Research on Green Building Incremental Cost Optimization

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Abstract. With the gradual improvement on people's awareness of environmental protection, green building is an inevitable trend for the future development of the construction industry. However, the existence of the incremental cost of green building has become the biggest obstacle to its development. This paper analyzes the factors that can optimize the incremental cost, proposes a reasonable optimization scheme for the calculation and analysis of actual cases, and extracts some other controlled measures and optimization suggestions of incremental cost. It provides a more scientific theoretical basis and feasible scheme for the comprehensive analysis of the optimization of green building incremental cost.

1. Introduction
With the gradual improvement in the consciousness of environmental protection, energy conservation and emissions reduction as the important strategy of sustainable development, compared with the traditional building, green building has obvious commercial value increment[1], such as energy saving, environmental protection, low carbon emissions, the pursuit of maximum benefits of whole life cycle[1], etc., so green building has become a kind of inevitable trend for the future construction[3]. The high incremental cost is the main factor hindering developers from investing in green buildings. In many advanced green building systems abroad, the late operation of green building only accounts for 60% of the operation cost of ordinary building[4]. The construction operation cost saved by reducing energy consumption represents quantifiable incremental benefit. The calculation results show that the incremental economic benefit is significantly higher than the earlier investment [5]. Therefore, this paper will start from the incremental cost control of green building, explore the reasons for the high cost, analyze the influencing factors, and find out a reasonable control method, in order to break the barrier that prevents the smooth development of green building.

2. Related concepts
2.1. green building
Basic can be summarized as: the definition of green building in satisfying the use requirement and target under the premise of building in the whole process from construction stage to the recycling scrap stage to minimize the load to the environment, and achieve the purpose of save energy use and reduce resource depletion, and to provide users with healthy, efficient, safe, comfortable space environment. Green buildings are characterized by less energy consumption and less harm to the environment. They always adhere to the concept of sustainable development by making rational and full use of existing resources.
2.2. Incremental cost of green building
In China’s green building design code, the definition of incremental cost of green building is: "the change of investment cost caused by the implementation of green building concept and strategy compared with the benchmark building that meets the current national and local standards. Incremental costs can be positive or negative, indicating an increase or decrease to the cost of investment.

3. Incremental cost-benefit evaluation of green buildings
The incremental cost of green building is mainly divided into green building consulting and design cost, green building certification cost and green building technology incremental cost, and the incremental benefit of green building is mainly divided into green building incremental economic benefit, green building incremental environmental benefit and green building incremental social benefit.

3.1. Composition of incremental cost of green building
Green building incremental costs reflect the whole life cycle stages and various aspects, but part from the incremental cost because of the use of green technology will not necessarily produce or negative, by summing up this paper when calculating the total incremental cost mainly includes: (1) the green building design consulting costs: refers to the green construction feasibility study, project to design, project simulation, application of materials and other expenses; (2) green building certification cost: it is mainly used for expert evaluation, and this part of the cost shall be collected according to the unified regulations of the construction department; (3) incremental cost of green building technology: incremental cost caused by the use of green technology and measures. (4) incremental cost of green building operation management. (5) demolition of green buildings to recover incremental costs. That is:

\[ \text{IC}_{\text{green building}} = \text{IC}_\text{consulting design} + \text{IC}_\text{certification} + \text{IC}_\text{green technology} + \text{IC}_\text{operation management} + \text{IC}_\text{demolition and recycling} \]

3.2. Incremental benefit composition of green building
The benefits of green building can be divided into economic benefits, environmental benefits and social benefits according to the nature of the benefits. The economic benefits of green building can be obtained by calculating the energy saving of all aspects. The environmental benefit of green building includes indoor environmental benefit and outdoor environmental benefit. The social benefits include the happiness of improving the quality of life of residents, the change of environmental comfort and the change of social values.

\[ \text{IB}_{\text{green buildings}} = \text{IB}_\text{economic benefits} + \text{IB}_\text{environmental benefits} + \text{IB}_\text{social benefits} \]

4. Application cases
4.1. Project overview
The project is divided into four stage of development, of which early designed began in June 2005, completed in January 2009, covers an area of about 96000 m², the building is 124600 m², including perfect supporting facilities supporting business and public schools for primary and secondary schools (about 30000 square meters, etc.), the objective of the demonstration zone for the green building project, the fourth stage project is given priority to with villas and high-rise, volume rate is 1.3. The project is to
be built into a state-level green building demonstration project to accumulate experience in the national promotion of green building technology. The main technical objectives and indicators of this project are: (1) the energy saving rate reaches 65%; (2) the proportion of renewable energy in total energy consumption of the building reaches more than 5%; (3) water to reuse reaches 30%; (4) the utilization rate of water-saving appliances reached 100%; (5) household garbage classification collection rate 70%, household garbage recycling rate 30%; 6. Noise insulation and noise reduction to meet the national requirements; 7 decoration materials to meet the requirements of national norms; 8 is not occupying quality farmland and natural reserve land; Pet-name was used to protect the native topography and epidermal soil.

4.2. measurement of incremental costs

The following is an incremental cost analysis of energy conservation and utilization during construction. The incremental cost of energy saving measures in this project includes the incremental cost of maintenance structure and new energy utilization.

- Incremental cost of containment structures
  The energy-saving technical measures adopted by the building envelope are mainly thermal insulation technology of the building. The external wall is taken to increase the thermal insulation board and reduce the heat transfer coefficient of the Windows. External insulation measures are adopted in this project. For the external wall, starting from reducing the overall heat transfer coefficient, the insulation layer of 200mm thick autoclaved aerated concrete block plus polyurethane insulation board is adopted. The roof is made of 50mm thick XPS board. The roof adopts flat roof and 25mmXPS extruded board to meet the insulation requirements of the roof. The glass curtain wall is made of low-e insulating glass and powder sprayed aluminum alloy. After professional design by the curtain wall company, the window ground coefficient of high-rise buildings is 0.23 and that of villas is 0.27. Among them, the proportion of high-rise buildings and villas is 48% and 52% respectively. Compared with the technology used in ordinary projects, only 200 thick autoclaved aerated concrete blocks are used for the external walls, 25mm thick XPS plates are used for the roof, and only one layer of alloy glass is used for the external Windows.

- New energy utilization
  To a certain extent, the use of new energy has become a symbol of green building, the project for the use of new energy including solar power generation and solar heat generation, villa area with household solar water heater to effectively save electricity. Project did not adopt relevant new energy utilization technology ever.

- Energy saving equipment
  The average elevator relies on a counterbalance system, which requires no power to operate in fewer people, up at no load, and down at full load, but the motor still rotates and generates electricity. Due to technical limitations, this generated electricity is consumed as heat. The new energy renewable elevator can collect 30 to 70 percent of the electricity consumed in the operation of the elevator and feed it back to the power grid of the same building in the form of "clean electricity". This technology can not only save electricity bills, but also reduce waste heat generation and improve the thermal environment of buildings. In addition to energy-saving elevators, energy-saving lamps are also used, mainly for floor access and residential road lighting, which can effectively reduce the consumption of electricity during operation. After the data onto external wall, roof, external window, new energy utilization and energy-saving equipment are sorted out, the incremental cost calculation of energy conservation and energy utilization in Table 1 is obtained.

| Table 1 calculation table of incremental cost of energy saving and energy utilization |
|---------------------------------|-----------------|-------------------|
| Incremental project cost        | Regular project cost | Incremental cost  |
| (yuan / ㎡)                    | (yuan / ㎡)       | (yuan / ㎡)       |
| external wall insulation        | (65.8×80×52%+(65.8×8×48%)=145.8 | 65.8 | 145.8-65.8=80 |
| roof insulation                 | 80×14970=124680=9.6 | 15×14970=124680=1.8 | 9.6-1.8=7.8 |
4.3. Incremental cost integration
After calculation, the project total incremental cost is 324.9 yuan / ㎡, and the main part of incremental cost occurred in the construction stage, especially for energy saving and energy use, to project the total incremental cost of each part of from big to small in turn is: energy saving and energy use incremental cost > indoor environment measures incremental cost > water conservation and water resources utilization in dynamic incremental cost incremental cost > > operation system and the outdoor environment > incremental cost saving material and material resources use incremental cost > green building certification incremental cost.

4.4. Project incremental cost optimization
Combining with the actual situation of the project, the target cost optimization method, it is proposed to correspond to the corresponding grade average incremental cost as the optimization target, put forward the reasonable and effective green building incremental cost optimization strategy, and through optimizing calculation and comparison of data before and after the intuitive to reflect the effect of the incremental cost optimization measures and its feasibility.

4.4.1. Reasonable allocation of "four sections and one ring" proportion of green buildings An example.
In this article, through reference to similar projects, the project of new energy to replace the original for solar water heater and air can heat pump water heater, the incremental cost of this part are as follows: 3.37+19.25 = 22.62 yuan / ㎡, therefore the incremental cost reduction for: 41.63-22.62 = 19.01 yuan / ㎡, proportion fell to 7.39% from 12.81%, can visually see that this optimization method in a more rational use of energy at the same time, depending on the type of construction effectively reduces the incremental cost. Through reasonable allocation percentage of green technology, using the passive design and clear the measuring standard of incremental cost after incremental cost optimization in the three aspects of the project, the parts can satisfy the requirement of the project indicators and energy conservation and environmental protection under the premise of the incremental cost per square meter of project from 324.9 yuan / ㎡ dropped to 221.86 yuan / ㎡, three-star green building with 222 yuan / ㎡ incremental cost average is consistent, it can be seen that in the incremental cost of green buildings for now, there are a lot of space can be optimized, and with the continuous development of green architecture system in our country and the technology and mature, According to the law of learning curve, incremental cost can be controlled more and more effectively.

4.4.2. Adopt passive design. According to the local climate and geological environment characteristics of the project location, the so-called passive design is to make full use of the existing conditions and follow such principles to design in a non-mechanical and low-energy way, so as to realize the requirements of functions and indicators of green building in heating, ventilation, lighting and other aspects. In the hot summer and warm winter areas, the external wall using aerated concrete block can achieve better thermal insulation performance, do not need to add additional thermal insulation materials, reduce the cost, but also reduce the building operation thermal insulation layers maintenance and maintenance costs. Compared with other thermal insulation technology, the self-insulation system of aerated concrete block has achieved better application effect than other technologies on the premise of not much increase in cost. According to the project data onto aerated concrete block unit price is 158.9 yuan / ㎡, ordinary concrete hollow block unit price is 26.22 yuan / ㎡, exterior wall according to the 46000 ㎡ calculation of quantities, the incremental cost of the optimized exterior wall is: (158.9-26.22)×46000 present 124680 = 48.95 yuan / ㎡, namely so bring incremental cost reduction for: 80-
48.95 = 31.05 yuan / ㎡, the total accounted for from 24.62% to 16.66%, can see visually, the optimum way in accord with local characteristics with hot summer and warm winter, where the project is located at the same time, effectively reduce the incremental cost.

4.4.3. define the measurement standard of incremental cost. Due to the current government issued by the green building related laws and regulations, no incremental cost of green building to give a clear standard of measure, so some of them came out a grey zone, different regions in calculation scope and the factors to be considered by an incremental cost is not the same, and some construction unit for the purpose of their own interests in the incremental cost the phenomenon of computing, so to a large extent, is now showing on the surface of the incremental cost is artificially high is the result of measurement is not standard, so in order to effectively optimize the real incremental cost, good clear incremental cost metric is very necessary. Specifically, we can start from the following aspects : (1) clarify the benchmark of incremental cost comparison; (2) clarify the range of green building measurement; (3) keep pace with The Times

4.4.4. project optimization summary. Through the above three aspects of optimization: the rational allocation of the proportion of green technology, the adoption of passive design and the definition of incremental cost measurement standard, the optimization effect of incremental cost obtained is shown in table 2 below:

| Prioritization scheme                          | The optimization of incremental cost value (yuan / ㎡) |
|-----------------------------------------------|-------------------------------------------------------|
| The proportion of green technologies should be reasonably allocated                  | 19.01                                                |
| Use passive design                            | 31.05                                                |
| Identify incremental costs                    | 6.85×45+1.13=52.98                                     |
| Total                                         | 103.04                                               |

From the table 2 shows that through the study of the rational distribution of proportion of green technology, using passive design and clear the measuring standard of incremental cost after incremental cost optimization in the three aspects of the project, the parts can satisfy the requirement of the project indicators and energy conservation and environmental protection under the premise of the incremental cost per square meter of project from 324.9 yuan / ㎡ dropped to 221.86 yuan / ㎡, three-star green building with 222 yuan / ㎡ incremental cost average is consistent, it can be seen that in the incremental cost of green buildings for now, there are a lot of space can be optimized. With the continuous development and maturity of China's green building system and technology, incremental costs can be controlled more and more effectively according to the rules of the learning curve.

In addition to the above optimization measures, which can be directly reflected by data changes, there is some hidden optimization methods. Although they are directly reflected by data, they have a significant impact on incremental costs. The construction unit shall, in combination with its own capacity, invite tenders and purchase main materials, high-value materials and high-value equipment by itself when conditions permit. Through carrying out quota design, the design quota of the whole project is stipulated in the design specification or investment estimation to reduce the incremental cost; Strictly control engineering change to avoid serious impact caused by engineering change.

5. Conclusion
In serious environmental pollution and the shortage of natural resources today, the concept of sustainable development has been implemented into the construction industry, and countries around the world pay close attention to the things. Along with the related supportive and mandatory policies by government
in our country, the development of green building is the inevitable trend of this kind of situation, but the adoption of green building technology makes the green building cost to a certain extent to be higher than ordinary buildings. The more material incremental cost is the main reason for the promotion and the development of green building. Therefore, comprehensively understanding the green building incremental cost, analyzing the influential elements of the green building incremental cost to produce, reasonably calculating the incremental cost caused by adopting green building technology to provide theoretical reference for the decision of green building investors for the whole life cycle of green building cost, consumers have a more clear and quantitative understanding and it will contribute to the development and popularization of green building in China.

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