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A Study on the Cost Estimate System Development Method for Nuclear Power Plant Construction Projects

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Abstract: Nuclear power plants in Korea are usually built based on a duplicated model; so the project cost data of the preceding unit can be used as reference when estimating the project cost for the succeeding unit. However, since the contracting method is oriented towards the price, empirical factors such as making top-down estimations using the reverse calculation method based on the completion cost of the preceding unit is dominant. In order to develop a project cost database to resolve such problems, the detailed cost boundary of the project cost data must be categorized by project and by system. This study proposes a method to connect the code of account with the base quantities and the IAEA account, and proposes a database structure for the development of a project cost estimation system. The estimation system developed in the future is expected to utilize the proposed project cost data structure.

Key words: cost database, estimate cost, quantity, code of account, nuclear power plant

1. INTRODUCTION

The economics of nuclear power involves the consideration of several aspects. Capital costs which include the costs for site preparation, construction, manufacturing, commissioning, and financing of a nuclear power plant. Plant operating costs, which include the costs for fuel, operation and maintenance, and a provision for funding the costs of decommissioning the plant and treating and disposing used fuel and wastes. External costs to society from the operation is usually assumed to be zero for nuclear power plants, but could include the costs of dealing with a serious accident that are beyond the insurance limit and in practice need to be picked up by the government [1]. Nuclear energy additionally needs to take into account costs from an environmental aspect owing to carbon reduction as it is an environment-friendly energy, as well as costs for plant post-management (radioactive waste treatment costs, spent fuel disposal costs, decommissioning costs) and costs related to social conflicts.

Capital costs comprise the EPC cost (usually identified as engineering-procurement -construction cost), the owner's cost (land, cooling infrastructure, administration and associated buildings, site works, switchyards, project management, licenses, etc.), cost escalation and inflation. The term "overnight capital cost" is often used, meaning EPC plus owner's costs and excluding financing, escalation due to increased material and labor costs, and inflation.

Since construction project cost (capital cost) estimates depend on how the cost elements are set (including escalation and financing costs) [2], the estimates for new power plants are quite uncertain and frequently the actual construction project cost ends up being significantly higher than the original contract project cost. Recently the nuclear industry has increased requirements for safety equipment as a result of strengthened safety regulations and technical standards, and this has led to actual construction project costs exceeding the contract project cost. Also since the estimate baselines of the construction project cost differ by country, site, project conditions, and work scope, it is difficult to accurately calculate costs and make comparisons. Trends in costs have varied significantly in magnitude and in structure by era, country, and experience [9]. Moreover, there is a lack of experts capable of estimating construction project costs process and systems to reasonably estimate and calculate construction project costs. Costs systems need data frameworks (modeling) and historical databases.

2. LITERATURE REVIEW

The project cost management scheme of KHNP is comprised of the conceptual cost, which is estimated at the time of the basic plan, and the baseline cost and definitive cost, which is estimated when the supply agreements for the major equipment are concluded. The forecast cost is developed while the project proceeds by incorporating the contract requirements and risks, and then the final cost is developed after project completion based on the actual cost [4, 5, 6]. The project cost management scheme utilizes the numbering system of a project and is composed of the corporate budget code of accounts (CBCOA) which is used to develop and operate the budget by contract or purchase order; the project budget code of accounts (PBCOA) which is comprised of units categorized by procurement, construction, and contract, or purchase order and is the code of account for efficient management of the project investment cost; and the cost element code of accounts (CECOA) which categorizes all costs into material, labor, and other costs [4]. In order to estimate the conceptual cost and the baseline cost and definitive cost, the detailed costs are categorized by item and then categorized by constant price, which applies the escalation rate in order to reflect the time value of the currency, and also by the current price, which represents the actual prices of the year that the construction project cost is to be executed. The constant price is used to compare the costs of the base year, and the current price can be used when forecasting the cost to be executed at a certain period and when establishing a budget plan for a certain period. The forecast cost is estimated by developing the cash flow which reflects the contract changes and additional work performed during the project period, and applying the estimated escalation rate at that time [5].

According to KHNP's standard project cost management procedure, the project cost for a Korean nuclear power plant has the following three data attributes [7]. One, the conceptual cost and the baseline cost and definitive cost are related to project cost estimation. The lowest level project cost data are based on prices, namely in the format of subcontracts/purchase orders and cost, and the preceding unit data is mainly the reference data. Two, the quantities and unit prices for each payment category by BOP purchase agreement, and the material and labor cost for each payment category of the construction design documents of the main equipment. The construction design documents, in particular, apply the Construction Standard Estimation System to identify the detailed construction material list, quantities, and labor manhours by commodity. But the construction design documents are for bidding, and comstruction completion details do not exist after construction is completed. And three, the actual cost based on facility systems as construction completion data. Details on the facility systems including quantities do not exist, but they have meaning in terms of proportions against the total cost.

3. APPROACH AND METHODOLOGY

Nuclear power plants in Korea are usually built based on a duplicated model; so the project cost data of the preceding unit can be used as reference when estimating the project cost for the succeeding unit, but there is no database or procedure that comprehensively manages the project cost data of preceding units [7]. The construction cost per unit generation amount (KWe) of a nuclear power plant project is estimated for the purpose of comparing the economics of power generation sources. Rather than extracting data from the project completion database of the preceding unit, empirical factors are dominant as an estimation is made by performing top-down reverse calculations of the capacity based on the final cost and experience. Project cost estimation of a nuclear power plant project after the feasibility study is made for each supply contract (major equipment, BOP, design services, construction, etc.). The estimation criteria of the project cost are based on the preceding unit and experience to reflect the capacity, site, and data interval correction, and afterwards are adjusted accordingly to meet the purpose of the budget. The forecast cost for order placement and negotiations is adjusted based on the supply contracts (architectural engineering, system design, construction contract, etc.) of the preceding unit completion cost or the contract price. Project cost data is managed by type of the estimated project cost (conceptual cost, baseline cost and definitive cost, forecast cost), and since the project cost is an estimation oriented on prices, the detailed cost boundaries for each project and each account are not provided, making comparison and analysis difficult. The following is proposed to resolve such issues.

3.1. Cost code connection methods based on quantity

The most accurate project cost estimation method is to multiply the quantity by the unit price. The quantity is defined to be a quantification of the project scope. Since the purpose of project cost estimation is to calculate the commercial value of equipment, manpower, material and other resources required to realize the project plan and project scope, the most accurate estimation method is to calculate the project cost based on the quantity data.

Since the project cost estimation method based on quantity data is currently not being applied, there is no connectivity between the project scope and quantity data. The bidding quantities required for equipment and material procurement and to calculate the construction bid price are developed based on the supply scope of the Invitation to Bid and the technical specification, and so this maintains their connectivity. However, the initially planned quantity does not exist (because budget control was not applied) and so cannot be compared with the bid quantity, and the final supply quantity and construction quantity after project completion only exist on paper or the quantity at completion was not calculated. The development of the construction design documents for the main facilities is the typical project cost estimation method based on quantity data. That is, the material quantity, manpower, and equipment required for construction work is estimated and multiplied by the unit price. In actual practice, when the cost baseline is ambiguous, the project cost estimation personnel attempt to estimate the project cost based on the quantity data of the preceding unit. Therefore, as construction planning and project cost estimation in the early phase of the project tend to depend on the top-down data and information of the preceding unit, improving the accuracy of the project plan and project cost is limited. Project cost data should be managed through hierarchical cost codes and each cost code should be clearly defined.

In order to ensure the consistency and systemicity of the cost codes, the project scope and the cost boundary of the cost codes generally need to be in alignment. They are comprised of technical factors and project characteristics which directly impact the project cost, and engineering data values need to be applied concurrently. Since quantities, which have the biggest impact on the project cost, have innate characteristics by area, the definition of each quantity should be data structured.

Since the production cost, which is the most important element for estimating the project cost, is based on the actual data from the preceding unit, the final contract prices (including quantities and unit prices) of all subcontracts of the preceding unit, data regarding the quantities from the planning stage (design) and the procurement/construction stage, payment items regarding the construction cost, budget execution details, and contract details need to be entered into and managed by the database. And this should also be linked to the payment settlement database as shown in Figure 1. However, the construction cost for the main and auxiliary facilities are to be based on the final construction design documents or the calculation details or detailed contract changes submitted after contracting of preceding units. Other data such as the project management cost also serve as bases for estimation and should be included in the database.

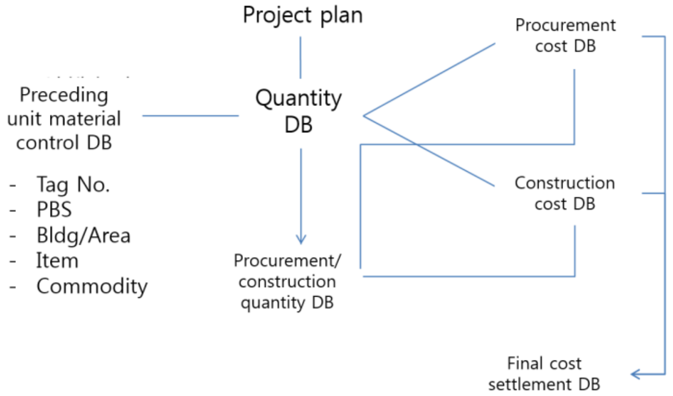

Fig. 1. Structure of quantity-based project cost data

3.2. Method of connection to IAEA accounts

The International Atomic Energy Association (IAEA) acknowledged that different types of reactors partake in the international bidding for new build projects and that the categorization of project cost varies by bidder and thus, developed and presented a project cost breakdown that can commonly be used for international bids. The IAEA's construction cost account is being used as the code of account of international nuclear power plant bids, but the actual proposed tender price is used by adjusting the upper level (IAEA Level 1), and the lower level (IAEA Level 3) is mostly applied to the supply scope relevant to the project cost. Also the bid supply scope is comprised of the nuclear island scope and the turbine island scope considering the supply chain of the project owner. A unique feature of the construction base cost is that unlike Korean and overseas construction cost breakdowns, costs expended for direct construction work including labor cost and start-up are categorized as direct costs.

$$\text{Base costs} = \left\{ \begin{array}{c} \text{Direct costs (Account nos 21–29)} \\ + \\ \text{Indirect costs (Account nos 30–41)} \end{array} \right\}$$

$$\begin{array}{l}\text{Fore costs} \\ \text{(overnight costs)}\end{array} = \text{Base costs} + \left\{ \begin{array}{c} \text{Supplementary costs (Account nos 50–54)} \\ + \\ \text{Owner's capital investment and services} \\ \text{costs (Account no. 70)} \end{array} \right\}$$

$$\begin{array}{l}\text{Total capital} \\ \text{investment costs}\end{array} = \text{Fore costs} + \left\{ \begin{array}{c} \text{Escalation costs (Account nos 60, 71)} \\ + \\ \text{Interest during construction and fees} \\ \text{(Account nos 61, 62, 72)} \end{array} \right\}$$

Fig. 2. Breakdown of total capital investment cost by the IAEA and relevant accounts [11]

In contrast, it is determined that the direct connection between the code of accounts for nuclear power plant projects in Korea and the international code of accounts will be quite difficult as the former is comprised of a very complex supply structure based on the pricing of contracts by area and purchase orders. The international code of accounts clearly differentiates the supply scope and cost boundary based on detailed technical bases, and so the level of direct connectivity decreases heading towards the lower level [8].

The PBCOA of the KHNP cost account consists of contract/order unit and other expenase at the upper level of the amount standard. Therefore, it is difficult to match 1:1 with the IAEA construction account, which has a facility system and a unique project cost range. However, the BOP(Balance of Plant) equipment of tag has a payment item itself associated with the equipment number, this equipment number includes the physical breakdown structure and can be used to verify consistency with the IAEA account. If is is unclear at the lower level, it is determined whether or not it is coincident at th near high level.

This paper proposes substituting the unit of assets in the final cost scheme for Korean nuclear power plants with the IAEA construction account as a method for connecting the project cost ratios. Since the unit of assets in Korea is the physical breakdown structure, if the logical project cost distribution ratio developed during the cost settlement process is adequately applied, a rough connection between the accounts will be possible. The configuration of the Korean code of accounts should be based on the upper level of the IAEA construction cost account, and the supply scope and cost boundary should be categorized based on the Korean standards. But the supply scope must be clearly defined in order to prevent any misunderstanding on the scale of the construction cost by code of account. The Korean scheme may have the equipment/material and commodities which comprise the physical breakdown structure be categorized and connected similarly to the IAEA construction cost account.

In conclusion, in order to respond to the international code of accounts, code of accounts based on quantity data and clear cost boundaries should be defined, and the direction to development should be made towards establishing the databases of all nuclear power plant project costs to these accounts.

4. FUTURE WORK

This study aims to establish standardized estimate baselines and develop a cost estimate system for nuclear power plant construction project in order to resolve the abovementioned problems.

Since the unit price estimation bases of the construction cost varies by country, site, project conditions, and the supply scope, it is difficult to make accurate unit price estimations and comparisons. Also, there are not enough experts for systematic construction cost management nor a reasonable system to estimate and forecast the construction cost. This study proposes the data format that could serve as basis for the NPP project cost management system by looking into the related management procedures and international code of accounts for the development of such a system. NPP project cost data is being managed according to the project cost estimation format (conceptual cost, baseline cost and definitive cost, forecast cost). And since the detailed cost boundaries are not provided for each project and for each account, because cost estimates are price oriented, a comparative analysis is also difficult. Alignment of the project scope and the cost boundary of the code of accounts is necessary in order to solve such problems, and subsequently a project cost estimation scheme based on quantity should be established. A method on how to comprise the data system to be linkable to the IAEA accounts in order to make estimations reflecting international projects based on the scope was proposed.

The project cost data breakdown scheme proposed through this study will be used to develop a system in the future as follows. First, a statistical analysis will be performed on collected data regarding contract costs and the actual costs of recent nuclear power plants. The project cost data by project phases of four APR1400 projects—from Shin Kori Units 3&4 to Shin Hanul Units 3&4—will be analyzed along with the existing project cost estimation methods and separating cost data structure. Second, estimate baselines will be established by developing cost estimation methodologies and identifying influence factors based on the analysis results. As the final step, a cost estimate system will be established according to the nuclear power plant construction project cost estimation process and baselines which are based on the aforementioned. Based on the accumulated estimate and actual data from preceding projects, by utilizing the system to perform result analyses and trend analyses including comparative analyses by project, it is expected that a project's economic feasibility may be evaluated and accurate construction project costs will be estimated.

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