Vinnytsia National Technical University
(full name of higher education institution)
Faculty of Construction, Civil and Environmental Engineering
(full name of the institute, name of the faculty (department))
Department of construction, urban planning and architecture
(full name of the department (subject, cycle committee))

MASTER'S QUALIFICATION THESIS

Management system for contemporary material utilization in the exterior wall construction of energy-efficient buildings

Executed: Second grade student, group__III B-22m
specialty 192 Construction and Civil Engineering
(code and name of training direction, specialty)
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Supervisor: PhD., Associated Prof. Olena LIALIUK
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Approved to be defended
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(full name of the higher education institution)

Faculty of Construction, Civil and Environmental Engineering

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Department of construction, urban planning and architecture

Education level master

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Educational program industrial and civil engineering

APPROVED

Head of Department CUPA

SHVETS V.V.

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T A S K

OF MASTER'S QUALIFICATION THESIS

Zhang Haibiao

(full name)

1. Master's thesis topic Management system for contemporary material utilization in the exterior wall construction of energy-efficient buildings

Master's thesis supervisor LIALIUK O., PhD, Associated Prof.,

(surname, first name, patronymic, academic degree, academic title)

approved by order of the higher educational institution from «13» 09 2022 No 3

2. Deadline for submission of work by a master's student

3. Initial thesis data: Data from the literature review of sources regarding methods of construction project management taking into account energy saving and environmental requirements.

4. The content of the explanatory note (list of issues to be developed): Introduction, which should reflect the relevance of the topic, purpose, scientific novelty, practical significance, task, object and subject of research. The research part, consisting of four sections: In the first section, an overview of the current state of theory and practice, research methods are considered.

In the second chapter, consider the main problems of green construction.

In the third section, analyze the optimization of the management of green construction projects using BIM technology.

In the fourth chapter, perform an engineering check of the application of BIM technology on a specific example. In the fifth chapter - the economic part, to assess the importance and scientific significance of scientific research, the economic efficiency of scientific work is assessed for its possible commercialization by a potential investor.

Conclusions in which to reflect the main scientific and practical results of the work done

5. Consultants of thesis parts

Part	Surname, initials and position of consultant	Signature and date	
		Task issued	Task accepted
Introduction, Chapter 1	LIALIUK O., PhD, Associated Prof	[signature]	[signature]
Chapter 2	LIALIUK O., PhD, Associated Prof	[signature]	[signature]
Chapter 3	LIALIUK O., PhD, Associated Prof	[signature]	[signature]
Chapter 4.	LIALIUK O., PhD, Associated Prof	[signature]	[signature]
Chapter 5. Economic part	LIALIUK O., PhD, Associated Prof	[signature]	[signature]

6. Issue date of the task 14.09.2022

CALENDAR SCHEDULE

No	The name of the stages of the master's qualification work	The term of performance of work stages	Note
1	Scientific analysis of the energy-saving buildings, search for relevant scientific sources, analysis of the modern regulatory framework. Preparation the Chapter 1.	14.09 - 30.09	
2	Preparation the Introduction.	03.10 - 17.10	
3	Preparation the Chapter 2. Problems faced by Green Construction	18.10 - 25.10	
4	Preparation the Chapter 3. Optimization of construction process based on BIM and value engineering	26.10 - 16.11	
5	Preparation the Chapter 4. Engineering Case Verification of China-Denmark Scientific Research and Education Center of Chinese Academy of Sciences	17.11 - 24.11	
6	Preparation the Chapter 5. Economic part	25.11 - 01.12	
7	Preparation for publication and publication of MQT results. Approbation	02.12 - 09.12	
8	Checking work for plagiarism	05.12 - 08.12	
9	Preliminary defense of the master's qualification thesis	12.12 - 16.12	

Graduate student [signature] Zhang Haibiao
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Master's thesis supervisor [signature] LIALIUK O.
(signature) (surname and initials)

ABSTRACT

UDC 691:699.86

Zhang Haibiao. Management system for contemporary material utilization in the exterior wall construction of energy-efficient buildings. Master's qualification thesis on specialty 192 - construction and civil engineering, educational program - Industrial and Civil Engineering. Vinnytsia: VNTU, 2023. 91 p.

English language Bibliography: 61 titles; Fig.: 20; table 22.

This thesis contains the following:

(1) On the basis of case studies, problems and shortcomings of current green construction are classified. Based on the characteristics of the combination, combine LEED (Leadership in Energy and Environmental Design), the Ministry of Construction "Green Building Guidelines" and other standards and construction cases outside of green construction, the proposed overall construction planning and the specifics of green management. (2) In order to improve the economic efficiency of the entire life cycle is added to the traditional selection of schemes based on Value Engineering based on schemes to optimize the construction process.

(3) The ANP model (Analytic Network Process) was used to determine the importance of the functional index based on the full consideration and clarification of the relationship between the functional factors. The implementation of BIM (Building Information Modeling) technology helps to optimize construction at the design decision-making stages, design, construction and engineering management.

(4) Using the example of the green demonstration project of the China-Danish Science and Education Center, the application of BIM technology and the value engineering method in green construction is presented.

Key Words：Green Building, Construction Process Optimization, BIM(Building Information Modeling),Value Engineering

CONTENTS

INTRODUCTION

Actuality of theme. Commercial and residential buildings account for about a third of the total global energy consumption, while industry and transportation each account for about a third. Energy conservation in the construction field has become one of the common concerns of the world. In the field of construction, the proportion of energy consumption varies in different types of countries, with 52% in industrialized countries, 25% in Eastern Europe , and in developing countries for 23%. However, building energy consumption in developing countries grew the fastest: 6.1% / year in developing countries, 3.4% / year in Eastern European countries, and 0.6% / year in industrialized countries. [1-3].

Japan has established a sound residential energy conservation system, promoted the industrialization development of energy conservation and environmental protection, and attaches importance to raising the awareness of energy conservation and environmental protection in the whole society. For example, the "residential performance" is based on the "Product assurance method (residential quality assurance promotion method)", which began its implementation in 2000. In the representation system ", the residential thermal environment, energy conservation and other projects have been set an evaluation benchmark. As a model of efficient building operation and management, Japan implemented the Revised Energy Conservation Law, which was implemented in 2003, incorporated energy conservation in building operation process into daily management to maximize the benefits of various measures of building energy conservation.[4-6]

The guarantee of energy saving is correctly calculated and built enclosing structures: carefully insulated walls, floor, roof, windows and doors.

Connection of work with scientific programs, plans, topics.

This work was carried out within the framework of the directions of scientific research of the Department of Construction, Urban Economy and Architecture of VNTU, specialty 192 "Construction and Civil Engineering".

Purpose and tasks of the research

The purpose of the work is to increase the energy efficiency of buildings by creating theoretical foundations and developing and implementing into the practice of management of the construction industry a scientifically based system for making effective organizational and technological decisions at residential, civil and industrial facilities using the construction of a VIM model.

Research tasks:

Research and compare different green and energy efficient building management methods.

Identify the similarities and differences of green construction projects from conventional engineering projects, identify the main problems.

Optimize the construction process based on bim and value engineering.

Is to take the project of China-Denmark Scientific Research and Education Center of Chinese Academy of Sciences as an example, to verify the optimization of the green construction process, and to analyze the rationality of the results

Write conclusions about the obtained results and propose measures to manage the construction of a green and energy-efficient house.

Object of study

The object of the study is management of construction production projects taking into account environmental and energy parameters..

Subject of study

The subject of the study is management system for the use of materials in the construction of green energy-efficient buildings.

Methods of research

Methods of process and functional approaches in the management of green construction projects. The theoretical basis of the research was made up of publications by foreign and domestic authors in green construction.

Scientific novelty of the obtained results.

The value engineering is used to green construction according to green building construction characteristics, and the functional requirements and life cycle cost factors of green building are clarified .Then the construction schemes are optimized and selected via engineering. The ANP (shorter form of Analytic Network Process) ,model was used to determine the importance of functional index on the basis of full considering and clarifying the relationship among the functional factors. Then BIM(Building Information Modeling)technology as a new technology is introduced to assist the construction optimization in project decision-making, design,construction and maintenance management phases.

Practical significance of the obtained results.

Taking the example of green demonstration project of China-Denmark research and education and education center, the application of BIM technology and value engineering method in green construction is introduced.

The results of the examples show that, as a new technique for the application of BIM in green construction and value engineering in construction scheme optimization and selection can play good roles in the whole life period; the ANP method which determine the functional interdependencies on the value analysis using, is easy to promote and operate in practical projects. It also has good guidance for the geen construction Optimization , with the application of BIM and value engineering. It provides new ideas and methods for the demonstration and promotion of green construction.

Personal contribution of the master's student.

Using the example of the green demonstration project of the China-Danish Science and Education Center, the application of BIM technology and the value engineering method in green construction is presented.

Approbation of the results of the master's thesis.

The main results of this work were presented at the thesis in the electronic version on the website of VNTU in the international scientific and practical conference "Innovative technologies in building and construction" – «The use of modern materials in the construction of external walls of energy-efficient buildings» (23.11.2022) in Vinnytsia. Https://conferences.vntu.edu.ua/index.php/itb/itb2022/paper/view/16682

Publications.

1. Olena LIALIUK, *Zhang Haibiao, Andriy Oleksandrovich Lyalyuk*. «The use of modern materials in the construction of external walls of energy-efficient buildings» / the thesis in the electronic version on the website of VNTU in the international scientific and practical conference "Innovative technologies in building and construction"/ (23.11.2022) in Vinnytsia. https://conferences.vntu.edu.ua/index.php/itb/itb2022/paper/view/16682

1 ANALYSIS OF THE CURRENT STATE OF THEORY AND PRACTICE ON THE TOPIC OF THE MASTER'S THESIS

1.1 Research background and significance

Green energy-saving building (Green Building) refers to the building that saves resources (to the maximum extent, land saving, water saving, material saving), protects the environment and reduces pollution, provides healthy, applicable and efficient use space, and coordinates with the nature[1]. Nowadays, the rapid urbanization process, the huge amount of infrastructure construction, natural resources and environmental restrictions determine the great significance and time urgency of China's building energy conservation work[2][3]Therefore, it has become the trend of construction projects from the traditional high consumption to the efficient development mode, and the promotion of green building is the key to realize this transformation[4]. Green and energy-saving building construction, in line with the strategic goal of sustainable development, is conducive to the innovation of building construction technology, and to achieve the maximum realization of green building design, construction and management, so as to obtain greater economic benefits[5]Social benefits and ecological benefits, optimize the allocation of manpower, material resources and financial resources in the construction process[6]This is of great benefit to improving the level of construction management and the cost efficiency of green buildings.

However, the current green construction has not been fully popularized, just started, there are still many problems to be solved [7][8][9]:

(1) lack of green construction concept;

(2) lack of relevant policy support;

(3) lack of construction technology Foot;

(4) Poor supervision of green construction.

In the process of green construction implementation, the relevant laws, regulations and rules are not perfect, resulting in the lack of supervision. In the current green construction environment, there are no mandatory standards on energy consumption and waste discharge. Moreover, the government does not require mandatory construction enterprises to use green construction technology and technology, and still use the traditional standards in the construction management work. These problems greatly restrict the development of green construction in China. It can be seen that in the background of booming green construction, there are still many deficiencies, some of which are uncontrollable external factors, such as lack of relevant policy support, which is difficult to solve from the enterprise level; some are the deficiencies of the enterprise itself, such as the shortcomings of construction technology, lack of green construction concept, and poor supervision of green construction. The reason is that traditional construction methods are used in the organization and management of construction, but less involved in green construction[10]When considering the constraints of green construction, there is a lack of a reasonable and scientific green construction management mode to optimize the process and balance the goals. Therefore, this article will mainly study:

1) sort out the current situation and problems faced by green construction;

2) summarize the characteristics and key problems of green building construction management;

3) optimize the construction process of green building.

It is expected to establish a set of reasonable green building construction process to meet the new needs of green and energy-saving building, solve the problems facing, and consider the key problems of green construction, so as to improve the green construction level of enterprises and enhance the core competitiveness of green and energy-saving building construction.

1.2 Review of relevant studies at home and abroad

1.2.1 Green and energy-saving building and green building construction

"Green Building Evaluation Standard" (cB50378-2006) defines "green building" as: in the whole life cycle of the building, the maximum limit of saving resources (energy saving, land saving, water saving, material saving), environmental protection and pollution reduction, to provide people with healthy, applicable and efficient use of space, and the harmonious coexistence of the nature of the building. Green construction refers to the premise of ensuring the basic requirements of quality and safety in the project construction. Through scientific management and technological progress, the maximum saving of resources and reduce the negative impact on the environment of the construction activities, to achieve "four sections and one environmental protection"[11][12]。

"Green Construction Guidelines" of the Ministry of Comprehensive Construction[13]Definition and LuRongli's definition of green building construction summary: on the premise of ensuring the safety and quality of the project, in the construction of "four sections and one environmental protection", through scientific and effective technical and management measures, optimize the energy structure, reduce the negative impact of the environment, people-oriented, to ensure the safety and health of personnel construction mode[14]。

Traditional construction is mainly concerned about the project progress, project quality and project cost, and there are no high requirements for resource and energy conservation and environmental protection[15], Unless the contract. Therefore, when the traditional construction conflicts with the construction period, the resources and environmental protection will not be taken into account, because the project payment is only related to the progress and the completed work, and the waste of resources and environmental pollution will not be punished. And green construction not only the quality, safety, progress to meet the requirements, but also starting from the whole process of production, according to the concept of sustainable development to the whole planning and construction process, priority to use the green building materials, improve the traditional construction technology and construction technology, on the premise of completing the project, as far as possible to reduce the pollution of the environment and the consumption of materials. The characteristics of green construction can be summarized:

(1) while meeting the traditional needs, give priority to the environmental properties of the building;

(2) maximize the full life cycle of renewable energy to save resources;

(3) pay attention to the overall optimization, take the value engineering as the optimization foundation to ensure the balanced construction target balance;

(4) innovate the technology and methods to realize innovation. Therefore, the requirements of the green construction is much stricter than the requirements of the traditional construction.

1.2.2 Green building construction organization and planning

The construction organization and planning documents provide a basis for the deployment of construction activities, so that the construction can be organized, planned and organized. In order to achieve the scheduled goals of the plan, it must be implemented according to the contents of the construction organization design to ensure the smooth progress of the project[16]. Traditional construction organization planning considering project progress, engineering quality and engineering cost, to save resources and environmental protection has not high requirements, unless the contract is specified, in order to ensure the continuity of construction, rhythm and balance, in the construction process of manpower, material resources, financial overall arrangement, ensure the rationality of the construction scale, make the complex construction activities have unified.

The basis of action, according to the construction organization design plan arrangement, you can coordinate the overall situation to ensure that the construction activities in an orderly way, the smooth completion of the construction task. The focus of construction organization planning is "one case, one table and one map", namely: construction plan, construction schedule plan, construction plan layout[17]。

Different from the traditional building construction organization, the green building construction should consider the benefit constraints of environmental green, energy saving and emission reduction in the whole life cycle based on value engineering. Article 3.3.3 of the Green Construction Management Regulations stipulates: "The construction unit shall prepare green construction technical measures or special construction plans in the construction organization design, and ensure the effective use of green construction costs". That is to say, green construction should start from the preparation of construction organization design (scheme), and the whole process of construction should be strictly controlled and managed, so as to realize land saving, energy saving, water saving, material saving, protect the environment and the health and safety of construction personnel. On the basis of the traditional construction organization and planning, special planning for green construction should also be done, including: special measures for energy saving, special measures for land saving, special measures for water saving, special measures for saving materials and resources utilization, and special measures to control the impact[18]. After the special planning, the traditional construction and green construction should be systematically considered, and the organization process should be optimized under the constraints of green construction[19], Ensure the progress of the project, quality, cost, environmental protection, energy saving, safety, health and other goals of the realization.

1.2.3 Research status quo of green and energy-saving building construction management

Green construction is a systematic project, so the real green construction management work should have the overall nature, should run through the whole project construction process, the requirements of each part of the system, each link and various mechanisms to achieve coordination, give full play to the overall efficiency. From the perspective of sustainable development, Sun Yi had an in-depth discussion on the construction management of green building construction from the aspects of green construction management, green construction environmental protection, utilization of energy saving and environmental protection building consumables[20]; Li Xuecai et al. analyzed the quality and schedule cost of green building construction, and put forward corresponding management measures[21]; On the basis of "three control, two tubes and one coordination" in the traditional project management, Yang Wei actively uses the idea of sustainable development, reflect the harmony between man and nature, adopt corresponding policies and measures to promote the development of construction projects in green construction, and establish a resource-conserving and environmentfriendly green building[22]. BoYang put forward the whole life cycle theory of building energy saving management mode dominated by real estate enterprises[23]. ShaoShuai uses the three-dimensional structure model of HALL to give the multi-stage management model of green building, which has some reference significance but the research is too broad[24]. In engineering practice, GuoNi etc.[25]Taking the green construction management of Qingdao AoFan Base project as an example, it systematically expounds the green construction project management plan, implements the construction management principles of whole process, all-round and full participation, widely adopts green construction technology, and adopts management measures such as ecology, environmental protection and waste reduction. LiuHaifeng told about the specific construction management measures of "four sections and one environmental protection" of Suzhou ZhongYin Building project[26], Can be used for reference for similar projects.

At present, the commonly used green building construction evaluation systems at home and abroad include: Environmental Evaluation method of British Building Research Institute (BREEAM)[27], Green Building Challenge (GBC), US Energy and Environmental Design Pilot Program (LEED) [28], Comprehensive Building Environmental Assessment Method in Japan (CASBEE) [29]; Domestic "China Ecological Housing Technical Evaluation Manual", "Green Olympics Building Evaluation System" (Green Olympic Building Assessment System, GOBAS), "Green Building Evaluation Standard"[30]. Table 1-1 summarizes the proposed countries, applicable stages, use scope and core evaluation indicators of these green building evaluation standards at home and abroad.

Table 1-1 Comparison of different green building evaluation standards at home and abroad

standard	country	Applicable stage	scope of application	Core indicators
BREEAM	Britai	Design stage, the construction stage	Environmental assessment of the new office building design,Environmental assessment of new supermarkets and stores, environmental assessment of new industrial buildings, and	environment pointer

			environmental assessment of existing office buildings	
GBC	Canada	Design stage, the construction stage	Office buildings, school buildings, and collection houses	Resource consumption, environmental load, indoor environment quality, and service quality .Sustainable site design, the effective use of water resources, and energy
LEED	America	Full life	Commercial buildings, public buildings and residential buildings	Source and atmosphere, raw materials and period Resources, indoor environment quality, innovation and design process[30]
CASBEE	Japan	Full life period	Public buildings, schools, and public buildings Environmental efficiency of the building object	
China's ecology Residential Technical Assessment Manual	China	Planning, design,	Design, construction, and build a new residential community	Energy,greening And water, gas, sound, light, thermal environment and waste management and disposal, green building materials environment, energy,water resources,Materials and resources, and indoor environment quality.
GOBAS	China	Construction and acceptance and operation	The Olympic buildings and industrial parks	
Green building evaluation criterion	China	life period	Residential buildings and office buildings, shopping malls, hotels and other public buildings[31]	Land saving and outdoor environment, energy saving and energy utilization, water saving and water resources utilization, material saving and material resources, indoor environment quality and operation management

To sum up, the current domestic green construction management research and practice on the basis of traditional project management has a certain basis, the whole life cycle and sustainable development of ideas applied to the green engineering construction, but the focus is one-sided, just focus on part of the key work, not a set of system for green special construction management mode, for the practical guidance is not strong. At the same time, the green construction standards have played a good guiding role in the green building construction at home and abroad, and it is also necessary to learn from these standard measures in the green construction management.

1.3 Research content and technical route

1.3.1 Selection of the main study methods

⑴ The main methods adopted in the data collection and analysis are:

1)Literature research method. The history, definition, function and characteristics of green building construction at home and abroad, and the literature of green building construction evaluation, will be reviewed and sorted out, as the theoretical basis of this article;

2)case study method. Taking the project of China-Denmark Scientific Research and Education Center of Chinese Academy of Sciences as an example, conduct data analysis, expand theoretical research, and illustrate the green building construction model to be studied in this article;

3)Expert interview method. Due to the problems studied in this article, interviews with personnel with experience in implementing green building and experts with rich industry experience, obtain first-line example experience, and evaluate and revise the case and literature research.

This article focuses on the literature research method, supplemented by case studies, and finally revised and supplemented with expert opinions.

⑵ BIM technology

BIM technology was first produced in the United States, and then promoted to Europe, Japan, Singapore, South Korea and other countries, which was highly praised by these developed countries. At present, China is also working hard on the research and application of BIM technology. BIM technology is playing a huge role in increasingly complex engineering project applications. Currently, in the United States[32], Applied BIM technology. At the same time, the government also issued relevant BIM standards such as the National Academy of Building Sciences (National Institute of Building Sciences, NIBS) formulated the National BIM Standard (National BIM Standards) and created various BIM associations. In Japan, BIM use has been promoted from corporate push to government Government-led level[33]In March 2010, the department of the Ministry of Land and Transportation will use all the construction projects under its jurisdiction using BIM. In South Korea, government agencies have formulated a number of BIM application standards. In January 2010, the BIM Application Guide in the Construction Field was issued, and the 3D Design Guide in the Civil Field has also been approved[34].

In China, the research and application of B I M is in the tentative stage, but the effect is very great. There are many successful cases, such as the Olympic Games[35], World Expo venues[36], Hangzhou Olympic Sports Center Stadium[37]The design and construction of large projects have been applied to BIM technology and have received very good results. At the same time, B I M technology research has been highly valued by the government, and BIM technology has been listed as a key project of the "Tenth Five-year Plan" Science and Technology Breakthrough Plan and the "11th Five-Year Plan" National Science and Technology Support Plan[38]. During the "12th Five-Year Plan" period, the popularization and application of information systems of construction enterprises should be basically realized, and the application of new technologies such as building information model (B I M) and network-based collaborative work should be applied in engineering should be accelerated. Many domestic universities, such as Tsinghua University and Shanghai Jiao Tong University, have set up B I M research laboratories[39], Greatly promoted the application process of B I M in China[40]. It can be seen that B I M application in China is stepping into the track of rapid development. The value of B I M technology is mainly reflected in B I M 3D display ability, B I M accurate computing ability and B I M collaborative communication ability, according to price water house coopers of BIM technology in engineering application at home and abroad can be seen, B I M technology can shorten the construction cycle by 5%, (which, the communication time by 30% -60%, information search save 50%), cost reduction of 5%. The value of B I M can create new changes in traditional construction:

1)The emergence of new ideas. THE ability of BIM collaboration can make the process of architectural design, construction, operation and maintenance complete on the BIM platform, which can form the concept of the whole life cycle of buildings, and similarly, it can also form the concept of architectural knowledge management and a new architectural cognitive system.

2)Reintegration and configuration of resources. BIM technology is based on digital, which can combine "big data", "cloud computing" and other technologies to do a good job in the dynamic control of resources, and realize the reintegration and allocation of resources.

3) New ways of thinking and working. The thinking concept of "what you see is what you get" in BIM technology will bring new changes to building construction, such as 3D virtual models and derived nD functions (4D animation, 5D cost...) And so on, thinking change will also lead to the change of working style.

Main products of the BIM. The reason why BIM technology can operate easily and achieve good results in the application of increasingly complex engineering projects is inseparable from its powerful combination of software systems. The application of BIM involves different professionals, participants and application stages, and its complexity can be imagined, which can not be solved by one kind or one kind of software. With the application of BIM technology, a large number of related software has emerged. The American Building Smart League President Dana K. Smitn The assert: " The days of relying on one software to solve all the problems are gone forever[41]".

For a wide variety of BIM software, this article draws from the construction consulting company HeGuanpei[42] to BIM Classification of the software, see Figure 1-1. According to his classification, it can be divided into two categories: BIM core modeling software and analysis and management software based on BIM model, among:

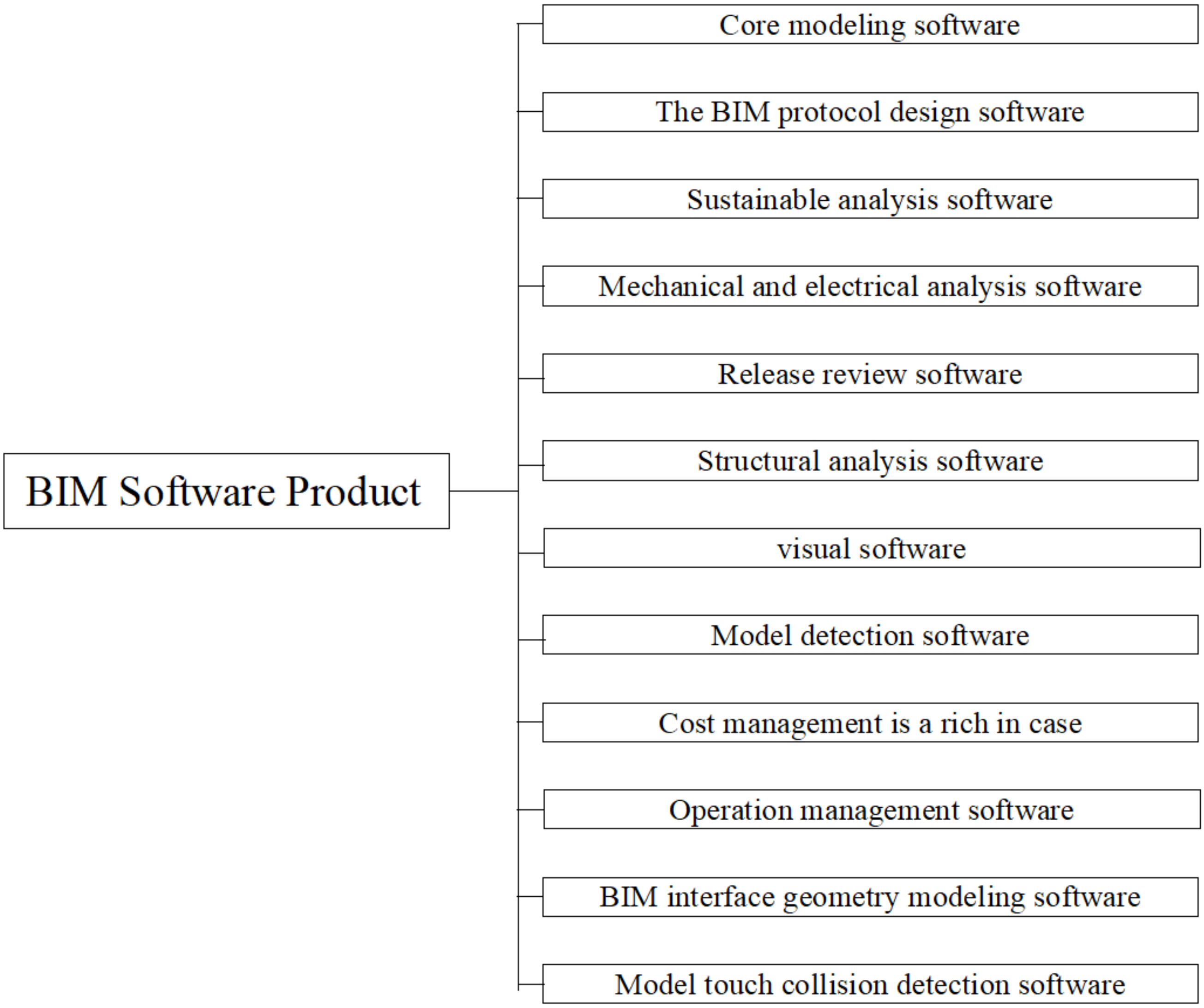


Figure 1.1- Classification of the BIM software

Type 1: BIM core modeling software, including the secondary development software of architectural and structural design software such as Autodesk Revit series, GraphisoftArchiCAD software, electromechanical and equipment design software such as Autodesk Revit series, Building Mechanical Systems series software of Bentley company and Digital Project software of Grey technology company[43].

Type 2: Analysis software based on BIM model, including: construction progress management software (such as MS Project, Navisworks, etc.), structural analysis software (such as PKPM, SAP2000, etc.), budget estimate software, equipment management software, visualization software (Navisworks), operation management software, etc.

1)value engineering

Value Engineering is a resource-saving management technology and thought method designed to save cost and improve value through the coordination of economy and technology[44]. Value in value engineering is a specific concept, which is the function and the realization of this function

The ratio of the consumption cost. The mathematical expression is provided as follows:

$$V=F/C \tag{1.1}$$

V：represents the value coefficient,

F：represents the function coefficient, and C represents the cost coefficient.

This formula makes function and cost comparable values that measure engineering, materials and components.

The function and cost matching problem, so as to achieve good technical and economic results.

2)Network hierarchy analysis (Analytic Network Process, for ANP)

In 1996, Professor Saaty considered the correlation between elements and proposed the AHP method (Analytic Network Process, ANP)[45].

Typical ANP, the structure is shown in Figure 1-2, including the control layer and network layer, the upper layer, containing the total target G and the relevant decision guidelines P1, P2,..., Pm, these decision guidelines are independent of each other, the control layer model is similar to the AHP model; the lower network layer contains multiple element groups (C lust e r), C1, C2,..., Cn Each set of elements contains multiple lower elements (Elem e nt), which are subject by the upper layer and form the network structure because of their internal correlation relationships.

Where the line with the arrow indicates the element that the arrow tail element affects the arrow. If you have your own arrow, it means that the index or the next level index of the element set are correlated, and the elements are not independent.

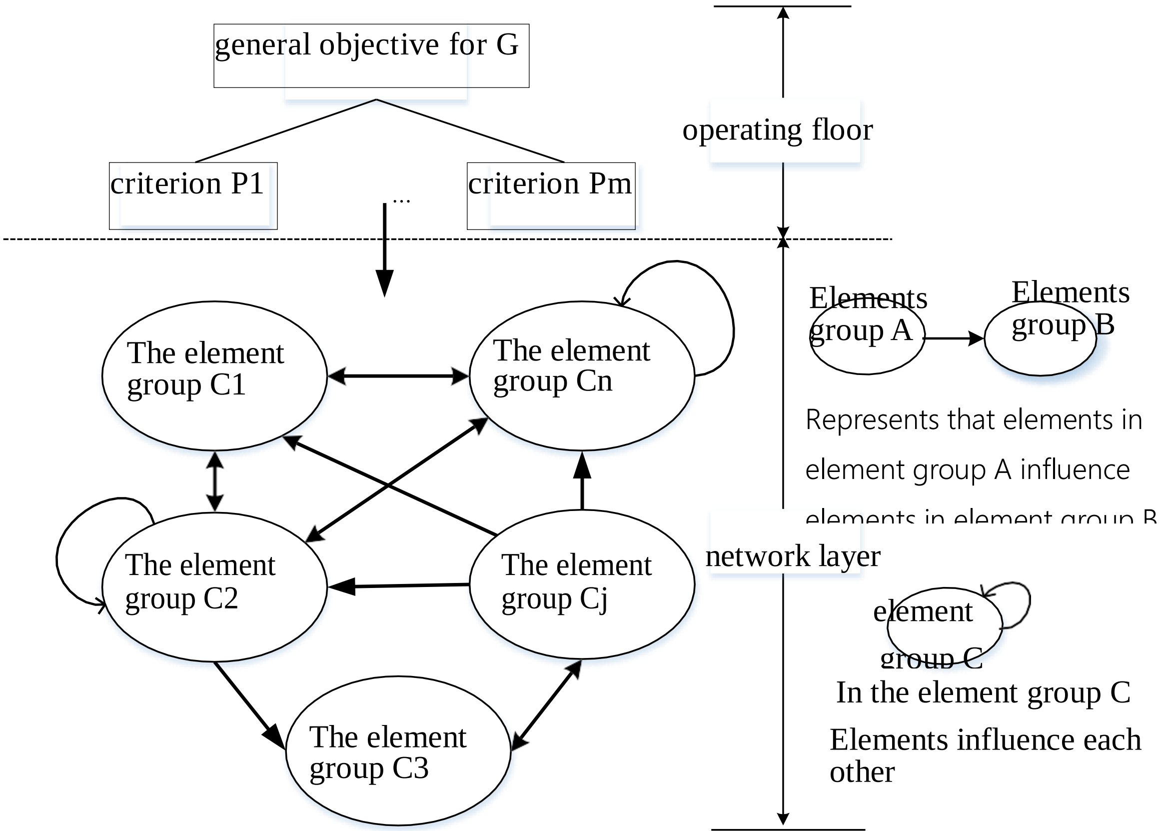


Figure 1-2 Typical network hierarchy of ANP

According to the constructed ANP model, the judgment matrix, weight-free supermatrix, weight matrix, weight supermatrix and limit weighted supermatrix are obtained successively, so as to obtain the weight of each network layer element to the target elements of the control layer. ANP method has been popularized and applied in finance, engineering construction, bidding and evaluation.

Insurance management and other fields. Considering that the functional indicators of the green energy-saving building scheme are not independent of each other, but there are interrelated relationships. Therefore, the importance of introducing ANP method into the index is relatively important. The importance evaluation model of the functional indicators is constructed under the correlation relationship, and the weight of each influence index is obtained through the limit weighted hypermatrix.

1.3.2 Main research content and structure

The research technical route is shown in Figure 1-3.

Chapter 1 Introduction. This chapter briefly introduces the research background, development process and the research status of the issues related to green building construction. After comparing the main research methods for green construction management, the research method and technical route of this thesis are given.

Chapter 2 Analyzes the problems in the current green construction management, clarifies the characteristics of green building construction compared with the traditional construction methods, finds out the key problems of green construction management, and does a good job in the special and overall planning of green building construction organization. This chapter mainly introduces the relevant concepts and theories in the field of green building construction, compares and explains the similarities and differences of such projects and conventional engineering projects, and finds out the key problems.

Chapter 3 Green construction process optimization. This chapter mainly starts from the characteristics of green construction and the requirements of green construction certification. On the basis of the traditional construction process, it adds the scheme optimization and the scheme deepening design link before construction, and extends the construction to the operation and maintenance stage.

Chapter 4 Is to take the project of China-Denmark Scientific Research and Education Center of Chinese Academy of Sciences as an example, to verify the optimization of the green construction process, and to analyze the rationality of the results.

Chapter 5 Conclusions and Outlook. This chapter summarizes the research of green construction management model, and gives the next prospect for the shortcomings in the research.

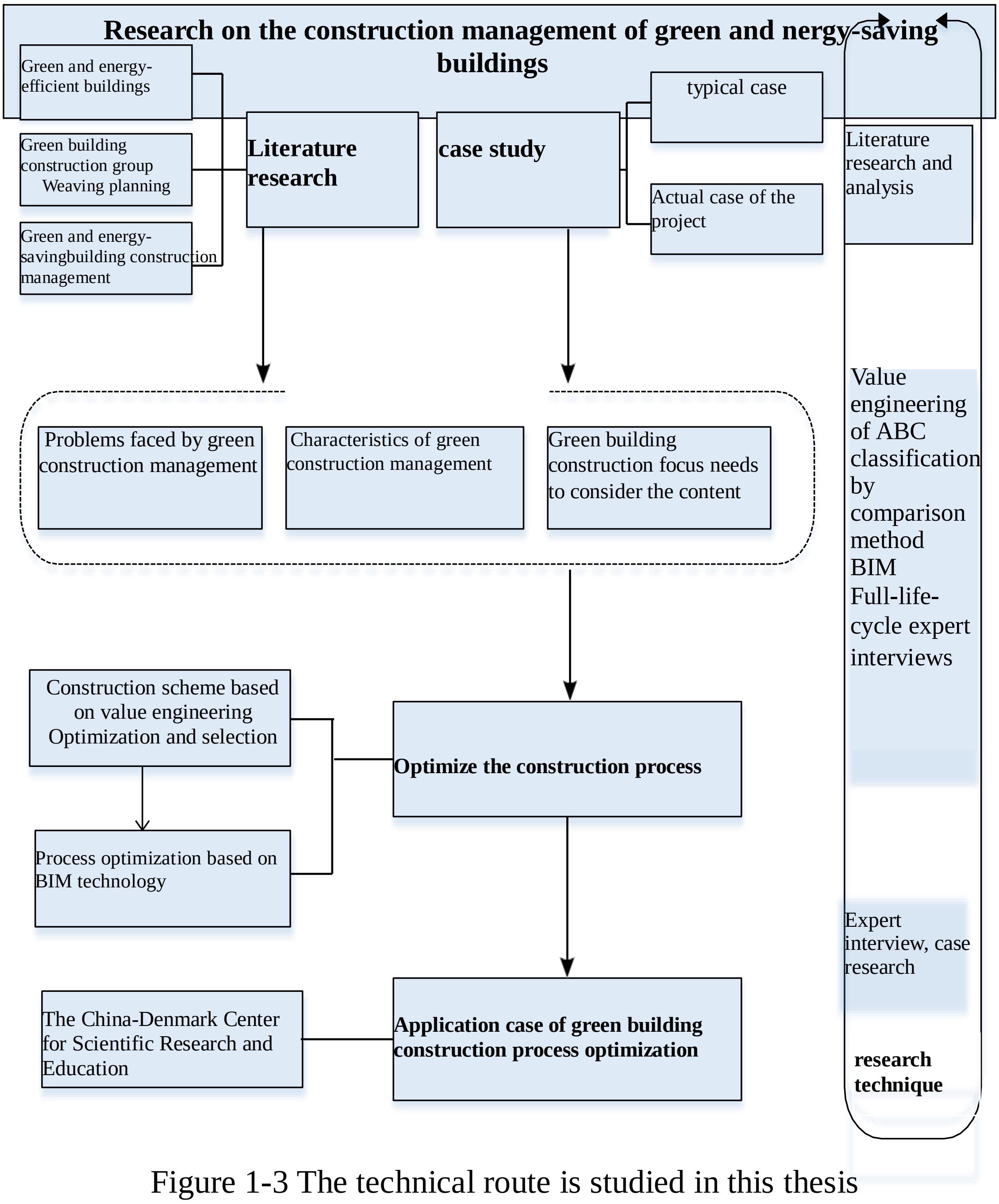


Figure 1-3 The technical route is studied in this thesis

1.4 Conclusions to chapter 1

Performed review of relevant studies green and energy-saving building and green building construction at home and abroad. The organization and planning of the construction of green construction are considered. Considered research methods. Considered classifications of the BIM software.

2 PROBLEMS FACED BY GREEN CONSTRUCTION

This chapter first clarifies the problems facing green building construction; analyzes the typical green construction cases, compares and explains the similarities and differences of green energy saving construction and conventional traditional projects, summarizes the characteristics of green construction, and determines the key issues to be considered in the construction process through literature and cases and green construction standards.

2.1 Problems faced by the green and energy-saving building construction

The research and practice of green construction management at home and abroad are based on the traditional construction process, considering the characteristics of green building construction, and applying the whole life cycle and sustainable development of project management to the practice of green engineering [46], Traditional construction projects can generally be divided into: decision-making stage, preliminary design stage, construction drawing design Stage, bidding stage, construction stage and completion acceptance stage. From the perspective of the whole life cycle of the project, the decision-making stage of traditional construction is the concept stage, the preliminary design to bidding is the design stage, the construction and completion is the construction stage, and then transferred to the owner and withdrawn from the operation stage, as shown in Figure 2-1. In this construction process, the owner generally in parallel contract bidding survey, design, construction, supervision and other units. However, these stakeholders have numerous and inconsistent goals, Not consistent with the cost-saving goal of green building, The unit is only concerned about their own work, Lack of communication, mutual disconnect, Give some units an opportunity, So that the preliminary investigation work will not be done in-depth refinement, Many survey stage problems will be exposed to the design, construction, operation, Reworking and remedial measures will increase the full life cycle costs, What is more, these remaining problems will cause great hidden dangers to the construction and operation; It will also lead to design units focusing on technology, quality and light economy, Cost is not considered in the construction drawing design, High improvement in technology, safety and quality, The balance of the technical economy is not considered enough.

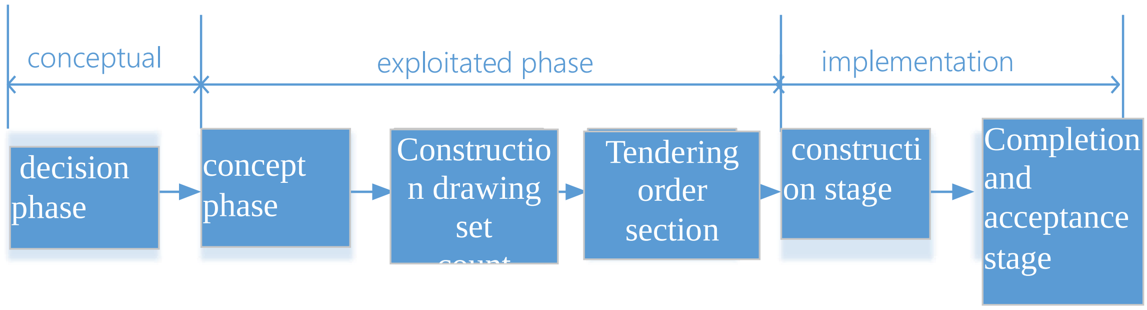


Figure 2-1 Construction process of traditional buildings

This article selects green building construction cases and literature at home and abroad, including an Olympic venues in Beijing, Shenzhen kangwo industrial park, Guangxi Qinzhou public security bureau command center complex building engineering case, the focus of the construction management, building function and cost design and the green certification standards and construction process. Analyzed and research, found that the current green energy-saving building construction: attaches great importance to the construction, despise the early decision, survey, design stage and late operation and maintenance phase, the whole life cycle of functional design and reduce cost starting point to improve, the existing construction process and the demand of green building certification does not match. Specifically:

(1)Pay attention to the construction stage and ignore the work in the operation and maintenance stage. Traditional construction projects can be divided into: decision-making stage, preliminary design stage, construction drawing design stage, bidding stage, construction stage and completion acceptance stage, from the point of the whole life cycle of the project, the traditional construction decision stage for concept stage, preliminary design to bidding design stage, construction and completion for construction stage, then transferred to the owner, withdraw from the operation stage, as shown in figure 2-1. At present, in addition to providing late protection for green and energy-saving buildings in the contract, there is no more consideration for the value-added and preservation of buildings.

(2)The functional design and cost reduction in the whole life cycle of the building need to be improved. To achieve the maximum benefit with the lowest cost, pay attention to economic benefits, sacrifice environmental benefits when necessary, and pay attention to the basic functions of the building in the design and construction stage, lack of sustainable development, life in the basic functions on the basis of energy saving green elements and the whole life cycle cost.

(3)The existing construction process does not match the requirements for green building certification. The current green construction certification for the building life span, green, energy saving, environmental protection and people-oriented requirements is the old construction process is insufficient in the consideration of these problems. After receiving the project work, it is often implemented in accordance with the construction design scheme provided by Party A.

In the green scheme and green construction drawings formulated by Party A according to the green construction and LEED certification standards, These schemes take into account factors such as green, energy saving, cultural, and full life span, These factors are bound to lead to an increased construction cost, a complicated process, Construction cycle and risk will also increase accordingly, After receiving the project, the construction enterprises are bound to be more cautious in the selection of materials, technology and process, How to achieve green goals under multiple constraints requires weighing cost and function, And after the scheme is determined, due to party A's unique requirements in building performance and structure. Often make the construction very difficult. A little careless will cause the high cost of rework, Ensure less rework in the construction process, It is also very important to construct as much as possible. Due to the lack of green building construction paying attention to the work of the construction stage, the functional design and cost of the whole life cycle of green energy-efficient buildings, and the mismatch between the existing construction process and the demand for green building certification, often lead to the lack of green building planning, design and construction; the consideration of the implementation of design drawings, the availability of materials, schemes, and the risk of economic and functional matching, which ultimately lead to the smooth implementation of green construction.

Therefore, in order to ensure that the project in the cost, schedule, quality and green certification standards under the constraints of the smooth completion.

Yes, the early scheme selection and the depth optimization of the design have become the most critical problem, which is relatively lacking in the traditional construction process. It is necessary to consider the characteristics of green construction on the basis of the traditional construction management process, the scheme selection and optimization of the design respectively, so as to consider and optimize the key issues.

2.2 Green and energy-saving building construction characteristics

Compared with traditional construction, green building construction has some similarities, but the requirements in terms of functionality and full life cycle cost are very different. Compare the traditional construction combined with domestic and foreign literature and green construction cases. Analysis the similarities, and from the construction target, cost reduction starting point, focus, function design, benefit and effect of the difference, it can be seen that the green building construction in building function design and cost composition considering the green environmental protection and the whole life cycle and sustainable development factors, see table 2.1.

Table 2.1 Similarities and differences between traditional construction and green and energy-saving building construction

		Traditional construction	Green building construction
same point		There are the same object, that is, the project is for the project construction task, with the same method to achieve, such as project management and technical management methods Use the same people, equipment, materials and other elements	
	Construction target	Progress (construction period), quality, cost	Progress (construction period), quality, cost (cost), safety and civilization, resources (energy),

		(cost), safety	environmental protection
Differentia	Starting point of cost reduction	To achieve the lowest cost to achieve the maximum benefits, most construction units pay attention to economic benefits at the expense of environmental benefits	To realize the sustainable development of construction, people and natural environment, when economic interests conflict with environmental benefits, put environmental benefits as the priority, and save resources under the premise of environmental protection
	respect	Equilibrium of progress, quality, and cost	"Energy saving, material saving, water saving, land saving", the goal of the "four sections", the focus is on the protection and utilization of natural resources
	functional design	Pay attention to the design, construction stage, the basic functions of the building	Sustainable development, full life period in the basis of basic functions to consider energy-saving green elements
	Benefit view	Short-term nature, pay attention to the construction stage	Sustainable development, long-term comprehensive benefits

On the basis of the comparison of similarities and differences with traditional construction, combined with relevant literature[14][47] [48]As well as my project practice, summed up the characteristics of green construction:

（1）Customer-centered, while meeting the traditional goals, while considering the environmental properties of the building;

Traditional building is progress, quality and cost as the main control target, and the starting point of green building is to save resources, protect the environment, meet the requirements of the user, to the needs of the customer, management needs to know more about customer needs, preferences, the impact on customers, construction process here not only include the final user, also include potential users, nature, etc. During the construction and use of traditional buildings, causing serious pollution to the ecological environment, the green building considers the environmental attributes, protect the environment, save energy, enjoy harmony with the natural environment, minimize the environmental damage, restore the damage, or convert the adverse effects, and provide the customer, healthy and comfortable living space to meet the customer experience is another goal. The final green building should not only deliver a comfortable and healthy internal space, but also create a warm and harmonious external environment, and ultimately pursue the highest goal of "the unity of man and nature".

（2）Maxthe use of passive energy saving design (Passive Design) and renewable energy[48]；

Different from traditional buildings, green building is aimed at the whole life cycle of the building, from the project planning, design, construction and operation to the demolition of the buildings to protect the environment and live in harmony with nature. Passive architectural design is advocated in the design, which is to collect and save energy through the building itself (rather than using energy-consuming machinery and equipment) to form a self-circulation system with the surrounding environment. This can make full use of natural resources, to achieve the role of energy conservation. The design methods include building orientation, heat preservation, shape, shading, best window-wall ratio, natural ventilation and lighting and so on. Now the strong advocacy of energy-saving buildings, passive design is constantly mentioned, and the most studied is passive solar buildings. In the operation stage of the building, how to reduce energy consumption and save resources, energy is the most critical problem, which requires the use of renewable energy as far as possible, achieve one investment, benefit in the whole life period, such as the rational utilization of light energy, wind energy, geothermal and so on.

（3）Pay attention to the overall optimization, take the value project as the optimization basis to ensure the balance of construction objectives;

Green building from the project planning, design, construction, operation until the building demolition process is the pursuit of the whole life cycle of building revenue maximization, is a kind of global optimization, the optimization is not only the lowest total cost, also includes social benefit and environmental benefits, such as minimizing the negative impact on the natural environment or damage degree, maximize environmental benefit, social demonstration benefit. Although green construction may lead to increased construction costs, but in the long run, it will increase the overall benefit of the country or related regions. Green construction practices can sometimes increase construction costs, and sometimes reduce construction costs. In general, the comprehensive benefit of green construction must increase, but this increase is also conditional. The construction process has a variety of constraints, progress, cost, environmental protection and other requirements, so it is necessary to take the value project as the optimization basis to ensure the balance of construction objectives.

（4）Attach importance to innovation, advocate the application of new technology, new materials and new devices;

Green building is an integration of technology. In the process of implementation, it will encounter technical problems such as reasonable planning and site selection, energy optimization, sewage treatment, renewable energy utilization, pipeline optimization, lighting design, system modeling and simulation optimization, etc. Compared with traditional buildings, green and energy-saving buildings have great challenges in the technical difficulty, construction complexity, and risk control. This requires architects and engineers of various professions to work together, using a variety of advanced technologies, new materials and new equipment, with the principle of sustainable development, the pursuit of high efficiency, low energy consumption will be the same unit of resources under the same objective conditions, play a greater efficiency. The better technical methods used in practice at home and abroad include BIM, lighting technology, water resources recycling and other technologies. The application of these new technologies can improve the construction efficiency and solve the problems that the traditional construction cannot reach. Therefore, green construction management needs a change in concept, but also needs the support of construction technology and new materials, new facilities and so on.

The promotion and application of new construction technology, materials, machinery and technology can not only produce good economic benefits, but also reduce the pollution of construction to the environment and create good social and environmental benefits.

2.3 Key issues of green and energy-saving building construction

From the characteristics of green energy-saving buildings, it can be seen that green energy-saving building construction is to add the constraints of green construction on the basis of traditional building construction, and green construction can be planned and managed as a special construction project. According to the characteristics of green construction, green construction cases and literature[13][49][50][51], combine LEED

(Lead ership in Energy and Environm ental Design) Standards and the Ministry of Construction "Green Construction Guidelines" and other standards comb out the key issues of green energy-saving building construction, these problems are not considered in the construction, but also to be considered in the future construction. Therefore, this article summarizes these green management contents and divides them from the perspective of the whole life cycle, divided into green management in the concept stage and green management in the planning stage.

The green management in the construction stage and the green management in the operation stage, see Figure 2-2. The following is the special content of green management in the whole life cycle of green and energy-saving buildings.

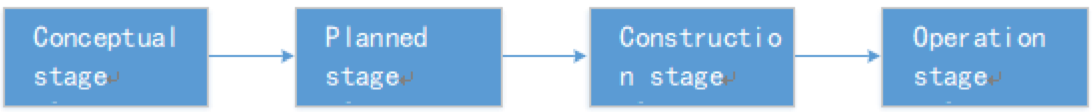


Figure 2-2 Green management mode for the whole life cycle

⑴ Green management in the concept stage

The conceptual phase of a project is a change phase for defining a new project or an existing project. In the green construction, according to the concept of "customer first, global optimal", the green management work in the green construction concept stage can be divided into four parts.first, Need to make a project plan according to the customer needs, Will the intention of the project, The general direction is determined; then, A set of project proposals, prepared by the Owner, The green management part should include the outline of the building environment assessment, Develop standards for environmental assessment, The construction party shall provide multiple sets of feasible schemes according to the standard; third, The Owner shall organize experts to review the feasibility plan, For the green management content, Be sure to do the project environmental impact assessment well, And select a set of feasible options; finally, The Owner needs to determine the scope of the project, Make the project plan according to the project scope, Including the green management arrangement, Set set goals, Establish the review and evaluation standards for the objectives. In this stage of this stage, the acceptance of the project plan is taken as the key decision point, and the deliverables are functional outline, engineering scheme and technical contract, project feasibility proposal, evaluation report and loan contract, etc. The green management workflow at this stage is shown in Figure 2-3.

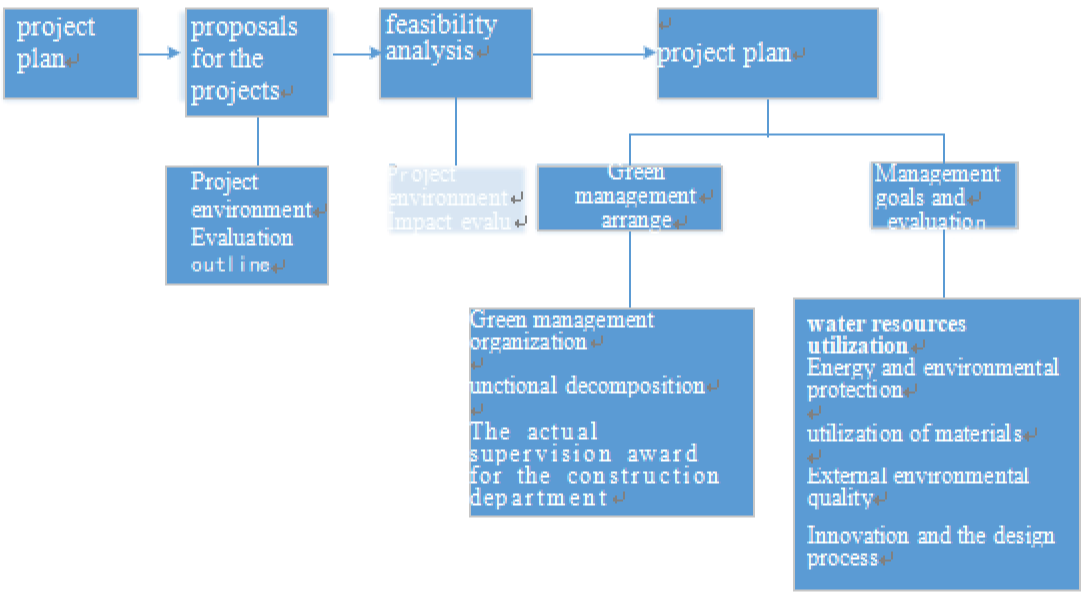


Figure 2-3 Green management in the concept stage

(2) Green management in the planning stage

When the project demonstration and evaluation are completed and the project meets the requirements, the planning phase begins, The project needs to be refined, but it is not only the refinement of the concept stage, but also the foundation of the construction stage. In this stage, three aspects need to be done well:

1) land acquisition, demolition and bidding;

2) Select good construction, design and supervision units, And invite the owners, construction units, supervision units have experienced experts to participate in the design work, Organize the design institute to draw and model the index parameters of the project, And make the corresponding management plan, Including: resources, capital, quality, progress, risk, environmental protection and other plans, This process will change, All parties must cooperate and support the work, Organize experts to review the design sketches and construction drawings submitted by the design institute;

3) Build the project team, Start the construction preparations, Do a good job of "seven access and one leveling" (electricity, water, access, mail, heating, communication, natural gas and site leveling). In this stage, the approval of the construction drawings and design specifications is taken as the key decision point, and the deliverables are the project sketch, design drawings, construction drawings, design specifications and the project personnel employment contract.

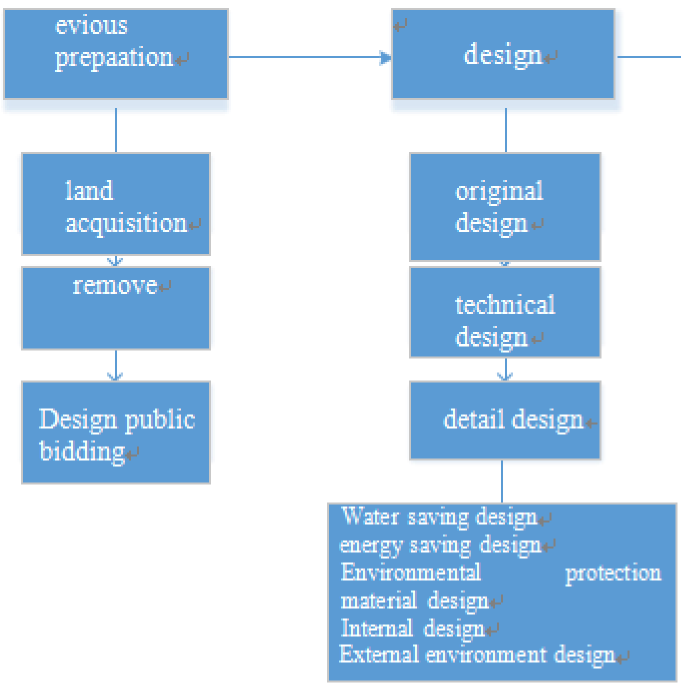


Figure 2-4 Green management in the planning phase

⑶ Green management in the construction stage

After passing the review in the design stage, the drawings and models should be embodied for construction and equipment installation. The construction party shall organize the construction of the main body and install the equipment with the supplier. At this time, the main responsible department is the construction party, the design department does a good job of cooperation and support, the owner and the supervision department do a good job of supervision and review of the project construction process, and do a good job of change management and process control. This stage is resource consumption and pollution production.

In the most stage, the construction unit should take four important measures at this stage:

1) establish a green management mechanism;

2) do the prevention and protection measures of construction waste and pollutants;

3) use scientific and effective methods to use the energy as possible;

4) the owner and the supervision department should do the tracking, reviewing, supervision and feedback of the construction process, especially the application of green materials and the treatment of pollutants.

In this stage, the completion and acceptance of the construction and installation project is taken as the key decision point, and the deliverable is the acceptance report of the main node of the construction and installation project, as well as the buildings, structures and corresponding equipment that meet the standards.

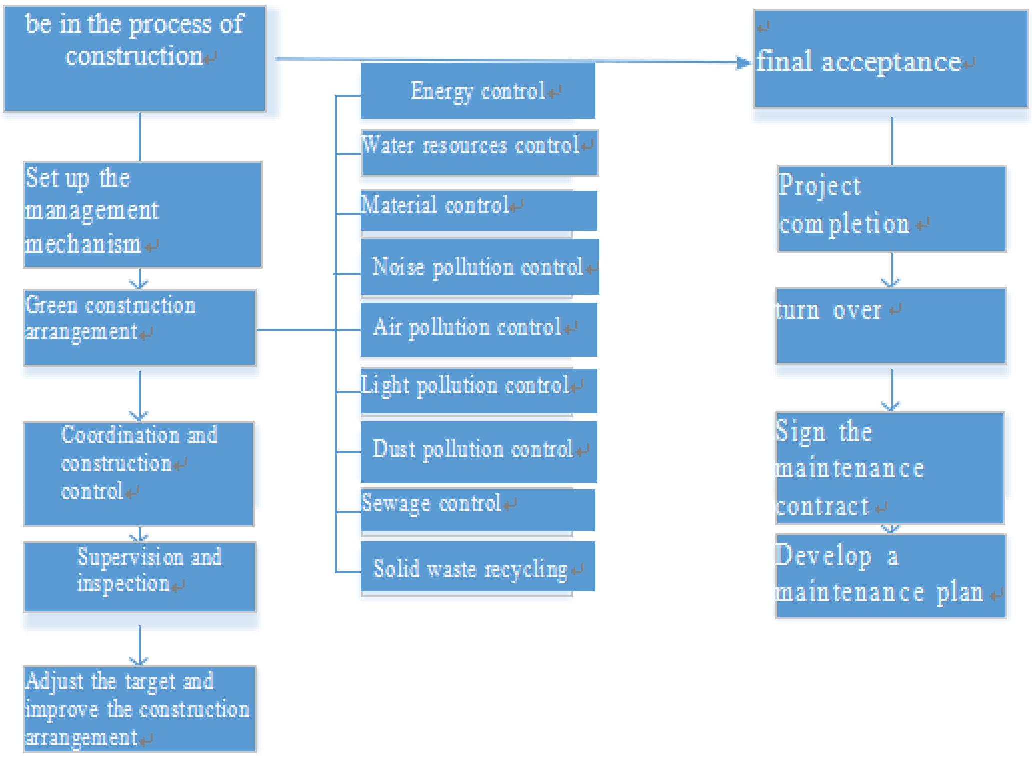


Figure 2-5 Green management during the construction phase

(4) Green management in the operation stage

The operation and maintenance phase is the longest phase experienced for green and energy-saving buildings. After the completion of the construction and installation project, the instrument needs to be tested, the owner shall organize raw materials and cooperate with the engineering consulting organization; when the building reaches the design life, demolition and resource recovery; after the project operation, the three-level evaluation is self-evaluation, peer review and post-evaluation, to refine the best practices in the construction operation of green energy-saving buildings, and further enhance the management capability to provide a pilot demonstration for the future green building construction and operation. The items delivered at this stage are the technology and system maturity inspection report of the project pilot test, the three-level post-evaluation report, the maintenance contract, the demolition and recovery plan, the buildings, structures, equipment and production process that meet the standard requirements, as well as the understanding of technology and operation The staff member of the work.

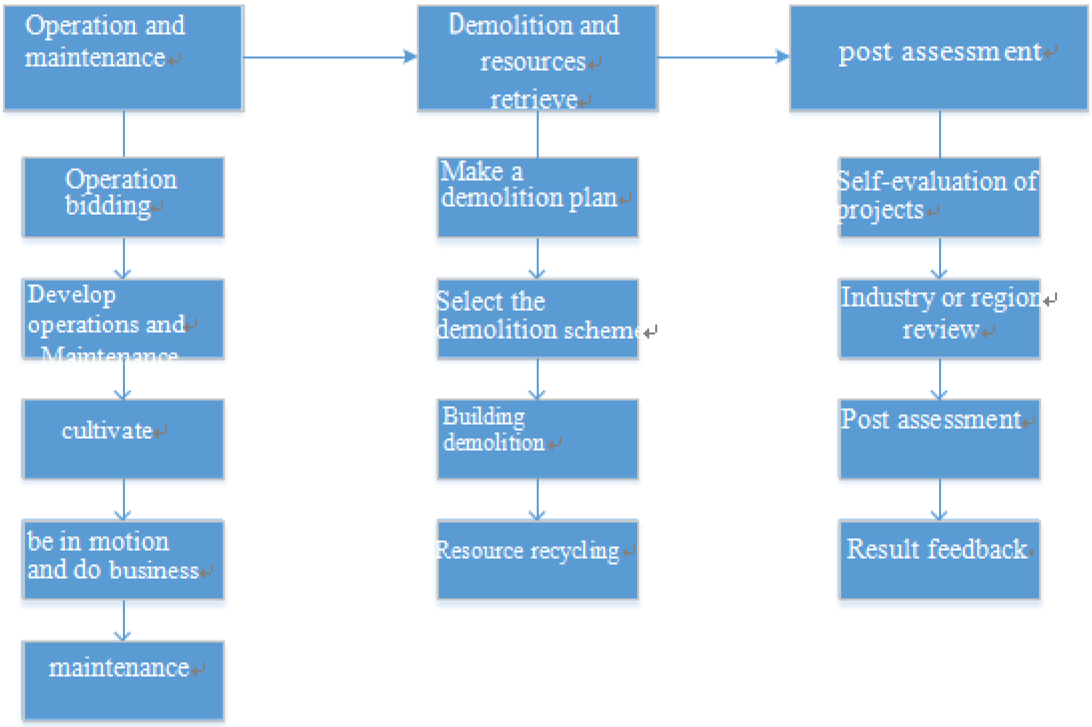


Figure 2-6 Green management in the operation phase

2.4 Conclusions to chapter 2

The main work of this chapter includes three aspects:

(1)Combined with the cases of green construction, literature and their own projects, we will sort out the problems faced by green and energy-saving building construction, and clarify the existing construction process in response to the needs of green construction and certification.

(2)Based on the domestic and foreign green construction cases and literature, comparing the similarities and differences between green building construction and traditional building construction, the characteristics of green building construction are summarized: 1) Take the customer and consider the environmental attributes of buildings while meeting the traditional goals; 2) maximize the renewable energy and save resources during the whole life cycle; 3) pay attention to the overall optimization and guarantee the balanced construction goals with value engineering as the optimization basis;4) innovate the technical methods and realize innovation.

(3)Starting from the construction characteristics, the literature and cases are used to sort out the key problems of green management in the whole life cycle of green construction, and it is clear that these problems are the contents that need to be considered as green constraints in green construction.

3 OPTIMIZATION OF CONSTRUCTION PROCESS BASED ON BIM AND VALUE ENGINEERING

In the last chapter, the relevant documents and cases of green construction were reviewed, which clarified the problems faced by green construction, and summarized the characteristics of green construction and the key work of green construction. It is clearly pointed out that the scheme selection and design are the most critical problems in the construction, which need to be added in the whole management process. In view of the role of value engineering in balanced selection under the constraint of multi-objectives, the powerful modeling, digital intelligence and professional collaboration performance of BIM technology, and can meet the new needs of green building energy conservation, environmental protection, people-oriented and green innovation. Therefore, starting from the characteristics of green and energy-saving building construction, value engineering is introduced into the scheme selection part, and BIM is introduced in the design optimization and construction guidance, in order to solve the problems of backward green management mode, full life cycle function and insufficient cost consideration.

3.1 Green construction process optimization

From the current situation and problems facing the green construction enterprises can be seen that the current green building construction of green energy-saving building life cycle functional design and cost requirements, in green environmental protection and the whole life cycle and sustainable development factors need to be strengthened, after the building demand drawings and green function requirements can implement, materials, scheme can be applied, economic function can meet the demand of these are yet to be verified. Introduction of these construction elements is bound to cause construction cost increase, process is complicated, construction cycle, risk will increase accordingly, how to achieve the green goal under multiple constraints is to weigh the cost and function, and after the scheme determined by party a on the building performance and structure of the unique requirements, often cause scheme construction is difficult, a little careless will cause rework high cost.therefore, In the early stage, after the preliminary design receives the conceptual design drawings, do the whole life cycle function and cost balance analysis, Choose the scheme matching the functional cost from the design source, Based on this, continuously increasing the design depth in the later design stages, Before the construction, after the construction drawings are issued, Deepen the design, Improve the professional coordination, simulation of the construction organization and arrangement, Reasonable disposal of construction risks, Reduce construction rework, ensure construction in place, It can deal with the problems of the construction stage, the lack of reasonable functional cost analysis and the mismatch between the construction process and the green certification requirements.

Lack of scheme selection in the existing construction process and design deepening part, can consider added on the whole management process, the focus is on the introduction of scheme selection and optimization, in view of the value engineering powerful cost analysis, function analysis, the role of the new scheme creation and evaluation and the international more than 60 years of practice advantage of low investment high return[44]From the perspective of the whole life period of green building, the main factors to be considered and the whole life cycle cost are given, and the value engineering is selected under the constraint of multiple objectives Analysis the function and cost of the green construction plan provided by the owner from the perspective of the whole life cycle, and improve the efficiency and benefit of the optimization and selection of the project plan. At the same time, the process and results of the selection and optimization can be used to persuade Party A and the designer, which can be used as the basis for changing the plan.

Although through scheme optimization choice to determine the construction scheme due to the complexity of building structure, construction difficulty makes the traditional construction cannot play a good role, can join the scheme before the construction of the depth optimization, using B I M powerful modeling, digital intelligence and professional collaborative performance, professional coordination, can use simulation, construction progress simulation, calculate the cost to deepen the construction scheme, reasonable arrangement of construction.

Finally, the management is extended to the operation and maintenance stage, and the final handover is not only the building itself, but also the corresponding service, training, maintenance and other work. See Figure 3-1 for the optimization of the construction process, and the content of the virtual box is the added process. It should be noted that the application of value engineering and B I M can run through the whole life cycle, but only after the preliminary design stage and before the construction are the most important application links of value engineering and B I M. Therefore, these two links are added to the original construction process. The following is the introduction of the added scheme optimization and selection and the in-depth optimization of BIM.

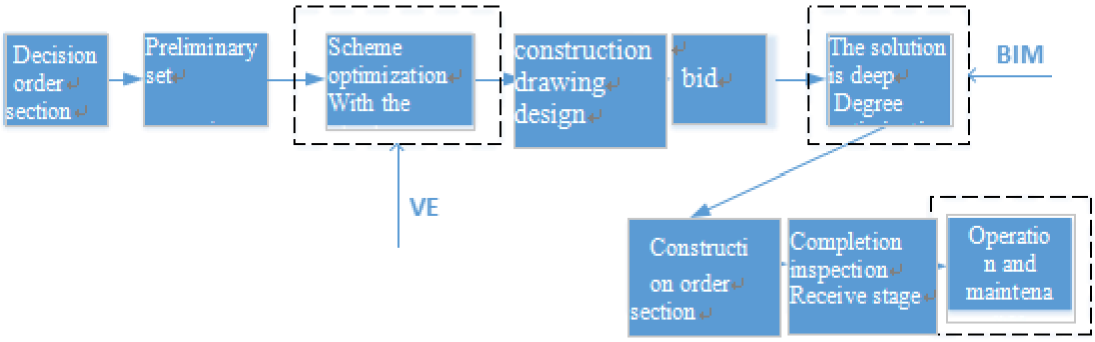


Figure 3-1 Optimization of green building construction management process

3.2 Construction process optimization based on value engineering

After the preliminary design and construction enterprises receive the conceptual design drawings, it is necessary to do a good job in the whole life cycle function and cost balance analysis of the proposed scheme, and choose the functional cost matching scheme from the design source. Based on this, the design depth will be continuously increased in the future design stage. Value engineering the main idea is to integrate existing resources, optimization arrangement to obtain maximum value, the pursuit of the whole life of low cost and high efficiency, focus on function and cost control, use of quantitative thinking, will be unable to measure the function of the quantitative, seize and use the key problems and the principal contradiction, integrate technology and economic means, systematically solve problems and contradictions, in solving the green building construction target equilibrium, improve the whole life building function and cost efficiency and choose new materials and new technology has a good practice guidance. Therefore, new process links can be added after the concept design of green construction is issued, and technical and economic analysis teams can be organized to conduct value analysis of important solutions and seek solutions.

Function and cost balance. The main uses of value engineering in the optimization and selection of schemes are: to pick out the problems with high value and great significance, improve them, compare and optimize the schemes. The process is as follows:

(1) determination of research object;

(2) definition of functional index and cost index for the whole life and cycle;

(3) sample test in harsh environment;

(4) value analysis;

(5) scheme evaluation and selection.

3.2.1 Identify the study subjects

On the basis of value engineering, ABC method and comparison method are commonly used. See Table 3-1 for the comparison between the two methods.

Table 3-1 Application of Value engineering in green buildings

Value for engineering purposes	the method of determining the object	characteristic	apply
Key issue improvement	ABC	Focusing on the cost analysis, we first take the key part of the large cost expenditure as the research object of the value engineering, and then use the principle of value engineering to improve the problem of functional technology mismatch according to the actual situation.	Review of high-value schemes; Optimization of high-cost components and processes; Key faults and response plan formulation
Protocol optimization	Antithe	Focusing on the "one-to-one" comparison of functions and costs of each part, the value engineering principle is used to find the mismatch between function and cost from the actual demand as the research object of value engineering.	Design, construction, operation and maintenance scheme optimization; Energy-saving scheme optimization; Comparison of new technologies, materials and machinery

3.2.2Full-life-cycle function index and cost index definition

After identifying the study subjects, functional definitions and cost analysis were performed. Refer to the LEED standard[28], Green building evaluation standard[13]And practical experience summarizing the main contents of the functions of green building research objects are shown in Table 3-2. Value engineering theory generally divides functions into: basic functions, auxiliary functions, upper function and hypothetical function[58]The basic function focuses on the use value and function value, that is, what the product can do; the auxiliary function is generally auxiliary function, generally appearance design, and other functions of the product; the latter two functions are beyond the product itself and are generally not discussed in the function analysis.

Table 3-2 Functional definition of green building research objects

Functional types	classify	function definition
essential attribute	basic function	Fire-proof, moisture-proof, insulation, anticorrosion, stability, reliability, etc Functional attributes.
Environmental protection function		The object used in the development, use, recycling process to save resources, protect macro and micro The function of the environment.
Comfort function		To create a comfortable and healthy internal and external building environment for the residents.
Energy saving function		The function of saving of natural resources and energy in the process of use.
Beautiful function	Affiliate function	The function of creating a pleasant environment for the user.
Operation function		Convenient for construction, operation, operation and maintenance functions.

The whole life cycle cost generally includes: initial input costs and later maintenance and operation costs[44]. In detail, the initial cost includes: direct cost (raw material cost, labor cost, equipment cost), indirect cost, tax, etc.; the later operating costs include: management fee, fuel and power cost, overhaul cost, regular maintenance fee, removal and return charge, etc.

3.2.3 Sample test in the harsh environment

Due to the green characteristics of buildings, in the design and construction will often use some new materials, components, sample processing, inspection, the inspector to sample bad environment such as high temperature exposure, dry, wet, acid and alkali environment test, by the quality supervisor according to the performance index of the sample to do the final review, and record the experimental indicators.

3.2.4 Value coefficient calculation

Value analysis of the study subjects can effectively avoid excess function and underfunction. When calculating the value coefficient, functional analysis is required to determine F, and cost calculation to determine C.

For functional coefficient, first perform functional definition of the required object, collect indicators related to function.

The size of the indicators can be determined by experiments, historical data statistics and expert scoring, and then the weight of the indicators can be determined by expert evaluation or historical data statistics. Finally, the functional coefficient is calculated, assuming that the research object contains n functional indicators, which is x_1, $x_2 \ldots x_i \ldots$, The corresponding weight is given in w_1, $w_2 \ldots w_i \ldots$ Then: n

$$F=\Sigma x_i * w_i \quad (3.1)$$

i=1....n

$$\Sigma w_i = 1 \quad (3.2)$$

i=1

among,i For the normalized index, for dimensionless data, make y_i For the original data of functional indicators, the data should be processed dimensionless.

Considering the correlation between green building function indicators, the indicators influence each other. Therefore, the ANP algorithm can be introduced into the calculation of the importance of the index. Element B in the ANP control layer$_1$, B_2, …, B_n . Represents the n main directions of the functional index, and the element set C of the network layer$_1$, C_2, „, C_{10} Is the set of control layer indicators, each element set C_i There are three-level indicators c_{i1}, c_{i2}, „, c_{in}（i=1,2,3, „, N）.Will control the layer element B_i (i= 1,2,..., n) as a criterion, and the C_{jk}（k=1,2,3, „, And k) treats the element set C as the subcriterion$_i$ The elements in the to C_{jk} The judgment matrix is constructed, normalized and the feature vector of 1 ( ) 2 ( ) 3 ( )... is obtained( ) ,The matrix W is obtained by summarizing the feature vectors of each judgment matri w_{ij}As shown in equation (3-3).

$$W_{ij} = \begin{bmatrix} w_{i1}^{(j1)} & w_{i1}^{(j2)} & \cdots & w_{i1}^{(jn_j)} \\ w_{i2}^{(j1)} & w_{i2}^{(j2)} & \cdots & w_{i2}^{(jn_j)} \\ \vdots & \vdots & \ddots & \vdots \\ w_{in_i}^{(j1)} & w_{in_i}^{(j2)} & \cdots & w_{in_i}^{(jn_j)} \end{bmatrix} \quad (3.3)$$

matrix W_{ij} Represents the element group C_iElements in and the element group C_jImpact relationship between the elements in. Similarly, by comparing the relationship between the elements of the element groups with B main criterion, n no-weight supermatrix s is shown in Equation (3-4).

$$Ws = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1N} \\ w_{21} & w_{22} & \cdots & w_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1} & w_{N2} & \cdots & w_{NN} \end{bmatrix} \quad (3.4)$$

Then, with Bi as the main criterion and the group of elements Cj as the secondary criterion, the relative importance of the group of elements is compared in pairs, and the judgment matrix is constructed and normalized to obtain the normalized feature vector a1 a2 a3a, from which the weight matrix As under a certain criterion is summarized as shown in Equation (3-5). … a11 a12 a1

$$As = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (3.5)$$

We weighted elements of the unweighted hypermatrix $\overline{Ws}$, among$\overline{ij}$= a (i=1,2, ,,, n ; j=1,2, ,,, n) 。Because of the complex interdependence of the elements in the ANP network, calculating the limit-weighted supermatrix is needed̅Process to obtain stable relative weights of the elements, as shown in Equation (3-6).

$$\bar{W}^{\infty} = \lim_{q \to \infty} \bar{W}^{q} \tag{3.6}$$

The limit weighted supermatrix is iterated to stabilize the matrix̅, exploitation̅The weight value of each element relative to the top index of the control layer can be obtained, that is, the weight value of the influence of the three-level index on the decision target. Although the ANP solution process is relatively complicated, it is more convenient with Super decision assistance and easy to popularize and apply. With the help of the calculation software, the weight of the functional index can be obtained.

According to the nature of the data, it can be divided into benefit type and cost type. For the benefit type data, that is, the larger the index, the better the performance, it can be used:

$$x_i = \frac{y_i - y_{min}}{y_{max} - y_{min}} \tag{3.7}$$

For the cost index, that is, the smaller the index, the better the performance, it can be used:

$$x_i = \frac{y_{max} - y_i}{y_{max} - y_{min}} \tag{3.8}$$

For the cost coefficient, it is necessary to collect the influence index first, then determine the size and weight of the index, obtain the dimensionless data through normalization

processing, and finally calculate the cost coefficient C:

$$C = C_{\text{earlier stage}} + C_{\text{maintenance}} \tag{3.9}$$

Where, C represents the cost coefficient, $C_{earlier\ stage}$ Represents the cost of the initial input, $C_{maintenance}$ For the cost of later operation and maintenance, the cost coefficient is also dimensionless data, and the calculation process is the same as the functional coefficient calculation.

Combine (formula 1-1), (3-1), (3-2), (3-7) (or (3-8)) and (3-9) to calculate the value coefficient of each scheme, and then analyze the value quantity.

3.2.5 Scheme evaluation and selection

According to the sample test and the desired value coefficient, use the value principle of value engineering to enhance the value of the existing scheme or optimize the new scheme. Generally, there are five ways to improve value, as shown in Table 3-3. Appropriate programs can be selected according to the information obtained by the project, market forecast, existing problems, and goals such as improving labor productivity, improving quality, controlling progress and reducing cost[59]

Table 3.3 -Ways to achieve value enhancement

Achieve means		concrete measure
F fixed	reduce C	Improve the way to realize the product function (such as changing the structure, material, process), to reduce the cost and improve the function;
raise F	C fixed	Through the optimization scheme, eliminate the redundancy to achieve the value improvement;
The F is greatly improved	C slightly increased	Integrate some new functions or upgrade the original functions on the basis of the original functions;
raise F	reduce C	It can generally be achieved by citing new technologies;
F has been reduced	C has a greater reduction	Determine the necessary functions of the product, eliminate and reduce the objectively unnecessary functions.

3.3 BIM technology in the green and energy-saving building construction process optimization application

After the scheme is determined, even if the function and cost of the scheme in the early stage have reached the optimal configuration,due to party A's unique requirements in the construction performance and structure, the construction of the scheme is often difficult, and a little careless operation will cause the high cost of rework. Therefore, before the construction of the construction process is deduced and simulated, to find out the incoordination of the professional drawings, analyze the resource bottleneck, deepen the design to ensure the construction process less rework, as far as possible to achieve the construction in place is also very important. In view of the strong modeling, digital intelligence and professional collaboration performance of B I M technology, and the advantages of low investment and high return in more than 10 years of international engineering construction practice[55], B I M In the pursuit of low cost and high efficiency during the full life span, Focus on feature enhancement and cost control, Using quantitative thinking, Show up all the detailed data, It aims to achieve maximum function with minimal input, This is consistent with the pursuit of building function and cost balance during the life period, citing the characteristics of new technology, Therefore, B I M technology can be introduced as a new technology in green construction into construction before the construction drawings, Add a design-deepening process link to the construction process, Organizing the B I M working group, Further optimization of the construction design, Ensure the smooth progress of the construction.

3.3.1Application of BIM technology in the scheme deepening stage

Considering the expensive value of the components after the optimization of the scheme and the unique complexity of the project, it needs to be done as far as possible。

Reduce the loss of rework and delayed work, ensure the smooth construction, establish the project department to set up the B I M technical team, and add the depth optimization of the scheme as a new link to the original construction process. 3D modeling using B I M technology, Energy simulation, roaming, And pipeline collision and other tests, Among them, the passive energy-saving design is fully considered in the modeling, The lighting and ventilation channels are reserved, Also through roaming application analysis and comparison and constantly optimize the design scheme, Figure 3-2 (left) is the deep optimization design scheme; The energy simulations were performed, On the energy efficiency of the building, To improve the unreasonable place, See Figure Figure 3-2 (middle); Collision test solves the integration of different professional design drawings of subject, structure, hydropower, and HVAC, Three unreasonable laying of pipelines were found in the collision test, As shown in Figure 3-2 (right); By optimizing the protocol and the design, It provides a reliable guarantee for the project calculation quantity and the comprehensive layout of the pipeline. In the increasing stage, BIM technology as a new technology reflects the characteristics of green building focusing on overall optimization and maximizing the use of passive energy-saving design and renewable energy in the whole life cycle.

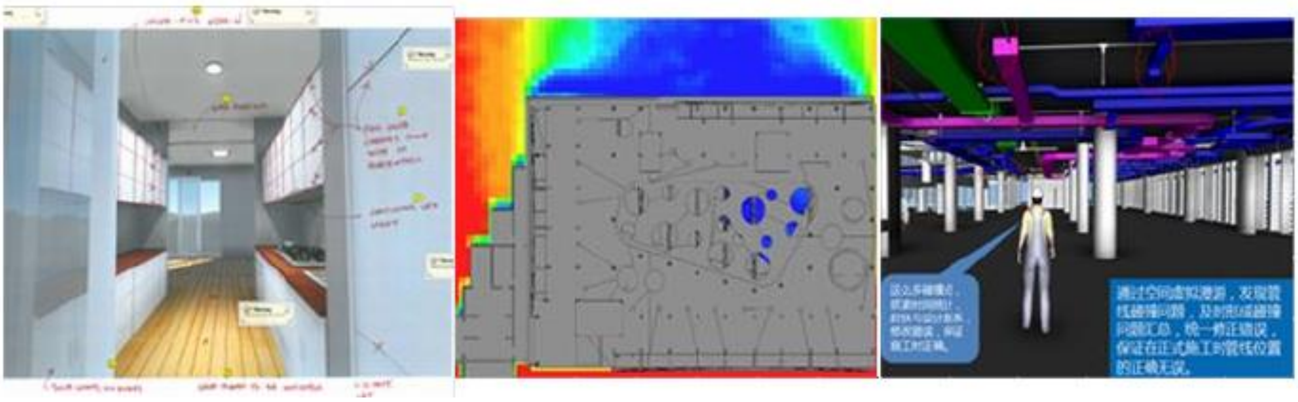


Figure 3.2- Application of BIM technology in the development stage

3.3.2 Application of BIM technology in other stages of green building

In other stages, BIM can also use its 3D display ability, accurate computing ability and collaborative communication ability, and its application to green buildings can well reflect the characteristics of green buildings. Drawing on the good practices obtained by BIM technology in the construction management of green building at home and abroad, BIM technology is applied to the whole life cycle of green building[56][57], This article introduces the application of BIM in other stages based on the practical application in the Danish green construction project.

Table 3.4- Application of BIM technology in the whole life cycle of green building

project stage	And BIM technology application	Reflect the characteristics of green construction
decision phase	1)Site modeling, roaming. In the technical scheme, according to the customers' demand for the green building, establish the 3D model of the building, so that all the participant have an intuitive and convenient understanding of the green building from the very beginning; 2)Planning and positioning, land use inspection.	Customer-centric, considering the environmental properties of buildings; new technology utilization
implementation phase	1) 4D simulation, dynamic allocation of resources. The combination of 3 D building model and schedule arrangement can realize a 4D dynamic simulation model, timely find out the risk of resource allocation in the construction process, and guide the front-line staff to be familiar with the construction process.	
	2) Use the construction calculation to realize lean construction. Accurately grasp the construction progress, cost, quality and other aspects of the information. The allocation of resources in the construction can be dynamically managed to make the lean construction possible.	New technology utilization Ensure the balanced construction objectives
	3) Construction guidance of the components. For some components with special structures, BIM can be used to build 3D models and make solid models in a certain proportion, so as to be familiar with the positioning of special components and template making and construction.	
End of the stage	1) Provide the use and performance of the building. Information on occupancy and capacity, the time and finance of the building, and the provision of the building	Life-span energy-saving management; New technology

	All the physical information, so that the owner can grasp the information, to make a reasonable decision fix.	utilization; Customer-centric
	2) Failure impact analysis. To facilitate the subsequent maintenance of the management personnel.solid The appreciation of the current construction, the value preservation.	

(1)Application of BIM technology in the decision-making stage

In the decision-making stage, in the technical scheme, according to the customer demand for green building, building 3D model, make the participants to green building from the beginning of the internal and external environment of intuitive convenient understanding, in the late architectural design, construction, operational solutions are easier to agree, but also facilitate to display, play a good demonstration propaganda, figure 3-2 for green engineering planning of internal and external environment. At this stage, the application of BIM technology fully reflects the characteristics of green construction being customer-centered and considering the environmental attributes of the building.

Figure 3.3- Application of BIM technology in the decision-making stage

(2)Application of BIM technology in the construction stage

In the construction stage, the 3D modeling guidance template support, provides guidance for the construction of complex structure construction, with spiral staircase, for example, the spiral staircase is composed of two different radius of the same center of the spiral grading, each step from the center of the outward, although the inner and outer step width is different, but the elevation of each radial surface is the same. The construction of the spiral staircase is complicated, so the internal work must be done first. This project uses BIM technology to derive the ID coordinates of the control point of the ladder beam and realize the construction operation of the spiral staircase with no less open folding plate. Ensure the smooth construction, no rework in the implementation process, save time and reduce the waste of materials, see Figure 3-4 (Part 1).

1) BIM technology guides the construction of woven weather-resistant steel sunshade board. Through the analysis of the shading screen connection nodes, reasonable construction technology and installation sequence are obtained, reducing the construction difficulty and increasing the construction efficiency by 10%;

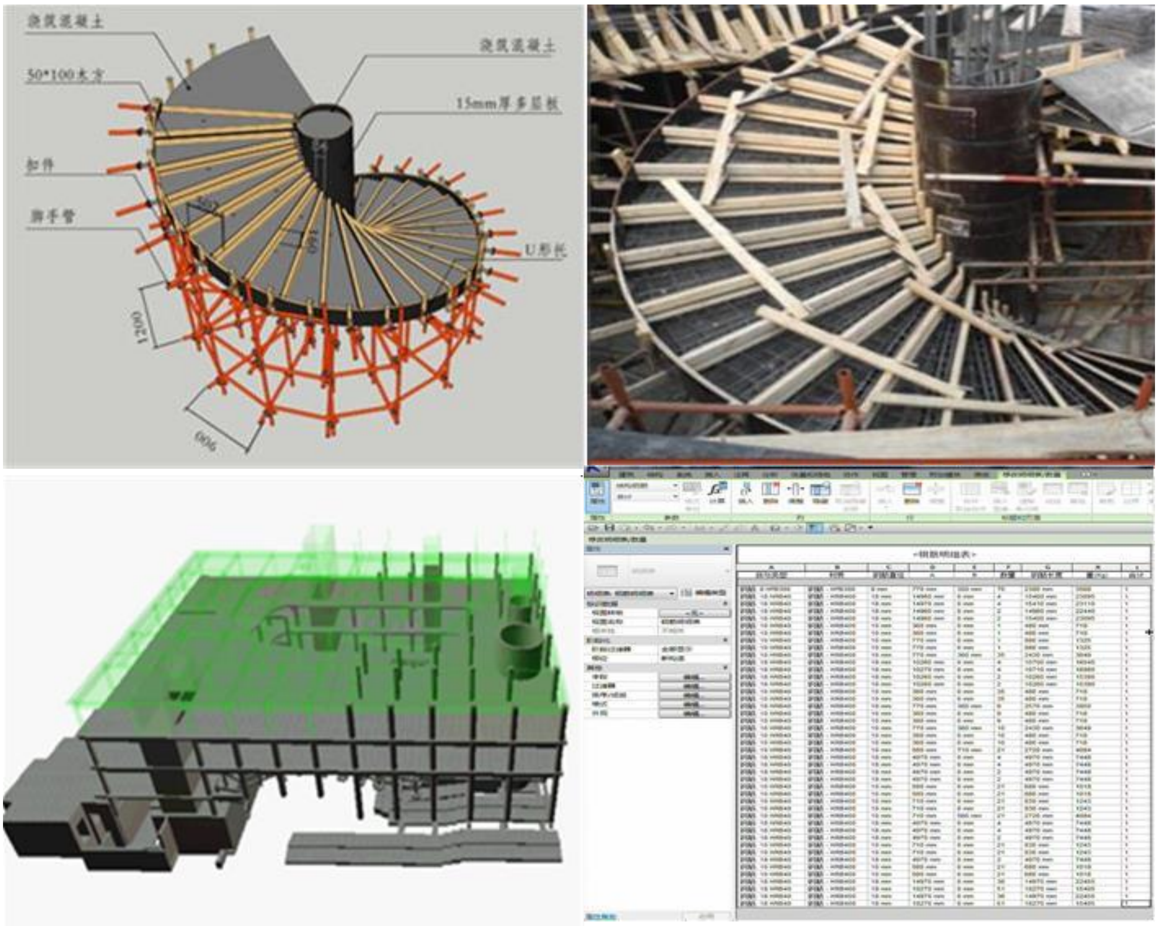
2) Through the selection of shading screen materials and installation technology of shading screen, the energy consumption of heating unit is reduced 240kWh / m2 is down to 15kWh / m2；

3）Change the traditional construction method, through the new technology, the new process to reduce the construction cost by 30%;

4）Change the traditional shading material to the weather-resistant steel material to improve the safety factor of the shading screen;

5）The establishment of the building comprehensive evaluation model can effectively judge the safety indicators in the building, and correct the problems in time, so as to ensure the smooth progress of the project.

In addition, the 4D progress visualization simulation saves labor cost, understanding the project entity and improving the construction efficiency see Figure 3-4 (lower left); in the construction stage, in the actual construction, guiding the consumption of rebar and concrete through B I M calculation, the deviation can be controlled at about 5%, in line with the green construction concept of low consumption, see Figure 3-4 (lower right). At this stage, B I M technology, as a new technology



reflects the optimization and pursuit of green building energy conservation Characteristics of the target equilibrium.

(3)Application of BIM technology in the operational stage

In the subsequent operation and maintenance stage, BIM technology will also help managers to do a good job in building information management and fault impact analysis, which will play an important role in facility management and maintenance.

Figure 3-4 Application of the implementation phase of BIM technology

3.4 Conclusions to chapter 3

The main work of this chapter includes three aspects:

(1)Starting from the characteristics of green construction and the requirements of green construction certification, on the basis of the traditional construction process, the scheme optimization and the scheme deepening design links are added after the preliminary design, and the construction is extended to the operation and maintenance stage.

(2)Based on the characteristics of green construction, the value engineering is introduced into the green building construction, and a method of construction scheme optimization based on value engineering is proposed. The steps are:

1)Determine the study object;

2)Define green building function indicators and whole life cycle cost elements;

3)Functional attributes are determined by the test of the samples;

4) Considering the correlation between the indicators, the ANP is used to determine the importance of the functional indicators, and then determine the functional coefficient and the cost coefficient;

5)Optimize and optimize the value analysis and implementation scheme.

(3)Considering that the current green building construction does not match the demand of green building, the construction process can be extended to the whole life cycle, and BIM technology can be introduced in the whole life cycle to optimize the decision-making, design, construction and maintenance management of the project.

4 ENGINEERING CASE VERIFICATION OF CHINA-DENMARK SCIENTIFIC RESEARCH AND EDUCATION CENTER OF CHINESE ACADEMY OF SCIENCES

Through the second chapter and the third chapter of green energy-saving building construction present situation and problems, combing the characteristics of green construction and green construction key consideration, and then the scheme selection based on value engineering optimization and BIM optimization scheme deepening as two important link into the construction process. This chapter will take the green construction project being implemented by the company as an example to introduce the application of the methods mentioned above in the actual projects.

4.1 Project overview

The Green Demonstration project of China-Denmark Scientific Research and Education Center is fully donated by Denmark, which is the first scientific research and education construction project invested in China. This project has one floor underground project, five floors above ground and six local floors. Area of 10865.48m^2. The project cost is 93.1 million yuan. The project is contracted by China Railway Construction Engineering Group. The planned completion date in the contract is expected to be completed by the end of 2016. The project strictly implements the green construction requirements of LEED from the process of project decision-making, design and construction, and the project department carefully plans in line with the concept of sustainable development, and scientifically organizes the green construction. The project is a comprehensive micro-energy consumption building integrating scientific research, education, teaching and apartment. The project is called a "breathing building" for its energy-saving, low consumption and environmental protection. From the perspective of the whole life cycle, the group company in the early planning stage in project demonstration, involved in the construction planning, design, construction process, in the whole life application of the BIM technology and value engineering method, received the good effect, among them, BIM technology application of the project won the second China construction engineering BIM competition won the first prize for excellence project award. Considering the requirements of green construction and the actual requirements of LEED certification of the project, the traditional construction first designs the construction drawings, and then the construction. At present, in order to balance the cost and functional factors of the whole life cycle, and ensure the smooth implementation of the project. The preliminary planning, design and construction are generally contracted by China Railway Construction Engineering Group, among, Preliminary conceptual design conducted by the Danish side, Deepening by the Chinese design institute, To achieve the concept of green and energy-efficient buildings, Must be deepened by the construction party after the preliminary design, Through the leadership of the construction party and the cooperation of the professional company, the unilateral preliminary conceptual design is deepened and secondary design, To meet the requirements of the building itself, In order to solve the green and energy-saving construction and the traditional construction is different, Therefore, after the conceptual design of Danish designers, it is no longer simply the problem of Chinese design institutes, But the Chinese Design Institute and the construction general contractor to deepen the problem, To meet the conceptual requirements of the Danish side, To meet the standards of green and energy-efficient buildings. Therefore, on the basis of the traditional construction process of the company, we will focus on adding the scheme optimization selection based on value engineering after the preliminary design and the BIM scheme design deepening link before the construction, so as to advance the green design optimization and extend the construction process to the operation and maintenance stage.

4.2 Application of construction process optimization of green and energy-saving building based on value engineering

As the engineering scheme, LEED certification standards and construction drawings are formulated by Denmark, Green construction has very high requirements, A lot of the functional properties of green construction need to be considered, At this point will increase the cost input, How to reasonably improve the functional cost and efficiency is the key, So after receiving the project proposal, The scheme comparison link was added to the preliminary design, Fully apply the value engineering to the main body and the green scheme, Small to the comparison of individual projects and components, Optimization and selection of the scheme, Such as lighting, ventilation passive energy saving scheme optimization, platfond materials, TABS pipe and other materials selection, Optimization of construction technology of braided weathering steel sun visor, by contrast, trial-produce, Determine the feasible scheme and select the key and main energy saving objects to improve the scheme. In addition, the value engineering will be applied to the selection of green materials and new technology in the construction stage. In later operation and maintenance phases, value engineering can also be used for the optimization of operation and maintenance schemes and the maintenance of critical faults. The following to the value of the project in the platfond scheme preferred application as an example, do the key introduction.

The construction scheme of platfond platfond is designed and improved according to the Danish design style and its design characteristics, process requirements and functional requirements. There are two schemes: scheme 1 is wooden , the material is pine aggregate, pine growth cycle, fine rings, flexible wood texture, low oil content of trees, and Yin and Yang distribution, beautiful and environmental protection; scheme 2 is bamboo , material for southern bamboo, bamboo itself, do simple treatment, bamboo strong reproduction ability, fast speed, small diameter, thin wall, hollow, special lignin and cellulose, is a special ecological vegetation type[60]. The following is based on the two schemes:

4.2.1 Platfond function index definition

Platfond is a special decorative structure, including many functional attributes, such as: environmental protection, energy saving, fire prevention, beauty and so on. Draw lessons from literature[11],[51],[61]And the functional criteria used in material selection in practice, and the functional indicators of F1 to F9 are selected, in which F1 to F7 are the basic functions, and F8 and F9 are the accessory functions. Based on the investigation of the owner unit, the project department, the design department and the supplier representative, the correlation between the functional indicators is determined, as shown in Table 4-1. Take F1 as an example, it is affected by F2, F3, F4, F5 and F8. Its environmental protection, energy saving, fire prevention, moisture-proof and construction will carry out secondary processing of the material, which has an impact on the green attributes, indicating that the constraints of these indicators should be taken into account in the construction.

Table 4.1 - Function index system

Primary functional indicators	**Secondary functional indicators**	**Indicator instructions**	**A secondary functional index that can affect this factor**
basic function	Green attribute F1	The use of green natural, renewable materials, less processing links, in order to reduce the natural capital The function of source damage and damage.	F2, F3、F4、F5、F8
	Environmental protection performance: F2	The object used is in the development, use, recycling process section About resources, to protect the function of the macro and micro environment.	F1、F2、F3、F6、F8
	Energy-saving performance of F3	Conservation of natural resources and energy in the process of use the function of.	F1, F2, F8
	Fire protection performance F4	The fire prevention performance of the research object, generally with fire prevention, etc Level to assess.	F1、F8
	Moisture-proof performance, F5	The moisture-proof performance of the study subjects.	F6、F8
	stability F6	Study subjects, after receiving an external force, the environmental impact is to maintain a stable performance.	F5、F7、F8
	Overall F7	The subjects maintained flat and uniform performance.	F1、F3、F4、F5、F8
Affiliate function	Simple construction F8	Convenient for construction, operation and maintenance functions.	F1, F2, F3, F4, F5,F7, F9
	Beautiful F9	To create a pleasant environment for the user ability.	F1, F6,F7

4.2.2 Calculation of the platfond function coefficient

The expert scoring method is used to score the satisfaction of the owner, the project department, the design department and the supplier representative, see Table 4-1; then use ANP to confirm the importance coefficient of each function, using Super decision, indicating the mutual influence between the element sets at the arrow and the circular arrow represents the influence relationship between the elements in the element set.

After constructing the ANP model, the pairwise comparison of elements and element sets is required to construct the comparison judgment matrix. Because this model does not use the criterion layer, the main criterion for the only target elements, the contrast between the elements, any element in the network layer, in turn of the elements of the concentration of other elements of indirect advantage comparison, using nine points method for score, also can use matrix, semantic and pie chart method between elements one by one comparison, and then get the judgment matrix between functional indicators. The contrast matrix was constructed using the green attribute F1 as shown in Table 4-3. Enter in the SD software,. The value of the consistency test CI=0.027 <0.10, through the consistency test.

Table 4.2- Functional satisfaction with protocol

scheme	Basic function (out of 10 points)							Auxiliary functions (out of 10 component)	
	Green attribute F1	Environmental protection performance: F2	Energy-saving performance of F3	Fire protection performance F4	Moisture-proof performance, F5	stability F6	Integrity, F7	simplicity of construction F8	pleasing to the eye F9
Scheme 1	8.2	7.6	7	7	7.8	9	9.2	9	8
Scheme 2	9	8	8	6.8	5	7	6.8	5.8	8

Table 4.3- Comparison matrix of each functional indicator under the green attribute F1 criterion

	F2	F3	F4	F7
F2	0	1/2	1	1/7
F3	2	0	1/3	1/6
F4	1	3	0	1/5
F7	7	5	5	0

According to the above process method, the remaining indicators are compared one by one, and the weight and ranking calculation results . At this time, the consistency test CR=0.034 <1, the consistency test is passed, and the ranking and weight are shown in Table 4.4.

Table 4.4 Indicator and the weight of the ranking

Level 1 indicators	Secondary indicators	weight	sort
basic function (0.8662)	Green attribute F1	0.138444	2
	Environmental protection performance: F2	0.131077	4
	Energy-saving performance of F3	0.126115	5
	Fire protection performance F4	0.038142	8
	Moisture-proof performance, F5	0.125377	6
	stability F6	0.172689	1
	Overall F7	0.134436	3
Affiliate function (0.1337)	Construction construction F8	0.108285	7
	Beautiful F9	0.025435	9

Combining the contents of Table 4-2 and Table 4-4, the coefficients of each functional index in Table 4-5 are multiplied accordingly.

Table 4.5 Functional scores of the protocol

scheme	basic function							Affiliate function	
	Green attribute F1	Environmental protection performance: F2	Energy-saving performance of F3	Fire protection performance, F4	Moisture-proof performance, F5	stability F6	integrity F7	simplicity of construction F8	pleasing to the eye F9
Scheme 1	1.14	1.00	0.88	0.27	0.98	1.55	1.24	0.97	0.20
Scheme 2	1.25	1.05	1.01	0.26	0.63	1.21	0.91	0.63	0.20

According to (equation 2):

Functional coefficient F of Scheme 11=8.23; Functional coefficient F of Scheme 22=7.14; after normalization,

F1=0.535, F2=0.455

In terms of scheme functional coefficient score, scheme 1 has a higher score than Scheme 2, but in terms of functional composition,

bamboo, Less adaptable to the northern dry climate than the pine, Easy to crack, Leading to its low scores on stability and integrity, at the same time, Bamboo production and processing manufacturers are less, Belongs to the custom products, Insufficient supply of goods, It also increases the difficulty of construction.

4.2.3 Platfond cost coefficient calculation

After fully considering the material cost, transportation cost, construction cost and operation and maintenance cost of Scheme 1 and Scheme 2, the unit cost of using bamboo is higher than that of circular barrel . The cost coefficient of the two schemes is as follows, see Table 4-6:

- C1=0.429, C2=0.571。

Table 4.6 Calculation of protocol cost coefficient

Scheme	form	cost coefficient
Scheme 1	Round wooden bucket	0.429
Scheme 2	Bamboo	0.571

4.2.4 Calculation of platfond value function coefficient

According to (equation 1):

V1 = F1/C1 = 0.548/0.429 = 1.247； V2 = F2/C2 = 0.452/0.571 = 0.813.

According to the value engineering principle, the value coefficient of Scheme 1 is greater than 1, indicating that the importance of various functions is greater than the cost; the value coefficient of Scheme 2 is less than 1, indicating that the importance of cost is higher than the function. From the actual cost of the two schemes and the evaluation of the functions of the two schemes by the core stakeholders of the project, it can be seen that the price and function of the pine circular barrel platfond scheme are high-quality and inexpensive materials, so scheme 1 is selected in the construction. Figure 4-5 shows the situation of the platfond, Figure 4-5 (left) is the decorative rendering of the platfond, Fig. 4-5 (middle) is the effect drawing of the platfond unit, and Figure 4-5 (right) shows the physical drawing of the selected pine cylinder assembly. Due to the natural weakness of bamboo and easy to crack in the north, and according to the value engineering comparison and experimental data, we persuaded the Danish side to replace the bamboo scheme with pine .

Figure 4.5- Unit type natural round wooden bucket, ceiling with ceiling

4.3 Application of BIM technology in the construction process of green and energy-efficient building

4.3.1Optimization application of BIM technology to the construction process

After receiving the construction drawings from the Danish side, considering the expensive value of various components and the unique complexity of the project after the optimization of the scheme, it is necessary to minimize the loss of rework and delay to ensure the smooth construction. The project department successfully established the B I M technical team and added the depth optimization of the scheme to the original construction process as a new link.

Using the Revit 2014 3 D modeling tool, MS Project2010 Schedule management software, Naviswok 2014 software and Ecotect energy consumption analysis software in the depth design stage of the overall implementation of 3 D modeling, professional collaboration, progress simulation, pipeline collision, internal roaming, engineering calculation and building energy simulation and other work, 3D modeling, 4D progress and 5D cost, The construction process was optimized by simulation, Reduced errors in the construction, do poorly done work over again, Delof work, etc.in addition, The BIM was applied to the subsequent work, As shown in Figure 4-6 for the application of BIM technology in dan Education Center, The demonstration of the internal and external environment was achieved using 3D modeling during the decision stage, Provides an intuitive visual architectural model for each participants, To facilitate the communication between all parties; In the design stage of BIM, technology plays the role of technology deepening, energy simulation and collaboration between professionals; The main role of BIM technology in the re-implementation stage is to play its 3D modeling, engineering calculation, 4D progress and 5D cost functions, Can guide the fine construction; In the subsequent operation and maintenance phase, BIM will also analyze the building information management and major fault effects. BIM technology can improve the efficiency of decision-making, design, construction and maintenance and protection, and reduce the cost during the whole life of green buildings. The construction management of BIM technology in the case of rotating staircase will be described in detail below.

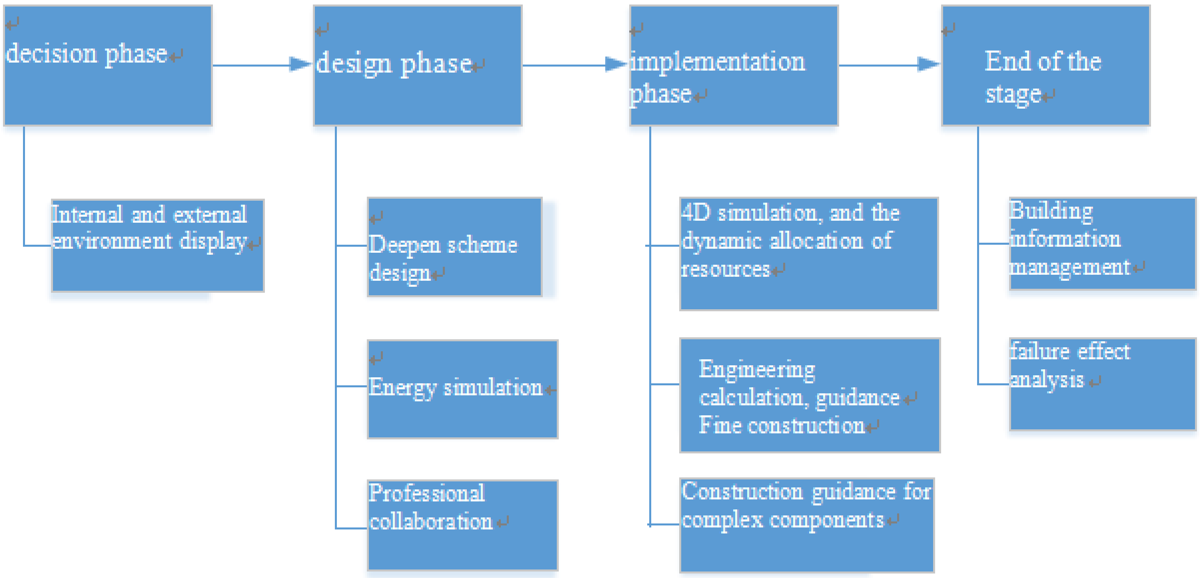


Figure 4-6 Application of BIM technology in the construction of green and energy-saving buildings

4.3.2Case introduction

The spiral staircase is a spiral plane composed of two inner and outer helices of different radii in the same center of the circle. Each step radiates outward from the center of the circle. Although the inner and outer step width is different, the elevation of the inner and outer steps is the same on each radial surface. Spiral staircase construction line is more complex, we must first do a good job in the industry

The project uses BIM technology to derive the ID coordinates of the control point of the girder and realize the construction operation of the rotating staircase with bederless open folding plate. The following is its construction management process:

（1）Use Revit 2014 to establish the 3D model of the spiral staircase, and the mold support situation;

（2）According to the ratio of 1:20 to guide the manufacture of mold, steel binding;

（3）Use Revit 2022, MSproject2010 and Naviswok 2014 to simulate the construction progress and export the project quantity, and guide the material arrangement and production guidance according to the simulation information and project quantity;

（4）According to the model and the BIM information, export the ID coordinates of the control point of the ladder beam, bind the steel bar, supporting formwork and pour the concrete slab, so as to realize the construction of the bederless open folding slab concrete rotating staircase.

（5）Follow up and improve the construction maintenance information, record the cost, progress and quality, and do a good job

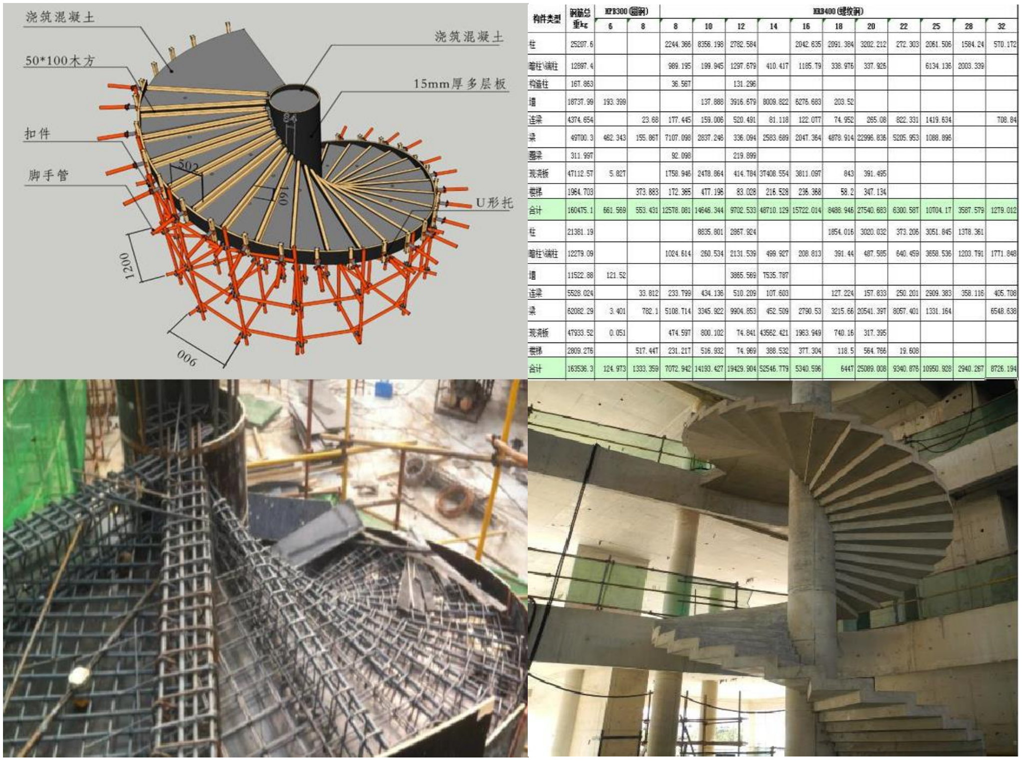


Figure 4.7 - Shows the formation of infinite rotating staircase from design to construction in the middle education demonstration project.

Figure 4.7 (top left) shows the 3D model using BIM, including formwork support and coordinate alignment; Figure 4-7 (top right); Figure 4-7 (bottom left) shows the reinforcement binding and formwork support; Figure 4-7 (bottom right) shows the physical drawing after stair construction and maintenance. After the comparison with the company's previous stair construction scheme, this project using BIM technology has made great progress in the following six aspects:

1) Through the analysis of the spiral staircase construction, the reasonable construction technology and operation sequence are obtained, to reduce the construction difficulty, reduce the rework, and improve the construction efficiency by 10%;

2) Change the traditional construction mode, through the new technology, new process, reduce the waste of working materials, save the construction cost of 30%;

3) Using the simulation before construction, maintenance and monitoring after construction, stair construction in place and later operation and maintenance monitoring, improve the safety factor of rotating stairs;

4）The establishment of the comprehensive evaluation model of the building can effectively judge the safety indicators in the building, and correct the problems in time, so as to ensure the smooth progress of the project;

5）Form the post-economic evaluation form for energy-saving buildings, which plays a guiding role in the evaluation of operation and maintenance costs in the later period;

6）The establishment of rotating stair gallery includes component library, structure library, decoration library and the corresponding construction method, which can provide reference for the subsequent construction of similar stairs.

4.4 Conclusions to chapter 4

Taking the Green Demonstration project of China-Denmark Scientific Research and Education Center as an example, this chapter mainly has two aspects:

（1）Focus on the value engineering in optimization stage application, with scheme value engineering method application in green construction scheme optimization, the results show that the construction scheme based on value engineering optimization method fully considering the function of the whole life cycle and cost composition, clear process, simple operation, obvious effect, can be used as green building construction scheme optimization and selection of decision-making method.

（2）This thesis introduces the application of BIM technology in the depth optimization stage, and then focuses on the application of BIM technology in bederless rotating staircase. The application results show that the application of BIM technology in rotating staircase can be:

1）Draw a reasonable construction technology and operation sequence, reduce the construction difficulty, reduce the rework, and improve the construction efficiency by 10%;

2）Change the traditional construction mode, through the new technology, new process, reduce the waste of working materials, save the construction cost of 30%;

3）Using the simulation before construction, maintenance and monitoring after construction, stair construction in place and later operation and maintenance monitoring, improve the safety factor of rotating stairs;

4）Provide guidance for the later operation and maintenance;

5）Knowledge accumulation, component database and construction technology can be used for reference for similar solutions of the group.

5 ECONOMIC PART

The final part of the master's qualification work is economic. In it, we will consider the main indicators, namely: the novelty of the work, the level of its theoretical development, perspective, the level of distribution of results, the possibility of implementation, the level of commercial potential and others.

5.1Conducting a scientific audit of research work

The scientific effect can be characterized by two indicators: the degree of scientific novelty and the level of theoretical elaboration.

The value of the indicators of the degree of novelty of research work in points specifically for our case is given in the table. 5.1.

Table 5.1 – Indicators of the degree of novelty of research work

The degree of novelty	Characteristics of the degree of novelty	indicator value degree of novelty, points
Nova	New information was obtained, which significantly reduces the uncertainty of existing values (known facts and patterns were explained in a new way or for the first time, new concepts were introduced, the content structure was revealed). A significant improvement, addition and clarification of previously achieved results was carried out	40...60

According to table 5.1. the degree of novelty of research work is k new = 55 points.

The value of the indicators of the level of theoretical development of research work in points specifically for our case is given in the table. 5.2.

Table 5.2 – Indicators of the level of theoretical development of research work

Characteristics of the level of theoretical study	indicator value theoretical level processing, points
Deep study of the problem: multi-faceted analysis of connections, interdependence between facts with the presence of explanations, scientific systematization with the construction of a heuristic model or complex forecast	60...80

According to the data of table 5.2. the degree of novelty of research work is k_{theory} = 75 points.

The indicator that characterizes the scientific effect is determined by the expression:

$$E_{нау} = 0,6 \cdot k_{нов} + 0,4 \cdot k_{теор}, \qquad (5.1)$$

where k nov , k theor – indicators of degrees of novelty and the level of theoretical development of research work, points;

0.6 and 0.4 – the specific weight (significance) of indicators of the degree of novelty and the level of theoretical development of research work.

$$E_{нау} = 0,6 \cdot 55 + 0,4 \cdot 75 = 63$$

We compare the obtained values with the limit values given in table 5.3.

Table 5.3 – Limit values of the indicator of scientific effect

The level of the indicator has been reached	Scores
Average	50...69

Having established the level of the scientific effect of the conducted research work, it can be said that the development and its implementation are relevant at the present time.

5.2 Conducting a commercial and technological audit of scientific and technical development

The purpose of conducting a commercial and technological audit is to assess the scientific and technical level and the level of commercial potential of the development created as a result of scientific and technical activity. The development is the implementation of BIM technologies in the implementation of energy-saving technologies .

We engage 3 independent experts to conduct a commercial and technological audit. We will evaluate the scientific and technical level of the development and its commercial potential using a five-point evaluation system based on 12 criteria, according to the recommendations.

Table 5.4 – Results of assessment of scientific and technical level and commercial development potential

Criteria	Experts		
	Expert 1	Expert 2	Expert 3
	Points awarded by experts		
1	3	4	4
2	4	4	3
3	4	4	4
4	3	4	4
5	3	3	3
6	4	4	3
7	4	3	3
8	4	4	3
9	4	4	3
10	3	3	4
11	4	4	3
12	3	4	4
Total points	43	45	41
Arithmetic average sum of points СБ c	43		

Based on the data in Table 4.4, we draw a conclusion about the level of commercial development potential. At the same time, we use the recommendations given in table 5.5.

Table 5.5 – Levels of commercial development potential

Arithmetic mean sum of points, calculated on the basis of experts' conclusions	Level of commercial potential developments
0 - 10	Low
11 - 20	Below average
21 - 30	Average
31-40	Above average
41-50	High

Since the average arithmetic sum of points is 43, the level of commercial potential of the development is high, therefore this development is realistic for its further implementation and implementation. This level was achieved due to a significant reduction in resource costs and time for the process of driving piles in horticulture, because our development helps to reduce the time for the operation. The development is new, as the problem of sinking piles in orchards and vineyards is currently relevant. Currently, there are a number of pile driving units on the market, but they are expensive, so not every company has the opportunity to purchase one. In addition, it becomes possible to use the equipment more conveniently, based on its compact size.

5.3Calculation of costs for carrying out scientific research work

Expenses related to the conduct of scientific research, experimental design, design and technological work, the creation of a prototype and the implementation of production tests, during the planning, accounting and calculation of the cost of scientific research work, are grouped under the following items:

− labor costs;

- deduction for social events;

− materials;

- fuel and energy for scientific and industrial purposes;

− expenses for business trips;

− special equipment for scientific (experimental) work;

− software for scientific (experimental) works;

- expenses for work performed by third-party enterprises, institutions, etc organizations;

− other expenses;

− overhead (general production) costs.

5.3.1 Salary expenses

Basic salary of researchers

Expenses for the basic salary of researchers (Zo) are calculated according to the salaries of employees, according to the formula:

$$З_o = \sum_{i=1}^{k} \frac{M_{ni} \cdot t_i}{T_p}, \qquad (5.2)$$

where k is the number of positions of researchers involved in the research process;

M_{ni} - monthly salary of a specific researcher, $;

t_i - the number of working days of a particular researcher, days;

T_p - the average number of working days in a month, T_r = 21...23 days.

This development will be carried out by an engineer, the salary will be $ 1,700 per month. The number of working days in a month is 21, and the number of working days of a researcher is 42. Let's summarize the total calculations in Table 5.6.

Table 5.6 – Salary of a researcher in a scientific institution of the budgetary sphere

Job title	Monthly salary, $	Pay per working day, $	Number of working days	Salary expenses, $
Project Manager	2500	119	5	595
Engineer	1700	81	42	3400
In total				3995

Basic wages of workers.

Expenses for the basic salary of workers (Z_r) for the relevant titles of work are calculated according to the formula:

$$З_p = \sum_{i=1}^{n} C_i \cdot t_i, \qquad (5.3)$$

where C_i is the hourly tariff rate of a worker of the corresponding grade, for the corresponding work performed, $;

t_i – the worker's working time to perform a certain job, hours

The hourly tariff rate of a worker of the corresponding grade is determined by the formula:

$$C_i = \frac{M_M \cdot K_i \cdot K_c}{T_p \cdot t_{зм}}, \qquad (5.4)$$

where $_{MM}$ is the amount of the minimum monthly salary of $1,700;

K_{and} – the coefficient of the inter-qualification ratio for setting the tariff rate for the worker of the corresponding grade;

Ks is the minimum ratio of the monthly tariff rates of first-class workers with normal working conditions of industrial associations and enterprises to the legally established minimum wage .

Tp – the average number of working days in a month, approximately Tp = 21...23 days;

t_{shift} – shift duration, hours

Let's calculate the hourly tariff rate of a procurement operations worker:

$$C_i = \frac{1700 \cdot 1{,}1 \cdot 1{,}5}{21 \cdot 8} = 16{,}69 \quad (\$.)$$

where the coefficient K_s is selected from table 5.7

Table 5.7 – Minimum coefficients of ratios of monthly tariff rates of first-class workers with normal working conditions of industrial associations and enterprises to the legally established size of the subsistence minimum for an able-bodied person

Types of production and work, professions of workers	Coefficients
Locksmiths-toolmakers and machine tools of a wide profile, employed on the universal equipment of tool and other production preparation shops in the manufacture of particularly accurate, responsible and complex molds, stamps, accessories, tools, devices and equipment; machine tools on unique equipment, which are engaged in the production of particularly complex products; locksmiths-repairers, electricians and adjusters who are engaged in repair, adjustment and maintenance of particularly complex universal equipment; other highly skilled workers who perform particularly complex and unique jobs	1.8
Workers of the main and auxiliary production	1.65
Workers employed in other jobs, not directly related to the main nature of the enterprise's activity	1.5

Table 5.8 – Value of the current tariff coefficients of workers [61]

Discharge	1	2	3	4	5	6	7	8

K_i	1.0	1.1	1.35	1.5	1.7	2.0	2,2	2.4

The calculations made according to expression (5.4) are listed in table 5.9.

Table 5.9 - Amount of expenses for the basic salary of workers

Name of works	Duration of work, hours	Type of work	Tariff factor	Hourly tariff rate, $	Amount of payment per worker, $
Procurement	3	2	1.1	16.69	50.09
Mechanical	2	3	1.35	22.54	45.08
Folding	2	4	1.5	25.04	50.09
Debugging	1	4	1.5	27.32	54,64
In total					199.9

Additional wages of researchers and workers

The additional salary is calculated as 10...12% of the basic salary of researchers and workers according to the formula:

$$З_{дод} = \left(З_о + З_р\right) \cdot \frac{Н_{дод}}{100\%}, \tag{5.5}$$

where $Н_{дод}$ is the rate of calculation of additional wages.

At this enterprise, additional wages are calculated in the amount of 12% of the basic wages.

$$З_{дод} = (3995 + 199{,}90) \cdot \frac{12}{100\%} = 503 \text{ (\$)}$$

5.3.2 Deductions for social events

The article "Deductions for social measures" includes deductions for contributions to mandatory state social insurance and for the implementation of measures for social protection of the population (EUV - single social contribution).

The calculation of the wages of researchers and workers is calculated as 22% of the sum of the basic and additional wages of researchers and workers according to the formula:

$$З_н = (З_о + З_р + З_{дод}) \cdot \frac{Н_{зп}}{100\%}, \quad (5.6)$$

where $Н_{зп}$ – rate of calculation of wages;

$З_о$ - basic salary of developers, $;

$З_р$ - the basic salary of workers, $;

$З_{дод}$ – additional wages of all developers and workers, $.

$$З_н = (3995 + 199,9 + 503,4) \cdot \frac{22}{100\%} = 1033,68 \ (\$)$$

Therefore, the calculation of wages is 1033.68 $

5.3. 3 Software for scientific (experimental) works

The article "Software for scientific (experimental) works" includes costs for the development and purchase of special software and software (programs, algorithms, databases) necessary for conducting research, as well as costs for their design, formation and installation.

The book value of the software is calculated according to the formula:

$$В_{прг} = \sum_{i=1}^{k} Ц_{iпрг} \cdot С_{прг.і} \cdot К_i, \quad (5.9)$$

where $Ц_{iпрг}$ - purchase price of a software tool of this type$;

$С_{прг.і}$ – the number of software units of the corresponding name, which were purchased for conducting research, pcs.;

Ki *is* a coefficient that takes into account the installation, debugging of the software, etc. (Ki = 1.10...1.12);

k is the number of names of software tools.

Let's calculate the cost of purchasing the software

$$В_{прг} = \sum_{i=1}^{k} 3000 \cdot 1 \cdot 1,1 = 3300 \ (\$)$$

5.3. 4 Depreciation of equipment, software and facilities

The article "Depreciation of equipment, software and premises" includes depreciation deductions for each type of equipment.

In a simplified form, depreciation deductions for each type of equipment, premises and software, etc. can be calculated according to the formula:

$$A_{обл} = \frac{Ц_б}{T_в} \cdot \frac{t_{вик}}{12}, \qquad (5.10)$$

where $Ц_б$ is the balance sheet value of equipment, software, premises, etc., which were used for conducting research, $;

$t_{вик}$ - term of use of equipment, software, premises during research, months;

$T_в$ - useful life of equipment, software, premises, etc., years.

A production facility, computers, lathes and milling machines, welding equipment, as well as other equipment are used for scientific work.

We carry out calculations for each type of equipment and reduce them to table 5.10.

Table 5.10 – Depreciation deductions for each type of equipment

The name of the equipment	Book value, $	Useful life, years	Term of use of the equipment, months	Depreciation deductions, $
Computer	23000	5	2	766.7

5.3. 5 Fuel and energy for scientific and industrial purposes

The article "Fuel and energy for scientific and industrial purposes" includes the costs of purchasing any fuel from third-party enterprises, institutions and organizations, which is used for the technological purpose of conducting research.

Power losses (B_B) are calculated using the formula:

$$B_e = \sum_{i=1}^{n} \frac{W_{yi} \cdot t_i \cdot Ц_e \cdot K_{впi}}{\eta_i}, \qquad (5.11)$$

where W_{yi} – the installed capacity of the equipment at a certain stage of development, kW;

t_i - duration of equipment operation at the research stage, hours;

$Ц_e$ – cost of 1 kWh of electricity, hryvnias; (the cost of electricity is determined according to the data of the energy supply company);

$K_{вні}$ – the coefficient that takes into account the use of power, $K_{вні}$ < 1;

η_i – coefficient of useful performance of the equipment, η_i < 1.

Let's calculate power consumption for the computer using expression (4.11):

$$B_e = \sum_{i=1}^{n} \frac{0,4 \cdot 352 \cdot 3,0 \cdot 0,9}{0,85} = 447,3 \quad (\$)$$

5.3. 6 Business trips

Expenses under the article "Business trips" are calculated as 20...25% of the amount of the basic salary of researchers and workers according to the formula:

$$B_{св} = (З_о + З_р) \cdot \frac{H_{св}}{100\%}, \qquad (5.12)$$

where *H* $_{sv}$ is the rate of accrual under the article "Official trips".

$$B_{св} = (3995 + 199,9) \cdot \frac{20}{100\%} = 838,98 \quad (\$)$$

Expenses for business trips of employees amount to 838.98 $.

5.3. 7 Other expenses

Expenses under the item "Other expenses" are calculated as 50...100% of the amount of the basic salary of researchers and workers according to the formula:

$$I_e = (З_о + З_р) \cdot \frac{H_{ів}}{100\%}, \qquad (5.13)$$

where *Niv* $_{is}$ the accrual rate under the article "Other expenses".

$$I_e = (3995 + 199,9) \cdot \frac{60}{100\%} = 2516,94 \quad (UAH)$$

Other expenses amount to UAH 2,516.94.

5.3.8 Overhead (general production) costs

Expenses under the item "Overhead (general production) expenses" are calculated as 100...150% of the amount of the basic salary of researchers and workers according to the formula:

$$B_{нзв} = (З_о + З_р) \cdot \frac{H_{нзв}}{100\%}, \qquad (5.14)$$

where $H_{\text{is the name}}$ - the accrual rate under the article "Overhead (general production) costs".

$$B_{нзв} = (15782+680{,}10)\cdot\frac{100}{100\%} = 16462{,}1 \quad (\$)$$

Overhead costs amount to $ 16,462.1.

Costs for conducting scientific research work are calculated as the sum of all previous cost items according to the formula:

$$B_{заг} = З_о + З_р + З_{дод} + З_н + B_{прг} + A_{обл} + B_е + B_{св} + I_в + B_{нзв}, \quad (5.15)$$

$$B_{заг} = 3995 + 199{,}9 + 503 + 1033{,}68 + 3300 + 766{,}7 + 447{,}3 + 838{,}98 + 2516{,}94 + 4194{,}9 = 17796{,}64 \quad (\$)$$

The costs of carrying out scientific and research work amount to 17796.64 $

The total costs **of B** for the completion of scientific research (scientific and technical) work and registration of its results are calculated according to the formula:

$$B = \frac{B_{заг}}{\eta}, \quad (5.16)$$

where η is the coefficient that characterizes the stage (stage) of the implementation of research work. So, if the scientific and technical development is at the stage of: scientific and research works, then η=0.1; technical design, then η=0.2; development of design documentation, then η=0.3; technology development, then η=0.4; development of the experimental sample, then η=0.5; development of an industrial model, then η=0.7; implementation, then η=0.9.

$$B = \frac{17796{,}64}{0{,}9} = 19447{,}04 \quad (\$)$$

The total costs for the completion of the scientific research work and its registration amount to 19447.04 $.

5.4 Assessment of the importance and scientific significance of research work

To substantiate the expediency of performing research work, a special complex indicator is used, which takes into account the importance, effectiveness of the work, the possibility of implementing its results into production, and the amount of work costs.

The complex indicator Kp of the level of research work can be calculated according to the formula:

$$K_p = \frac{I^n \cdot T_C \cdot R}{B \cdot t}, \qquad (5.17)$$

where I^m is the coefficient of importance of work, I^m = 2...5;

n – coefficient of utilization of work results; *n* = 0, when the work results will not be used; *n* = 1, when the work results will be partially used; n = 2, when the results of the work will be used in research and development; n = 3, when the results can be used even without R&D;

T_C – work complexity factor, $T_C = 1 \ldots 3$;

R – coefficient of work efficiency; if the work results are planned above the known ones, then *R* = 4; if the work results correspond to the known level, then *R* = 3; if below the known results, then *R* = 1;

B – cost of research work, thousand $;

t is the time of the research, years.

$$K_p = \frac{5^3 \cdot 3 \cdot 4}{19774{,}04 \cdot 1} = 0{,}075$$

Research work can be considered quite effective with good scientific, technical and economic levels.

5.5 Calculation of the economic efficiency of scientific and technical development for its possible commercialization by a potential investor

Analyzing the directions of scientific and technical development, calculating the economic efficiency of scientific and technical development, we obtained a situation that fully characterizes our work and is called: development or significant improvement of a machine (mechanism, device, device) for use by end consumers.

In this case, the future economic effect will be formed on the basis of the following data: ΔN - an increase in the number of consumers of the device, in the analyzed time periods, from the improvement of its certain characteristics; *N* - the number of consumers who used a similar device in the year before the implementation of the results of a new scientific and technical development; $Ц_в$ – the cost of the device (machine, mechanism) in the year before the implementation of the development results; $\pm \Delta Ц_о$ – change in the cost of the device (increase or decrease) from the implementation of the results of scientific and technical development in the analyzed time periods.

For our case, the potential increase in net profit of a potential investor $\Delta П_i$ for each of the years during which positive results are expected from the possible implementation and commercialization of scientific and technical development is calculated according to the formula:

$$\Delta П_i = (\pm \Delta Ц_о \cdot N + Ц_о \cdot \Delta N)_i \cdot \lambda \cdot \rho \cdot \left(1 - \frac{\vartheta}{100}\right), \qquad (5.18)$$

where $\pm \Delta Ц_о$ is the change in the main qualitative indicator from the implementation of the results of scientific and technical development in the analyzed year. Usually, such an indicator can be a change in the price of a unit of a new development in the analyzed year (relative to the year before the implementation of this development); $\pm \Delta Ц_о$ can have both a positive and a negative value (negative - when the price decreases relative to the year before the implementation of this development, positive - when the price increases);

N is the main quantitative indicator that determines the amount of demand for similar or similar developments in the year before the implementation of the results of a new scientific and technical development;

$Ц_о$ - the main qualitative indicator that determines the price of the implementation of a new scientific and technical development in the analyzed year, $Ц_о = Ц_в \pm \Delta Ц_о$;

$Ц_в$ – the main qualitative indicator, which determines the price of the implementation of the existing (basic) scientific and technical development in the year before the implementation of the results;

ΔN – change in the main quantitative indicator from the implementation of the results of scientific and technical development in the analyzed year. Usually, such an indicator can be an increase in demand for scientific and technical development in the analyzed year (relative to the year before the implementation of this development);

λ is a coefficient that takes into account the payment of value added tax by a potential investor. In 2022, the value added tax rate is 20%, and the coefficient λ=0.8333;

ρ is a coefficient that takes into account the profitability of an innovative product (service). It is recommended to take ρ = 0.2...0.5;

ϑ is the rate of income tax to be paid by a potential investor in 2022 ϑ =18%.

With an optimistic forecast of BIM application technology in the design of an energy-saving facility is $ 48,000 .

Implementation of the project will increase the price of each project by $ 2,000 , taking into account the demand and prices of competitors. It is also predicted that the demand for this product will increase, as this product differs in quality and mobility from the competition.

Demand will increase in the first year by 50 projects, in the next year by 20, and in the third year by another 10 projects.

The coefficient that takes into account the profitability of the product is equal to 0.3.

So, let's calculate the increase in the company's net profit for 2023-2025:

$$\Delta П_{2023} = \left(60 \cdot 2000 + (48000 + 2000) \cdot 50\right) \cdot 0{,}8333 \cdot 0{,}3 \cdot \left(1 - \frac{18}{100}\right) = 537078{,}51$$

$$\Delta П_{2024} = \left(60 \cdot 2000 + (48000 + 2000) \cdot (50 + 20)\right) \cdot 0{,}8333 \cdot 0{,}3 \cdot \left(1 - \frac{18}{100}\right) = 742070{,}32$$

$$\Delta П_{2025} = \left(60 \cdot 2000 + (48000 + 2000) \cdot (50 + 20 + 10)\right) \cdot 0{,}8333 \cdot 0{,}3 \cdot \left(1 - \frac{18}{100}\right) = 844566{,}22$$

Next, we calculate the present value of the increase in all the net profits *of the PE* that a potential investor can receive from the possible implementation and commercialization of scientific and technical development:

$$ПП = \sum_{i=1}^{T} \frac{\Delta П_i}{(1 + \tau)^t}, \qquad (5.19)$$

where $\Delta П_i$ - the increase in net profit in each of the years during which the results of the implementation of scientific and technical development are revealed, $;

T is the time period during which positive results are expected from the implementation and commercialization of scientific and technical development, years;

τ is the discount rate at which the annual forecast can be taken
inflation rate in the country, τ = 0.05...0.25;

t is the period of time (in years) from the moment of the introduction of scientific and technical development to the moment when the potential investor receives additional net profits this year.

The period of time during which the results of the implementation of the NDR are revealed is 2 years. The projected annual inflation rate is 0.25.

Let's calculate the present value of all net profits according to the formula (5.19):

$$ПП = \frac{537078{,}51}{(1+0{,}25)^2} + \frac{742070{,}32}{(1+0{,}25)^3} + \frac{844566{,}22}{(1+0{,}25)^4} = 1069604{,}6 \quad (\$)$$

We calculate the amount of initial investment PV, which a potential investor must invest for the implementation and commercialization of scientific and technical development. For this, you can use the formula:

$$PV = k_{інв} \cdot B, \qquad (5.20)$$

where $k_{інв}$ is the coefficient that takes into account the investor's costs for the implementation of scientific and technical development and its commercialization, usually $k_{інв} = 2...5$, but it can be higher;

B – general expenses for carrying out scientific and technical development and registration of its results, hryvnias.

$$PV = 5 \cdot 19774{,}04 = 98870{,}22 \quad (\$)$$

Then the absolute economic effect $E_{абс}$ or net reduced income from the possible implementation and commercialization of scientific and technical development will be:

$$E_{абс} = ПП - PV, \qquad (5.21)$$

where *PP* is the present value of the growth of all net profits from the possible implementation and commercialization of scientific and technical development, $;

PV is the present value of initial investments, $.

$$E_{абс} = 1069604,6 - 98870,22 = 970734,4 \text{ (\$)}$$

Since $E_{абс} > 0$, it means that the result of scientific research and its implementation will bring profit, i.e. investing funds for the implementation and implementation of the results of scientific work may be appropriate and the investor will be interested in financing this work.

The internal economic return on investments $E_в$ that can be invested is calculated according to the formula:

$$E_в = \sqrt[T_ж]{1 + \frac{E_{абс}}{PV}} - 1, \quad (5.22)$$

where $E_{абс}$ is the absolute economic effect of investments, $;

PV – present value of initial investments, $;

$T_ж$ - the life cycle of a scientific and technical development, i.e. the time from the beginning of its development to the end of obtaining positive results from its implementation, years.

$$E_в = \sqrt[4]{1 + \frac{970734,4}{98870,22}} - 1 = 0,8136$$

The minimum internal economic rate of return on investments $\tau_{мін}$ is determined by the formula:

$$\tau_{мін} = d + f, \quad (5.23)$$

where *d* is the weighted average rate for deposit transactions in commercial banks; in 2020-2022 *d* = 0.9...0.12;

f is an indicator characterizing the riskiness of investment; usually the value *f* = 0.05...0.5, but it can be much higher.

$$\tau_{мін} = 0,2 + 0,3 = 0,5$$

Value $E_в > \tau_{мін}$, then a potential investor may be interested in financing the implementation of scientific and technical development and bringing it to the market, that is, in its commercialization.

Next, we calculate the investment payback period using the expression

$$T_{ок} = \frac{1}{E_в}, \quad (5.24)$$

where $E_в$ is the internal economic rate of return on investments.

$$T_{ок} = \frac{1}{0,8136} = 1,22$$

Since $T_{ок} < 4$ -x years, the financing of the development will be expedient.

5.6 Conclusions to chapter 5

In this section, a commercial and technological audit of scientific research work was conducted. The calculation of labor costs, social measures, software, depreciation deductions, fuel and electricity, business trips and other expenses was also carried out. The final stage of the chapter assessed the importance and scientific significance of the research development, calculated the economic efficiency of the scientific work for its possible commercialization by a potential investor.

TOTAL CONCLUSIONS

With the deepening of green energy-saving construction concept in the construction project, put forward higher requirements for construction management: in the process of green energy-saving construction, need to construct each link of scientific, effective management, and should fully attention to the enterprise economy, technological innovation and promotion, so as to better promote the development of construction industry, make green energy-saving construction to comprehensive popularization in construction engineering, to ensure that the construction industry to achieve economic benefit and social benefit win-win situation. How to summarize the connection and difference between green construction and traditional building construction for green building, and find the key problems of green construction; make special planning of green construction organization, make overall planning, and optimize green building construction are the problems to be concerned in green energy-saving building construction.

Research conclusions and innovation points

On the basis of sufficient literature research and interviews with industry experts, combined with historical project experience, and on the premise of considering the correlation relationship, this thesis makes an in-depth analysis of the problems faced by green construction, in order to meet the needs of green construction, and use new technologies and methods to improve the green construction process and scheme selection. The research done on the above objectives can be summarized as the following points:

(1)From the concept of green building and green building construction, summarizes the current domestic and foreign in green construction management research and practice, found that the current domestic of green construction management research and practice in the traditional project management has a certain basis, the whole life cycle and sustainable development ideas applied to the construction of green engineering, but the focus is one-sided, just focus on part of the key work, not a set of system for green special construction management mode, for the practical guidance is not strong.

(2)Combined with literature analysis and case study, the current deficiencies of green construction are summarized, and then compare the similarities and differences between traditional construction and green construction, comb the characteristics of green construction, and then combine LEED from the characteristics (Leadership in Energy and Environmental Design) and the Ministry of Construction "Green Construction Guidelines" and other standards and construction cases sorted out the focus of green construction work.

(3) Considering that the current green building construction does not match the needs of green building, starting from the characteristics of green construction and the requirements of green construction certification, the optimization of the preliminary design and the deepening of the design after the construction, and the construction is extended to the operation and maintenance stage.

(4)Optimization and selection of construction scheme based on value engineering, and deep optimization of BIM scheme on the basis of optimization.

(5)Chapter 5 takes the actual green and energy-saving building as an example, introducing BIM and value engineering in the project practical application. The example verification results show that the new technology BIM in green construction can play a good role in the whole life period; using ANP method to determine the function coefficient of value analysis can reflect the correlation of functional indicators and easy to operate and popularize, and has good guiding significance for the function evaluation of green construction scheme,

To sum up, based on the characteristics of green construction, the BIM and value engineering optimization selection process applied to the key issues of green construction can optimize the green energy-saving building construction, which can provide new ideas and methods for the demonstration and promotion of green construction.

Can be seen from the research ideas of this thesis, from the characteristics of green construction and green construction certification requirements, on the basis of the preliminary design after the scheme design and construction, and extend the construction to the operation and maintenance stage, is a big innovation of this ерyiші, the first using the scheme selection and optimization process and results to persuade party a and designer, can be used as the basis for change the scheme, and through the optimization of the scheme and B I M application increased the implementation of the project. In addition, considering the relevance of the functional index in value engineering, and calculating the weight of the index is the innovative point of research. At present, most of the functional indicators are used to determine the relationship, and the correlation relationship between indicators is not considered. However, in reality, there are many indicators and the relationship is complex, so a better model is needed. The actual scheme selection needs to consider the correlation between indicators, so the introduction of ANP algorithm in the functional analysis can well consider the correlation between functional indicators, and get the weight of more practical functional indicators.

The research background of this thesis is the construction of green and energy-saving buildings in China. After all, the research based on the special mode of green building engineering and the relationship between stakeholders has certain industry limitations. Therefore, whether it can be widely used in all infrastructure construction projects is a subject for further discussion and research.

Through continuous verification and correction, the optimization of the green construction process proposed in this thesis can be improved, so that it can be applied to more infrastructure construction projects, can be promoted and applied in green building construction projects, and also provide new ideas and methods for the research of green construction.

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ПРОТОКОЛ
ПЕРЕВІРКИ КВАЛІФІКАЦІЙНОЇ РОБОТИ НА НАЯВНІСТЬ ТЕКСТОВИХ ЗАПОЗИЧЕНЬ

Назва роботи: Система управління застосування сучасних матеріалів при влаштуванні зовнішніх стін енергоефективних будинків. / Management system for the use of modern materials in the construction of external walls of energy-efficient buildings

Тип роботи: Магістерська кваліфікаційна робота
(БДР, МКР)

Підрозділ кафедра БМГА, ФБЦЕІ
(кафедра, факультет)

Показники звіту подібності Unicheck

Оригінальність 100 % Схожість 0%.

Аналіз звіту подібності (відмітити потрібне):

[V] 1. Запозичення, виявлені у роботі, оформлені коректно і не містять ознак плагіату.

[ ] 2. Виявлені у роботі запозичення не мають ознак плагіату, але їх надмірна кількість викликає сумніви щодо цінності роботи і відсутності самостійності її виконання автором. Роботу направити на розгляд експертної комісії кафедри.

[ ] 3. Виявлені у роботі запозичення є недобросовісними і мають ознаки плагіату та/або в ній містяться навмисні спотворення тексту, що вказують на спроби приховування недобросовісних запозичень.

Особа, відповідальна за перевірку ________ (підпис) Блащук Н.В. (прізвище, ініціали)

Ознайомлені з повним звітом подібності, який був згенерований системою Unicheck щодо роботи.

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OPPONENT'S REVIEW OF THE MASTER'S THESIS

Graduate student Zhang Haibiao______

Master's thesis topic "Management system for contemporary material utilization in the exterior wall construction of energy-efficient buildings"

The master's qualification thesis submitted for review was completed in full and within the set deadline. The work corresponds to the approved topic and task. The topic is relevant and dedicated to the management of energy saving in construction, green construction.

The thesis carried out by its topic is related to the topics of research works carried out by the department's employees

The material of the work is presented in a detailed and accessible form. Thesis consists of the following sections: analysis of the current state of theory and practice on the topic of the master's thesis; problems faced by Green Construction, Optimization of construction process based on BIM and value engineering, Engineering Case Verification of China-Denmark Scientific Research and Education Center of Chinese Academy of Sciences, economic part, total conclusions.

At the beginning of the thesis, the author in the introduction outlined the relevance, purpose and task, object and subject, scientific novelty and practical significance of research related to the sustainable development of the country.

In the first section of the thesis, a sufficiently detailed and qualitative review of the works of other authors with a close research direction is performed, which emphasizes the author's good understanding of the chosen topic. In the second chapter, problems in green construction are considered. In the third section, optimization of the construction process based on BIM is carried out.

In the fourth chapter, the application of BIM technology and the value engineering method in green construction is presented on the example of the green demonstration project of the China-Danish Scientific and Educational Center.

In the fifth chapter - the economic part, the author made a technical and economic justification for the use of BIM software products in the management of energy saving and green construction projects.

The results of the research were reported at the international scientific and practical conference and written in the abstracts of the report.

Execution of the textual part of the explanatory note, performed in accordance with the standards and in compliance with all necessary requirements.

Disadvantages of thesis include: inaccuracies in the design of work.

However, these shortcomings do not affect the positive impression of work.

The master's qualification work as a whole was performed at a good level and in accordance with the task with compliance with all requirements. The work deserves a grade (B), and its author is awarded the qualification "Master of Civil Engineering" in specialty 192 - "Construction and Civil Engineering".

Opponent
PhD., Associate Prof. Nataliia Rezydent

БУДІВНИЦТВА, ЦИВІЛЬНОЇ ТА ЕКОЛОГІЧНОЇ ІНЖЕНЕРІЇ

SUPERVISOR 'S REVIEW OF THE MASTER'S THESIS

Graduate student Zhang Haibiao

Master's thesis topic "Management system for contemporary material utilization in the exterior wall construction of energy-efficient buildings"

The actuality of the theme corresponds to programs of sustainable development, the proposed project management system for the construction of a green energy-saving building will be able to save resources as much as possible, ensure a healthy, suitable and efficient use of space. The topic of the thesis corresponds to the given task. When completing each section, the student demonstrated independence, erudition, showed a sufficient level of theoretical and practical training, knowledge and ability to analyse professional, normative literature.

The student independently researched and compared various ecological and energy-efficient building management methods, determined the similarities and differences between green construction projects and conventional engineering projects and considered the main problems, proposed appropriate measures to solve these problems, considered construction optimization based on BIM.

The results were tested: the materials of the report " The use of modern materials in the construction of external walls of energy-efficient buildings " were published, in the international scientific and practical conference "Innovative technologies in building and construction", (23.11.2022) in Vinnytsia.

The student completed the sections of the master's thesis in a timely manner according to the calendar plan. Disadvantages of the work - there are minor errors in the design of the work, as an example of the use of BIM modeling in the fourth chapter, it would be possible to show the construction of walls taking into account energy-saving requirements.

The master's qualification work as a whole was performed at a good level and in accordance with the task with compliance with all requirements. The work deserves a grade (B), and its author is awarded the qualification "Master of Civil Engineering" in specialty 192 - "Construction and Civil Engineering".

SUPERVISOR
PhD., Associate Prof. Olena LIALIUK

ФАКУЛЬТЕТ БУДІВНИЦТВА, ЦИВІЛЬНОЇ ТА ЕКОЛОГІЧНОЇ ІНЖЕНЕРІЇ