clustering method can facilitate to analyze multi-dimensional building data in order to predict space area distribution(Guo et al., 2010 ;刘佳凝 and 庄惟敏, 2016). The parallel coordinates visualize the clustering results of the dimension data of rooms or the area distribution data of a building type. Among all kinds of clustering methods, we choose the most common method of K-means clustering to iterate the evaluation function until obtaining the optimal result. In Figure 6.19, D, L, and H is the clustered data of width, length and height of 21 loft housing layout, while d and d’ respectively show the corresponding widths of kitchen and canteen. These three lines are the clustered result of 3 types of loft apartment. In Figure 6.20, Liu collects 33 design briefs of cultural architecture and applies K-means clustering methods to classify them into two types of buildings: one focuses more on exhibition space and the other one offers more open space for activities.

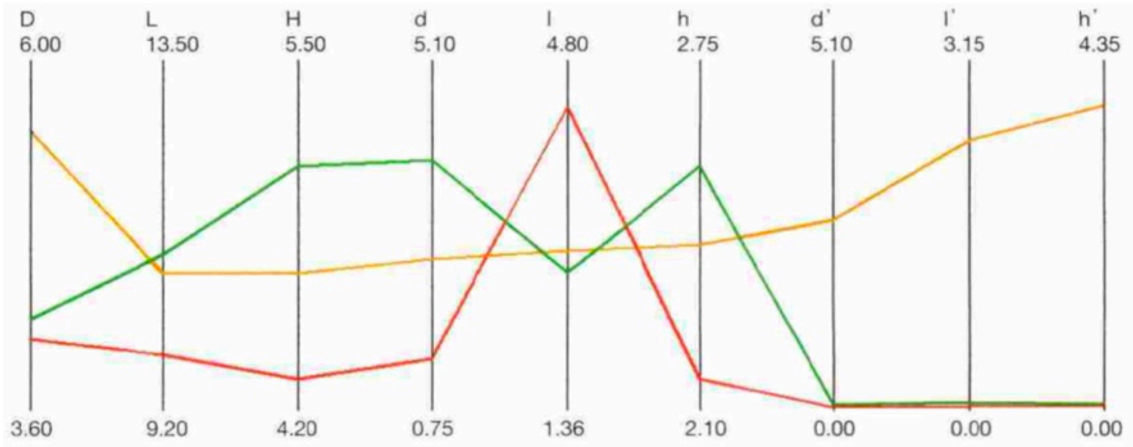


Figure 6.19 Clustering result of the dimension proportion of apartment, kitchen and canteen in Loft plans(刘佳凝 and 庄惟敏, 2016)

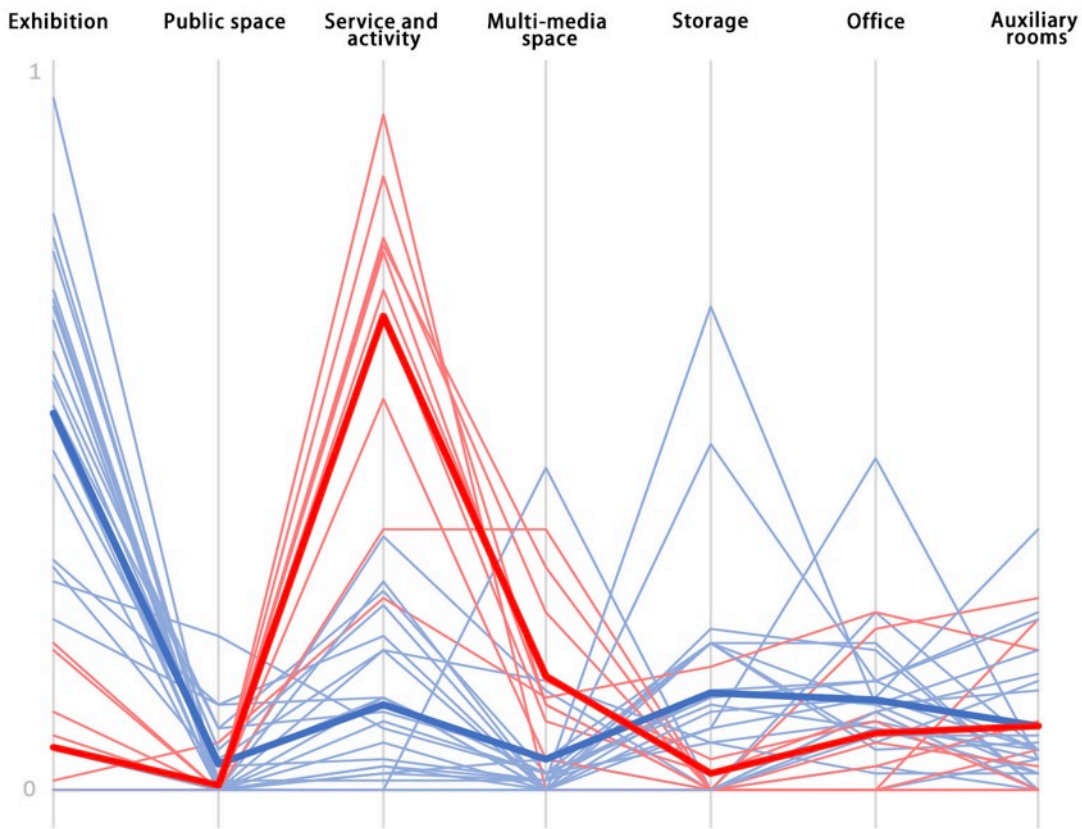


Figure 6.20 Clustering result of the area distribution of 6 function sectors in cultural buildings, translated by the author (刘佳凝, 2017 [132])

When obtaining the average result of function distribution or room size of a certain building type, programmers can use cosine similarity measure to compare the draft function program with the clustered result. It is noticed that all the vector can only be compared and calculated cosine similarity only if they have the same number of dimensions. As (6.3 shows, for the clustered function F and potential function program f_i, they both have m functional sectors. They are both abstracted as feature vectors with m dimensions. The larger the cosine value of the two feature vectors is, which means the smaller the angle between the two vectors is, the shorter the distance between them are, and thus the similar the area distribution of two function programs are. If the data of the draft program deviate much from the clustered average data, then programmers should warn the risks to the decision makers.

$$C_i = \cos(\theta_i) = \frac{\sum_{j=1}^{m} F_j f_{ij}}{\sqrt{\sum_{j=1}^{m} F_j^2}\sqrt{\sum_{i=1}^{m} f_{ij}^2}} \tag{6.3}$$

6.3.2 Analysis of spatial potential based on topology

After analysing the rationality and risks of draft function programs, programmers can uncover spatial potential before evaluating the suitability of these two issues, since renovation projects usually involve demolition, expansion, addition and modifications that can change the spatial topology of the existing buildings. This section will introduce preliminary analysis on spatial potential preparing for the suitability evaluation afterwards.

The spatial potential here indicates the modification of walls, partitions, or even floors that not only affect the connectivity and adjacency of spaces, but also change the size and area of each room itself, which means the transformation of spatial topology. Usually, architects use drafts and drawings through a trial-and-error process to explore the potential layout and accommodate the function and plan iteratively. Here we attempt to first obtain different conversed layouts and the corresponding attributes of each room by means of computer programming process. The purpose of this process is to provide potential layout alternatives for suitability evaluation with the draft function program in the next two sections, in order to improve the function program and generate the final design proposal. The process consists of three steps: 1) transform the existing floor plan layout into a graph with room attributes and connectivity relations that are intelligible to computer language; 2) identify the potential walls or partitions that can be demolished or added in the layout under various conditions; 3) obtain the potential new layout through the transformation and corresponding new attributes of rooms and relations.

Step 1 - structure a graph G_0 for the existing floor plan: input the number of rooms as nodes R_1, R_2 …… R_n in the graph with the attributes of floor area, width, length, and height. Programmers can also add qualitative features such as structure, color, etc. to the attributes; then input edges according to the room connection and the corresponding weights of edges which represent the degree of adjacency. Here we set weight of 2 as connection through open wall or door, weight of 1.5 as adjacency by a partition, and weight of 1 as partitions which can be demolished. After setting these parameters, the existing floor plan has been drawn as the graph G_0 in the python computer language. Figure 6.21 and Figure 6.23 shows the graph and programming interface of an example. There are four rooms of R_3, R_4, R_5, R_6, with floor area of 24, 24, 36 and 12 m^2, and a corridor R_9 that connects the four rooms with 18 m^2. Therefore, the weights of all edges linking the four rooms with the corridor are valued 2, while the edges of two partitions linking R_3 and R_4, R_5 and R_6 are weighted as 1 that can be demolished.

Step 2 – remove the potential walls and partitions: programmers or architects can first identify *n* partitions that can be demolished and set the weights of the edges as 1 so that these edges can be deleted. Then the programming will exhaustive search for the potential demolished scheme with 1 partition each time as E_1, E_2……E_n, 2 partitions, until all *n* partitions are deleted at the same time. Here we use iterate methods to search for all the potential schemes. In the example, there are two partitions that can be demolished, three schemes thus can be generated including demolishing E_1 linking R3 and R4, E_2 linking R5 and R4, and E_1 and E_2.

Step 3 – generate new potential plan layouts: after deleting the edges in the graph, C_n^n schemes can be generated. Then the adjacent rooms will merge into a bigger room, which in the graph two nodes will be merged into one node and their attributes will added together to represent the feature of the bigger new room. The topology of the new layouts is shown as well. The attributes of each room in each new graph are also generated into a table for presentation and later evaluation.

It should be clarified that if the number of partitions is relatively large, programmers can identify the potential new layout without consideration of functions and input the data of space list.

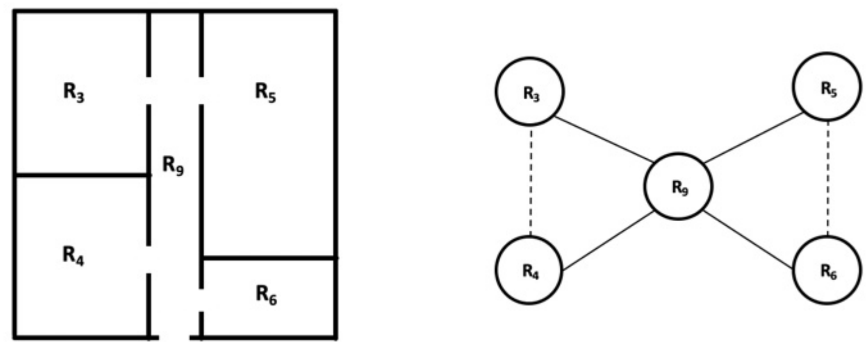


Figure 6.21 Floor plan layout and graph of the example

```python
import itertools
import networkx as nx
import matplotlib.pyplot as plt

G0 = nx.Graph()

G0.add_node('R9', area=18)
G0.add_node('R5', area=36)
G0.add_node('R6', area=12)
G0.add_nodes_from(['R3','R4'], area=24)

G0.add_edges_from([('R9','R5'),('R9','R6'),('R9','R4'),('R9','R3')], weight=2)
G0.add_edges_from([('R5','R6'),('R3','R4')], weight=1)
```

Figure 6.22 Programming interface of drawing the graph G_0

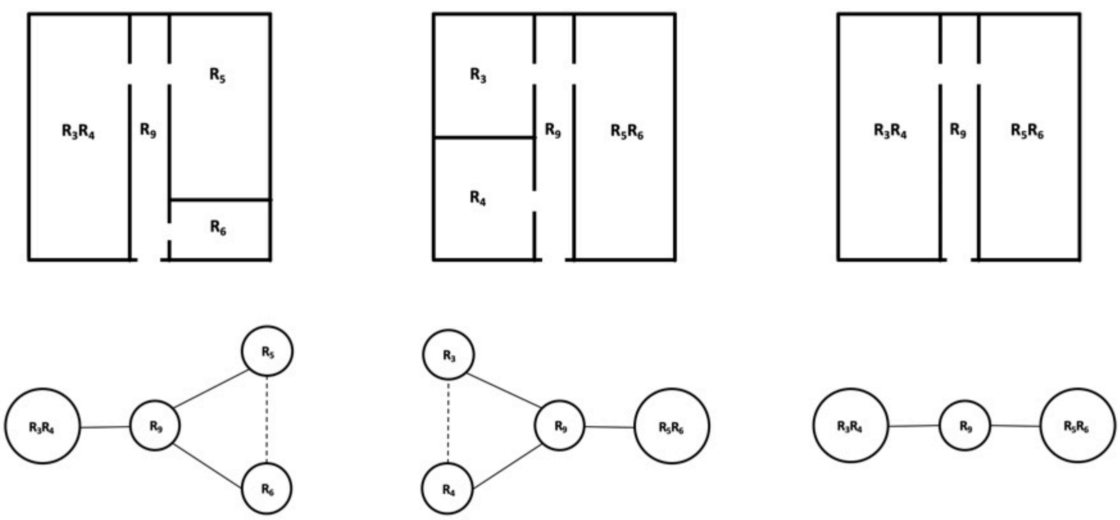


Figure 6.23 Floor plan layout and graphs after modifying partitions

```python
def merge(G,a,b):
    G_new = nx.contracted_nodes(G,a,b,self_loops=False)
    mapping = {a: a+b}
    G_new = nx.relabel_nodes(G_new,mapping,copy=False)
    G_new.nodes[a+b]['area'] = G.nodes[a]['area'] + G.nodes[b]['area']
    if G.nodes[a]['length'] == G.nodes[b]['length'] and G.nodes[a]['width'] == G.nodes[b]['width']:
        G_new.nodes[a + b]['width'] = G.edges[(a, b)]['distance']
        G_new.nodes[a + b]['length'] = G.nodes[a]['length'] + G.nodes[b]['length']
    elif G.nodes[a]['length'] == G.nodes[b]['length']:
        G_new.nodes[a + b]['length'] = G.nodes[a]['length']
        G_new.nodes[a + b]['width'] = G.nodes[a]['width'] + G.nodes[b]['width']
    elif G.nodes[a]['length'] == G.nodes[b]['width']:
        G_new.nodes[a + b]['length'] = G.nodes[a]['length']
        G_new.nodes[a + b]['width'] = G.nodes[a]['width'] + G.nodes[b]['length']
    elif G.nodes[a]['width'] == G.nodes[b]['length']:
        G_new.nodes[a + b]['width'] = G.nodes[a]['width']
        G_new.nodes[a + b]['length'] = G.nodes[a]['length'] + G.nodes[b]['width']
    elif G.nodes[a]['width'] == G.nodes[b]['width']:
        G_new.nodes[a + b]['width'] = G.nodes[a]['width']
        G_new.nodes[a + b]['length'] = G.nodes[a]['length'] + G.nodes[b]['length']

    if G_new.nodes[a + b]['length'] < G_new.nodes[a + b]['width']:
        x = G_new.nodes[a + b]['length']
        G_new.nodes[a + b]['length'] = G_new.nodes[a + b]['width']
        G_new.nodes[a + b]['width'] = x

    return G_new
```

Figure 6.24 Part of programming codes for demolish partitions and generate new graphs

Table 6.1 Space data of transformed potential layouts

Layout	Space No	Area (m^2)	Length (m)	Width (m)	Height (m)	L/W
Graph 1	R3R4	48	12	4	3.2	3
	R5	36	9	4	3.2	2.25
	R6	12	4	3	3.2	1.33
	R9	18	12	1.5	3.2	8
Graph 2	R3	24	6	4	3.2	1.5
	R4	24	6	4	3.2	1.5
	R5R6	48	12	4	3.2	3
	R9	18	12	1.5	3.2	8
Graph 3	R3R4	48	12	4	3.2	3
	R5R6	48	12	4	3.2	3
	R9	18	12	1.5	3.2	8

Although the spatial analysis of potential topological transformation is applicable for the buildings with walls and partitions inside, this approach can also be used in open-space building renovation projects such as the factory cluster reuse projects in China. In that circumstance, the **outdoor open space** among factories can also be considered as a room space, while the boundaries of outdoor and indoor spaces can be seen as the partitions. Programmers should first identify the boundaries of potential outdoor open space and the existing buildings, and then input the corresponding data to be analyzed, considering the site as a plan layout, which will be introduced in detail in the case study of the section 6.4.2.

6.3.3 Suitability evaluation of function unit

Units represents a single function in the functional relationship graph, or a single room in the spatial topologic graph. Matching the unit function and rooms are the first step from the perspective of individuals. As discussed in section 6.2.3, each space or function unit can be abstracted to be a **feature vector** to quantitatively indicate the unit with characteristics. Therefore, the unit similarity model is built through **three steps**: we first identify the dimensions of the vector; second, we quantify and encode all the quantitative and qualitative features, and at last, we use similarity measure of Normalized Euclidean Distance to compare the existing space and the target function unit and obtain an evaluation score.

The features of space can be classified into 2 categories: shape and architecture. The shape features include floor area, size and the proportion of length and width. The existing space unit has a certain floor area, length, width, and height. While the required function doesn't have these detailed data——the requirement of a function can be translated into spatial language with quantitative data. The most common method to estimate the floor area is to multiply number of users with the unit area per person. The number of users can be obtained from the client or users. The unit area per person can be obtained from the architects' experience, design reference, or the previous cases. The translated spatial language of area, length and proportion can a range to be evaluated with the features of existing spaces.

The architectural features include the vertical position, structure strength, the orientation, etc. Vertical position indicates the preferred floor or story that a function is positioned, such as the ground floor, middle floor, or the top floor. This feature relates to the required degree of privacy, the building fire codes, the accessibility to the users, and other elements. For example, the office space can be positioned on the middle floor if the client requires high degree of privacy. The structure strength is for some special spaces such as storage room, bookshelf space for higher strength requirement than normal.

Orientation feature is for spaces like classrooms, patients' wards, etc., which are required by the building codes in China to be oriented to the south.

These are the basic feature of a unit function and space. Since the feature vector can have multiple dimensions, the programmers can add any quantitative or qualitative dimension according to a certain project. It is noticed that all the vector can only be compared and calculated the Euclidean distance only if they have the same number of dimensions. Table 6.2 shows some of the basic features of space and function units and their common dimensions to be compared by Euclidean distance method.

Table 6.2 Some basic features of function and space unit

No	Feature of space	No	Feature of function	No	Overlapping feature	Scale
1	gross floor area (GFA)	1	number of users/equipment			
		2	m^2/person or m^2/equipment			
		3	floor area	1	floor area	quantitative
2	length(l)					
3	width(w)					
4	dimension of l/w	4	dimension of l/w	2	dimension of l/w	quantitative
5	story height (h)	5	minimum story height (h)	3	story height	quantitative
6	ceiling height (h)	6	minimum ceiling height (h)			
7	dimension of l/h	7	dimension of l/h	4	dimension of l/w	quantitative
8	link to the outside	8	requirement of link to the outside	5	link to the outside	qualitative
9	vertical position	9	preference to the floor	6	floor/story	quantitative
10	structure	10	bearing capacity	7	structure strength	qualitative
11	orientation	11	orientation requirement	8	orientation preference	qualitative
12	……	12	……	9	……	……

For a single function unit F_i and space unit S_i with m dimensions of features, the similarity score is the Euclidean distance of the two feature vectors in a m-dimensional spaces. The smaller the number is, which means the shorter the distance between them are, and thus the similar the two units are. However, the scaling of each variable has huge impacts on the distance since dimensions have distinguishing magnitudes and units of measurement, and some dimensions may have extreme maximum values. It is necessary to normalized all the dimensions to a certain range for comparison. Considering the characteristics of features in this architectural situation with few extreme values, we choose to normalize the variables to the range of [-1, 1] before applying the Euclidean distance equations Equation (6.4). We obtain the normalized equation to calculate Euclidean distance of a function unit F_i and a space unit S_i with m dimensions as Equation (6.5) shows.

$$x' = \frac{x - average(x)}{\max(x) - \min(x)} \tag{6.4}$$

$$D_i = \sqrt{\sum_{j=1}^{m} (\frac{F_{ij} - S_{ij}}{s_j})^2} \tag{6.5}$$

An existing building may have multiple spaces inside with different significance. Due to the large number of space units and complex spatial organization with architectural experience, tt is difficult to compare all the space units with function requirements. Even in architectural design practice, architects never arrange each unit at the same time and many relatively insignificant functions have a certain degree of flexibility in terms of floor area, size and positions. Therefore, we first consider the primary function unit of the target building type. The definition of major function and space usually considers the size of floor area, or the people capacity. There are also some necessary functions or spaces difficult to be transformed. According to the interview with architects, they firstly focus on the major function and space when drafting the renovation design scheme. The Pareto Principle, 80% of outcomes roughly come from 20% of causes (Pareto, 1964), applies to the problem as well. Therefore, matching of the major room and the major function is the first problem to cope with. Once the major function can be positioned in a suitable space, the other minor functions and rooms can be adjusted accordingly. The method of normalized Euclidean distance can facilitate the selection of potentially suitable space units for the major functions to be evaluated further from the perspective of function relationship and positions. Section 6.4.2.2 will introduce the application of this method in a renovation project.

6.3.4 Suitability evaluation of function relationship

Topologic similarity here indicates the relationship of functional graphs or spatial graphs from the perspective of panoramic relationship on the connection. Since graph similarity is a NP-hard problem now and the existing studies only focus on the mathematical problem without consideration on architectural language, this research will apply indexes in space syntax to evaluate the relative positions and relationships of the target space in the whole floor plan, which have been verified broadly by cases and researchers. These two indexes are connectivity and integration.

Connectivity indicates the number of spaces that the target space connects to, or the number of lines that the target axis intersects with (Hillier and Hanson, 1984 [103]). **Integration,** the other index, indicates the relations and relative positions of the space from the perspective of the overall layout. The value of integration calculates the degree of adjacency of the target space to all other spaces(Hillier and Hanson, 1984 [108-109]). The larger the value is, the larger degree of adjacency of the target function unit is to all the other spaces.

Since the same building type should have similar function organization and relationships, the connectivity and integration values of the significant function unit in that building type are supposed to be similar as well. Otherwise, the position of the function unit will have risks in the connectivity and adjacency with other spaces. This kind of problem occurs less in the new construction building since the function adjacency and relationships are arranged from the beginning. While in renovation projects, the existing spaces have fixed spatial organization and adjacency relations, which limits the function arrangement and have the risk mentioned above. Evaluating the connectivity and integration of primary functions in the renovation function program after matching the area and size of it can further ensure the feasibility of the draft function program in the existing spaces.

Here is an example of the floor plans of a performance building. This building has three floors with one main performance hall on the first floor. As seen in the Figure 6.25 and Figure 6.26, the primary function unit has a connectivity value of 3, which means it connects with 3 other rooms, and an integration value of 0.945874, which is higher than 94.1% of the rooms in the existing building. The result shows that the primary function

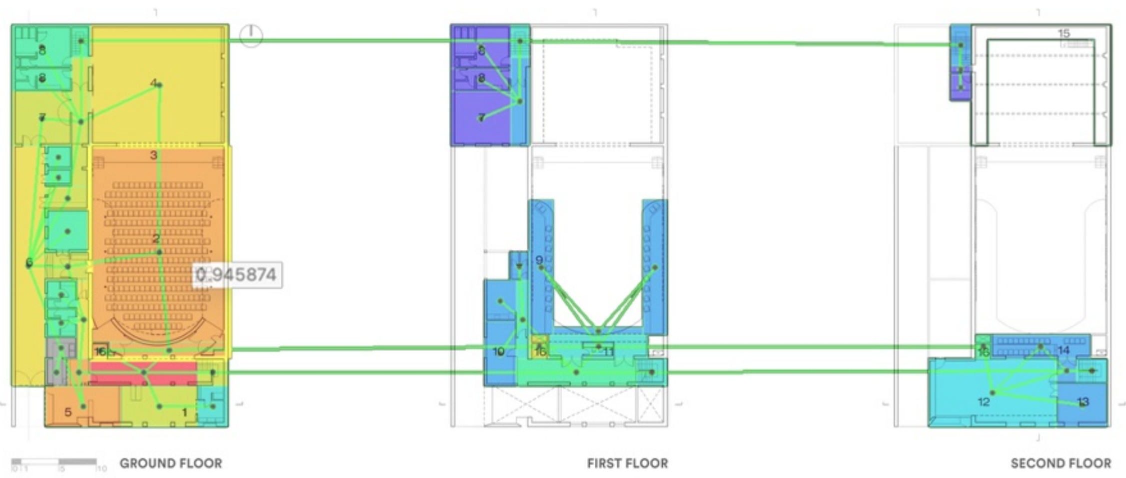


Figure 6.25 Integration analysis of the primary function in the example in Space syntax software

Ref Number	Connectivity	Choice	Choice [Norm]	Entropy	Integration [HH]	Integration [P-val	Integration [Tekl]	Intensity	Harmonic Mean D	Mean Depth
6	2	109	0.0966312	2.96095	0.780952	0.780952	0.598711	0.747868	5.02903	5.0625
16	2	94	0.0833333	2.90505	0.780952	0.780952	0.598711	0.73375	2.98549	5.0625
21	2	184	0.163121	2.92013	0.789045	0.789045	0.599883	0.745242	3.00955	5.02083
3	6	869	0.77039	3.00584	0.801504	0.801504	0.601674	0.779292	5.3773	4.95833
10	3	151	0.133865	2.78994	0.81874	0.81874	0.604124	0.738958	5.60612	4.875
44	3	1042	0.923759	3.08697	0.81874	0.81874	0.604124	0.817629	3.03957	4.875
17	4	228	0.202128	2.91272	0.836734	0.836734	0.606648	0.788526	4.21848	4.79167
8	2	624	0.553191	2.77346	0.846032	0.846032	0.607939	0.759214	5.51422	4.75
9	7	499	0.442376	2.89927	0.875205	0.875205	0.611934	0.82118	6.79428	4.625
15	2	300	0.265957	2.69672	0.89056	0.89056	0.614004	0.77729	4.13261	4.5625
49	2	990	0.87766	2.83935	0.91189	0.91189	0.616843	0.838122	2.92089	4.47917
18	3	487	0.431738	2.89557	0.934268	0.934268	0.619779	0.875822	3.94816	4.39583
22	3	679	0.60195	2.56464	0.945874	0.945874	0.621285	0.785421	6.70213	4.35417
50	2	624	0.553191	2.65684	0.945874	0.945874	0.621285	0.813658	4.03656	4.35417
19	5	1313	1.16401	2.79261	1.01524	1.01524	0.63006	0.918374	3.20129	4.125

Figure 6.26 Connectivity and integration value of the primary function in the example

The process of evaluating suitability of the function includes two steps. First, collect data and analyze the connectivity and integration values of the target function space in other cases. Second, analyze the two indexes of the potential space units that may accommodate the target function and compare the value with the safety scope of the database and obtain the evaluation result to provide suggestions on the modifications of the function program. The detailed application process will be introduced in the next section.

6.4 Case study

All projects do not use the above 4 steps, but depend on the certain situation. The following two cases represent two situations with either draft function program and clearly-defined function requirements, focusing on different aspects and using part of the above process.

6.4.1 Jingdezhen grain depot reuse

After identifying livehouse and bar as the primary function of the target existing building in section 5.6, the stakeholders approved this decision and the further development of the function program. Jingdezhen grain depot renovation is a function transformation project, and the existing buildings are a factory without any partitions. Therefore, the function distribution is **only limited by the envelop structure**, not by the existing partitions. Based on the draft function program, the next step in the architectural programming is to evaluate the suitability of the functional program based on the existing spaces. The suitability evaluation will focus on the following three questions:

• the distribution and proportion of function area: is there any risk of the area distribution and proportion in the draft function program based on those in average projects?

• the suitability of the existing space for the primary function: if the existing factory can accommodate the main function – livehouse and bar, not only the size and capacity, but also the structure and equipment?

• the design strategy of the target two factories: should they be separate or linked with each other?

The process consists of four basic phases following the methods in the previous sections:

1) Check the sum area of the functional program with the floor area of the existing building; provide suggestions on demolition, expansion or adjustment of the program based on difference value.

2) Evaluate the function distribution and proportion of the program compared with average data of this building type to warn any risks;

3) Evaluate the suitability of primary unit function and space from the perspective of the size, capacity and technology feasibility;

4) Analyze the relationship of spaces and function: analyze the integration and depth of different strategies on linking the two target factories.

6.4.1.1 Check the rationality of the function program

1) Area sum check

Existing building floor area:

a0 = 2700 *2 = 5400

Sector area:

ai = [540,800,700,1650,600,600]

First category area:

a1i = [300,80,80,40,40]

a2i = [550,150,50,50]

a3i = [100,100,100,200,200]

a4i = [500,400,150,600]

a5i = [100,50,100,200,150]

a6i = [350,100,150]

Second category area:

a12i = [40,40]

a15i = [20,20]

a31i = [50,50]

a33i = [20,20,20,20,20]

a34i = [50,50,100]

a35i = [100,100]

a43i = [50,100]

a44i = [50,50,100,100,300]

a61i = [20,20,20,20,60,60,60,90]

a62i = [50,50]

Input the data into the computer interface, and the programming will sum it up from bottom level to the up in order to check the sum area of each level is equal to the total area. After that, it will compare the sum area of the function program with that of the existing buildings. In this case, the sum area of the function program is bigger than that of the existing building. There is a hint of “expansion or partial mezzanine”.

2) Function area distribution check

The research uses a set of project data from 20 projects with similar function. Since the total ground floor area of existing buildings are around 5000 m^2, and could be 10000

m^2 with mezzanines, the range of gross floor area of selected projects is from 3000 to 1000 m^2. All of the functions are classified into 6 spatial categories based on same standards. Since the function involves small theaters as livehouse, cultural spaces in cultural center, and service function in community center, the spatial categories refer to room types in the *Code of Theater Design JGJ 57-2000* and literature review of livehouse and black-box theater design, cultural center and community center.

• **Auditorium**: lobby and lounge which include ticket box, cloak room, VIP room; seat, aisle

• **Stage**: main stage; performance technology room including light and sound control room, equipment room

• **Back court/ backstage**: performance room including dressing room, costume room, green room, bathroom and restroom; auxiliary room including rehearsal room, piano room, stage property room, instrument room, and other isolated equipment rooms.

• **Cultural space**: exhibition space, meeting room, classroom, multimedia room, library.

• **Commercial space:** store, book store, café, restaurant and kitchen, tea room and other clubs

• **Auxiliary room**: maintenance room, administration office, other restrooms

Table 6.3 shows all the detailed information of the 20 cases including the area data of these six function categories.

Table 6.3 Area proportion of 20 cases with similar functions

No.	Project	Area proportion					
		Stage	Audience	Backstage	Cultural	Commercial	Auxiliary
1	Politeama Theatre	0.186	0.316	0.279	0.098	0.039	0.083
2	Théâtre de Quat'sous	0.214	0.458	0.192	0.000	0.000	0.136
3	Hattiloo Theatre	0.439	0.153	0.162	0.094	0.000	0.152
4	360 Paris Music Factory	0.063	0.253	0.258	0.000	0.127	0.299
5	Odsherred Theatre	0.140	0.227	0.310	0.073	0.100	0.149
6	Peter Hall Performing Arts Centre	0.084	0.404	0.120	0.328	0.041	0.023

No.	Project	Area proportion					
		Stage	Audience	Backstage	Cultural	Commercial	Auxiliary
7	Renovation of the Oscense Theatre	0.089	0.319	0.124	0.245	0.000	0.223
8	Blue Barn Theatre & Boxcar 10	0.153	0.243	0.212	0.000	0.164	0.228
9	The You Art Centre	0.102	0.141	0.000	0.469	0.249	0.039
10	Theatre 95	0.130	0.314	0.234	0.072	0.064	0.187
11	Theater Jacques Carrat	0.131	0.172	0.151	0.355	0.017	0.173
12	Writers Theatre Opens New Theatre Center	0.030	0.360	0.287	0.236	0.000	0.088
13	Polyvalent Theater	0.073	0.146	0.000	0.531	0.085	0.166
14	Multicultural Centre in Isbergues	0.070	0.151	0.161	0.368	0.075	0.175
15	Young Centre for the Performing Arts	0.054	0.302	0.132	0.274	0.008	0.231
16	Neushoorn	0.251	0.117	0.179	0.109	0.172	0.172
17	Everyman Theatre	0.039	0.176	0.263	0.053	0.176	0.292
18	House of Music and Theater	0.112	0.322	0.077	0.437	0.000	0.052
19	Freight & Salvage Coffeehouse	0.038	0.482	0.165	0.135	0.015	0.165
20	Theatre de Kampanje	0.110	0.143	0.140	0.363	0.106	0.138

After collecting the function area distribution data, we apply K-means clustering method to cluster the cases into two types with 10 iterations. Figure 6.27 shows the final result of the clustering process. Two clustered centers are obtained as [0.166, 0.261, 0.222, 0.081, 0.085, 0.185] and [0.085, 0.246, 0.119, 0.361, 0.058, 0.131]. The first type in red color has a relatively average area distribution among the 6 categories with the most quota in audience and backstage, which represents cases with major functions on performance and rehearsal. The second type in blue color has a prominent function of cultural spaces which represents cases focusing on promoting performance education, exhibition and other activities; among them, some are more likely to be serve the community as a community center, others are more likely to be the multi-functional open spaces that can be rented to host various activities and exhibitions.

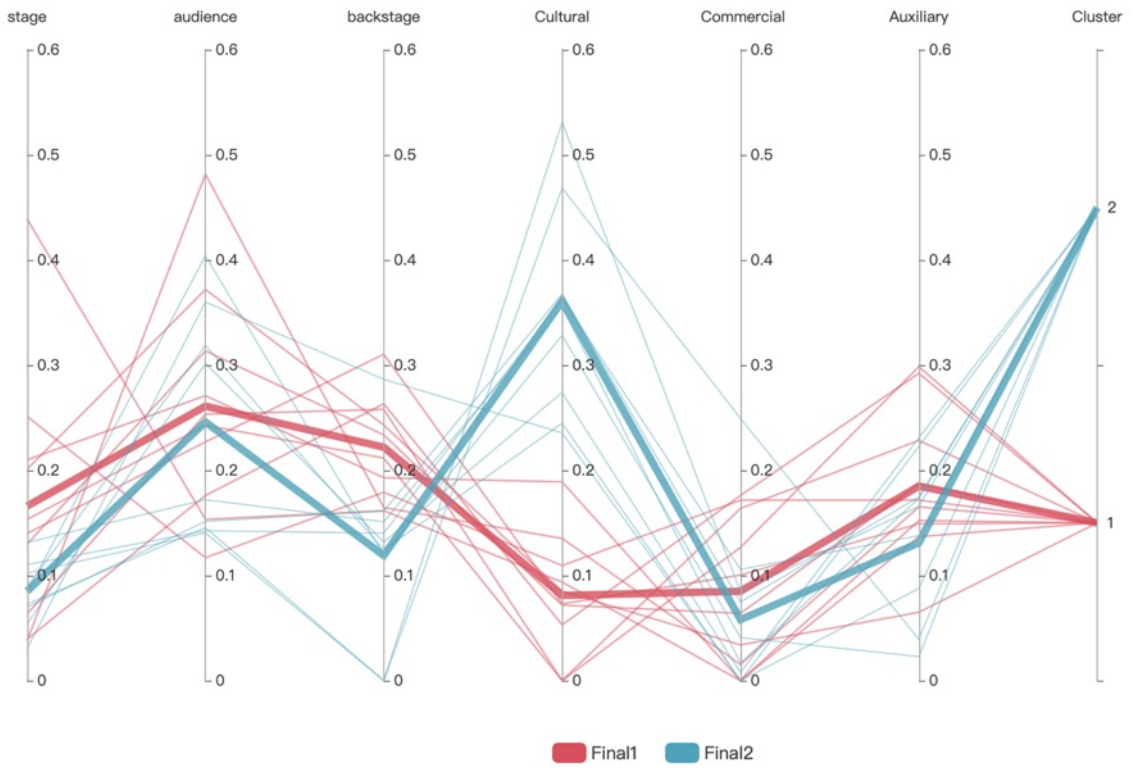


Figure 6.27 Clustering result of the cases

As for the draft function program, the function area distribution is [0.110, 0.164, 0.143, 0.337, 0.123, 0.123]. According to Equation 6.1, the distance of this program with final 1 clustered center is 0.774, while that with final 2 clustered center is 0.973. The Figure below shows the target function program comparing with cases clustered into two types. It shows that the program is closer to the second type in blue color with major functions on cultural spaces such as exhibition halls, meeting rooms, banquet, multi-media rooms and so on.

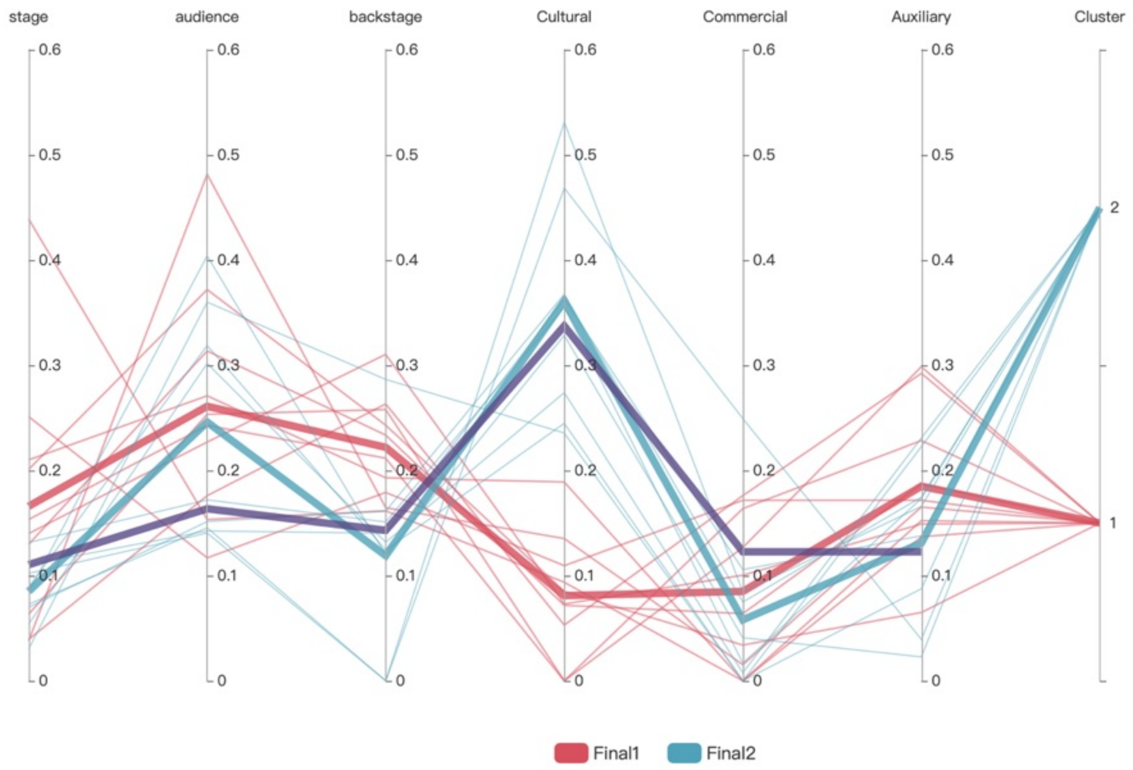


Figure 6.28 The function program of Jingdezhen grain depot comparing with cases in database

6.4.1.2 Suitability of the primary function unit

Although the function for existing buildings is identified as cultural center with a livehouse and exhibition halls, the live house is the one with most limitations and requirements in this function program. Therefore, it should first study the feasibility of this function unit.

Due to the equipment of performance, the net height of the performance space is significant for the function feasibility. Table 6.4 shows the net height data of black-box theaters. The factory in this project has a total height of 10.7m with net height of 7.8m, which is feasible for most cases. Apart from the height condition, the length and width of performance spaces should also be suitable for the existing factories, which are 105.52m long and 24.45m wide. Therefore, the width here is the main limitations for the suitability evaluation, which can only accommodate the small theater spaces smaller than 450 m^2. Considering the flexibility of the performance space in future transformation to exhibition halls, banquet, conference halls, etc., the performance space should be in a prominent position with large space. Therefore, the existing single factory space is hardly possible to accommodate this kind of function unit.

Table 6.4 Net height data of black-box theaters

Livehouse or black-box	Floors	Net height(m)	Length * width (m * m)
Renyi experimental theater	1	5	18.5*18.8
Penghao theater	2	4.3	13.75*9
Small theater of National Drama Theater	1	5	22*19.36
TNT theater of Chaoyang	1	5	28*20.5
Blackbox of Hongkong cultural center	1	4.2	27.68*18
Blackbox of Hongkong Kuiqing theater	2	8.2	14.45*13.8
Entertainment hall of Niudiwan center	1	4.9	14.5*14.3

Considering the size and proportion of the space requirement, the final strategy of the program is to partially add some space to connect two factories in order for a performance hall with enough spaces of backstage, which not only meets the technical requirements, but also regenerate the central outdoor spaces between the two factories (Figure 6.29). This strategy has been applied in the design scheme of the project when the thesis is submitted.

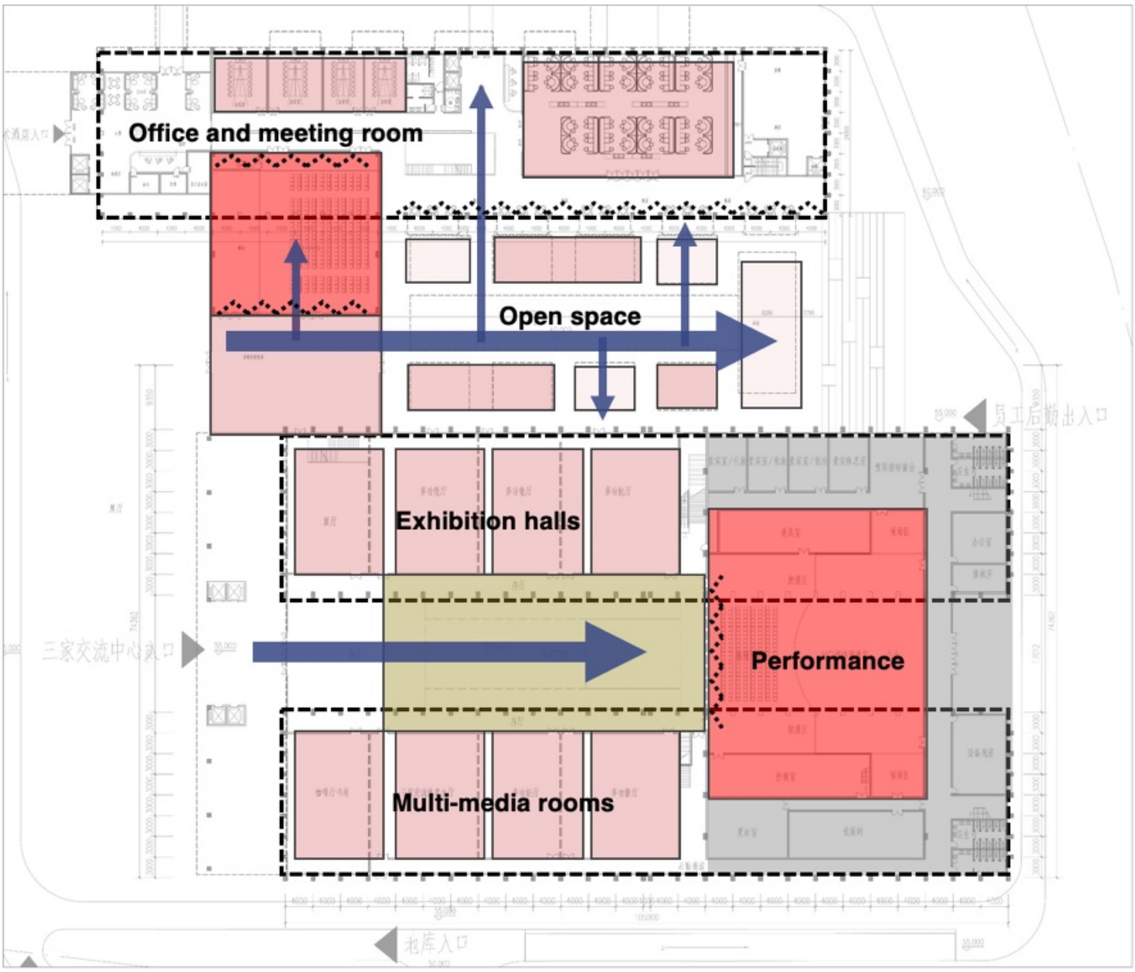


Figure 6.29 Function organization in Jingdezhen Grain Depot revised from THAD

6.4.2 Pingyao Film Palace reuse

The Pingyao Film Palace project is a completed project. However, during the communication with the architect, the author learned that the suitability evaluation of function and space is one of the first issues to be solved in the pre-design stage. The architects obtained the strategy through a large number of sketches and by trial and error. The author is thus intended to use quantitative methods for screening, which can present the available options for selection and save time of trial and error in the preliminary stage. and the results are also consistent with those obtained by the actual sketch trial and error method, so they can prove the effectiveness of the method.

The case of Pingyao film palace has a clearly-identified function program required by the international film festival. Therefore, the rationality of the function program itself is not the focus in the suitability evaluation. On the contrary, the special functional requirement and strict limitations in the historic district are the major problems of this case. And searching for the suitable space for functions are the main task in the suitability evaluation of this case. Although it is completed project, the clients made decisions based on architects' professional experience and comparison of design schemes. In this section, the author will apply the second to the fourth step of the suitability evaluation process introduced in the section 6.3 in order to provide an example verifying the effectiveness of the research.

6.4.2.1 Analysis of spatial potential

There are 13 separate existing buildings on site. The goal of the architectural programming is to put the function program required by the film festival into the existing building. As for the **functional requirements**, a 1500-seat theater, a 200-to-500-seat cinema hall and the main venue for the film festival are the most important function units among the function program. Other functions include several small video halls, news office, meeting hall and so on. When it comes to the **limitations**, the site is in the historic district of Pingyao and thus is strictly supervised on the preservation of existing buildings, the degree of intervention, the 8-meter height limitations, etc. Therefore, before evaluating the suitability of the required function program and the existing spaces, we should first explore the potential topologies of the site and organize the spatial data for the following analysis and evaluation.

As mentioned in section 6.3.2 of analysis of spatial potential based on topology, the spatial analysis not only applies to buildings with inner partitions and walls, but also facilitates the exploration of potential schemes for building clusters. Here, we consider the **vacant outdoor space** also as potential spaces beside all the existing buildings in the circumstance of expanding existing factories, demolishing factories and reconstructing new buildings on the vacant space. Based on the demands of fire codes, the boundaries of all the vacant outdoor space will draw back 6 meters as the fire separation distance from the building lines of existing factories. As shown in Figure 6.30, there are six vacant outdoor spaces are identified as potential spaces for any expansion and reconstruction.

The topological transformation follows the three steps introduced in the section 6.3.2: 1) identifies all the existing spatial unit and organize the data to structure a graph G_0 for the existing plan layout; 2) removes the potential walls and partitions that identified by programmers to be possibly demolished; 3) generates new potential plan layouts by deleting the edges in the graph and merging adjacent spaces, and obtains the data list of new spaces. In this case, we identify five dimensions as the features of each space as below:

Length (m) and *width* (m): length is the size of the longer side of the rectangular space and the width the other shorter side, which are basic features drawing the space.

Area (m^2): area is the product of length and width indicating the floor area of the building or vacant space; it reflects the capacity of the space and even the number of future users in this space.

Length/width (L/W): this feature indicates the ratio of the rectangular shape which always has close relations with the building type and space functions.

Net height (m): height here indicates the net height of the existing factories that are feasible for the function transformation; height for the vacant outdoor space is 8.00 meters, which is the maximum feasible height demanded by the historic district.

As shown in Figure 6.31, we input the feature data of eleven existing spaces and vacant outdoor spaces as nodes into the programming procedure, and then identify the edges with different weights linking adjacent spaces. Edges weighted 2 indicates existing connection through open wall or door, represented in straight lines; edges weighted 1.5 means adjacency but inappropriate to be merged, represented in dot lines, edges in dash line weighted 1 means the boundaries which can be merged by adjacent two spaces. In this case, edges between D5 and S1, D6 and S1, D4 and S4, D4 and S5 are identified as potential edges that can be demolished for new spaces.

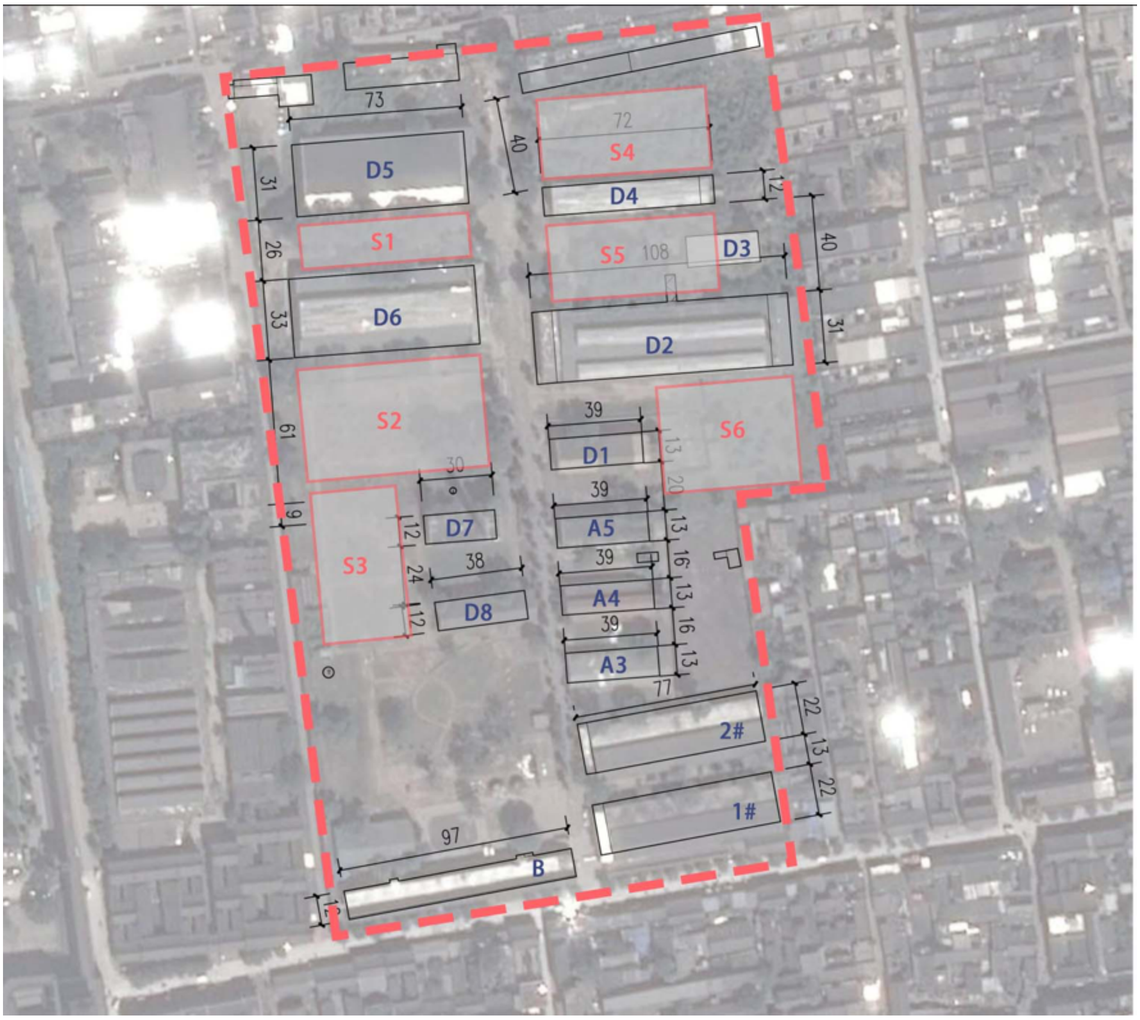


Figure 6.30 Existing building spaces and vacant outdoor spaces

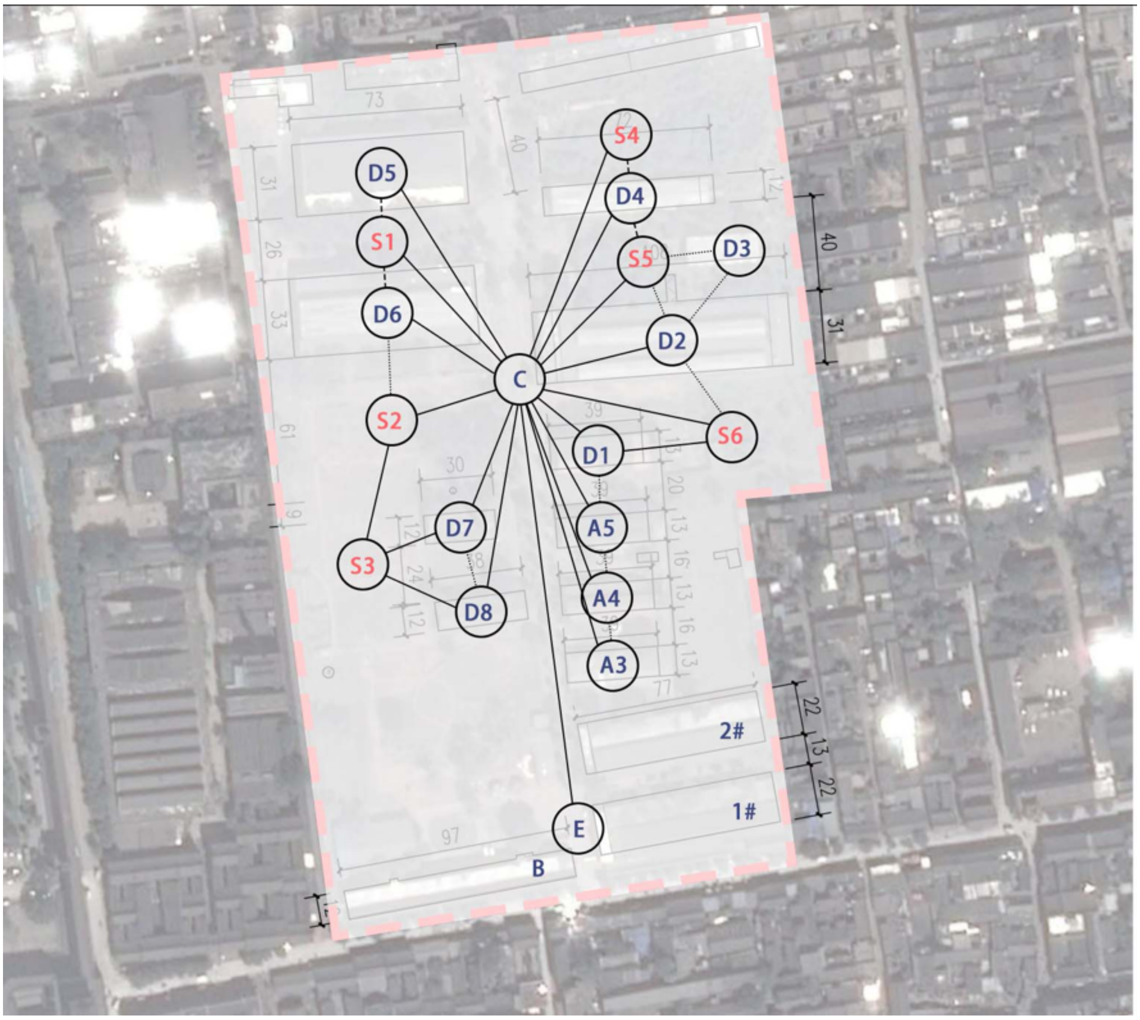


Figure 6.31 Topological graph of existing space units

New nodes in generated graphs after demolishment and merger are labeled with new features shown in Table 6.5. These nodes in architectural language means new spaces transformed from extending the existing building to the vacant space, or new vacant site obtained from demolishing the existing factories. The existing spaces, vacant spaces and new merged spaces are the potential units that can be evaluated for the primary function unit in the next section.

Table 6.5 Features of existing nodes in graph and new merged nodes after topological transformation

Layout	Space No	Area (m^2)	Length (m)	Width (m)	Net height (m)	L/W
Existing spaces	D2	3348.00	108.00	31.00	8.60	3.48
	D3	414.80	30.50	13.60	9.00	2.24

Layout	Space No	Area (m^2)	Length (m)	Width (m)	Net height (m)	L/W
	D4	864.00	72.00	12.00	8.00	6.00
	D5	2263.00	73.00	13.00	7.00	2.35
	D6	2475.00	75.00	33.00	7.00	2.27
	S1	1500.00	75.00	20.00	0.00	3.75
	S2	3675.00	75.00	49.00	0.00	1.53
	S3	2911.00	71.00	41.00	0.00	1.73
	S4	2160.00	72.00	30.00	0.00	2.40
	S5	3672.00	108.00	34.00	0.00	3.18
	S6	2552.00	58.00	44.00	0.00	1.32
Merging spaces in new graphs	D4S4	3024.00	72.00	42.00	8.00	1.71
	D4S5	3312.00	72.00	46.00	8.00	1.57
	D5S1	3723.00	73.00	51.00	7.00	1.43
	D6S1	3975.00	75.00	53.00	7.00	1.42

6.4.2.2 Suitability evaluation of function unit

Evaluating the suitability of the primary function unit is a significant step in the architectural programming of Pingyao film palace project. The approval of holding an international film festival demands cinema halls with capacity of 1500 and 500 people, as well as several small video halls. Apparently, the 1500-seat cinema hall is the primary function unit that is both demanding and difficult to satisfy considering the size, capacity and technical requirements, and the position of it is the primary problem that should be solved. The programming team first collect the data of various cinema halls with different capacity (Table 6.6). According to the calculation of cinema area per capital as 1 to 1.5 m^2, the largest cinema hall can be 2450 to 3750 m^2. The width and net height of the cinema hall should be more than 1.2 to 1.8 times of the IMAX screen of 20-to-25m width and be not shorter than 11-to-15m height based on previous design experience and knowledge. In order to maximize the number of potential spaces which are suitable to the primary function requirement, we identify the minimal and maximal size of the 1500-seat theater as seen in Table 6.7. Spaces that are closer to any of the two endpoints can be recognized as suitable spaces for further analysis.

Table 6.6 Different capacity data of cinema halls

Cinema hall	VIP	Small	Medium	Large	MAX
Seats	20-60	<150	150-250	>250	>350
Area (m^2)	80-150	150-250	250-350	350-450	>450
Width (m)	8-12	10-12	12-15	15-20	around 30
Length (m)	13-20	15-20	18-24	24-32	around 30
Net height (m)	6-8	7-9	8-10	10-12	14-16

Table 6.7 Requirement of function units

Cinema hall	500-seats	1500-seat (min)	1500-seat (max)
Area (m^2)	750-1250	2450	3750
Width (m)	20-30	35	50
Length (m)	35-45	70	75
Net height (m)	14-16	11	15
L/W	1.6	2	1.5

The 15 potential spaces in Table 6.5 should be evaluated for the capability of accommodating the required function units. Apart from the basic geometric features listed in Table 6.5, some other features should also be considered based on the limit conditions in order to select the most suitable and feasible space for holding a 1500-seat theater. Since the site is in the historic district with strict planning conditions, the renovation project is demanded to be within 8-meter height and should preserve existing buildings as many as possible, which are the two most significant limitations on site demanded by the historic district in this case. Therefore, we should first transform these two demands into two measurable dimensions in the feature vector for later evaluation.

Height limit: Pingyao historic district limits the new construction buildings under 8-meter height. Since the existing buildings have fixed structure and roofs which should be preserved as much as possible and thus minimize the intervention, the approach to satisfy the height requirements of the theater can be lowering down the ground floor, which should also be controlled as much as possible to reduce potential risks and damage. We choose the absolute difference of the net height and the elevation of the foundation height as the index for the maximum height of each space, in the name of *Feasible height*. The larger this value is, the closer the space is to the function requirement, and the smaller distance of lowering down the ground is, which means the less intervention will be implemented. For the vacant space, the height is calculated based on absolute difference of the elevation of the ground and the maximum construction height of 8 meters.

Degree of intervention: based on the preservation demands of the historic district, we should judge beforehand the degree of *Intervention* for each possible space, which in this case indicates demolishment on site or expansion of the existing factories. The floor area of demolishment thus is estimated to present this index.

Table 6.8 shows the requirement features of function units and the features of space units for evaluation. We use area and length/width (L/W) to represent the basic geometric features without length and width anymore, with feasible height and intervention to represent the limitations.

Table 6.8 Data of potential spaces for the primary function unit

	No	Area (m^2)	L/W	Feasible height (m)	Intervention (m^2)
Function units	F1	2450.00	2.00	11.00	0.00
	F2	3750.00	1.50	15.00	0.00
Space units	D2	3348.00	3.48	11.10	0.00
	D3	414.80	2.24	11.50	0.00
	D4	864.00	6.00	10.50	0.00
	D5	2263.00	2.35	9.50	0.00
	D6	2475.00	2.27	9.50	0.00
	S1	1500.00	3.75	10.50	0.00
	S2	3675.00	1.53	10.50	0.00
	S3	2911.00	1.73	10.50	0.00
	S4	2160.00	2.40	10.50	0.00
	S5	3672.00	3.18	10.50	414.80
	S6	2552.00	1.32	8.00	0.00
	D4S4	3024.00	1.71	10.50	864.00
	D4S5	3312.00	1.57	10.50	1278.80
	D5S1	3723.00	1.43	9.50	2263.00
	D6S1	3975.00	1.42	9.50	2475.00

After identifying the evaluation feature and organizing the data, the next step is to preparing for cleaning data through screening all the alternatives to exclude some distracting data before analyzing the similarity of function units and space units by Euclidean Distance. Here we set up two minimum limits for cleaning data for all space units: one is the feasible minimum floor area of 2450 m^2, the other one is the feasible minimum width for the function with 35 meters wide. Under these conditions, eight units are excluded including all the existing factories and two vacant spaces (S4 and S5). It also verifies that neither of the existing factories on site can contain the function unit of 1500-seat theatre, drawing to a preliminary conclusion that new construction or expansion is inevitable in this case. The selected seven space units are the alternatives to be evaluated similarity to the features of function units. After normalizing the variables to be scaled to a unit norm from [-1, 1], we apply Equation X to calculate the Euclidean distance between each pair of units and obtain the results as seen in Table 6.9. Figure 6.32 shows the similarity distance of each space units to the two function units. It is clear that distance of space units S2, S3 and D4S4 to the function 1 and 2 are shortest which means they are most similar to the function requirement among all the alternatives. Among them, S2 and S3 are exactly the two final alternatives considered by architects in practice based on professional experience, lots of drawings and scheme comparison, which verifies the evaluation method is effective in searching for the most suitable potential space units for the function requirements.

Table 6.9 Euclidean Distance of the function units and space units

Unit No	F1	F2	S2	S3	S6	D4S4	D4S5	D5S1	D6S1
F1	0.000	1.261	1.060	0.501	1.090	0.667	0.999	1.508	1.668
F2	1.261	0.000	0.646	0.912	1.299	0.928	0.879	1.210	1.286
S2	1.060	0.646	0.000	0.581	0.876	0.614	0.571	0.937	1.043
S3	0.501	0.912	0.581	0.000	0.742	0.358	0.629	1.155	1.313
S6	1.090	1.299	0.876	0.742	0.000	0.826	0.880	1.224	1.392
D4S4	0.667	0.928	0.614	0.358	0.826	0.000	0.334	0.850	1.013
D4S5	0.999	0.879	0.571	0.629	0.880	0.334	0.000	0.538	0.701
D5S1	1.508	1.210	0.937	1.155	1.224	0.850	0.538	0.000	0.188
D6S1	1.668	1.286	1.043	1.313	1.392	1.013	0.701	0.188	0.000

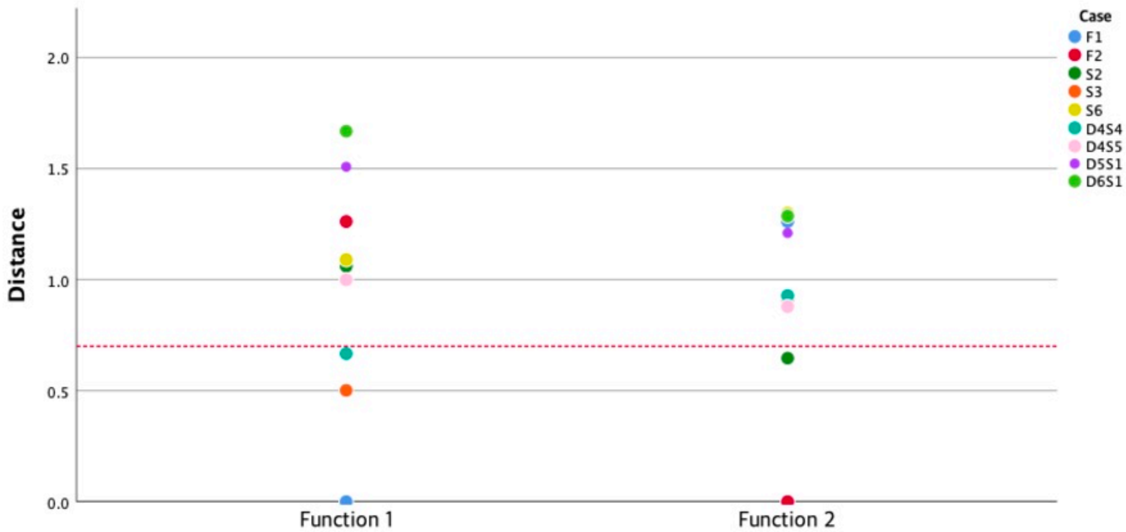


Figure 6.32 Results of similarity evaluation between function units and space units

6.4.2.3 Suitability evaluation of function relationship

With the result of potential suitable space units for the primary function units, programmers still need to evaluate the suitability of the function relationship and spatial organization to test the feasibility of the layout arrangement. As introduced in section 6.3.4, we analyze the risk of spatial organization by means of two indexes as connectivity and integration in space syntax approach.

As for common existing buildings with inner partitions, we usually analyze the integration value in the convex map to compare the accessibility of each rooms in the building. In this case, the existing site is a building cluster and potential space units for the primary function are complete vacant spaces or extension of the existing building. Therefore, each factory and outdoor spaces can be considered as a room in the whole site. From this perspective, we divide all of existing factories and vacant outdoor spaces into combination of convex shapes and link them as the existing relations shows. Figure 6.33 shows the integration analysis results applying DepthmapX software. Spaces in red color have higher integration values than those in dark blue color. Then central corridor in red color has the highest integration value of 2.703 and 1.978, while the space of D5 building in dark blue on the northern edge of the site has the lowest integration value of 0.795. Comparing the alternative space units for the 1500-seat theater of S2, S3 and D4S4, it is seen that the space unit S2 has higher integration value than S3 and D4S4, which means higher accessibility in the whole site layout. Table 6.10 provides the detailed data for these three alternative spaces. Space S2 has higher integration, connectivity and choice values than those of S3 and D4S4, verifying its higher accessibility, longer duration of stay, and bigger possibility of going through, which facilitates to attract people to come from other spaces and to stay here for longer time.

Figure 6.33 Integration analysis of convex map of space units

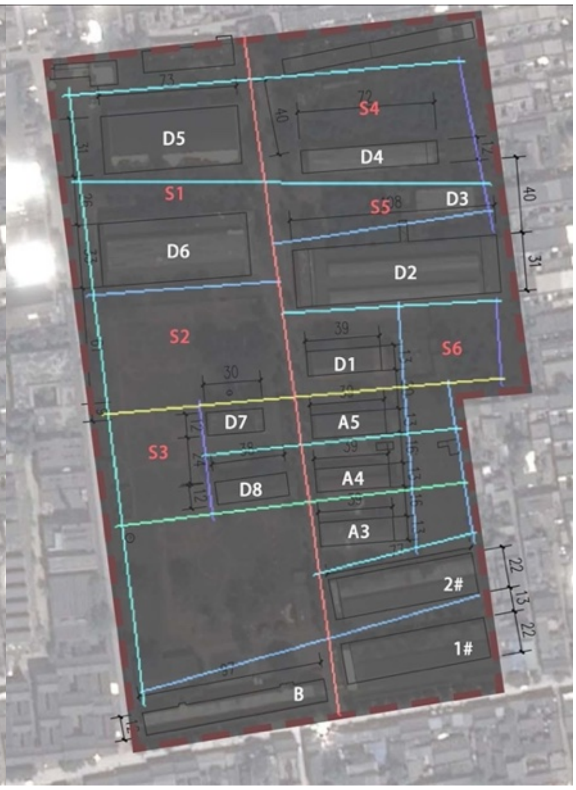


Figure 6.34 Integration analysis of axis map of roads on site

Apart from analyzing the integration of each space considered in a whole site, we could also apply common analysis of road axis to compare the accessibility of roads in front of each space to deduce the accessibility of the potential function unit. Figure 6.34 shows the axis map analysis of the site. Each line is the longest axis in the space of roads. Same as the visualization in the convex map, lines in red color have higher integration values than those in dark blue color. It is the same that the central corridor which connects most spaces has highest integration value than any other paths. Table 6.11 gives the detailed data of the integration, connectivity and choice values of the paths that are adjacent to the alternative space units, and calculate the average values of the northern, eastern, southern, and western paths around the space unit. Again, Space S2 and D4S4 are connected directly to the central corridor and thus are closer to the space with high popularity. It will be a good opportunity to position the entrance of the theater facing to the central corridor to attract visitors. On the contrary, the path of highest integration value of space S3 is the northern path to it, which means the most probable entrance of theater in S3 vacant space will be facing to the north. It will be more difficult to attract people to come and stay here. In conclusion, space S2 is the most preferred space unit for the 1500-seat theater functions in the site.

Table 6.10 Accessibility analysis of space units in convex map

Space units	Integration [HH]	Connectivity	Choice
S2	1.622	4	61
S3	1.267	4	29
D4S4	1.096	2	0

Table 6.11 Accessibility analysis of boundaries of space units in axis map

Boundaries	Integration [HH]	Connectivity	Choice
S2-N	1.541	2	1
S2-E	4.878	10	128
S2-S	2.661	6	32
S2-W	1.552	6	29
S3-N	2.661	6	32
S3-E	1.330	3	2
S3-S	2.252	5	40
S3-W	1.552	6	29
D4S4-N	1.722	3	4
D4S4-E	1.045	3	2
D4S4-S	1.722	3	8
D4S4-W	4.878	10	128
S2-Average	2.658	6	47.5
S3-Average	1.949	5	25.75
D4S4-Average	2.342	4.75	35.5

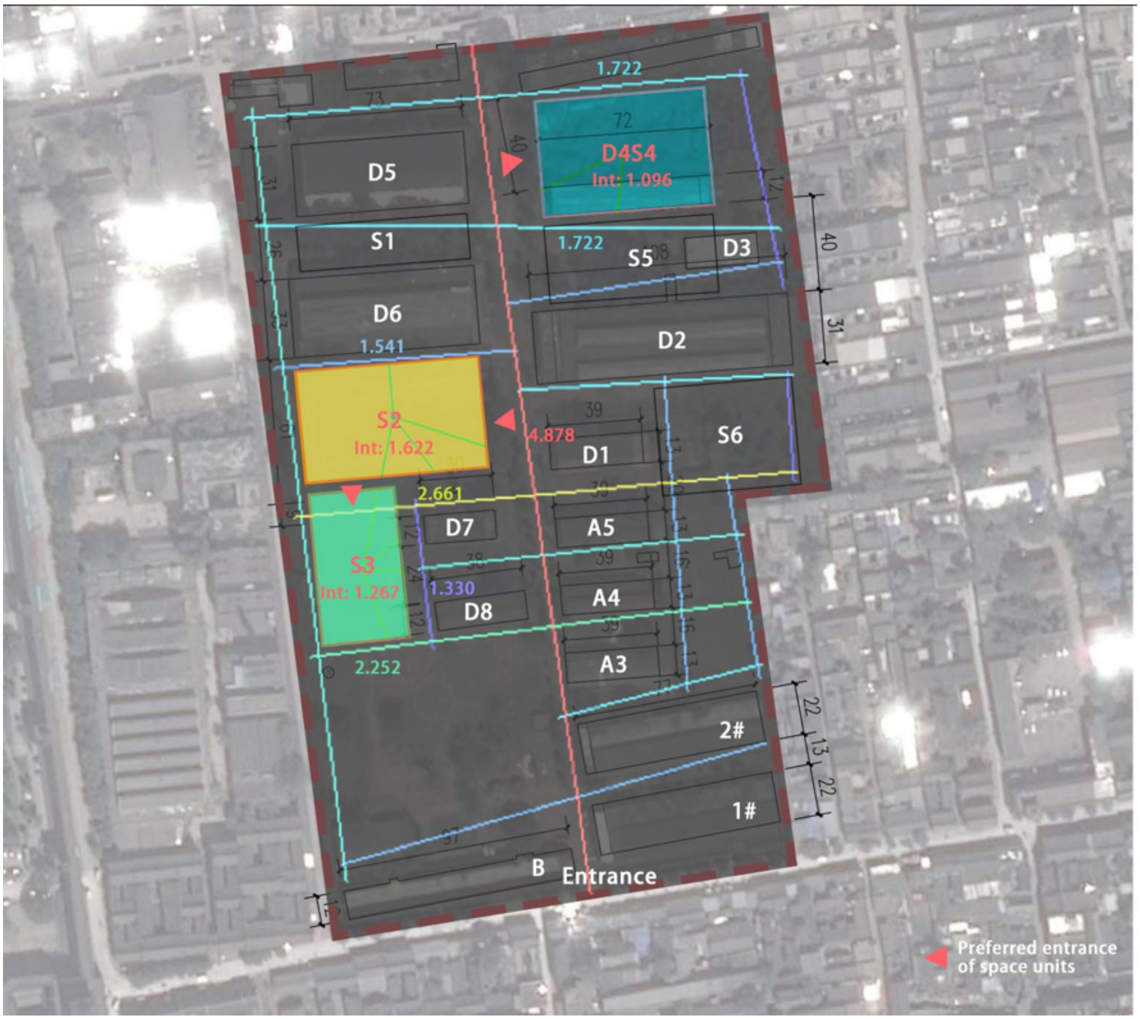


Figure 6.35 Final result of suitability evaluation

Figure 6.35 visualizes the results of the suitability evaluation for the primary function in the case of Pingyao film palace. This case applies the three steps in the process of suitability evaluation including topological transformation, evaluation of function unit and function relationship. The final choice for the primary function is the same as the one chosen by the architects and in the final project (Figure 6.36), which verifies the effectiveness of the process and methods developed in this chapter.

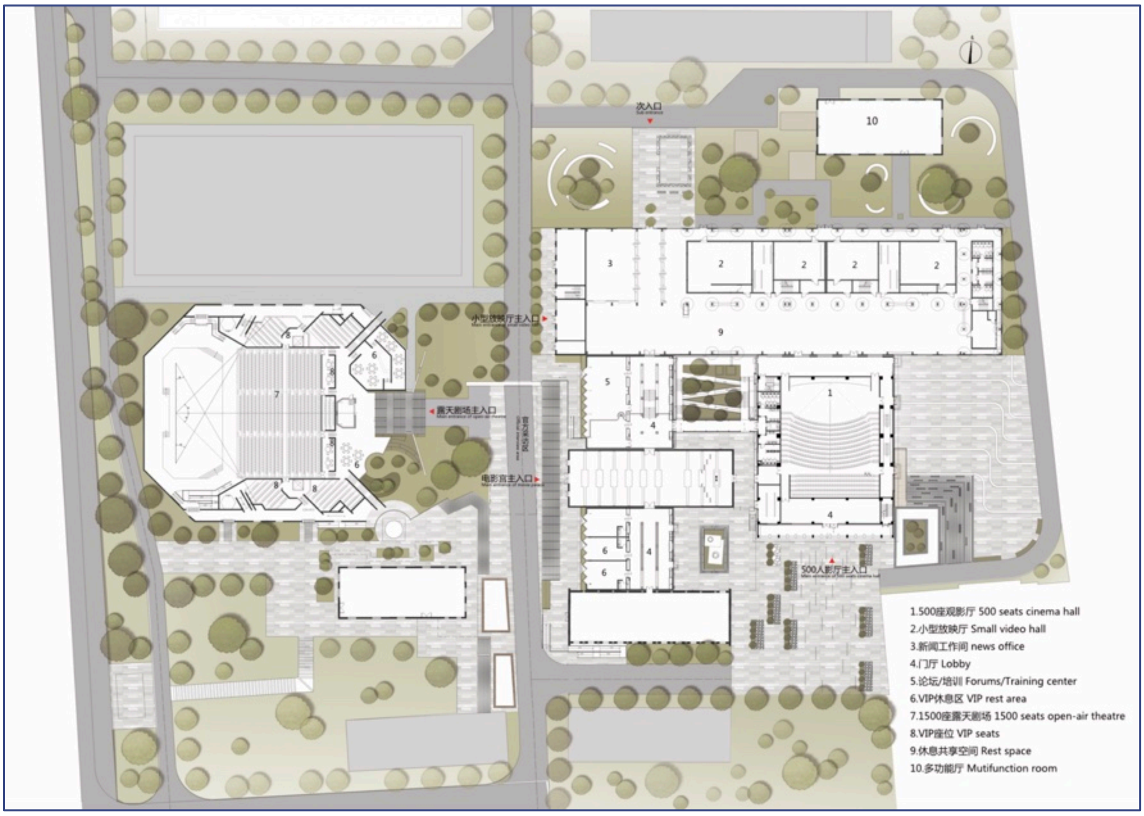


Figure 6.36 Ground floor plan of Pingyao Film Palace © THAD

6.5 Conclusion

This chapter represents the research on last missing step in renovation architectural programming, which is the suitable analysis of existing space and proposed functional program in program evaluation step. It is also a necessary and even last step before drafting the design proposal.

The conclusions in this chapter are as below:

1) **Identify the definition and contents of suitability evaluation of function and space.** Based on literature review of program evaluation or pre-evaluation in classic architectural programming, it first analyzes the deficiency in the current researches and the requirements of program evaluation for renovation projects. Then it provides the definition of suitability evaluation, to match the requirements of proposed function program in the previous step with the features of existing spaces. The contents of suitability evaluation include three parts: rationality of the function program, feasibility of primary function and feasibility of function relationships.

2) **Provide the evaluation model and methods to evaluate the suitability of new**

functions and existing spaces. Based on the content framework, the research provides corresponding methods for the evaluation model. The model first assesses the function program and explore the spatial potential respectively, and then matches the function and space from two perspectives of unit and relation. In the process, data science methods of distance measure, similarity measure, and typology methods of space syntax are utilized comprehensively to provide a practical tool set for programmers and architects.

3) **Verify the evaluation model in two different cases**. Since renovation projects have various kinds and differ in many aspects, they do not all apply each step in the evaluation model but can partly utilize the assessment method instead. This chapter provides two cases with different situations and concerns of program evaluation, which apply different steps in the evaluation model based on the requirements and initiation conditions. The application of the suitability evaluation models in two cases is expected to provide reference for future practice.

The purpose of evaluating suitability between the function program and existing spaces is to uncover problems of the draft version of function programs, and then warn the potential risks for adjustment and improvement of the function program, which facilitates to generate rational design proposals.

CHAPTER 7 Conclusion

7.1 Summary of research content

The thesis is based on the background of quantities of building stock in China nowadays, with relevant problems of irrational and unscientific decision-making regarding renovation function programs in practice. To cope with this problem, the thesis engages architectural programming theory for universal construction projects into the pre-design phase of renovation projects. It is intended to enhance the process and framework of architectural programming for existing building renovation, and to provide corresponding scientific methods for making decisions on renovation functions.

The thesis has two research purposes. One is to engage architectural programming theory to the pre-design phase of renovation projects to cope with the issues above. The other one is to extend the architectural programming theory and its methodology from universal construction projects to renovation of urban existing buildings.

To achieve the research purposes, it first cognizes the distinguishing characteristics of renovation projects; it then analyzes the concept and core idea of traditional architectural programming theory, and summarizes the limitations of it when dealing with renovation projects. After that, it absorbs experience from practice to supplement the theoretical research. At last, it improves the framework and methods of architectural programming to solve the problems in renovation of urban existing buildings.

Based on the research purposes and research path, it extracts three main research questions:

1) What are characteristics and framework of architectural programming for existing building renovation projects that satisfy multiple objectives and benefits of different stakeholders?

2) What are methods to facilitate identification of suitable new functions for the existing building that could regenerate both the building and the surrounding urban spaces?

3) How can architects analyze the suitability of existing building space and potential functional program to generate renovation design proposal?

For the first research question, it starts from the classic framework of architectural programming composed of five steps including goal setting, information collection, program conception, program evaluation and generation of the design proposal. It then analyzes the theory, renovation characteristics and practice. The final result for this question is to propose the updated framework of architectural programming of urban renovation projects. In this framework, it supplements renovation information collection, function identification and suitability evaluation of function and space into three steps of the universal framework of architectural programing, which are information collection, program conception and program evaluation. Chapter 4, 5 and 6 are researches for each supplemented step respectively.

As for the second question, which is presented in Chapter 5, the research is based on multiple criteria decision analysis (MCDA) theory and proposes a basic decision-making process with multi-stakeholder participation, including three steps of structuring the decision situation, structuring the MCDA model, and evaluating the function alternatives. It provides a criteria index of function identification for reference from social, economic, environmental, cultural, aesthetic and technical dimensions. With the help of ELECTRE III method, it can obtain the final ranking of function alternatives. The structured multi-criteria decision-making process and method can facilitate a transparent and rational decision-making for identifying the new function.

For the last question, which is studied in Chapter 6, the research proposes evaluation contents for evaluating the suitability between new functions and existing spaces in architectural programming, including rationality of the function program, analysis of spatial potential based on topology, suitability of function unit as well as suitability of function relationship. It utilizes topology theory to generate potential space organization, and comprehensively applies distance measure, similarity measure and space syntax, to evaluate the three contents above, in order to generate at last the design proposal for the existing building renovation projects.

7.2 Implications

This thesis researches on the framework and methods of architectural programming in urban renovation projects with function transformed or enhanced. From the perspective of theory, it proves the architectural programming theory can be developed specific to the field of renovation. From the perspective of practice, it provides the working process and relevant methods to facilitate decision-making in the pre-design phase of renovation projects. The thesis also has implications for the discipline to develop architectural programming theory in a certain context.

7.2.1 Implications for theory

• Extends the architectural programming theory and method system from universal construction projects to renovation of urban existing buildings

For the theoretical perspective, the thesis enhances the classic architectural programming theory to adapt to specific renovation projects. Urban existing building renovation in this research is considered as a specific building type, to be studied from perspectives of design characteristics, programming process, methods and tools. It is not only due to the necessity in the development of the era of stock, but also helps to enhance the theory system of architectural programming. Before, architectural programming was studied mainly for common new construction projects. However, the existing building renovation should consider comprehensively the characteristics of the building itself, its multiple values, elements to be preserved, the identification for its new functions, feasibility of regulatory, technical, and financial aspects, in order to achieve sustainable development in the long run for the existing building and surrounding urban spaces.

7.2.2 Implications for practice

For the practical perspective, the thesis updates both the working process and the methods and tools for architectural programming of urban renovation projects, to support architects and stakeholders to conduct scientific analysis and make rational decisions in the pre-design phase.

• Provide working process for the pre-design phase of urban renovation projects

The thesis provides a suggested working process for the pre-design phase of urban renovation projects based on architectural programming theory. Architects, clients, or the architectural programming team can refer to this procedure when organizing the group work in the pre-design phase.

• Provide checklists, methods and tools to support the pre-design phase of urban renovation projects

The thesis provides checklists, methods and tools to facilitate architects or programmers to collect information and make decisions in each step of the working process for the pre-design phase of urban renovation projects. It also presents examples of applying them in real projects. The methods and tools can also support the promotion of architect responsibility system in China, to extend the service scope of architects to the pre-design phase of construction projects.

7.2.3 Implications for discipline

• Conduct research in a two-clued structure of theory and practice rather than conventional dichotomized research in discipline

The thesis applies architectural programming theory in the context of urban renovation, developed in a two-clued structure of theory and practice throughout the research. In each chapter, it not only reviews and develops the theory by synthesis and deduction, but also extract experience of architects and cases in practice, synthesize these two clues to deduct the final results and conclusions. It also presents a path to develop architectural programming theory in any subdivision field.

This research path poses a critical reflection on the conventional dichotomy between theory and practice in the architectural discipline. On the one hand, Unilateral theoretical research sometimes has the risk of lacking practicality in real projects, which architects cannot apply to the design practice. On the other hand, architectural design is considered as an experience-based profession, which relies much on the accumulated experience of architects. If this kind of experience cannot be extracted and refined to theory and methodology, it is difficult to pass on the experience and young architects with less experience will find it hard to make scientific design decisions and schemes.

7.3 Limitations and future work

This thesis has several limitations as below to be researched in the future work.

1) The framework and methods should be verified in more real cases: the thesis is based on literature review from theoretic perspective and case study from practical proper perspective. But it still needs more real projects to verify the proposed framework. It should collect cases and construct a database of renovation projects to provide more comprehensive reference for the architecture programming in urban existing building renovation. The database of renovation cases can further develop the framework and refine the process and methods to cope with more situations in practice. Besides, application can be developed for collecting renovation information: the thesis provides an information index system for collecting renovation information in the pre-design phase, but it can further develop an application or online tools to support information collection

with online checklist or plug-ins to support the step in practice.

2) Research on integrative decision-making on function distribution for clusters and function identification for single buildings: the function identification in this thesis is based on a determined function distribution in the circumstance of building cluster projects. But for many cluster cases like industrial parks, which are common in China, the function distribution for clusters and function identification for single buildings are sometimes an integrated problem which requires an integrated method to make decisions. In future researches, the multi-criteria decision analysis method can be applied in the whole process of function distribution and identification.

3) Potential in the form and spaces of existing buildings: this thesis focuses on the decision-making in the pre-design phase for identifying new functions and evaluating suitability of function space to generate the design proposal. While this question can be researched from another perspective of architecture, which is the potential in the form and spaces of existing buildings. The potentials in the form, function and space can be studied through building values, conditions, structures, time, financial conditions, etc., combining the building typology theory with multi-criteria decision-making analysis, in order to provide suggestions for building reuse.

4) Suitability evaluation of function and space applies graph matching theory: the thesis divides the problem of suitability evaluation function space into four contents. But since both function programs and existing spaces are graphs in abstract, it can use machine learning methods if graph matching problems. Graph matching problems are always an issue in graph. Since it is an NP-hard question, it still needs further researches in machine learning and graph theories to be implemented in architectural programming.

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Appendix A Questionnaire

Questionnaire of Decision-Making Mechanism in the Renovation of Urban Existing Buildings

Hello! Thank you for taking 5-8 minutes out of your busy schedule to fill out this questionnaire. This questionnaire is only for the academic research of PhD students from the school of architecture, and the personal information you fill out is in an anonymous form and will be kept strictly confidential.

The renovation objects involved in this questionnaire are urban existing buildings, not including heritage buildings, old residential quarters or other rural buildings. Thank you for your understanding and cooperation!

1. What is your gender?

   ○Female ○Male
2. What is your age?

   ○20-29 ○30-39 ○40-49 ○50-59 ○Above 60
3. What is your education?

   ○Bachelor's degree and college

   ○Master's degree

   ○PhD and post-doctoral
4. Have you ever participated in urban renewal projects of existing buildings? [Single-choice] *

   ○Participated in the whole project process

   ○Participated in the project evaluation and preliminary research

   ○Not involved, but have some understanding

   ○Not involved and have no idea
5. Which party's interests do you represent in urban building renovation projects? [Single-choice] *

   ○Government

   ○state-owned financing platform company

   ○Planners/architects

   ○Investment company

○Other

6. Which of the following types of urban existing building renovation projects have you been involved in? [Multiple choice] *

   ☐ Government-led renovation (including investment companies led by them)

   ☐ Investment company-led renovation

   ☐ Planner/architect-led renovation

   ☐ Other

7. What is the percentage of projects you are involved in that have government involvement versus no government involvement? [weighted question] *

   With government involvement ________________________

   No government involvement ________________________

   Hint: Please fill in the numbers, the sum of all items must be equal to 100

8. In the renovation projects led by the government and its affiliates that you are involved in, what is the weight of opinion of each party regarding the functional identification of the building after renovation? [weighted question] * (Total weight is 100%)

   Government and its lead company ________________________

   Investment companies ________________________

   Planning and architecture experts ________________________

   Citizens, community residents ________________________

   Hint: Please fill in the numbers, the sum of all items must be equal to 100

9. Which of the following contents of pre-design phase have you been involved in regarding architectural programming for renovation projects led by the government and its affiliates? [Matrix Scale Questions] *

	Involved	Not ever involved but want to participate in	Not ever involved and think it's unnecessary to participate in
Building diagnosis (deterioration of structural elements, etc.)	○	○	○
Existing building analysis (historical information, value analysis, etc.)	○	○	○
Analysis of the surrounding urban area	○	○	○
Functional identification study for renovation (feasibility of renovation)	○	○	○
Goal setting with municipalities	○	○	○

	Involved	Not ever involved but want to participate in	Not ever involved and think it's unnecessary to participate in
and investors			
Discussion with structural experts on the potential modifications	○	○	○
Study of cost control strategy	○	○	○
Study of project phasing strategy	○	○	○
Interviews with former users	○	○	○
Interviews with surrounding residents and citizens	○	○	○

10. In the renovation project led by the investment company you are involved in, what is the weight of opinion of each party regarding the functional identification of the building after renovation? [weighted question] * (The total weight is 100%)

    Government and its lead company ________________________

    Investment companies ________________________

    Planning and architecture experts ________________________

    Citizens, community residents ________________________

    Hint: Please fill in the numbers, the sum of all items must be equal to 100

11. Which of the following contents of pre-design phase have you been involved in regarding architectural programming for renovation projects led by the investment company? [Matrix Scale Questions] *

	Involved	Not ever involved but want to participate in	Not ever involved and think it's unnecessary to participate in
Building diagnosis (deterioration of structural elements, etc.)	○	○	○
Existing building analysis (historical information, value analysis, etc.)	○	○	○
Analysis of the surrounding urban area	○	○	○
Functional identification study for renovation (feasibility of renovation)	○	○	○

	Involved	Not ever involved but want to participate in	Not ever involved and think it's unnecessary to participate in
Goal setting with municipalities and investors	○	○	○
Discussion with structural experts on the potential modifications	○	○	○
Study of cost control strategy	○	○	○
Study of project phasing strategy	○	○	○
Interviews with former users	○	○	○
Interviews with surrounding residents and citizens	○	○	○

12. In the renovation project led by the planners or architects you are involved in, what is the weight of opinion of each party regarding the functional identification of the building after renovation? [weighted question] * (The total weight is 100%)

    Government and its lead company ________________________

    Investment companies ________________________

    Planning and architecture experts ________________________

    Citizens, community residents ________________________

13. Which of the following contents of pre-design phase have you been involved in regarding architectural programming for renovation projects led by the planners or architects? [Matrix Scale Questions] *

	Involved	Not ever involved but want to participate in	Not ever involved and think it's unnecessary to participate in
Building diagnosis (deterioration of structural elements, etc.)	○	○	○
Existing building analysis (historical information, value analysis, etc.)	○	○	○
Analysis of the surrounding urban area	○	○	○
Functional identification study for renovation (feasibility of renovation)	○	○	○
Goal setting with municipalities	○	○	○

	Involved	Not ever involved but want to participate in	Not ever involved and think it's unnecessary to participate in
and investors			
Discussion with structural experts on the potential modifications	○	○	○
Study of cost control strategy	○	○	○
Study of project phasing strategy	○	○	○
Interviews with former users	○	○	○
Interviews with surrounding residents and citizens	○	○	○

14. In order to regenerate existing buildings and their urban areas and make them sustainable, how important do you think the following factors are? [Matrix question]* (If you have nothing to add, you may not fill in "specify".)

	Not important	Slight important	Important	Fairly important	Very important
Full understanding and exploitation of the value of existing buildings	○	○	○	○	○
Accurate functional identification (fitting the building's characteristics and urban development strategy)	○	○	○	○	○
Good integration of the building with the urban environment	○	○	○	○	○
Visually attractive renovation solutions	○	○	○	○	○
Building performance enhancement	○	○	○	○	○
Consideration of phased renovation (e.g. micro-renewal, incremental renewal)	○	○	○	○	○
Ability to sustain operations in the long run	○	○	○	○	○
Others (if not, please click very small)	○	○	○	○	○

15. What degree of influence do you think do the following factors have on limiting the renovation of urban existing buildings? [Matrix question]* (If you have nothing to add, you may not fill in "specify".)

	No influence	Slight influence	Moderate influence	Fair influence	Significant influence
Lack of policy support	○	○	○	○	○
Inadequate industry standards and norms	○	○	○	○	○
Government decision-making capacity and preferences	○	○	○	○	○
Lack of pre-planning steps and methods	○	○	○	○	○
Single investment model / high investment risk	○	○	○	○	○
Professional level of designers	○	○	○	○	○
Deficiencies in retrofitting construction techniques	○	○	○	○	○
Lack of post-operation	○	○	○	○	○
Deficiency of design and construction cycle	○	○	○	○	○
Others (If not, please click very small)	○	○	○	○	○

16. Please write down the most satisfying urban renovation project you have done for existing public buildings: [fill in the blank] *

____

17. Please check the reasons why you think this project is successful: [Multiple Choice] *

☐ Comprehensive preliminary research ☐ Accurate function identification

☐ Excellent design scheme ☐ Good construction quality

☐ Good cost control ☐ Full consideration of the relationship with the city

☐ Good post-operation ☐ Tactful cooperation among all parties involved

Appendix B Renovation cases in characteristic analysis

Owner & Investor: G (government), PE (private-enterprise), SE (state-owned enterprise)

Decision-type: G-led (government-led), E-led (enterprise-led), Ex-led (expert-led)

Location	Project	Function renovation		Renovation drivers			Decision-making		
		Transformation	Enhance ment	Status before renovation	Not reconstruction	Motivation	Owner	Investor	Decision type
China	Longfu Building, Beijing	Commercial to Office mixed-use	/	Obsolete	Historic value	Economic, social value	SE	SE	G-led
China	Hongyi media building, Beijing	/	Office	Bad performance	Budget limit; regulation	Economic	SE	SE	E-led
China	Huamu office buildin, Beijing	/	Office	Bad performance	Regulation	Performanc e	SE	SE	E-led
China	Zhongguancun Jinyu Park, Beijing	Industrial park to office	/	Obsolete	Regulation	Transformi ng industry	PE	PE	E-led
China	Lang Station, Bejing	Industrial park to cultural creation park	/	Obsolete	Social value	Transformi ng industry	SE	SE	E-led
China	Lang Vintage, Beijing	Industrial park to cultural creation park	/	Obsolete	Social value	Transformi ng industry	SE	SE	E-led
China	Tongniu factory, Beijing	Industrial to office	/	Obsolete	Social value	Transformi ng industry	SE	SE	G-led
China	the 7th Paper production plant, Beijing	Industrial to office	/	Obsolete	Social value	Transformi ng industry	SE	SE	G-led

APPENDIX B CASES FOR CLUSTER ANALYSIS

Location	Project	Function renovation		Renovation drivers			Decision-making		
		Transformation	Enhancement	Status before renovation	Not reconstruction	Motivation	Owner	Investor	Decision type
China	Shougang park, Beijing	Industrial park to Olympic venue	/	Obsolete	Historic value	Mega-event	SE	SE	G-led
China	Xidan regeneration park, Beijing	/	Commercial	Bad performance	Social value	Economic	SE	SE	E-led
China	Qingpu gymnasium and trainning center, Shanghai	/	Gymnasium	Bad performance	Budget limit	Social	G	G	G-led
China	Xi'an office building, Shanghai	/	Office	Bad performance	Budget limit; regulation	Performance	SE	SE	G-led
China	Department of future design of BNU, Zhuhai	/	Educational	Bad performance		Performance	G	G	G-led
China	Pingyao film palace, Pingyao	Industrial park to film festival venue	/	Obsolete	Time limit; cultural value	Mega-event	G	G	G-led
China	Taoxichuan museum, Jingdezhen	Industrial park to cultural creation park	/	Obsolete		Transforming industry	SE	SE	G-led
China	Jinwei Beer factory, Shenzhen	Industrial park to new industry park	/	Obsolete	Social value	Transforming industry	SE	SE	G-led
China	SMOORE Liutang industrial park, Shenzhen	Industrial park to office	/	Bad performance		Transforming industry	PE	PE	E-led
China	E'ling second factories,	Industrial park to cultural creation park	/	Obsolete		Transforming industry	SE	SE	G-led

APPENDIX B CASES FOR CLUSTER ANALYSIS

Location	Project	Function renovation		Renovation drivers			Decision-making		
		Transformation	Enhancement	Status before renovation	Not reconstruction	Motivation	Owner	Investor	Decision type
	Chongqing								
China	Hongguang electric plants, Chengdu	Industrial park to cultural creation park	/	Obsolete		Transforming industry	SE	SE	G-led
Italy	Eataly Lingotto, Turin	Factory to Commercial	/	Obsolete		Transforming industry	G	PE	E-led
Italy	Pastificio Italiano, Turin	Factory to hotel	/	Obsolete	Historic value	Economic	G	PE	E-led
Italy	Enrico Fermi School, Turin	/	Educational	Bad performance		Performance	G	PE	E-led
Italy	OGR,Turin	Industrial to cultural center	/	Obsolete	Historic value	Transforming industry	PE	PE	E-led
Italy	Vittoria International school, Turin	Historic to school	/	Obsolete	Historic value	Performance	PE	PE	E-led
Italy	Former Arsenal, Turin	Industrial to school	/	Obsolete	Historic value	Transforming industry	PE	PE	E-led
Italy	National Automobile Museum, Turin		/	Bad performance			PE	PE	E-led
Italy	Torre Velasca, Milan	Commercial and residential to mix-used with office	/	Bad performance	Historic value	Economic	PE	PE	E-led
Italy	Milan Verdi school Bosco della musica	Industrial to school	/	Obsolete	Historic value	Transforming industry	G	PE	G-led

APPENDIX B CASES FOR CLUSTER ANALYSIS

Location	Project	Function renovation		Renovation drivers			Decision-making		
		Transformation	Enhance ment	Status before renovation	Not reconstruction	Motivation	Owner	Investor	Decision type
						+ Social			
Italy	Aparto Milan Ripamonti, Milan	industrial to residential	/	Obsolete	Economic, time limit	Social + economic	PE	PE	E-led
Italy	Foundazione Prada, Milan	Industrial to arts center	/	Obsolete	Historic value	Economic			
Italy	Eridania sugar factory, Parma	Industrial to performance	/	Technical problems	Historic value	Economic + social	G	PE	G-led
France	La Poste du Louvre	Post office to Mix-ed use	/	Bad performance	historic value; cultural value	Social + economic	SE	SE	E-led
France	La Samaritaine depart ment store, Paris	Commercial to mix-ed use		Technical problems	Historic value	Economic	PE	PE	E-led
France	Bourse de Commerce, Paris	Stock exchange to museum		Obsolete/ Bad performance	Historic value	Social + economic	G	PE	E-led
France	Morland Mixité Capitale, Paris	Public administration to mixed-use		Bad performance	Historic value; policy	Economic	PE	PE	E-led
Netherlan ds	Rijnstraat 8, Hague		Public administ ration	Bad performance	Economic, time limit	Performanc e	G	G	G-led

Appendix C Information collection checklist in architectural programming of urban renovation projects

Here is the outline of information collection checklist studied in Chapter 4.

Macro level: urban information

Urban planning information

1. Master planning
2. Detailed planning
3. Sectoral planning
4. Urban renewal planning: unit scheme of urban renewal, unit plan of urban renewal
5. Industrial planning
6. Supporting policy: function-oriented; project-oriented
7. Design criteria of specific area

Uncertain initiation conditions

8. The motivation for the renovation
9. Reasons for renovation instead of reconstruction
10. The goals of the renovation
11. Financial source
12. Conditions of land leasing
13. Property rights
14. Stakeholders and decision makers
15. Time constraints

Site and surroundings

16. Geography and geology: geography, geology, hydrology
17. Sunlight and acoustics: over-shading analysis, acoustics analysis
18. Landscape
19. Social: surrounding resources, facilities, people
20. Human and Culture: population, cultural resources nearby
21. Aesthetic: local aesthetic feature

22. Transportation: on site, surrounding traffic
23. Economic: market value
24. Technical: parking, construction
25. View (visuality)

Medium level: building information

Basic information: technical and historical

1. Architectural drawings
2. Function-space list
3. Building codes
4. Historic information
5. Phases division
6. Detailed recordings for each phase

Building diagnosis

7. Surveying and drawings: horizontal surveying, vertical surveying, details, 3D scanning
8. Structural diagnosis: investigations, analysis of current state
9. Energy audit: current state, upgrade potential
10. Geological geotechnical and seismic report
11. Site photos: surroundings, outdoor space, interior space

Spatial analysis

12. Characteristics of each space unit
13. Internal flows
14. Spatial relationship matrix
15. Space mapping: convex map, axial map, segment map

Micro level: user information

User profile

1. Basic feature
2. Behavior patter: living habits, social behavior, social distance, travel modes
3. Attitude feature

4. Individual requirement: functional, psychological
5. Organization structure

Using pattern and requirement

6. User organization
7. User capacity
8. Daily activities
9. Movement trails

Operation mode

10. Social organizations
11. Business operation
12. Cultural operation
13. Property management

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To be added…

声　明

本人郑重声明：所呈交的学位论文，是本人在导师指导下，独立进行研究工作所取得的成果。尽我所知，除文中已经注明引用的内容外，本学位论文的研究成果不包含任何他人享有著作权的内容。对本论文所涉及的研究工作做出贡献的其他个人和集体，均已在文中以明确方式标明。

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