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# Research on the Legal Supervision System in the Quality Management of Engineering Projects Based on the Whole Life Cycle

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***Abstract:***

Based on the theories of system thinking, whole life cycle management of engineering projects, PDCA cycle management, etc., this paper clarifies the institutional framework system for the government to supervise the whole process of engineering quality. This paper divides the institutional framework into two parts: system and mechanism. Among them, the system mainly analyzes the problems of engineering quality supervision laws and regulations system, responsibility system and organizational system from the macro-level industry management level. The mechanism is mainly to analyze the related issues of engineering quality behavior supervision and engineering entity quality supervision from the relatively microscopic engineering project implementation level. Based on this, we propose to establish a framework for the government to supervise the whole process of engineering quality in order to build a more comprehensive and systematic engineering quality supervision system.

***Keywords**: Engineering Project; Quality Management; Whole Life Cycle; Government Supervision; Smart Construction; Information Flow; Platform Construction.*

## I. INTRODUCTION

A large amount of information generated in the whole life cycle of engineering projects is transmitted with low or high efficiency in different ways between different participants and different stages of project construction. The efficiency of information transmission not only affects the connection of various stages of project construction, but also affects the communication, decision-making and coordination between internal and external parties involved. The field of engineering construction is a typical public service field, providing various types of facilities such as housing, roads, bridges, water conservancy, culture, and education necessary for economic and social development and people's production and life [1]. The quality level of engineering construction is related to economic and social development and the level of people's production and living, and is related to social public interests, so it belongs to the category that the government must supervise. Since the government's third-party supervision of project quality began in the mid-1980s, China's construction project quality supervision and management work has been increasingly improved in the deepening reform, and has gradually embarked on a legal, standardized and scientific

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development track. However, after years of practice and exploration, with the development of the industry and changes in the situation, the government still has problems such as insufficient enforcement of relevant laws and regulations, unclear definition of regulatory responsibilities, lack of focus on regulatory content, and lag in regulatory systems and mechanisms. need to be further improved. In September 2017, the State Council issued the "Guiding Opinions on Carrying out Quality Improvement Actions", which reiterated that to improve the quality of construction projects, it is necessary to improve the project quality supervision and management mechanism, and strengthen the quality supervision of the whole process of project construction. In September 2018, the Ministry of Housing and Urban-Rural Development issued the "Engineering Quality and Safety Manual (Trial)", which, as a guideline document for engineering quality supervision, refines the content of supervision. This series of policy documents laid the foundation for strengthening the government's supervision of project quality, and also pointed out the direction for the research on the system and mechanism of the government's supervision of project quality.

BIM-based integrated life cycle assessment research has also begun to develop around the world. It links the building life cycle assessment process with the architectural design process, reduces the isolation between evaluation and design, and makes the guiding significance and feedback role of evaluation fully utilized.Some scholars apply the BIM-LCA idea to carry out life cycle evaluation and analysis of residential cases, calculate the life cycle ecological results of architectural design variables (orientation, form factor, building construction materials, etc.) and conduct sensitivity analysis to obtain the main impact indicators for optimizing architectural design [2]. Also conduct BIM-LCA framework discussion and technical research, establish environmental impact feedback and calculation framework and discuss the relationship between life cycle management and analysis. Some scholars have combined BIM with building greenhouse gas effect calculation in intelligent building design research, compared the simulation of two BIM-related energy consumption simulation tools, discussed existing problems, proposed a framework for use, and pointed out its limitations and development expectations. Some scholars combine BIM with building energy consumption analysis, discuss the greenhouse gas effect and energy consumption in several important stages of the building life cycle, and conduct sensitivity analysis on several results. Some scholars have reviewed and analyzed the existing BIM-LCA theory and practice in the world.

## II. PROJECT QUALITY GOVERNMENT SUPERVISION AND MANAGEMENT SYSTEM

The government supervision system refers to the government as the core, through the government's guidance to encourage and support cooperation with non-governmental organizations (the five parties responsible for construction projects, quality inspection agencies, etc.) A system of collective oversight and management by government organizations [3]. At the same time, the government's system of project quality supervision is a collection of supervision elements, and its function is determined by the organic connection and structural level of various elements within the system. Therefore, it can be specifically divided into four parts: supervision subject, supervision content, supervision method and supervision effect. These four parts are interconnected and constrained to each other, and jointly ensure the formation of high-quality construction projects, as shown in Figure 1 (the picture is quoted from Quality

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Management Evaluation Based on Self-Control and Cosupervision Mechanism in PIP).

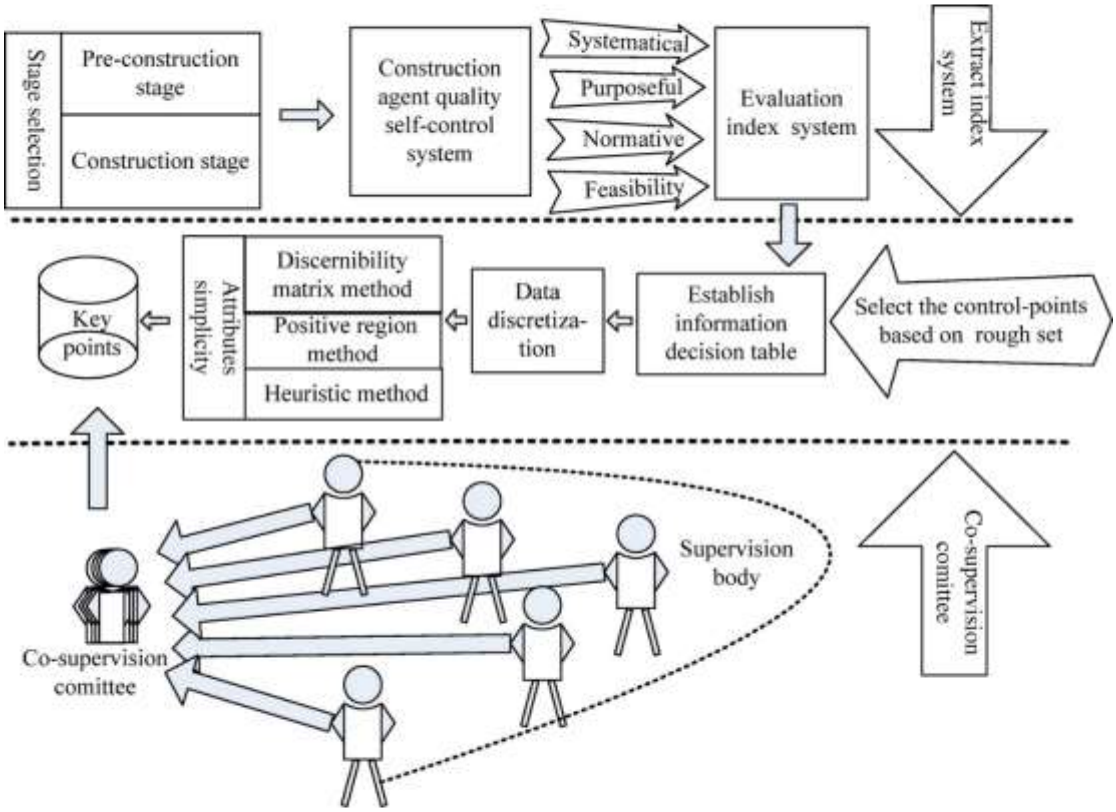


Fig.1 Connotation of government engineering quality supervision system

## 2.1. Supervisory body

In the field of engineering construction, according to the government's organizational structure and functional division of labor, the competent authorities of the construction industry are mainly responsible for the supervision of quality, safety, and market order. However, project quality is a systematic project, which not only includes the quality of survey, design, construction, material procurement and other aspects of the project implementation process, but also is closely related to market order, integrity system, and personnel quality. If it is not enough, it also needs the assistance and cooperation of relevant departments such as industry and commerce administration, market supervision, public security, and urban management. In addition, the task of project quality supervision is heavy, involving supervision at different levels such as industries, enterprises, and engineering projects [4]. The construction authority mainly focuses on macro-level supervision at the industry level, while the specific quality supervision responsibilities in the process of project implementation are delegated to quality supervision. Professional supervision agencies such as the station, the safety supervision station, the drawing approval office, and the market station. Therefore, the government supervision bodies for the quality of construction projects (referring to housing construction projects and municipal infrastructure projects) at this stage mainly include construction authorities, bidding supervision departments, quality and technical supervision departments, public security fire departments, housing management departments and professional quality

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supervision agencies, etc.

### 2.2. Regulatory content

According to the regulations on the functions of the construction administrative department and the project quality supervision agency entrusted by it, the main content of the current government's supervision of project quality includes two aspects. The first is to supervise the quality behavior of the main players in the engineering construction market (construction units, survey units, design units, construction units, supervision units, testing units, and suppliers of materials, equipment, components and accessories); Supervision of physical quality such as design, construction, materials and equipment.

### 2.3. Supervision method

Order No. 5 of the Ministry of Housing and Urban-Rural Development established a project quality supervision model with "supervision and inspection as the main means and administrative law enforcement as the basic feature". The main means for the government to carry out project quality supervision is supervision and inspection, including daily inspections, special inspections, comprehensive inspections, and supervision and spot checks [5]. On the whole, although some regions have begun to use new inspection methods such as random inspections and unannounced inspections, adopt a "double random, one open" supervision mechanism to promote the form of information-based inspections, the supervision methods in most regions are still relatively Traditionally, supervision and inspection, differentiated supervision, and the linkage of market and on-site supervision have not been practically popularized.

### 2.4. Regulatory effects

Judging from the current supervision effect, in the process of construction project quality supervision, relevant information cannot be shared among multiple responsible entities and project quality supervision agencies, and it is impossible to achieve collaborative work with each other, and it cannot be timely for each construction project responsible entity. Provide support for collaborative decision-making with the construction administrative department. In addition, the project quality supervision agency did not have a systematic understanding of the entire process of project quality formation, and the monitoring of key nodes in the quality chain was insufficient. From the perspective of process supervision, combined with the irreversibility and complexity of the formation process of construction projects, quality supervision should pay equal attention to pre-approval, in-process control, and post-examination inspection and rectification, and should not be neglected. shared.

## III. THE TARGET MODE OF PROJECT QUALITY MANAGEMENT

Combining the status quo and deficiencies, this paper sets the goal of the government's research on the whole process of engineering quality supervision system and mechanism as: to build a legal, systematic, standardized (taking into account differentiation) and informationized engineering quality supervision system covering the whole process of engineering quality. mechanism.

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### 3.1. Legalization

Engineering quality supervision belongs to the supervision of the quality management of the engineering construction industry by the government industry competent department and its subordinate management agencies, and it is also an aspect of national administrative management. All links are adjusted and standardized [6]. At the same time, the main body of supervision should comprehensively do a good job in the formulation of laws and regulations, the application of laws, and law enforcement, so as to achieve project quality supervision that has laws to follow and laws that must be followed.

### 3.2. Systematization

Engineering quality management and supervision have many subjects and complex contents, covering different stages of the life cycle of engineering projects. Therefore, systematic thinking should be widely used in management to make complex problems specific and simple, so as to solve them one by one and achieve the overall goal. Engineering quality supervision can be structured and decomposed according to one standard such as subject, content, logical order, or a combination of multiple standards, but it is not a simple decomposition, and it is necessary to pay attention to the interrelationships between different subsystems and different elements [7]. In addition, systematic sorting is also the premise and foundation for the implementation of standardized management and the use of information technology.

### 3.3 Standardization

Standardization emphasizes the extraction of commonality, and its conventional means is to establish rules and procedures and process management. The core value is to help establish a unified, standardized and repetitive management model, promote cooperation, exchange and information sharing, thereby greatly improving management efficiency. Standardization emphasizes commonality, but at the same time, individuality cannot be ignored. In engineering quality supervision, the economic society and engineering construction industry in different regions have different development conditions, and the technical characteristics of different professional types of projects are also different [8]. Therefore, there will be differences in engineering quality supervision, which cannot be completely copied. Because the basic structure and management process are the same, the commonality is the main one, but at the same time, some space for differentiated management should be reserved.

### 3.4 Informatization

Informatization of engineering quality management refers to the application of information technology to fully develop and utilize various information resources such as organization, management, economy, technology, and regulations in the entire process of engineering quality management, improve the efficiency and effectiveness of management entities and the construction industry, and promote the

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realization of in-depth process of change. Informatization helps to implement the responsibilities of the main body of project quality management, regulate market competition behavior, and improve the standardization and efficiency of project quality supervision. The main means of informatization include project management information system (MIS), information portal (PIP), building information model (BIM), mobile communication, Internet of Things, big data, artificial intelligence, etc. The whole process of supervision, all-round. Based on this, the research problems of the engineering quality management system and mechanism are summarized into the "3+5" framework, as shown in Figure 2.

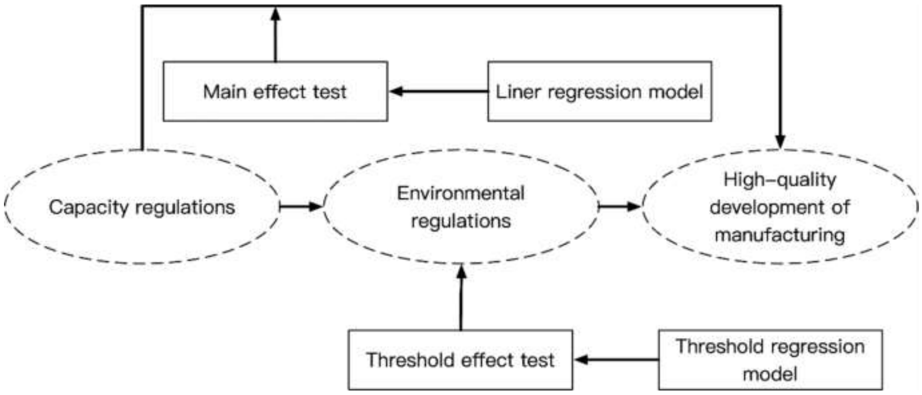


Fig.2 The research framework of the government's supervision system and mechanism for the whole process of project quality

## IV. LIFE CYCLE ASSESSMENT AND BUILDING EVALUATION SYSTEM

There are many types of LCA tools based on LCA methods, and these tools are roughly divided into three levels: the first level is product comparison tools, including Gabi (Germany), SimaPro (Netherlands), TEAM (France), LCAIT (Sweden) ; The second level is the overall building design decision or design support tools, such as LISA (Australia), Ecoquantum (Netherlands), Envest (UK), ATHENA (Canada), BEE (Finland); The third level is the overall building evaluation framework or system , such as BREEAM (UK), LEED (US), SEDA (Australia). In developing countries, LCA analysis and application are problematic due to the relative lack of databases. Establishing a database relevant to China is the basis for promoting and conducting LCA evaluation and analysis.

### 4.1. Application of LCA in DGNB

The German DGNB evaluation system was established in 2008 and was jointly proposed by the German Ministry of Building and Transport (BMVBS) and the German Sustainable Building Council (DGNB). Different from the previous evaluation system structure and focus, DGNB applies the integrated life cycle method, according to the international standards ISO14040 and ISO14044 and the domestic building code (DIN), uses the life cycle assessment method (LCA) to measure the impact of the built environment, and applies the life cycle cost method (LCC) to quantify the economic cost of construction. DGNB does not only rely on the form of the weighting system for the points given by the list, it starts from both quantitative and qualitative aspects, focusing on the performance of the building, and at the same time

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examining the ecological, economical and socio-cultural aspects of the building.

A top-down process sustainable building evaluation system is established, which is called the second-generation sustainable building evaluation system. The development of the database as a basis for life cycle assessment has contributed to the establishment of the German architectural LCA method [9]. The German Building Environment Product Declarations (EPDs) established by the German Building and Environment Council (IBU) and the first German building product Life Cycle Assessment (LCA) database Oekobau.dat developed by the German Ministry of Building and Transport (BMNVBS) have become part of the German LCA method. Data and Standards Basis. Its data format (xml format) is the same as the ELCD format specified by the European Commission. It contains 850 commonly used construction product life cycle assessment (LCA) data and is open to the public. It also includes data provided by third-party groups and manufacturers recognized by the Building and Environment Council for the Built Environment Product Declarations (EPDs), and is constantly expanding and updating. DGNB has also started to build a European-wide LCA database (ESUCO) to expand the use of DGNB. At the same time, German data standards are converging with European and international standards, for example, German data are part of the European standards EN15804 and EN15978. The main environmental classifications of buildings and their components include the following Life Cycle Inventory (LCI) and Life Cycle Inventory Assessment (LCIA) indicators (Table 1), which are included in the databases Oekobau.dat and ESUCO, Environmental Council Built Environment Product Declaration Environmental classifications such as abiotic depletion potential of non-fossil and fossil resources, waste indicators and total water consumption are also included in the (EPDs). The building LCA results in the DGNB system accounted for 14.1% of the total building rating, which shows the importance of this method in the rating.

**TABLE 1** LCA application phases of DGNB system

| | |
|---|---|
| construction stage | Simplify building components, reduce the complexity of the building structure, technical equipment of the building |
| Maintenance phase | Consider frequency of component replacement |
| End of life | Recycling of different materials, such as recycling, landfill or incineration, etc. |
| Functional unit | Building area per square meter per year |

The building life cycle assessment in DGNB has two goals: one is to quantify the performance of the building environment and score it according to the benchmark value; the other is to assist design decisions, compare the environmental performance of different schemes or determine the potential for environmental improvement [10]. Life cycle assessment in DGNB considers the environmental impact of building production, use and end-of-life stages. A building description needs to be carried out before the evaluation, including the building's technical system, functional characteristics, building form and usage (such as the number of users and timetables), etc. For example, for office buildings, the reference study period is limited to 50 years, and for industrial buildings, it is limited to 20 years. During this period, the operating energy consumption of the building and the replacement of building components are considered. The specific system boundary conditions are described as follows: 1) building product stage (raw material supply, transportation, building component production); 2) use stage scenario (operational energy

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consumption and component material replacement, transportation and life cycle end); 3) End-of-life (EoL) (waste processing and disposal); 4) potential benefits and loads outside the system (reuse, recycling, reduction potential). Excluded stages are: construction stage (site transportation and construction and installation process), user equipment, water use, maintenance, repair, renovation, demolition and subsequent transportation. DGNB carries out the economic evaluation of building sustainability from the perspective of investors and users. The life cycle cost analysis according to the German building industry standard includes the following contents: 1) Construction cost and service cost (DIN276 (2006)); 2) The cost of use (DIN18960 (2008)) includes supply cost, disposal cost, cleaning and maintenance cost, inspection and maintenance cost, structural repair cost and service cost; 3) The replacement cost of building components and the cost of building service equipment within the life span of a specific building survey. The basis of the assessment is the monetary value of the cost of use within the life and boundary conditions of the building, and the relevant calculation results in accordance with the standard are compared with the standard value, minimum value and target value. LCC tools optimize life cycle costs (including investment, use, maintenance, and dismantling costs) at the beginning of a construction project, provide cost information to decision makers, provide proactive guidance for project management, and control building life cycle costs (Table 2).

**TABLE 2** LCC index items involved in the DGNB system

| economic quality | Refers to the building within the inspection period (such as 50 years) NPV | Percentage of points in DGNB |
|---|---|---|
| Construction-related life cycle costs | | 13.5 |

### 4.2 Application of LCA in SB Tool

The SBToolPT method is based on the standard LCA method, and the integrated LCA database is an important tool to guide designers to select building materials and components with better environmental performance. Since it includes a rating scale, SBToolPT can also be used to rate the sustainability of buildings. Sustainable design, construction and use of buildings are based on a trade-off between environmental pressures (environmental impacts) social aspects (use comfort and social benefits) and economic factors (life cycle costs). Sustainable design does not compromise on supply and demand and additional costs, and strives for a design that is more compatible with man-made and natural environments. Many countries have developed or are developing national sustainable evaluation methods, which makes international exchanges and cooperation more harmoniously related. The different categories of sustainability factors are integrated and considered through the standard LCA method to evaluate environmental factors.

## V. BUILDING INFORMATION MODELING AND INTEGRATED DESIGN METHODS

### 5.1. Building Information Modeling

Since the world energy crisis in 1973, architectural problems have attracted more and more attention due to energy consumption, and with the upgrading of technology and services, architectural design is no

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longer a designer's personal creation problem, it has become owners, designers and investors. As well as some comprehensive labor of common concern of evaluation managers. The relationship between architectural design and energy environment is complex, which makes the previous single traditional analysis tools unable to systematically analyze and manage architectural problems. The development of integrated architectural design methods can solve complex architectural design problems and is gradually gaining wider acceptance [11]. The building information model (BIM) based on IFC provides a powerful information storage function, and integrates the information of buildings, sites and construction costs, materials, and physical performance values one by one. The BIM platform supports the editing of the data list, and the life cycle list can be used in the process of scheme design and renovation, so as to establish a visual building information model based on environmental analysis. The BIM interactive platform that supports other professional analysis software such as energy consumption analysis combines the impact analysis of the building environment with the building design, and provides a relatively complete technical method for the design and evaluation of the building environment.

In traditional design, different designers (architects, engineers, building evaluation experts, etc.) use different tools for design, which increases the time and labor cost of data combination in the later stage, and there are many unknown problems in the combination of different tools, which reduces the design efficiency. The goals of integrated design are: to integrate quantitative design methods in software tools; to consider all stages of the building life cycle; to ensure the smooth connection of all aspects of the design process. The integrated design approach requires the intersection of architectural graphic and non-graphical information under uniform principles specified by third parties (Table 3).

**TABLE 3** Integrated data collection and collation process

| building data | Design participants | Tools used | Norms and Standards |
|---|---|---|---|
| CAD model and IFC data interaction (BIM) | Architect | Component-based data model | drafting specification |
| | Engineering cost engineer | Integrated software or suitable for all application software | Construction Cost Specifications |
| | Construction engineer | | Energy saving, lighting, HVAC standards |
| | LCC Planner | | life cycle cost specification |
| | LCA Planner | | Lifecycle checklist and impact specification |

### 5.2. Platform for Integrated Design - Building Information Modeling (BIM)

Building Information Modeling (BIM), also known as building product model, is a method of building information data model establishment, data exchange and data maintenance based on the Industrial Foundation Classification (IFC) standard. Its advantages and feasibility lie in: 1) Corresponding description and expression of architectural form and data information; 2) Reduce data inconsistency in all aspects of construction projects, facilitate real-time data update, and reduce information asynchrony or other unsafe factors; 3) Fast Correct or replace component attributes and types; 4) It is convenient to display and read the graphic and non-graphical data information of a project; 5) Unify various professional

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tool platforms, as long as the compatibility of IFC data is guaranteed and no longer depends on each independent and IFC system other software. In order to complete the connection and unification of the above majors and various design processes, computer-aided tools and analysis have become the trend of development. The integrated design follows the following principles: 1) Establishment of basic data and database; 2) Information system; 3) Component classification; 4) Computer-aided program; 5) Use of specific tools.

## VI. BIM DESCRIPTION

### 6.1. Construction phase

BIM standardized modeling and life cycle management methods have issued their own component classification formats and standards in Europe and the United States, which is a necessary method for unified BIM construction and life cycle management. This article refers to the German BIM component classification standard (NISTuniformat) and the American component classification standard (CSIMaterFormat) to classify the components of the BIM model. In order to study the environmental impact of materials and the overall construction, the key steps of the BIM-LCA framework are determined as follows: the description of the model construction is expressed according to "construction layer + thickness parameter"; the detailed list of materials is extracted through Revit (Figure 3), and the automatic information about materials is obtained. Code (ID/Code) and physical information parameters (basic material size, volume, area); export to text editing format (Microsoft Excel/Microsoft Access); Actual environmental impact; as feedback, results can be re-imported into the Revit model for added environmental impact information.

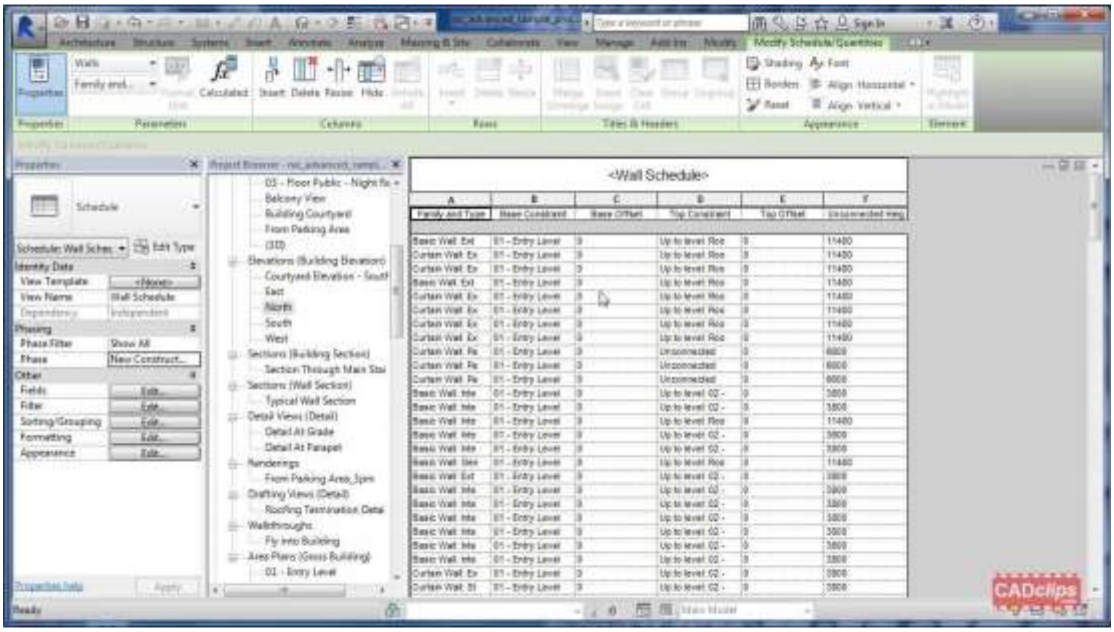

Fig.3 Revit Wall Schedule

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### 6.2. Building energy consumption during operation phase

Design builder is the main energy simulation tool used in this study. It uses Energy plus as the simulation engine and has the function of dynamic coupling. Compared with static calculation tools such as EQUEST, the simulation results are more credible. In addition, Design builder can receive the gbxml format file exported by Revit [12]. In theory, the model can be directly output and imported into Design builder for simulation, avoiding the time-consuming remodeling and the problem of model inconsistency (but in actual modeling, in order to make the calculation efficient , this study simplifies the building plane, and establishes a simplified model of simplified interior space separation in the DB model (see Figure 4). In addition, the Revit model is directly uploaded to Green Building Studio. First, it can be used as a comparison result to compare with the DB model results. Second, the application has the ability to compare and compare options, and automatically generate simulation results for different scenarios with different design variables, which can be used as Convenient adjustment means for the life cycle analysis of sustainable buildings in the early stage of the scheme.

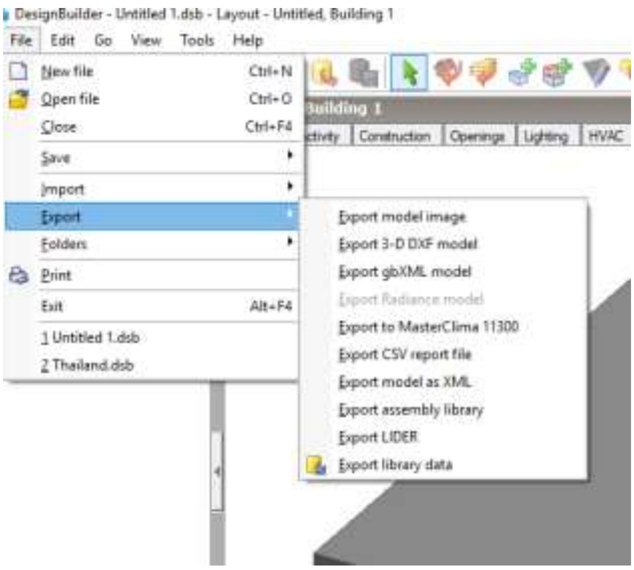


Fig.4 How to import Design builder from Revit

The calculation results of the energy consumption simulation software are exported in the form of EXCEL, and the annual average cooling load and heating load, as well as the annual average lighting and other energy consumption sub-items are obtained. According to the energy type of cooling and heating, select the corresponding Ecoinevnt database to query the unit amount, and obtain the environmental impact of the annual average operating energy consumption after calculation.

$$E_{ei} = \Sigma_{t \in T} e_i i_i \tag{1}$$

$Eei$ is the total energy environmental impact, $e$ is a single energy product, $i$ is the corresponding environmental impact value, and n is the type of energy product. For cost calculation, it should be

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calculated according to the corresponding energy price. In various LCA calculation methods, the calculation results will be affected due to the different design conditions and boundary conditions. The LCA calculation method in BIM-LCA refers to the calculation model in the German BNB/DGNB evaluation system, simplified and adjusted under the existing data resources, and formed a simple calculation method with the help of Excel formula editing method. The ecological assessment process of the building life cycle is to sum up the index results of each stage of the building. In the BIM-LCA method, several stages of new construction, operation, maintenance and renewal, and the end of the life cycle (demolition and old material disposal) are mainly considered:

$$EIs_{tol} = EIs_{new} + EIs_{oper} + EIs_{refur} + EIs_{Eol} \tag{2}$$

$EIs$ represents the building environmental impact of each building environmental impact index. $EIs_{new}$ represents the environmental impact of the production and processing of building materials and the environmental impact of anxious construction. $EIs_{oper}$ represents the environmental impact of energy consumption during the building operation phase. $EIs_{refur}$ represents the environmental impact of the replacement and renewal of building components during the building's use, including the environmental impact of the disposal of the replaced components. $EIs_{Eol}$ represents the environmental impact of building demolition treatment at the end of the building's life cycle. In the BIM-LCA method, the water consumption in the transportation process and maintenance update is temporarily not taken into account [13]. In the expression of the calculation results, the BIM-LCA method is expressed in two ways: "the environmental impact index of a certain building of a unit/50 years" and "the environmental impact index of a certain building of a unit/square meter building area/year" (Table 4).

**TABLE 4** Inspection units of each environmental impact index in the BIM-LCA method

| impact Indicator | Inspection unit | |
|---|---|---|
| Renewable primary energy | GJ-Eq | MJ-Eq/ $m^2a$ |
| Primary energy consumption | GJ-Eq | MJ-Eq/ $m^2a$ |
| Greenhouse Gas Effect | Ton $CO_2$-Eq | Kg $CO_2$-Eq/ $m^2a$ |
| Acidification (AP) | Kg $SO_2$-Eq | Kg $SO_2$-Eq/ $m^2a$ |
| Eutrophication (NP) | Kg $NO_3$- | Kg $NO_3$-/$m^2a$ |
| Landfill (solid waste) | Kg waste | Kg waste/ $m^2a$ |
| Stratospheric ozone depletion | Kg CFC-11-Eq | Kg CFC-11-Eq/$m^2a$ |
| Photochemical Ozone | Kg ethylene-Eq | Kg ethylene-Eq/ $m^2a$ |

The domestic calculation and pricing software and the domestic base price list specification have always been used to calculate the construction cost, machinery cost, labor cost and real-time price. Some of these software have integrated BIM into it (Luban Software 32), eliminating the need to re-estimate the budget Time-consuming and tedious remodeling. However, there is no software for calculating the life cycle cost of buildings in China, and they only focus on the cost of the construction stage. According to

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domestic and foreign literature, operating cost is an important part of building life cycle cost. This study is based on the LCC calculation principle in the German life cycle analysis software LEGEP, and based on the existing Chinese construction engineering cost data, using EXCEL to calculate the LCC.

## VII. SYSTEM SIMULATION ANALYSIS

In the life cycle cost analysis, the proportion of the renovation cost in the initial stage is very important. In the 20th, 25th, 30th and 40th years, more building components were replaced and replaced (solar boiler system, with a design life of 20 years), and the construction cost increased significantly; 1%) and the inflation rate, the cumulative year-on-year graph of building operating costs is shown as a curve; the proportion of renovation costs to the total cost is decreasing year by year, and 29% of the cost is composed of operating costs and maintenance and replacement components (Figure 5 quoted at https ://ppt-online.org/482701). This paper conducts a cost study on the energy composition of operating energy consumption [14]. If coal-fired boilers are used for heating (the average annual operating cost is 212,000 yuan), the life cycle energy cost will be higher than the energy cost of solar energy and coal-fired boilers (annual the average operating cost of 123,000 yuan) increases by about 25%. Therefore, the use of solar boilers can save operating costs to a certain extent (Figure 6 is quoted in A Lifecycle Cost Analysis of Residential Buildings Including Natural Hazard Risk).

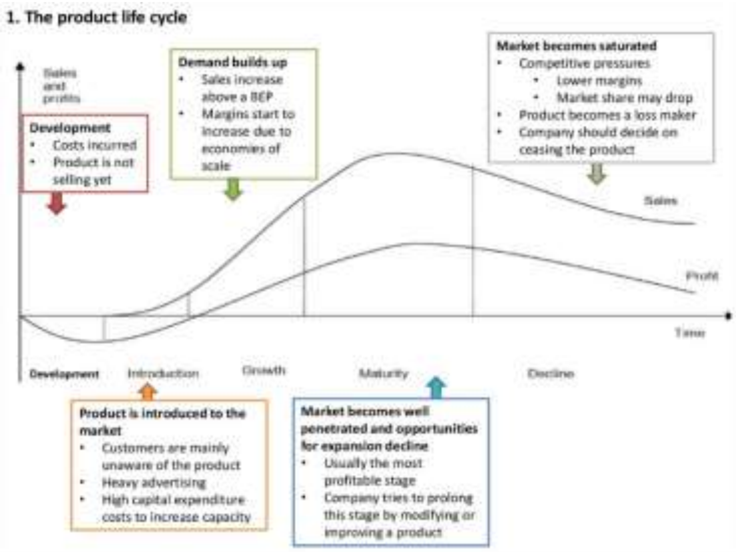


Fig.5 Proportion of life cycle costs by stage

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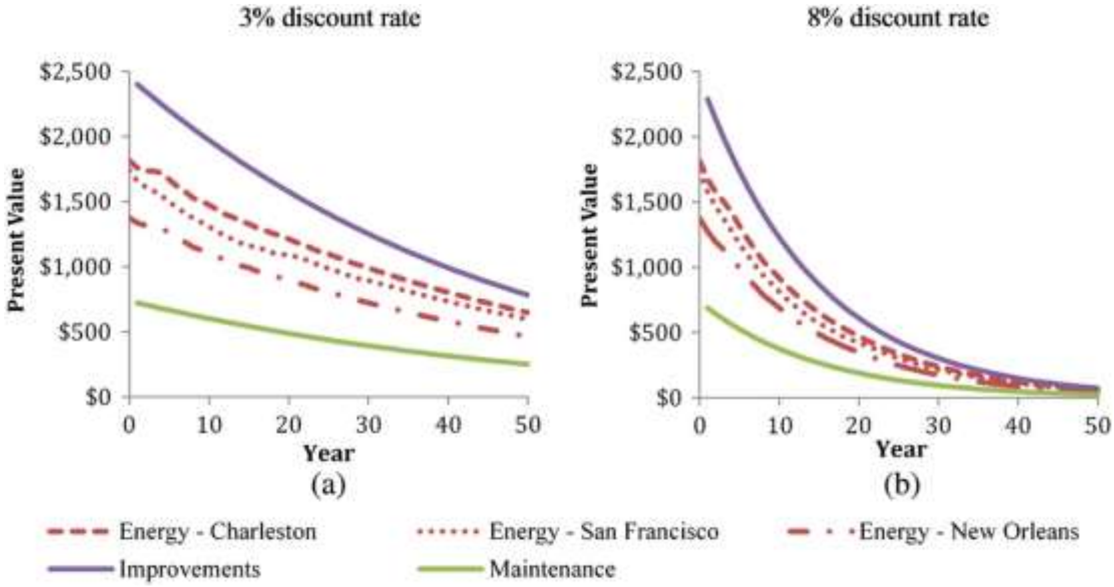


Fig.6 Cost accumulation in each stage of the building life cycle of the retrofit case

## VIII. CONCLUSION

This paper proposes an integrated BIM-LCA building sustainability evaluation framework, discusses the theoretical background and model steps of the framework in detail, and conducts a quantitative investigation and analysis from the perspective of the life cycle of the environmental impact of building energy resources. In-depth analysis and application of two cases of new residential buildings and renovation of existing public buildings were carried out, and preliminary data on the life cycle environmental impact of several building components were obtained, and the physical and chemical energy consumption, environmental impact and The economic impact is the value of functional units and the proportion of sub-items in the total life cycle, the environmental and economic value of solar boilers are investigated, and the problems to be solved in the BIM-LCA process are summarized.

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