

Construction Economics & Finance

Module 5

Lecture-1

Cost Estimating:-

The purpose of cost estimating is to forecast the cost of a project prior to its actual construction. Cost estimating is a method of approximating the probable cost of a project before its construction. The exact cost of a project is known after completion of the project. Cost estimate is prepared at various stages during the life of a project on the basis of the information available during the time of preparation of the estimate. Generally for any construction project, three parties are involved namely owner, design professionals and construction professionals. In some cases the design professional and construction professional are from the same company or they form a team through a joint venture for providing service to the owner in the project. It is the responsibility of each party involved in the project to estimate the costs during various stages of the project. An early estimate helps the owner to decide whether the project is affordable within the available budget, while satisfying the project's objectives. For cost estimating, work breakdown structure (WBS) serves as an important framework for organized collection project cost data and preparing the cost estimates at different levels. It is a technique that involves the hierarchical breakdown of the project into different work elements at successive levels and defines the interrelationships between them. For preparation of cost estimates, the estimator performs quantity take-off to quantify each item of work by reviewing the contract drawings and specifications. In cost estimation, quantity take-off is an important task that is carried out before pricing each item of work and quantities should be represented in standard units of measure. Before bidding for a project, the estimator (along with his or her group) of a construction firm needs to determine the total cost of the project in accordance with contract documents consisting of drawings, specifications and all other technical documents and requirements. The total project cost consists of two components namely direct cost and indirect cost. Direct cost includes cost of materials, equipment and labor associated with each item of work and also includes cost of

subcontracted works. Indirect costs are the costs which are not associated with each item of work rather these costs are calculated for the entire construction work and includes overhead costs (both job office or site office overhead and general head office overhead), contingency i.e. cost for any unforeseen work and profit. It is important to accurately estimate all the cost components of the project before bidding. The material cost for each item of work can be calculated by multiplying required quantity of materials by its unit price. The material quantity take-off or the quantity of materials for an item of work can be easily calculated by using the information from contract drawings and specifications. The current unit price of materials can be obtained from the material suppliers. In addition, the estimator has to add a certain percentage for wastage of materials while calculating the material cost. The equipment cost consists of two components i.e. ownership cost and operating cost. Generally the equipment cost is expressed on hourly basis. As already mentioned (in Module 4), equipment operator wages which vary from project to project are normally calculated as a separate cost category and are added to other components of equipment operating cost. The procedure of calculating hourly equipment cost is already stated in Lecture-1 and Lecture-2 of Module 4. The hourly equipment cost and production rate of the equipment are used to calculate the cost per unit production of the equipment. The production rate of the equipment depends on its rated capacity, production cycle time, efficiency and also on job site conditions. The labour cost depends on the productivity of labourers which vary with the nature of work. The productivity of labourers depends on various factors namely their skill, number of working hours in a day, supervision, nature of job, job site conditions etc. The portion of work that is to be accomplished by the labourers can be found out from project documents i.e. from contract drawings and specifications. The labour cost is generally expressed on hourly basis. Historical data from past projects can also be referred for calculating the cost of materials, equipment and labor. For the contractors, the calculated bid price (sum of direct cost and indirect cost) for the project must have a balance with the associated profit margin such that the bid price should be low enough to be within the owner's budget and to win the bid and at the same time, it should be high enough to complete the project with the expected profit.

Lecture-2

Types of Estimates

As already stated in the previous lecture (Lecture-1 of this module), there are different types of estimates which are prepared at various stages during the life of a project starting from the initial phases to its final phase on the basis of the available information at the time of preparation of the estimates. The range of expected accuracy is more in the estimates which are prepared during initial stages and it narrows down as the project progresses with the availability of more detailed information and increase in the level of project definition. In addition to the project parameters, the degree accuracy of an estimate also depends on the experience, ability and judgment of the estimator. The construction cost estimate is broadly classified into two types approximate estimates and detailed estimates. The approximate estimates are prepared during initial stages of the project life cycle. These estimates are also known as preliminary, budget or order-of-magnitude estimates and are prepared to determine the preliminary cost of the project. From the approximate cost estimates, the owner of the project can be able to know whether the project can be undertaken within the available budget. There may be more than one design alternative for a project depending on the location, site conditions, type of structure etc. The estimator can determine the approximate cost of various alternatives for the project by taking preliminary design information from designer and can obtain the economical alternative that is affordable within the available budget for the project.

Detailed estimates are prepared in accordance with the complete set of contract documents. As already stated, the contractors prepare the detailed estimates before bidding for the project by thoroughly reviewing the contract documents. Project site visit by the contractor personnel may be required to identify the parameters that can influence project cost and accordingly the estimate can be adjusted. The detailed cost estimate showing the bid price of the project is important to both the project owner and the contractor, as the bid price represents the amount the contractor will receive from the owner for completing the project in accordance with contract documents. The different types of cost estimates which are prepared during various phases of a project are described below.

Estimates during conceptual planning:

This estimate is prepared at the very initial stage i.e. during conceptual planning stage of a project. It is based on little information and on broad parameters namely size of the project, location and job site conditions and the expected construction quality of project as a whole. The size of the project may be expressed in terms of its capacity namely number of rooms for a hostel, number of beds for a hospital, length (km) of a highway etc. Owner of the project provides adequate input for defining scope of the project and this scope of the project forms the basis on which the conceptual estimate is prepared. This estimate is prepared to establish the preliminary budget of the project and accordingly project funding can be arranged. The degree of accuracy of this estimate is lowest among all the estimates those are prepared during various stages of a project.

Estimates during schematic design:

During this phase of the project, the cost estimate is prepared on the basis of preliminary design information along with required schematic documents. The designer may incorporate different design alternatives and the cost estimate is prepared for these design alternatives by the estimators depending on the available information. The cost estimates of different design alternatives are reviewed keeping in view the project scope and budget and the acceptable alternative(s) selected in this phase is analyzed in a detailed manner in the next phase of the project. This cost estimate is prepared by calculating the cost of major project elements by unit pricing from the available preliminary design information. Subcontractors or material suppliers may be asked to furnish information while pricing the major project elements. As the cost estimate is prepared using preliminary design information, a contingency may be added in the estimate to accommodate for the unknown design details. With the improved scope of the project, the expected degree of accuracy in this estimate is more as compared to that in conceptual estimate.

Estimates during design development:

During design development phase of the project, the cost estimate is prepared on the basis of more detailed design information and schematic documents. With the improved level of information, the most of the major project items namely volume of earthwork (m^3), volume of concrete (m^3), weight of steel (tons) etc. can be quantified and the cost

estimate is prepared using the known unit prices. Detailed information from subcontractors or material suppliers should be obtained and used in pricing the major project items. During this phase, all the identified major systems of the project namely structural systems (reinforced concrete vs. structural steel), masonry (clay brick units vs. concrete masonry units), pile foundation (concrete pile vs. steel pile) etc. are priced and then cost of each system is compared with that obtained from past similar projects. The project elements costing too high or too low as compared to past data should be reviewed and accordingly adjusted. With the availability of detailed design information and improved system definition, the expected degree of accuracy in this estimate is higher as compared to that in estimate prepared during schematic design phase of the project.

Estimates during procurement (i.e. estimates for construction of the project):

During this phase of the project, the cost estimate is prepared on the basis of complete set of contract documents that defines the project. The contractors bidding for the project prepare the cost estimate in accordance with contract documents by taking into consideration the estimated project duration. As already mentioned in the previous lecture (Lecture-1 of this module), the total cost of project can be divided into two categories namely direct cost and indirect cost. Direct cost includes cost of materials, equipment and labor associated with each item of work and cost of subcontracted works. Indirect costs are the costs which are not attributed to each item of work and are calculated for the entire project and include overhead cost, contingency and profit. The owner team also prepares the cost estimate to check the accuracy of the bid prices quoted by the contractors and negotiate a reasonable price with the contractor. As this cost estimate is prepared in accordance with complete set of contract documents of the project, the degree of accuracy of this estimate is extremely high.

Estimates for change orders during construction:

This estimate is prepared to cater the changes in the project scope as required by the owner during construction phase of the project.

Lecture-3

Approximate estimates

The different types of cost estimates, those are prepared during various phases of a project are already stated in Lecture 2 of this module. As already mentioned in Lecture 2 of this module, the approximate estimates (also known as order-of-magnitude estimates) are prepared during initial stages of the project life cycle. The different methods used in the preparation of approximate estimates are described below. In addition to use in the preparation of estimates during early stages of project development, these methods may also be sometimes used for cost estimating in the detailed design phase.

Unit estimate

This technique is used for preparing preliminary estimates (i.e. order-of-magnitude type estimate). This estimate is generally prepared during the conceptual planning phase of a project, with less information available with the estimator. In this method, the total estimate of cost is limited to a single factor. The examples of some of the ‘per unit factor’ used in construction projects are construction cost per square meter, housing cost per boarder of a hostel, construction cost per bed for a hospital, maintenance cost per hour, fuel cost per kilometer, construction cost per kilometer for a highway etc. The total cost is calculated by multiplying the cost per unit factor with the number of units of the corresponding factor. For example, a preliminary estimate is required to estimate the cost of constructing a new house with floor area of 170 square meter. If the cost per square meter is Rs.26,900 (assumed), then the cost of constructing the house will be Rs.45,73,000 ($\text{Rs.}26,900 \times 170$). Similarly the preliminary cost estimate of constructing a given length of highway can be calculated by multiplying the unit cost i.e. construction cost per kilometer by the length of highway (in km).

The details of unit cost of different factors can be obtained from records of past projects. The ‘per unit factor’ obtained from past similar projects can be adjusted by taking into account different parameters namely location and size of the project, prevailing market conditions etc. The accuracy of this technique depends on the quality and reliability of the data available with the estimator.

Factor estimate

In this method, the estimate is divided into individual segments and then the cost of each segment is calculated followed by adding all the individual costs to estimate the total cost. Unlike unit technique, the factor technique includes separate factors for different cost items. Thus compared to unit technique, factor technique is a more detailed method of preparing the cost estimate and shows improved accuracy. The factor method is useful when several components are involved in the preparation of cost estimate.

Considering a simple example, a preliminary estimate is required to find out the cost of constructing a new multi-storey hostel of an educational institute. By unit method, the preliminary cost will be simply the cost per square meter multiplied with the total floor area (square meter) of the hostel. However a comparatively improved estimate can be prepared by using factor method wherein the total cost estimate is divided into different components. The hostel will consist of individual living rooms for students, hostel office, a kitchen cum dining room, a reading room, a common room, an indoor sports room, lavatories on each floor and other common amenities. The estimate of the total cost of the hostel will comprise of cost of these components. The cost of residing rooms for the students can be calculated by multiplying the cost of constructing one room (the information can be obtained from past similar projects with adjustment for different parameters as mentioned in unit estimate technique) by the required number of rooms. The estimate of the construction cost of the kitchen cum dining room can be calculated by multiplying its area in square meter by construction cost per square meter. Similarly the estimate of the construction cost of other common areas (i.e. reading room, common room etc.) can be calculated by multiplying the respective areas (in square meter) by construction cost per square meter. Then the total estimate of the construction cost of the hostel will be equal to the sum of all the cost components. As already mentioned the information about construction cost per square meter of common amenities can be obtained from past data on similar projects. In this example the estimate of construction cost of living rooms of students can also be calculated by multiplying the total area to be occupied by the rooms (square meter) by the cost per square meter.

Taking another example with more details, a preliminary cost estimate is required obtain the cost of materials to be used in constructing reinforced concrete sections of a structure. For reinforced concrete sections, the total cost estimate will comprise of cost of concrete and cost of steel reinforcement bars. For estimating the cost of concrete (considering normal strength concrete), the quantities of different ingredients namely cement, coarse aggregate and sand are calculated from known volume of concrete by using the mix proportion (either known or using data of similar grade of concrete from past projects). The cost of the individual ingredients of concrete can now be calculated by multiplying the quantities of the ingredients in the appropriate units with the respective unit cost. For example, the required quantity of cement can be expressed in kg or in terms of number of bags (i.e. total quantity of cement in kg divided by quantity of cement in kg per bag). Similarly the required quantities of both coarse aggregate and sand can be expressed in m^3 (i.e. quantity of aggregate in kg divided by bulk density in kg/m^3). The information about unit cost of different materials can be obtained from material suppliers. Similarly the cost of steel reinforcement can be obtained by multiplying the quantity of steel in tons with its unit price. Now the total cost of materials to be used in constructing reinforced concrete sections is calculated by summing the cost of concrete and cost of steel reinforcement. Similarly the preliminary estimate of other cost items can be obtained by using factor estimate method.

Cost indexes

The method involving cost indexes is used for obtaining preliminary cost estimate by considering the historical data of similar past projects. Cost indexes (or indices) are dimensionless numerical values which represent the price change of individual or multiple cost items over time with respect to a reference year. Cost indexes are used to update the historical cost figures and to obtain the current cost estimates. The relationship used for updating the historical cost figures to the cost at another point of time using cost index is presented below.

$$C_n = \frac{C_r I_n}{I_r}$$

Where

C_n = estimated cost of the item in year 'n'

C_r = cost of the item in year ‘ r ’ (at earlier point of time and $n > r$)

I_n = index value in year ‘ n ’

I_r = index value in year ‘ r ’

Here ‘ r ’ is the reference year (i.e. at earlier of point of time) at which the cost of the item known and ‘ n ’ is the year for which cost of the item is to be estimated. Cost indexes are periodically published by various public and private agencies.

Cost indexes are generated for an individual item or for wider variety of items. For a single item, cost index can be calculated as the ratio of cost of the item today (i.e. in current year) to the cost of the same item at some point of time in past (i.e. reference year) multiplied with cost index value of the reference year. Similarly for multiple items, a weighted-average index or composite index for a specific year can be obtained from known cost of the selected group of items in the given year and in reference year and the composite index of these items in the reference year by assigning the appropriate weightage factors to these items. In construction, the expected cost estimate of materials, equipment and labour for new projects can be obtained from the known cost of these items from similar past projects and cost indexes (in reference year and current year) using the above relationship.

Example -1

For estimating the expected cost of materials for a new construction project, the following information is available;

The material cost of a similar construction project that was completed four years ago was Rs.1,12,64,000 and the material cost index was 512. Calculate the approximate material cost for the new project, if material cost index now is 625.

Solution:

The approximate material cost for the new project ‘ C_n ’ is calculated using the above relationship and is presented below.

$$C_n = \frac{C_r I_n}{I_r}$$

Where

C_n = approximate material cost (present cost estimate)

C_r = material cost of similar project four years ago = Rs.1,12,64,000

I_n = material cost index now = 625

I_r = material cost index four years ago = 512

$$C_n = \frac{\text{Rs.1,12,64,000} \times 625}{512} = \text{Rs.1,37,50,000}$$

Thus the approximate material cost for the new construction project is Rs.1,37,50,000.

Lecture-4

Parametric estimate

Parametric cost estimate is prepared during early stages of project development. The cost estimate is based on various parameters which define characteristics of the project and includes physical attributes such as size, capacity, weight etc. The parametric cost estimate is based on cost-estimating relationships those use past cost data to obtain the current cost estimate. Cost estimating relationships are statistical models those relate the cost of a product or system to the physical attributes those define its characteristics. One of the most commonly used cost-estimating relationships is power-sizing model.

Power-sizing model

Power-sizing model is most commonly used for obtaining preliminary cost estimate of industrial plants and equipment. The power sizing model relates the cost of a plant or system to its capacity or size and uses the following relationship for cost estimate.

$$\frac{C_1}{C_2} = \left(\frac{Q_1}{Q_2} \right)^x$$

Where

C_1 = cost of Plant 1

C_2 = cost of Plant 2

Q_1 = capacity or size of Plant 1

Q_2 = capacity or size of Plant 2

x = power-sizing exponent or the cost-capacity exponent

In the above expression C_1 and C_2 are the costs at the same point in time, at which the estimate is required. Both Q_1 and Q_2 are in same physical units. The power-sizing exponent 'x' represents the economies of scale. The economies of scale indicate that the cost per unit output decreases as the size of operation increases. The decrease in cost per unit output occurs as the fixed cost is distributed over more number of output units as the scale of output increases and in addition the efficiency grows in production with increasing size of operation. Taking a simple example, the cost of constructing a four-storey hostel building will normally be less than twice the cost of constructing a similar

two-storey hostel building. One of the factors that gives rise to cost advantage in case of four-storey building is the cost of land (fixed cost), which is same for both buildings.

If the value of power-sizing exponent 'x' is less than 1, it indicates economies of scale whereas greater than 1 indicates diseconomies of scale. When the value of power-sizing exponent is equal to 1, it indicates a linear relationship between cost and capacity or size.

While using this technique to predict the current cost of an industrial plant of a given capacity (Q_1) from known past cost of the same plant of a different capacity (Q_2), first it is required to update the known past cost of the plant with capacity (Q_2) to the present time by using the relationship for cost index (as stated in previous lecture) from the known values of cost indexes in past and in current time. After that, the cost of the plant with capacity Q_1 is estimated using the power-sizing model (as stated above) from the updated cost of plant with capacity Q_2 (i.e. cost at current time) and value of the power-sizing exponent for this particular plant.

Learning curve is also another cost estimating relationship and it is based on the principle that with increase in number of repetitions, the performance becomes faster with increase in efficiency. In other words the time or cost of producing a unit output of a product/system reduces, each time it is produced. Learning curve relates to improvement in performance with increase in repetitions. A learning curve model is based on the assumption that, the time to produce a unit output reduces by a constant percentage as the number output unit is doubled. The reduction in time depends on the learning curve rate. Taking a simple example, if the time required to complete the production of first output unit is 20 hours, then the time required to complete the production of the second output unit at 80% learning curve rate will be 16 hours ($20 \text{ hours} \times 0.80$). This 80% learning curve rate indicates a 20% reduction in production duration, each time the output is doubled. Similarly the time required to produce the fourth output unit will be 12.8 hours ($16 \text{ hours} \times 0.80$). The reduction in production time for fourth unit as compared to the second unit is 3.2 hours ($16 \text{ hours} - 12.8 \text{ hours}$) which is 20% of production time for the second output unit.

Life cycle cost

Life cycle cost is equal to sum of all the estimated costs associated with a product, service or system over its life span starting from conceptual planning at the beginning to schematic design, detailed design, construction or production, operation and maintenance till its disposal at the end of the life span. The concept of life cycle costing lies in designing/producing the products, services or systems with systematic identification of both recurring and nonrecurring costs during various phases of their life cycle and estimating the cash flows during these phases over the life cycle. The economic evaluation of an alternative on the basis of life cycle cost results in a detailed analysis of the of both present and future costs and thus helps in taking the right decision regarding the selection of the most economical alternative. For construction projects, it is important to accurately estimate all the cost components during various stages of the project life cycle.

The life span of a product, service or system depends on the different phases starting from conceptual planning to its disposal. The end of life cycle may be governed by economic requirement or by functional requirement and depends on specific product, service or system. The economic life of a product/system is normally shorter than its physical life. The product/system may still be functional (over physical life) but may not be economical for the entire life period and may be replaced. The details about the replacement analysis of an asset are already stated in Module 4.

The life cycle cost of a product, service or system increases, if the design changes are made during later stages of the life cycle. The cost of design change increases with each stage of life cycle with lower cost during the early stages. Further the flexibility in design changes during the early stages is more as compared to that in the later stages of life cycle. Thus the potential for cost savings is more during the early stages of the life cycle and thus the selection of the most economical alternative and the effective design procedure during the design stage results in higher cost savings. Thus it is essential to have a detailed design of the product/system (as per the required technical specifications and operational requirements) during the design stage of life cycle and to avoid or minimize the design changes during production and operation stages of life cycle to have a minimum impact on the life cycle cost of the product/system.

The life cycle cost analysis is more useful for selecting the alternatives for products, services or systems having longer life periods namely, infrastructure projects and projects involving more research and development components. The economic evaluation of alternatives using life cycle cost analysis can be carried out by finding out the equivalent worth of the each alternative by including all the cash flows occurring over various stages of life cycle by present worth analysis and selecting the most economical alternative that results in minimum life cycle cost.