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Study on the Life-Cycle Engineering Cost Management of Large Chemical Projects

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This paper conducted a study on the life-cycle engineering cost management of large chemical projects, with the purpose of standardizing the management process and reducing the costs at all stages. Specifically, the LCC analysis method was adopted to analyze the life cycle cost of large-scale chemical engineering projects through detailed introduction to the theory, cost structure and cost analysis steps, based on which the all-factor LCC model of large-scale chemical projects was established. Finally, through the determination of constraints, the optimization of the life-cycle engineering cost model for large-scale chemical projects was realized. This research is helpful to strengthen the engineering cost management for large-scale chemical projects at all stages, and is instructive for the investment decision in large-scale chemical engineering projects.

1. Introduction

In the context of global economic growth slowing down and commodity prices continuing to fall, the downward pressure on the domestic economy has been increasingly growing. And the petroleum and chemical industries are facing more and more fierce competition worldwide (Demeulemeester, 2015; Zhong and Zhang, 2006). In order to reduce the engineering cost and improve economic efficiency comprehensively, all major petrochemical enterprises have paid more attention to the management of engineering costs, so as to reduce the life-cycle engineering cots of large-scale chemical projects (Jiang, 2002).

The schedule, cost, quality and safety of large-scale chemical projects are the four major elements of project management, among which cost management is directly related to the project costs (Gluch and Baumann, 2004). The engineering cost is the manifestation of the monetary cost in all stages of the project, which is reflected in the decision-making phase, implementation phase, operations phase and closure phase of the large-scale chemical projects (Guo and Zhang, 2015). Although the decision-making phase takes fewer costs out of all engineering costs, it affects the total engineering costs by over 90% (Nikolay, 2016). Therefore, it is necessary to improve the life-cycle cost management of large chemical projects life cycle, especially during the feasibility and design phase (Kirk and Dell'Isola, 1995).

This paper first gave an overview of the LCC (Life Cycle Costing) theory, analyzed the composition of engineering costs in each phase of the project, and then used the LCC method to analyze other factors that affect the engineering costs of large-scale chemical projects based on the classic LCC model to established an all-factor model for large chemical projects; Finally, the life-cycle engineering costs of large-scale chemical projects optimization were optimized by setting constraints.

2. Analysis of life cycle costs of large chemical project

2.1 Overview of LCC analysis theory

LCC analysis is an effective tool for analyzing investment decisions in engineering projects that was proposed in the cost management industry of Western countries in the 1980s (Swarr et al., 2011; Morris, 2010). LCC contains two basic points, namely the total costs that are directly related to products and consumed in the life cycle, and the correlation between LCC and the time value of funds. Also, the LCC analysis includes three main contents (Liang, 2014). First, determine the elements of the life cycle costs, and minimize the cost of

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each element (Cleary et al., 2015). Second, associate life-cycle costs and system efficiency. Third, research the relationship between life-cycle costs and system efficiency (Emblemsvåg, 2003).

2.2 Breakdown of life cycle costs of large-scale chemical projects

The breakdown of the life cycle costs of a large-scale chemical project corresponds to the four phases of the project, namely the decision-making phase (Zhang, 2005), the implementation phase, the operations phase and the project closure phase (He and You, 2016).

(1) Decision-making phase and implementation phase

In the decision-making stage, the main construction contents and supporting facilities of the proposed chemical project are analyzed, such as raw material supply, process-oriented pipelines, equipment selection, environmental impact, and economic effect (Lenior and Verhoeven, 1990; Kohl and Wulke, 2004). As for the implementation stage, costs can be divided into design costs and construction costs. The design covers the total layout, process and technologies, and the overall design of various aspects, while the construction mainly refers to the construction based on the design drawings of all aspects, including manpower, materials, equipment loss, etc. (Peñamora et al., 1999; Bhimani, 1994). The cost compositions in the decision-making phase and the implementation phase are shown in Figure 1:

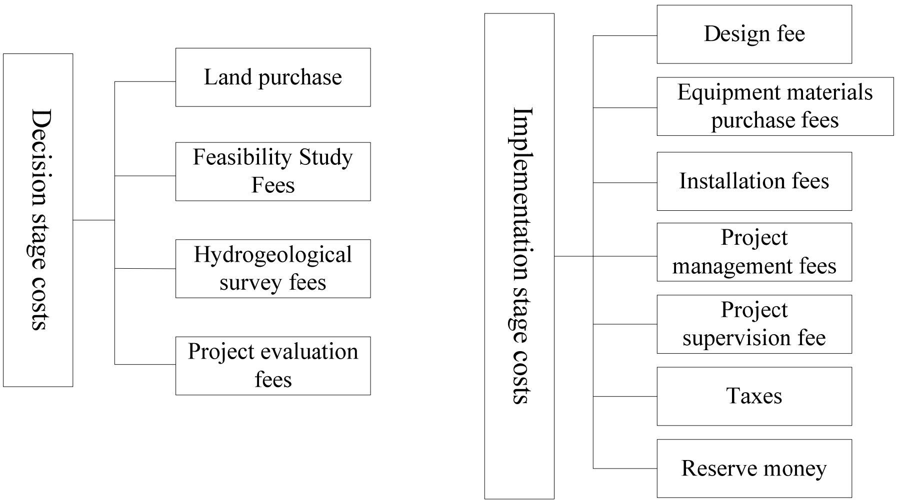

Figure 1: The Cost Composition in the Project Decision Stage and Implementation Stage

(2) Operations phase and project closure phase

Operational costs mainly represent all costs incurred during the equipment operations in a chemical project, including costs for production, and equipment renewals and maintenance (White and Fortune, 2002; Ruiz-Martin and Poza, 2015). And the costs in the project closure phase mainly refer to the costs generated in the refurbishment or demolition phase of major chemical equipment (Stevens, 1986; MehranSepehri, 2012). The costs in the operations phase and the project closure phase can be seen in Figure 2:

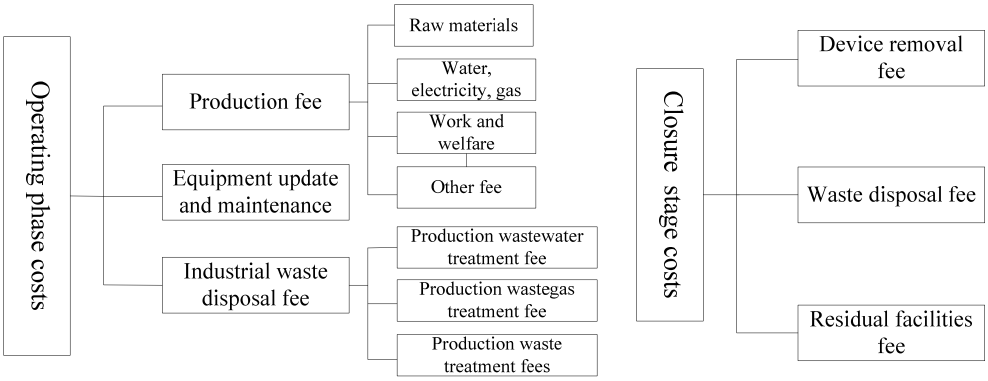

Figure 2: The Cost Compositions in the Project Operating Stage and Closure Stage

2.3 Steps to analyze life-cycle costs of large-scale chemical projects

According to the characteristics of large-scale chemical projects, life-cycle cost analysis can be divided into seven steps as follows (Yu et al., 2006; Chen, 2003). Firstly, determine the research target and identify the target requirements and performance parameters. Secondly, propose a number of feasible plans that meet the performance requirements of the project. Thirdly, establish a life-cycle costs estimation model (Ogihara et al., 2003; Hollmann and Querns, 2003). Fourthly, collection data and information to make different assumptions about discount rates, inflation rates, economic lifetimes, etc. Fifthly, calculate the life-cycle costs of each plan. Sixthly, choose the optimal plan. Seventhly, give decision-making recommendations (Zakeri and Syri, 2015). Figure 3 displays the process of analysis of large-scale chemical projects' life cycle costs.

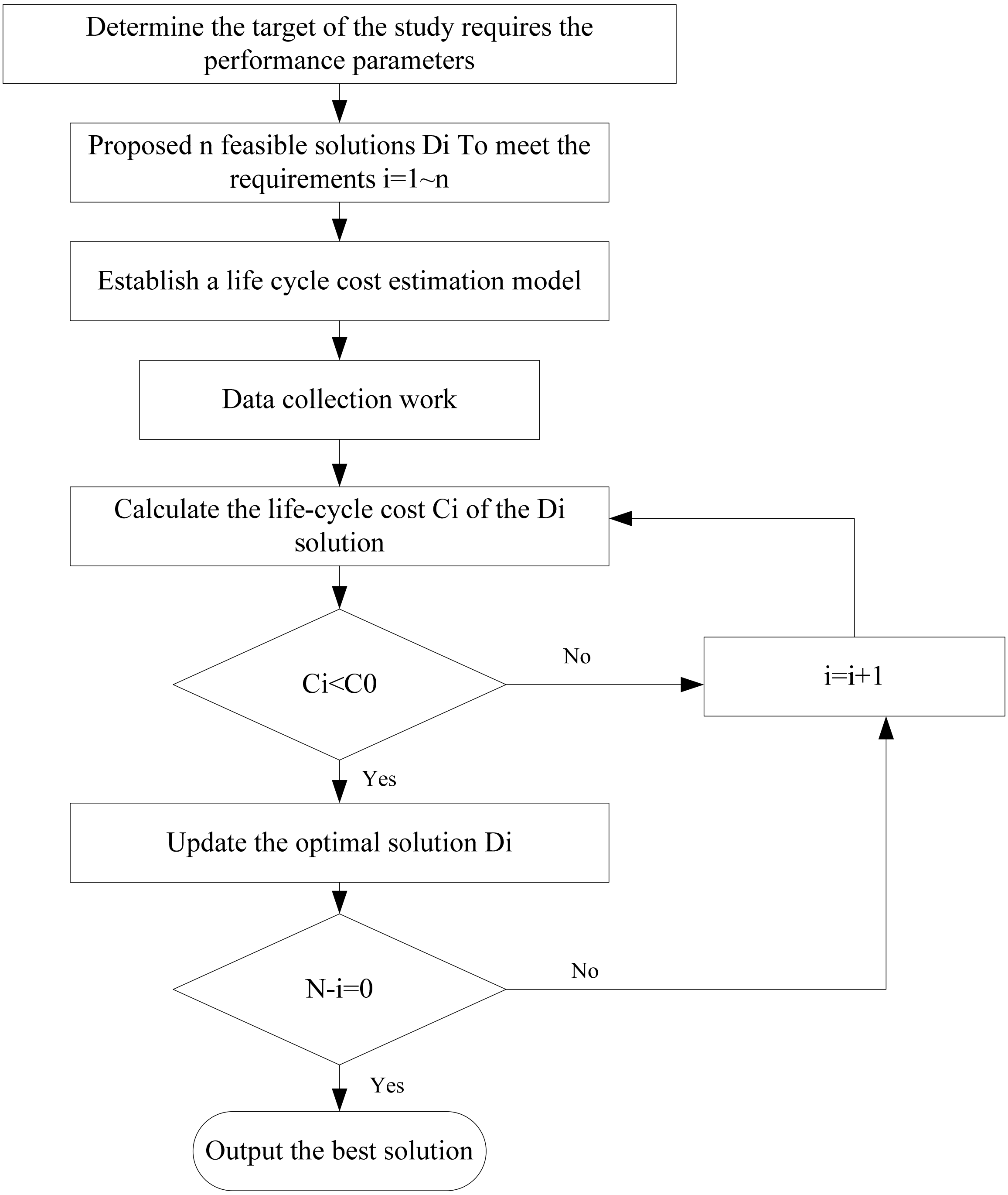

Figure 3: Large-scale Chemical Project Life Cycle Cost Analysis Process

3. Life cycle cost models of large-scale chemical projects

3.1 Basic LCC Model

The life cycle cost estimation methods for engineering projects have changed from the initial static estimation model into a dynamic estimation model with consideration of the time value (Zapalac et al., 1994). Despite different manifestations, models, in essence, all consider the project's initial construction fee, operating expenses, end-of-use disposal costs, and the time value of money (Ferchichi et al., 2015). The classic LCC estimation model is shown in Formula 1.

LCCpv=K0+M0+i=1T(Kt+Mt+Et)(1+r)t-VT1+rT (1)

In the formula, LCCpv is the total costs, and K0 and M0 refer to the investment cost and management cost of the chemical project in 0 year respectively. Kt and Mt are the investment cost and management cost of the project in the t^{th} year respectively. Et means other costs in the he t^{th} year, with VT as the residual value of the chemical project and T as the life of the project.

In fact, due to the long investment cycle of large-scale chemical projects, both the internal and external investment environment in the project implementation stage are changing. At the same time, due to the impact of changes in raw materials, product demands, labor costs and investment environment on the costs of chemical projects, the accuracy of this model remains to be improved.

3.2 All-factor LCC model of large-scale chemical projects

Considering the time value of funds, the author introduced the idea of real options to correct the project value changes caused by the uncertainties such as the changes in the real value in the construction process. And based on the project’s risk cost, quality risk cost, safety risk cost, and environmental risk cost, the all-factor LCC model of large-scale chemical projects was obtained, as shown in Formula 2.

LCCpv=t=0T1-1i=1nPit(1+r)-t+t=T1T1+T2-1i=1nCit1+r-t+t=T1+T2T1+T2+T3-1i=1nRit1+r-t+t
=0T1+T2+T3-1i=1nQit1+r-t-i=1nVTi1+r-T1+T2+T3+ROs (2)

In the formula, LCCpv denotes the total discounted value, and Pit, Cit, Rit, and Qitt represent the decision-making and research costs, design and construction costs, operating cost, and the discounted value of factors of the device i in the t^{th} year respectively. VTi refers to the end-of-use disposal residue value of the device i. T1, T2, and T3 respectively mean the decision-making and research time, design and construction time, and operations time. R represents the discount rate, and ROs represents the real option value of the chemical equipment. The above model involves the life cycle costs of chemical engineering projects at all stages, cost of influencing factors, real option value of the project, and the time value of funds for the above expenses, making it an open all-factor LCC model (Liu et al., 2012).

3.3 Life-cycle engineering costs optimization for large chemical projects

The optimization is to reduce the construction cost under the guidance of LCC theory by selecting the decision-making variables and establishing the optimization objective function and constraints. And then the global optimal costs is achieved by realizing local optimal costs at all stages of the life-cycle engineering costs of chemical projects.

The main objectives of LCC optimization are multiple feasibility plans in the project decision-making phase. The optimization covers the construction scale, product solutions, raw material and fuel power supply solutions, process technology and equipment plans, utilities and supporting facilities solutions, environmental protection solutions, and operating costs and benefits in the operating stage.

3.3.1 Constraints

LCC optimization needs to meet the basic requirements of various technologies. P (x) is a function of the design scheme. YsX, YTX, YFX, YEVX, YENX, and YAX respectively represent the standard norms constraint, skills performance constraint, functional constraint, environmental constraint, energy consumption constraint, and aesthetic constraint, with all the constraints no more than P (x).

3.3.2 Optimized model

Bring the constraints into Formula (2) to obtain the optimized all-factor LCC model. As shown in Formula 3, the model can give the lowest life cycle engineering costs plan, a satisfactory result.

LCCpv=i=0T1-1i=1npi=1pnkpiit(1+r)-t+t=T1T1+T2-1i=1n[ci-1cnYciit+ck-1clpckit×Lckit×1+
dckit+fit(h)(1+r)-t]+t=T1+T2T1+T2+T3-1i=1n[(rj=1rmmrjit+rk=1reerkit+rl=1rssrlit+rh=1rwwrhit)×
(1+r)-t]+t=0T1+T2+T3i=1nQit(1+r)-t-i=1nRie×if=1igEif-Wic-Wi×1+r-T1+T2+T3+ROs (3)

$=f(p)+f(c)+f(r)+f(q)-f(v)+f(s)$

In the formula, $f(p)$ is the present value cost (PVC) function at the decision-making stage, with $f(c)$ as the PVC function at the project implementation stage, $f(r)$ as the PVC function at the operating stage, $f(q)$ as the PVC function of factors influencing the project costs, $f(v)$ as the present residual value function at the waste disposal phase, and $f(s)$ as the present value function of the real option of the project.
The mathematical optimized LCC model can be expressed as Formula (4):

$$\min LCC_{pv}=W[\, f(p)+f(c)+f(r)+f(q)-f(v)+f(s)] \quad (4)$$

Since it is extremely difficult to find the global optimal solution directly from the above formula, for specific projects, only a few major factors can be considered to establish a simplified mathematical model to find the local optimal solution to the costs.

4. Conclusion

In order to optimize the management of life-cycle engineering costs of large-scale chemical projects and optimize the investment decisions in chemical projects, this paper conducted relevant studies by following the LCC theory. The main innovations are as follows:
(1) The structure of life cycle costs of large-scale chemical projects has been identified, as well as cost analysis steps.
(2) In line with the basic LCC model, an all-factor LCC model for large-scale chemical projects has been built by taking the factors such as quality, safety and environment into consideration. Additionally, the model has been optimized based on the constraints, leading to the optimized all-factor LCC model for the investment decision-making in large-scale chemical engineering projects.

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