CHAPTER 5

ESTIMATING AND TENDERING

The estimating process involves the identification and analysis of the many items of cost that will enter into the construction process. Such estimating, which is done before the work is actually performed, requires careful and detailed study of the tender documents together with a familiar knowledge of the costs, availability and characteristics of materials, construction equipment and labour. The process of producing a cost estimate is described in the following steps:

1. Arrangements for the estimating process
2. Preparation of method statement
3. Estimating direct cost
4. Estimating indirect cost
5. Setting the contract duration.

Tendering is a subsequent commercial process where the produced cost estimate is converted into a price. Allowances for risk, cost of finance and profit and choice of the tender pricing policy would be made by the firm higher management at this stage. Tendering is a market oriented function. It relates to the external environment within which the firm operates. The chapter starts now with demonstration of the estimating process.

5.1 Arrangements for the Estimating Process

Programming the Estimate

The time required to prepare an estimate and submit a bid is usually limited. The management of the estimating process should ensure that all the ingredients of the estimate are given adequate attention within the limited time available. Therefore the estimator should prepare a programme for the jobs required to complete the estimate.

Preparatory Contract Study

The enquiries to materials suppliers and subcontractors have to be issued as early as possible. Therefore a preparatory contract study should be

undertaken in order to:

1. establish the principal quantities of each work type by totaling the bill items or by preparing a quantity survey using tender drawings
2. establish an approximate cost for the whole contract and for each type of work using rough rates
3. establish the delivery dates for the materials by preparing a rough construction schedule
4. identify the items of work to be subcontracted.

Collection of Cost and Productivity Information

Materials Costs

The estimator has to send out enquiries for the specific job materials. The enquiries include information such as quantities required, specifications, and approximate delivery dates. An allowance for wastage, damage, storage and others should be made. This allowance will range from zero for structural steel members to 20% for masonry mortar. Written quotations are required so that prices and delivery schedule are known.

Bids from Subcontractors

The factors that control the decision of which work to subcontract are the specialization of the work involved and the size of the contract. In issuing enquiries to subcontractors the subcontract programme and the subcontractor's responsibilities should reasonably be stated.

The estimator has to analyze the subcontractors' quotations. Sometimes the subcontractors require that the general contractor is responsible for providing electricity, water, storage facilities for materials and many others.

The estimator should prepare an estimate for the subcontracted items in order to:

1. determine which bid is unrealistic
2. avoid wild guess in case he has not obtained any bid from the subcontractors; a situation he may not realize until just before his bid is due.

Labour Costs and Production Rates

The estimator has to maintain a comprehensive library of labour costs and production rates from previous contracts. Reports of completed work are the most reliable source of Labour productivity information but anyone preparing an estimate for the first time must rely on published figures and his own estimate of what is realistic in the circumstances.

Labour rates are usually calculated for labourers, craftsmen and plant operators. In addition to the labour basic hourly rate, tax, insurance and any form of social security should be added.

Plant Costs and Production Rates

It is better to buy a new equipment for the contract and to sell it at the end of construction when the duration of the contract will be about equal to the service life of the equipment. Equipment is usually rented or leased. Renting is advantageous to satisfy temporary peak demand, or for providing seldom-used equipment. It is usually of short term; several weeks or months. Leasing provides that at the expiration of the lease period the contractor has a purchase option. Lease agreements normally extend for periods of one year or more.

For hired plant:

basic cost = rate quoted by the plant company

For bought plant:

hourly rate = total cost in a year / average working hours per year

The total cost must cover ownership and operating costs. Ownership cost includes depreciation, cost of capital and insurance. Depreciation is a function of initial cost and resale value . Operating cost includes running cost and repairs and maintenance. The running costs include operator rate, fuel costs and a 10% addition for oil, grease and consumables. Example 4.6 demonstrates calculation of the hourly rate of a construction equipment. In addition to plant basic cost or hourly rate, the costs of move-in, erection, dismantling and move-out must be included in the estimate.

Equipment production rates are obtainable from the suppliers but these need to be reviewed in the light of specific job conditions such as haul distances, grades, rolling resistance and site conditions.

Site Visit

The site visit gives the estimator an opportunity to study the site and set notes which include:

- description of site and ground conditions
- labour availability
- location of existing services
- problems relating to site security
- access to the site
- details of any demolition.

5.2 Preparation of Method Statement

A full appreciation of the work involved in the contract is gained by studying the tender drawings, and analysis of the bill of quantities and other tender documents. However, the following step is the preparation of method statement; that is the way in which the work will be carried out. This includes:

1. Details about site staff who are going to supervise the works: a given supervisor may be experienced with getting a job out of the ground but not with another.
2. A schedule of materials required for the permanent work and the proposed sources of supply.
3. A schedule of basic costs at the time of tender of the plant, labour and materials required to complete the works.
4. Details of the proposal for staff housing, offices, workshops and stores.
5. A list of subcontractors the estimator proposes to use.
6. Site layout.
7. Construction method of each part of the contract: detailed comparative studies may be needed for, for example, bracing an excavation, method of scaffolding and dewatering the site. Included in this step is the selection of construction plant required for the completion of the contract together with the proposed method of transporting the plant to the site.

8. A list of the risks and uncertainties the contractor is going to carry and management responses to deal with them.

9. A schedule of the activities required to complete the work showing for each activity a detailed breakdown of the plant, labour and materials required together with proposed outputs and wastage allowances.

10. A detailed programme of work showing the proposed duration of each activity and any assumed overlapping.

Out of the above contents of the method statement, the process of construction risk and uncertainty management will now be given in detail.

5.3 Risk and Uncertainty Management

Large schedule delays and significant cost overruns are associated with risk and uncertainty. The early assessment of the risks and uncertainties which affect the construction of a project may improve the performance in terms of time and money. However, the systematic process of construction risk and uncertainty management includes:

1. Identification of risk sources
2. Development of responses to avoid, reduce or transfer risk
3. Assessment of residual risk effects (risk analysis)
4. Providing for residual risk in estimates.

The first two steps of this process should be included in the method statement. The latter two will be included in calculation of the cost contingency.

Risk and Uncertainty Identification

Construction risk means that there is a possibility of undesirable extra cost or delay due to factors having uncertain future outcome. Construction uncertainty means that the variables concerned may vary over a wide range and as a result there will be economic loss or gain. For simplicity, the word risk may be used to mean both construction risk and uncertainty.

Table 5.1 gives main categories of sources of risks and uncertainties for construction contracts. These risks will be carried by the parties. In allocation of risk within a construction contract, the risk should, generally, be carried by the party best able to make the assessment. If there is any doubt, it should be accepted by the client. This is because it is better for the client to pay for what does happen rather than for what the contractor thought might happen in these risks.

In the tender stage, the contractor has to identify both the risks and uncertainties allocated to him in the contract and those inherent in the nature of his work. Identification of risks and uncertainties by asking the engineers involved in the operations ensures that all the factors will be identified.

Management Responses to Risks and Uncertainties

Having identified the risks and uncertainties the contractor is going to carry, management should develop responses in terms of reduction, transfer or retention. The following actions may be taken by the contractor to reduce or transfer risks:

- using construction methods which have high degree of certainty of success
- using extra resources to enhance flexibility of the construction programme required to absorb possible delay
- securing alternative suppliers and advanced delivery dates for materials
- providing temporary roads to give flexibility of operations
- allowing free housing in the camp for labourers and staff to reduce problems arising from remoteness of job site
- locating site facilities away of the working space to give sufficient area for construction works
- assuming realistic reduced resources output to satisfy unskilled labour and activities specific requirements
- maintaining good roads to provide assumed production figures for hauling equipment
- using plant models for which spares are easily available to reduce uncertainty of shortage of spare parts
- providing facilities on site for all mechanical maintenance to reduce effect of equipment breakdown
- using expatriates to reduce effect of shortage of skilled labour
- submitting a detailed programme of work to warn the client of likely consequences of indecisions or delay
- purchasing insurance to offset the risk of site injuries.

Table 5.1 Main Categories of Sources of Risks and Uncertainties for Construction Contracts.

Administrative

- delay in possession of site
- late hire of wayleaves
- access to the site
- troubles encountered with different public services
- limited working hours
- maintaining flow of the traffic during construction

Logistical

- shortage and/or late supply of different resources
- site remoteness problems
- communications

Construction

- ground problems
- suitability of different resources
- achieving productivity of different resources
- weather and seasonal variations
- limited working space
- strikes and wage increase
- construction method
- equipment breakdown
- mistakes and failure to construct to programme
- subcontractor's performance
- capability of professional staff

Physical

- placing fill in dry seasons
- diverting a river in time of low flow
- driving a tunnel from one end
- no work in high tides

Design

- incompleteness
- suitability of design
- design changes
- new technology
- errors resulting from poor surveys or site investigations
- appropriateness of specifications and interaction of design with method of construction

Continued .....

Table 5.1 Continued

Financial

- inflation and shortfall in reimbursing cost escalation
- exchange rate fluctuation
- loss due to default of contractor
- availability of funds
- inadequate payment for variations
- taxes
- early high investment in plant
- delay in payment by client

Management

- space congestion
- effect of learning curve
- scheduling errors
- estimating data
- errors in B.O.Q.

Contractual

- suitability of contract type - conditions of contract
- liability to others
- co-ordination of work

Political

- changes in local laws
- import restrictions
- complex requirements for permits
- necessity to use local resources
- war or revolution
- inconsistency of regulations within the country

Disasters

- floods
- landslip
- fire
- earthquakes
- accidents
- diseases
- stormy winds
- lightning

Time Contingency

Time contingency is one of the contractor's responses to risks and uncertainties. Time allowances are added into the contract programme to reflect the risks which are known to the contractor in advance such as late delivery of materials. Two procedures are followed with respect to adding time contingency allowances into networks:

a. A general allowance is added to the overall contract duration when the majority of the activities may be affected by the risk, for example, effect of bad weather on highway contracts.

b. Allowances for time lost are commonly applied to particular activities easily affected with the risk, for example, specific activities that are deemed to be weather sensitive such as building an earth dam embankment.

In addition to the above responses, the contractor has to assess the risks he is going to retain and include appropriate cost contingency allowance for them in his estimate as given in section 5.7.

On the other hand, the client has a major role in the process of mitigating risks associated with construction of the works. He should:

- be involved to prepare for collaboration of the contractor and local authorities in order to discover locations of public services especially in urban districts
- be involved to resolve the inevitable regulatory problems with the individuals who enforce these problems
- assess possible design changes to predict any disruption to the construction programme and estimate subsequent compensation to the contractor.

5.4 Estimating Direct Cost

The direct cost of each bid item is obtained as the sum of its material, labour, equipment and subcontractor costs. The sum of all such bid-item direct costs gives the estimated direct cost of the contract.

The estimator should determine the direct cost rates of major contract items using the operational estimating, unit rate estimating, or both types of estimating. Only minor items which are not very significant to the direct cost of the contract may be estimated based on the estimator's previous experience.

Operational Estimating

This type of estimating is used in civil engineering because it allows for idle time which is common in most plant-dominated work; for example it would base the cost of an excavator on the time it is on site not on an assumed output. When used for a whole contract, the method includes the following steps:

1. Prepare a complete activity schedule, using one of the techniques mentioned in chapter 2. Adjust the schedule for resources requirements.

2. Add costs under the following headings to facilitate cash flow calculations:

- fixed cost: incurred once; at a specific point of time
- time-related cost: incurred every time period of the activity or resource
- quantity proportional cost: cost of materials.

However, the following example is a simple demonstration for calculating a direct cost rate using the operational estimating method.

Example 5.1

A grout curtain is to be formed underneath a dam. This involves drilling through the underlying rock. The dominant measurement of the quantity of work is the length of the grout holes to be drilled - 21390 m which is distributed over 388 holes. Table 5.2 shows the work divided into five activities together with the used resources.

Assume that the drilling rate equals 20m / day and the grouting rate equals the drilling rate approximately. The drilling rig must be moved from the hole before grouting and this requires 1/2 day for each move. Activity durations are calculated in Table 5.3 assuming a 6-day week. The histogram of the used equipment made up using the whole contract programme is shown in Figure 5.1. Shown also in the same figure is the likely usage of the equipment.

Determine the direct rate for drilling and grouting using the operational estimating method, given that the cost of the used equipment = LE 2300/wk/unit and cost of the grout material = LE 5.8/m.

Solution

Equipment total usage = 19 × 4 + 15 × 2 + 11 × 10 + 11 = 227 unit.week
Cost of equipment = 227 (2300) = LE 522 100
Rate for grouting = 5.8 + 522100 / 21390 = LE 30.21/m

Table 5.2 Data for Example 5.1

Act	Descrip-tion	No. of holes	Length (m)	No. of drill. & grout. plt.
100	Grout 1	154	7400	4
200	Grout 2	53	2870	2
300	Grout 3	55	3130	3
400	Grout 4	79	4510	4
500	Grout 5	47	3480	3

Table 5.3 Calculating Activity Durations for Example 5.1

Act	Drill & grout (days)	Moving rig (days)	Total duration (weeks)
100	7400 / (20 × 4) = 92.5	154 / (2 × 4) = 19.3	19
200	2870 / (20 × 2) = 71.8	53 / (2 × 2) = 13.3	15
300	3130 / (20 × 3) = 52.2	55 / (2 × 3) = 9.2	11
400	4510 / (20 × 4) = 56.4	79 / (2 × 4) = 9.9	11
500	3480 / (20 × 3) = 58.0	47 / (2 × 3) = 7.8	11

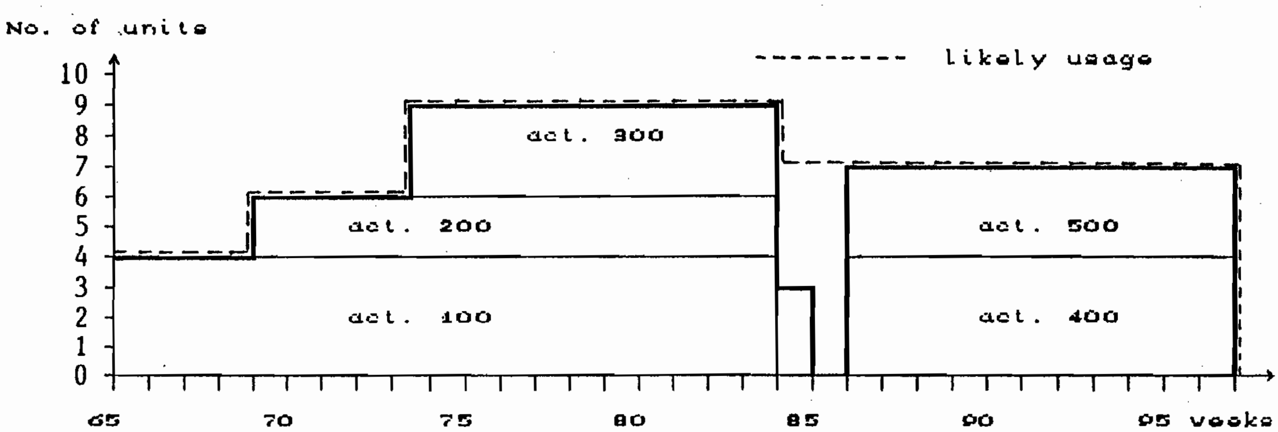


Figure 5.1 Histogram of the Used Equipment, Example 5.1

Unit Rate Estimating

This type of estimating is used in building work and for some items of civil work where the nature of the work is repetitive. It is based on the selection of resources required and their output rates for each category of work. The technique does not demand an examination of the construction programme.

Example 5.2

Calculate the rate for grouting for the data given in example 5.1 using the unit rate estimating technique.

Solution

The drilling and grouting rate is 20 m / day. The usage rate will be 0.05 day / m. If the time required for moving equipment is taken into consideration it will be 388 (0.5) = 194 days = 0.01 day /m. Total time = 0.06 day/m

Daily cost of equipment = LE 383.33
Rate for grouting = 5.8 + 0.06 × 383.33 = LE 28.80/m

5.5 Estimating Indirect Cost

Indirect cost of the contract is the contract site and head office overheads. The contract cost is the summation of the contract direct and indirect costs.

Site Overheads (On-Costs)

Site overheads are field costs that are incurred in achieving contract completion, but which do not apply directly to any specific work item. A detailed analysis of the particular demand of the contract is a reliable way to arrive at an accurate estimate of site overheads. They include cost of:

1. Technical and administrative staff, offices, workshops, stores, first aid, provision of water, electricity, and sanitary facilities, telephone, access roads, tests, temporary partition and stairs, surveys, photographs, parking facilities, clean up, housing and feeding staff, insurance and bonds.
2. General plant required to support the gangs operating in the field: lorries, buses, cars, small tools, pumps and scaffolding.

These charges will be a mixture of fixed and time-related charges. They may be 5% to 15% of direct job cost.

Head Office Overheads (General Overheads)

Head office overheads are costs that are incurred in support of the overall company construction programme and that cannot be charged to any specific contract. The allowance for head office overheads will cover cost of staff, directors, estimators, schedulers and design engineers. It should include the cost of running the office.

The amount of the head office overheads that should be allocated to a specific contract equals

$$\frac{\text{contract direct cost} \times \text{total head office overheads in a year}}{\text{expected sum of direct cost to be incurred on all contracts during the year}} \tag{5.1}$$

Monthly monitoring of the company's activities will give guidance as to what modifications of the elements of equation 5.1 should be made. However, the contract head office overheads may be 2% to 5% of the contract direct cost.

Example 5.3

Consider the construction of a rectangular reservoir 50m x 30m x 4m which is part of a large treatment works. The structure has mass concrete external walls, a central dividing brickwall, a reinforced concrete floor slab and precast concrete roof beams and slabs supported on reinforced concrete columns. The lower part of the excavation is in hard rock which is overlain by clay. The mechanical and electrical works are subcontracted. The contract of the work will be let on an admeasurement basis with method-related bill of quantities.

Compile a list of all costs (direct and indirect) which must be included in the contractor's estimate, indicating how they will be calculated (fixed, time-related or quantity-proportional) using the operational estimating method.

Solution

1. Direct costs:

Excavate in clay:

- excavator, trucks and bulldozer

transportation to site	fixed cost
hiring	time-related cost
operating	time-related cost

Excavate in rock:

- blasting:

material	quantity-proportional cost
labour	time-related cost
loader, trucks, bulldozer	as equipment above
- move equipment from site	fixed cost

R.C. floor slab:	
- steel reinforcement:	
material	quantity-proportional cost
steelfixers	time-related cost
- formwork:	
material	quantity-proportional cost
carpenters to prepare	fixed cost
carpenters to fix and strip	time-related
- concrete:	
batching plant:	
set up	fixed cost
running	time-related cost
material	quantity-proportional cost
labour	time-related cost
Central brickwall:	
- bricks and mortar	quantity-proportional cost
- bricklayers	time-related
External walls:	
- concrete:	
running batching plant	time-related cost
material	quantity-proportional cost
labour	time-related cost
- formwork:	as before
R.C. columns:	
- steel reinforcement	as before
- formwork	as before
- concrete	as before
Precast beams and slabs:	
- beams and slabs	quantity-proportional cost
- crane	as equipment
- labour	time-related cost
- move equipment from site	fixed cost
Mechanical and electrical works:	
- subcontracted	lump sum

2. Indirect costs:

Site overheads:	
- staff & labour	time-related cost
- connection of water, electr., etc	fixed cost
- consumption of water & electricity	time-related cost (approx.)
- offices, workshop, store, first-aid	fixed cost
- general plant items	time-related cost

Head office overheads:
- it may be uniformly distributed over contract duration

5.6 Optimum Contract Duration

In the process of estimating the duration of various activities, the duration which gives the minimum direct cost would be chosen. Consequently the contract might take very long period to complete while it should be completed earlier. Thus the problem of reducing contract duration arises. Other circumstances which call for time reduction are:

- to recover early delays in order to avoid liquidated damages
- to free key resources for other contracts
- to avoid adverse weather
- to receive an early-completion bonus
- to meet a client's desire for expediting the work.

Contract duration may be shortened by adjusting overlaps between the activities such that the critical path is diminished in length or by reducing the duration of critical activities if possible. However, the duration of an activity may be reduced by:

- working extended hours or more days,
- working on multiple shifts,
- achieving more output by offering incentive payments,
- using additional resources up to the practical limit, or
- using more quickly installed materials.

Activity Direct-Cost/Time Relationship

Shortening the duration of an activity will normally increase its direct cost; cost of labour, equipment and materials. The least direct cost required for completing an activity is called the normal cost and the corresponding duration is called the normal duration. The shortest possible duration required for completing an activity is called the crash duration and the corresponding cost is called the crash cost. The points between the above two limits must show the costs for various feasible times in which the activity can be speeded up by the different ways available. These data can be used to draw a graph showing the relationship between direct cost and duration for each of the contract activities. The relationship may be represented by a straight line, continuous curve or discrete values as shown in Figure 5.2.

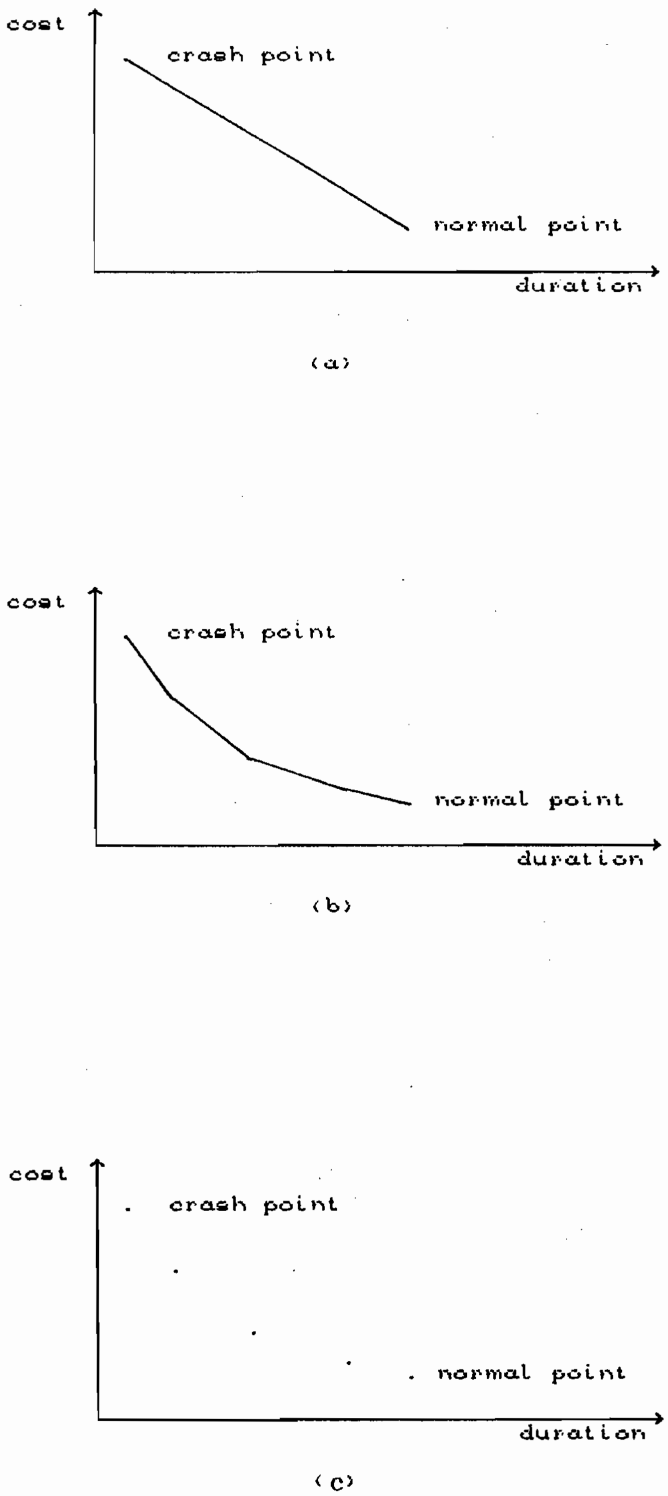


Figure 5.2 Activity Direct-Cost/Time Relationship Represented by (a) straight line (b) continuous curve (c) discrete values

Example 5.4

Consider the activity of excavation of a pipeline trench. Assume that the volume of work contained is 990 m^3 and the most efficient crew size is 10 men. The average output is 3 m^3/man/day. The normal wage is LE 10/ man/ day. The foreman wage is LE 15/day.

It is required to determine the crash duration and the corresponding cost for this activity using multiple crews. Assume that the maximum number of crews to be supervised by the foreman is three.

Solution

Increasing the number of crews will result in some reduction in the working efficiency. The reduction will be 10% for using 2 crews and 20% for using 3 crews. The corresponding activity duration and cost can now be calculated as shown in Table 5.4.

Table 5.4 Calculations for Expediting an Excavation Activity

Case	No. of crews	No. of men	Efficiency	Output (m^3/ day)	Duration (days)	Cost (LE)
Normal work	single	10	100%	10(3)1 = 30	33	3795
	double	20	90%	20(3)0.9= 54	19	4085
Crash work	triple	30	80%	30(3)0.8= 72	14	4410

Contract Cost/Time Relationship

The contract direct-cost/time relationship can be derived by shortening the duration of all crashable activities which lie on the critical path. The contract direct cost tends to increase if less time is available for construction but the contract indirect cost tends to increase if more time is consumed for the construction. This indirect cost is generally vary approximately linearly with contract time.

The contract indirect-cost/time curve can be superimposed to the contract direct-cost/time curve. Adding these two curves will produce the contract cost/time relationship. The result will look like Figure 5.4. The economic solution for the contract can be obtained by a proper balance between time and total cost. The optimum contract duration is associated with minimum contract cost.

Procedure for Shortening Contract Duration

The following method for shortening contract duration is based on the assumption that all the activities direct-cost/time relationships are linear. Whilst this assumption may not be precisely true, it is a reasonable one. According to this assumption an activity cost slope is defined as the incremental direct cost per unit time. The method can be demonstrated in the following steps:

1. Compute the cost slope of each activity from the following equation:

$$\text{cost slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal duration} - \text{crash duration}} \tag{5.2}$$

2. Draw the activity network and identify the critical path. Beneath each activity write the number of time units the activity can be crashed to and its cost slope.

3. Reduction in contract duration is obtained by shortening the activity on the critical path which has the least cost slope and which has not yet been shortened to its crash duration.

4. When multiple critical paths are involved, the activity(ies) to shorten is determined by comparing the cost slope of the activity which lies on all critical paths (if any), with the sum of cost slopes for a group of activities, each one of them lies on one of the critical paths.

5. The activity duration is reduced until its crash duration is reached, or a new critical path is formed.

6. Having shorten a critical path, you should adjust activities timings, floats and crashabilities. Continued shortening of a critical path will lead to the formation of new critical path(s).

7. The cost increase due to activity shortening is calculated as its cost slope multiplied by the number of time units shortened.

8. Continue until no further shortening is possible. Then the crash point is reached.

9. The results may be represented graphically by plotting contract completion time against cumulative cost increase. This is the contract direct-cost/time relationship. To this curve would be added the indirect cost curve to determine contract cost/time curve. The latter curve gives the optimum duration and the corresponding minimum cost.

10. The region of the contract minimum cost may be taken, for practical purposes, as being spread over a range of durations amounting to several time units. Hence, by selecting a project duration at the left end of this range,

a contractor can keep a few time units leeway in hand for late completion at no change in project cost.

Example 5.5

The durations and direct costs for each activity in the network of a small construction contract under both normal and crash conditions are given in Table 5.5. Establish the least cost for expediting the contract. Determine the optimum duration of the contract assuming the indirect cost amounts to LE 125/week.

Table 5.5 Data for Example 5.5

Activity	Preceded by	Normal		Crash	
		Duration (weeks)	Cost (LE)	Duration (weeks)	Cost (LE)
A	–	12	7000	10	7200
B	A	8	5000	6	5300
C	A	15	4000	12	4600
D	B	23	5000	23	5000
E	B	5	1000	4	1050
F	C	5	3000	4	3300
G	E,C	20	6000	15	6300
H	F	13	2500	11	2580
I	D,G,H	12	3000	10	3150

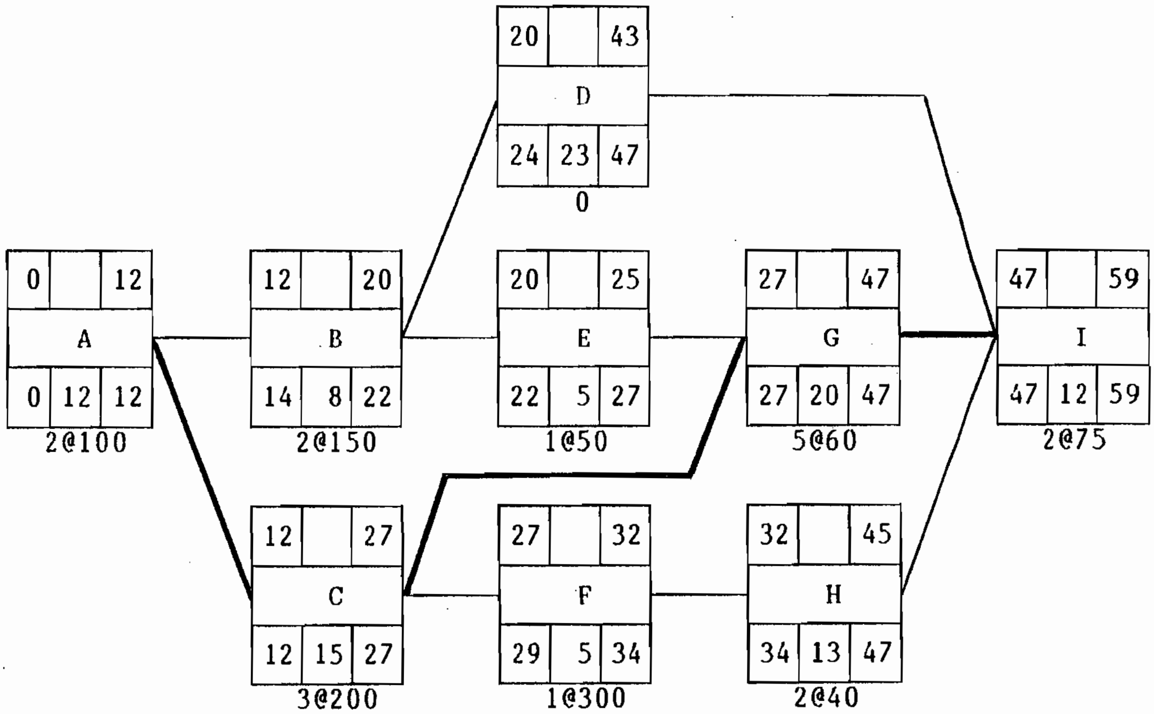
Solution

- The crashability of each activity is the difference between its normal and crash durations. Cost slopes are calculated using equation 5.2. Both the crashability and the cost slope are shown beneath each activity in the precedence diagram Figure 5.3a. The critical path is A-C-G-I. Contract duration = 59 weeks.

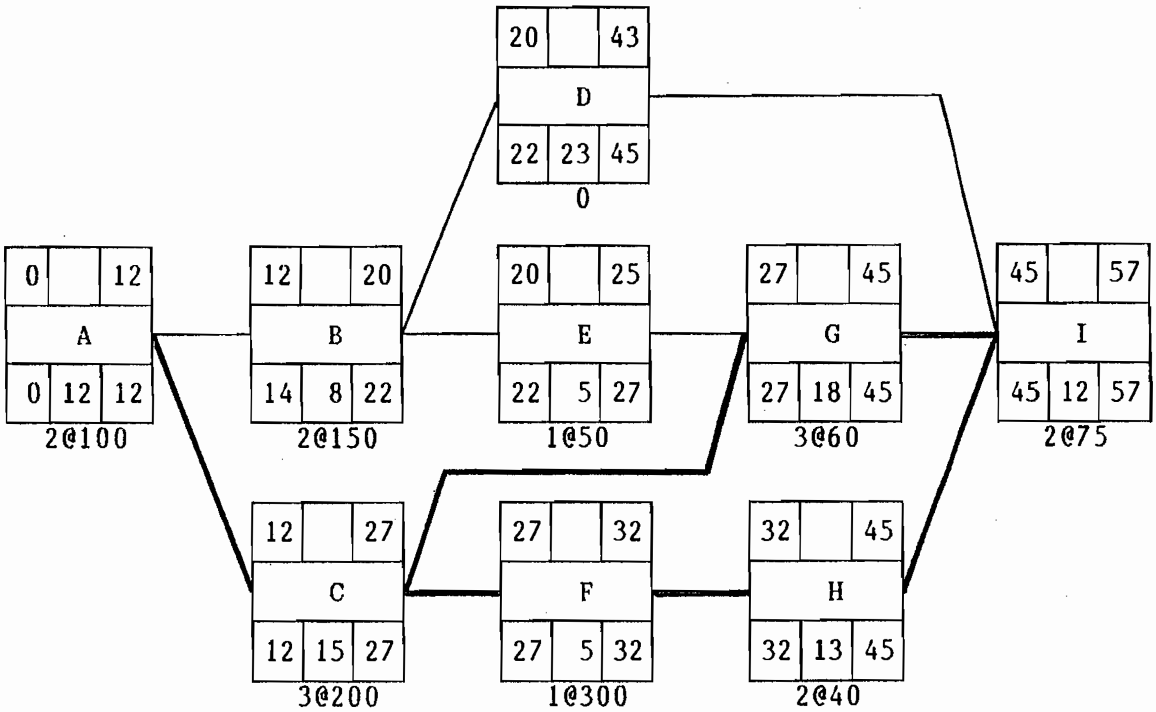
- The activity on the critical path with the lowest cost slope is G. This activity can be crashed by 5 weeks, but if it is crashed by more than 2 weeks another critical path will be generated. Therefore G will be crashed by 2 weeks only. Reduce crashability of G from 5 to 3 weeks. Adjust timing of I and consequently D, H and F. This is shown in Figure 5.3b. A new critical path A-C-F-H-I has been generated. Contract duration = 57 weeks and the cost increase is 2 × 60 = LE 120.

- Now we have two critical paths: A-C-F-H-I and A-C-G- I.

Either	crash A	at cost LE 100/week
or	crash C	at cost LE 200/week
or	crash I	at cost LE 75/week
or	crash F and G	at cost LE 360/week
or	crash H and G	at cost LE 100/week.

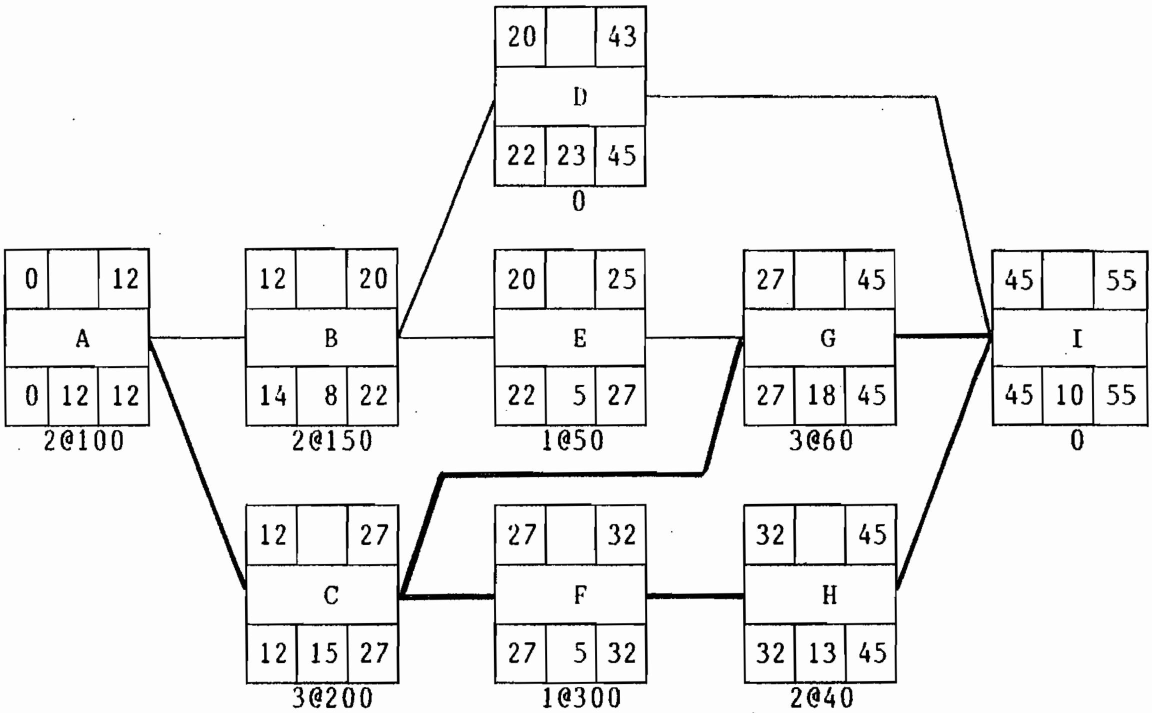


(a)

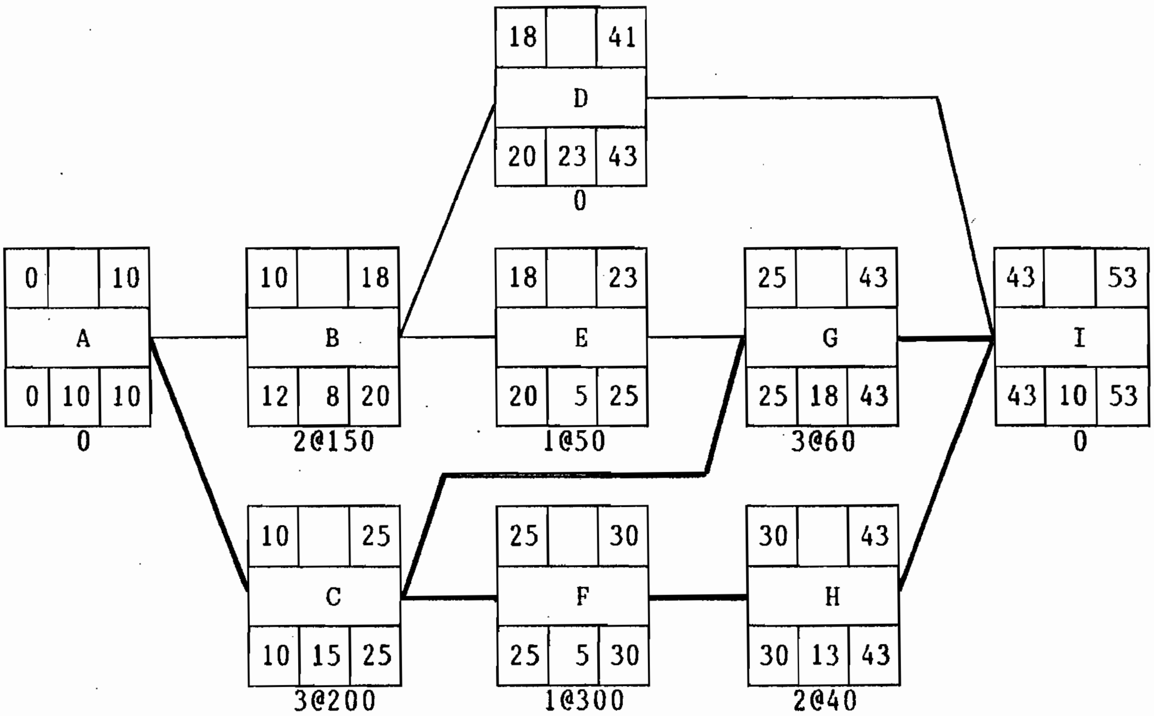


(b)

Figure 5.3 Network Compression
(a) Contract duration = 59 weeks
(b) Contract duration = 57 weeks

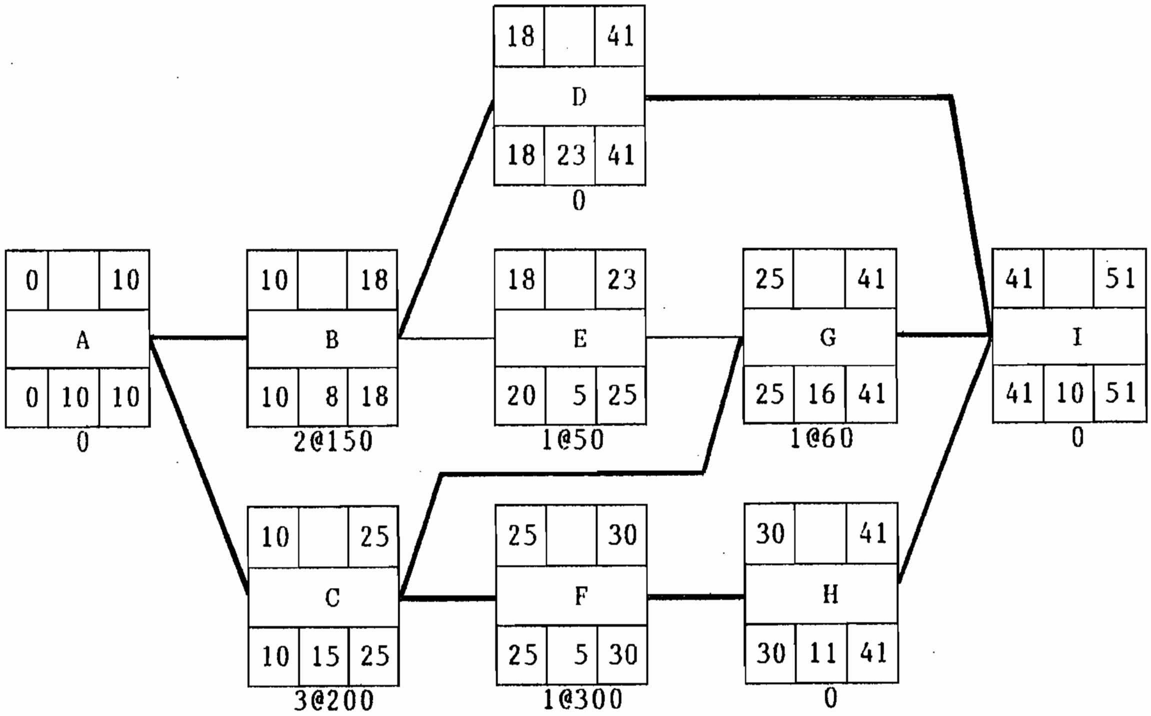


(c)

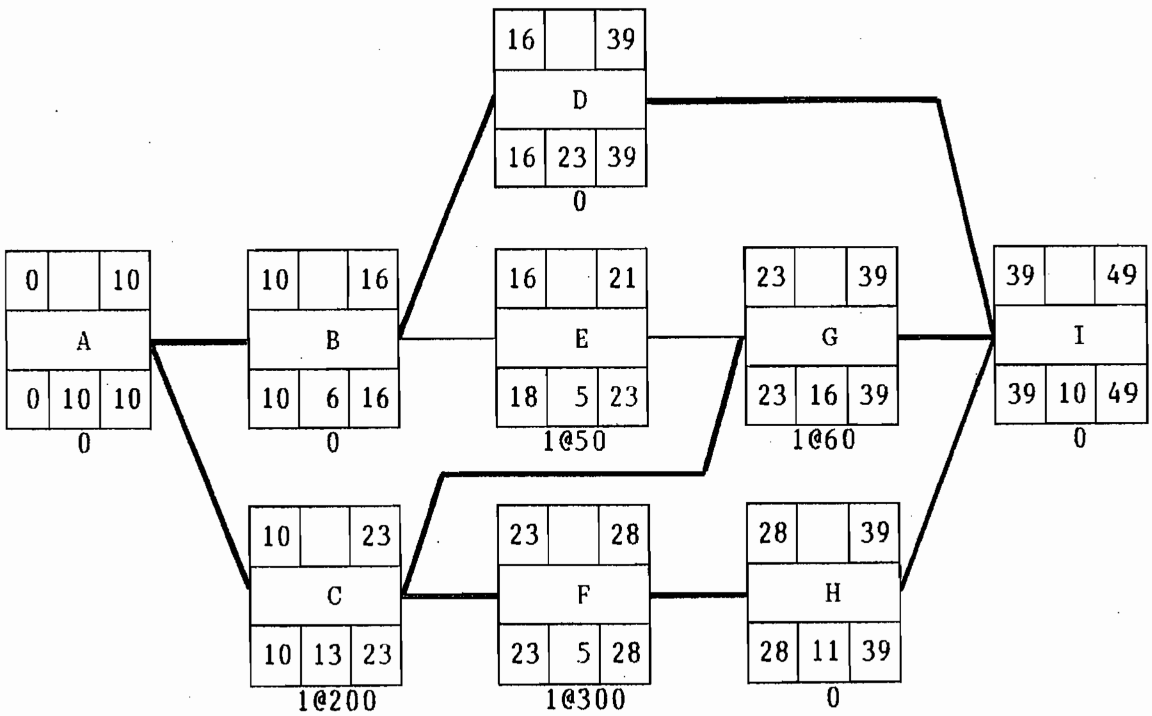


(d)

Figure 5.3 Network Compression
(c) Contract duration = 55 weeks
(d) Contract duration = 53 weeks



(e)



(f)

Figure 5.3 Network Compression
(e) Contract duration = 51 weeks
(f) Contract duration = 49 weeks

Activity I is chosen because it has the least cost slope. It can be crashed by 2 weeks. This has no effect on any other activity. This is shown in Figure 5.3c. Crashability of I is reduced to zero. Contract duration = 55 weeks at an increased cumulative cost = 120 + 2×75 = LE 270

- Now either to select A or both H and G to be crashed. They have the same cost slope. It does not matter which of them is selected. Activity A is chosen to be crashed first. This will change timings of all contract activities but will not change their floats. This is shown in Figure 5.3d. Crashability of A is reduced to zero. Contract duration= 53 weeks at an increased cumulative cost = 270 + 2 × 100 = LE 470.

- Activities H and G can now be crashed by 2 weeks each. This will change timings of activity I and consequently D and B. This is shown in Figure 5.3e. A new critical path A-B-D-I has been generated. Crashability of both G and H is reduced by 2 weeks. Contract duration = 51 weeks at an increased cumulative cost = 470 + 2 × 100 = LE 670.

- Now we have three critical paths: A-C-F-H-I,
A-C-G- I and
A-B-D- I.

Crashable activities are B, C, F, and G.
Either crash C and B at cost LE 350/week
or crash F, G and B at cost LE 510/week.

Activities B and C are chosen because they have the least cost slope. Each of B and C will be crashed by 2 weeks. Timings of other activities are adjusted accordingly. This is shown in Figure 5.3f. Crashability of both B and C is reduced by 2 weeks. Contract duration = 49 weeks at an increased cumulative cost = 670 + 2 × 350 = LE 1370.

- No further shortening is possible. The results are shown graphically in Figure 5.4. The contract cost curve is plotted by simple addition of the direct and indirect cost at any desired duration on the graph. It is immediately seen that a minimum contract cost exists. This is the most economical solution for the contract - the optimum duration and the least total cost.

Setting the Contract Duration

Usually the tender documents specify the contract duration. On some contracts, it would offer improvements in the quality of the contract award decision and its subsequent control to invite tenderers to bid the duration they require to complete the works. This is mainly because major plant is operated in teams of optimum size and the specified duration may require other than a whole number of teams.

The implications of setting an inappropriate contract duration can be considered by analyzing the contract cost/time relationship. If the contract duration is longer than the optimum the contractor may use the float as his own property and his programme may not declare it to the client. If the contract duration is less than the optimum, the contractor may base his tender on minimum cost plus the amount of liquidated damages he anticipates he will incur or he may base his tender on minimum cost and rely on extensions of time to avoid liquidated damages.

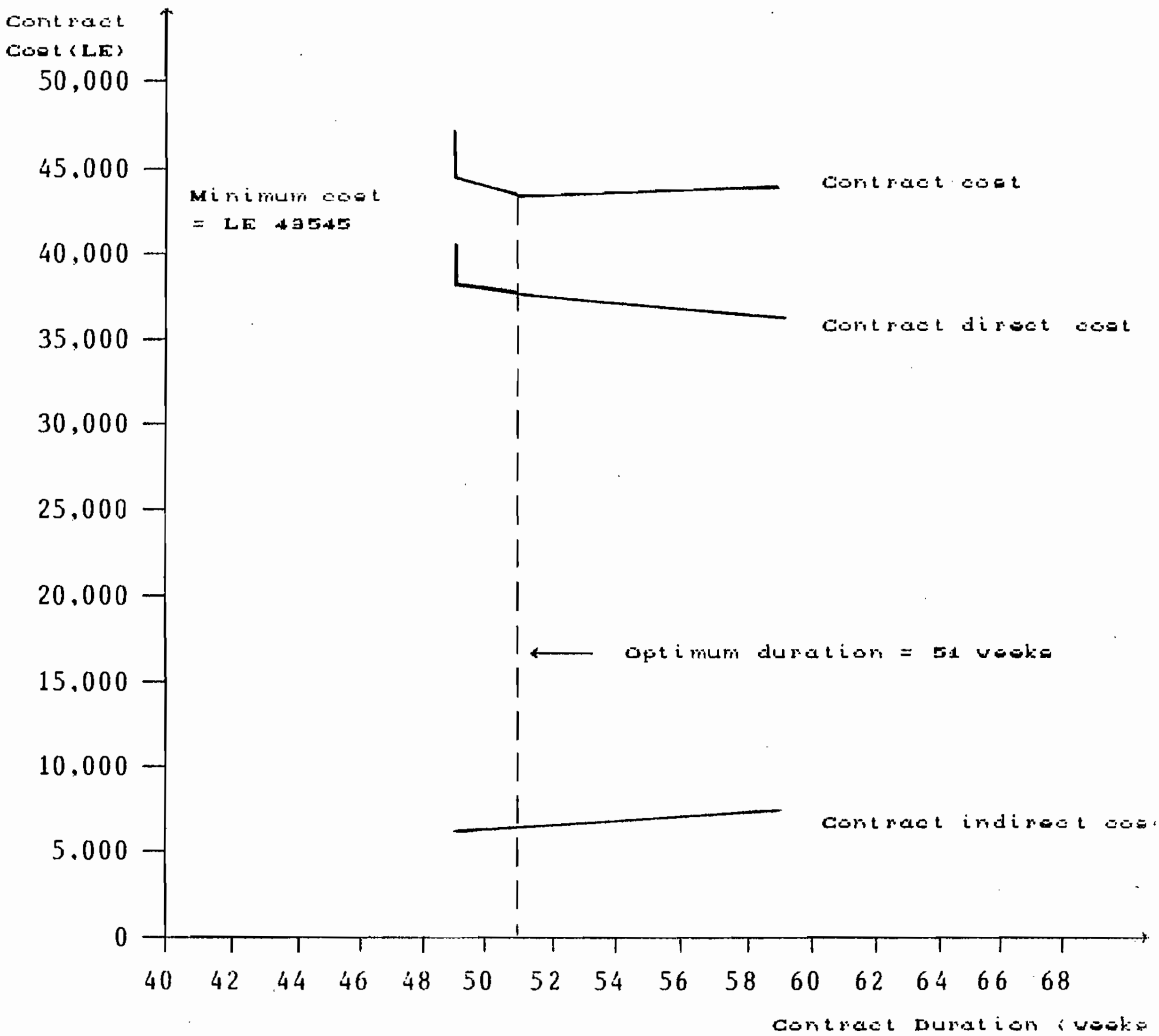


Figure 5.4 Contract Cost/Time Relationship

Therefore, project managers should try to ascertain a realistic duration of the contract through the production of the contract cost/time relationship. Contract duration may be specified as the optimum contract duration plus an allowance to cover the risks the contractor is going to carry.

5.7 Producing Tender Price

The difference between the contract cost and the tender price is represented by the mark-up. The mark-up contains two elements, an allowance for residual risk and the margin of profit.

Risk Allowance (Cost Contingency)

In the preparation of method statement the contractor has developed responses to reduce or transfer risks and uncertainties. However, some residual risks are still retained by the contractor. The contractor includes a cost contingency in his bid to cover these residual risks.

Two methods are available for calculating cost contingency. The first is to add a single sum of money equal to an agreed percentage of the contract direct cost. This approach has two main defects: (1) the percentage figure may be inappropriate for the specific contract and (2) it results in a single-figure prediction of estimated final cost, implying a degree of certainty that is simply not justified. However, this method may be used when there is no facility for risk analysis.

The second method is to quantify the effect of residual risks and uncertainties on contract cost through sensitivity and probability analyses and then to use the results of this analysis to calculate the cost contingency:

Sensitivity Analysis

Sensitivity analysis is used to identify those variables which contribute most to the risk of the contract. Three values for each risk variable will be supplied: a most likely, an optimistic and a pessimistic value. Then for each variable, two values of construction cost are determined when the variable is equal to its optimistic and pessimistic values, all other variables being kept equal to their most likely values in each case. The difference between the two values of construction cost provides a number which is comparable.

If the analysis indicates that the variation of the variable makes a little difference to the construction cost, then the most likely value of the variable can be used throughout. Otherwise the variable should be included in the probability analysis.

Probability Analysis

In probability analysis, each risk variable is considered as a random variable. The analyst has to specify the probability distribution of each variable. Monte Carlo simulation is used to estimate the distribution of the construction cost using the probability distribution of each of the risk variables. The details of this approach are outside the scope of this book. However, a typical result of the probability analysis is shown in Figure 5.5.

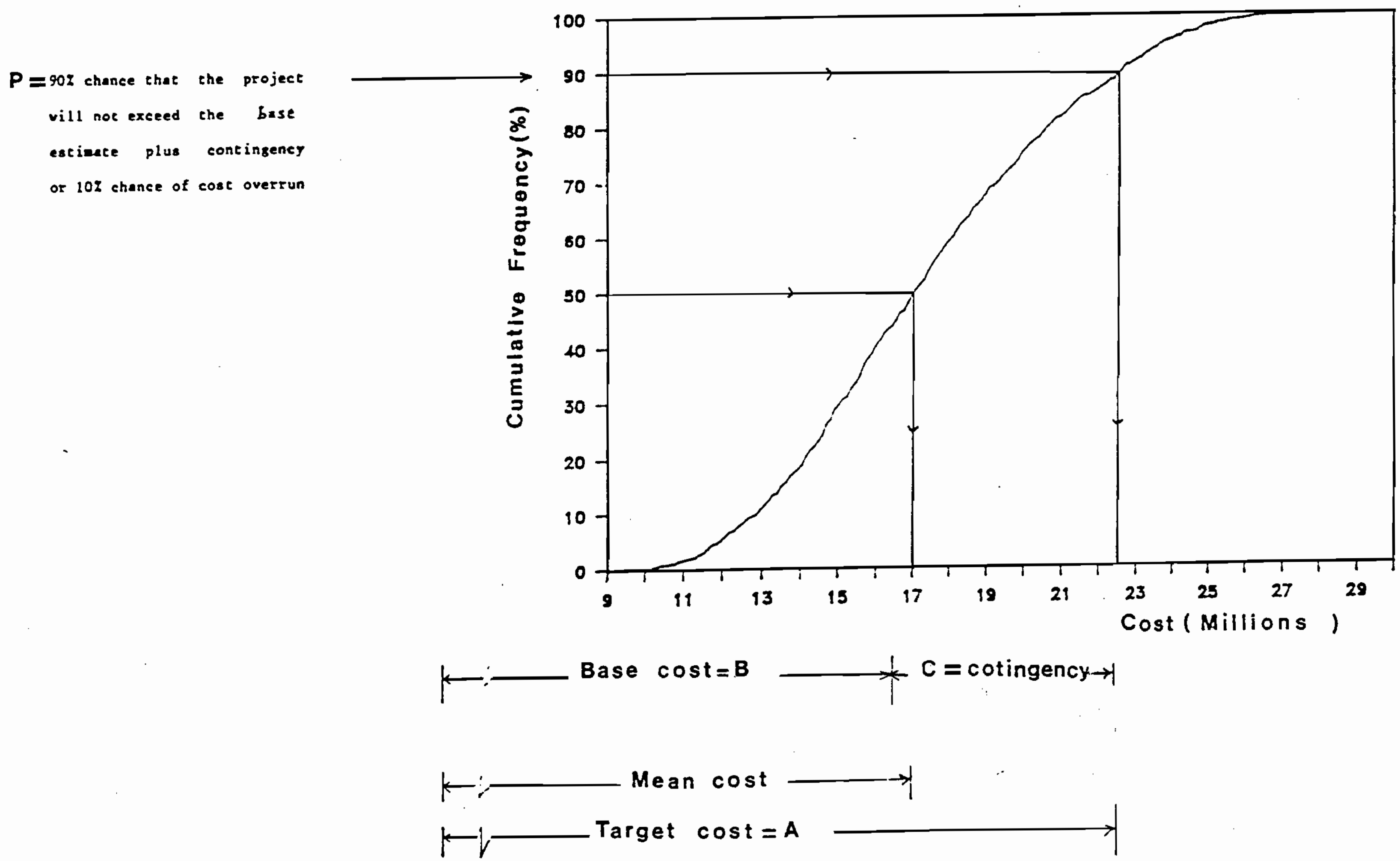


FIGURE 5.5 Estimating Cost Contingency Using the Probability Approach

Calculating Cost Contingency

The procedure for determining the cost contingency can be demonstrated as follows:

- choose P; accepted probability of construction cost overrun
- allocate P on the cumulative probability distribution of the cost estimate, see Figure 5.5, and determine the corresponding cost: A
- assuming that the base cost estimate before analysis of risks equals B, then contingency = A - B.

The Margin of Profit

The margin includes both the contractor's profit and the cost of finance for his investment in the contract. The profit is the reward the contractor expects for exercising his skill. Calculation of financial charges has been demonstrated in example 4.2.

The profit allowance is usually assessed at what is considered to be possible in the prevailing market conditions. However, the following factors should be taken into consideration in deciding the profit allowance:

1. Competition
2. Contractor's desire for work
3. Identity of the client and the Engineer
4. Size of the project and its complexity
5. Location of the project.

The net profit is that part of the profit that the contractor will retain after paying income taxes.

5.8 Pricing Policy

The contractor can allocate the contract indirect cost and mark-up to the bid items by choosing a suitable pricing policy. A straightforward method is to distribute these elements to all items according to their relative direct costs. This is known as "balanced bidding" and is demonstrated in the following example.

Example 5.6

Given that the tender price of a contract is LE 3.5 m and its direct cost is LE 2.8 m. Calculate the price of activity x, which is included in the contract and has a direct cost of LE 0.4 m, assuming a balanced bid case.

Solution

Indirect cost plus mark-up = 3.5 - 2.8 = LE 0.7 m

Price of activity x = $0.4 + 0.7 \frac{0.4}{2.8}$ = LE 0.5 m.

However, if the contractor raises the prices on certain bid items and decreases the prices on others proportionately so that the tender price remain the same, then the bid is called "unbalanced bid". This process is known also as weighting of rates.

Weighting of Rates in Admeasurement Contracts

The admeasurement contract is awarded on the basis of total price and paid on the basis of rates and actual measured quantities during construction. Therefore rates for items early in the contract may carry a greater percentage of the contract indirect cost and mark-up. This is known as weighting or loading of rates. The purpose behind this practice is to improve cash flow and reduce the capital locked up in the contract. Consequently the contractor receives more money earlier which he can invest or use to reduce his borrowing.

Loading of rates may be advantageous to the contractor in some cases. Generally, it is risky for both parties; client and contractor, especially when a very small number of bid items are loaded since the actual quantity of work done may be significantly greater or less than the quantity estimated in the tender documents. This situation will be demonstrated in the following example.

Example 5.7

Consider the simplified case of five sequential activities which are of equal duration. The quantity of work in each activity, and the corresponding direct cost rate and total rate for balanced and unbalanced bidding are given in table 5.6.

1. Compare cash flow curves for the two cases of balanced and unbalanced bids.
2. Test the effect of rate loading on the contractor's profit if:
   a) Completed quantity of activity 20 is increased by 50%.
   b) Completed quantity of activity 30 is increased by 50%.

Solution

1. Cash flow curves are given in Figure 5.6. It is obvious that the contractor would receive more money in the early stages of the contract if he unbalanced his bid.

Table 5.6 Data for Example 5.7

Activity	Quantity	Direct Cost Rate	Balanced Bid		Unbalanced Bid	
			Rate	Price	Rate	Price
10	100	4	5	500	6	600
20	100	8	10	1000	14	1400
30	100	16	20	2000	18	1800
40	100	16	20	2000	18	1800
50	100	8	10	1000	9	900
Tender Price				6500		6500

Table 5.7a Effect of Change in Quantity of Activity 20

Activity	Quantity	Direct Cost Rate	Balanced Bid		Unbalanced Bid	
			Rate	Price	Rate	Price
10	100	4	5	500	6	600
20	150	8	10	1500	14	2100
30	100	16	20	2000	18	1800
40	100	16	20	2000	18	1800
50	100	8	10	1000	9	900
Contract Price				7000		7200

Table 5.7b Effect of Change in Quantity of Activity 30

Activity	Quantity	Direct Cost Rate	Balanced Bid		Unbalanced Bid	
			Rate	Price	Rate	Price
10	100	4	5	500	6	600
20	100	8	10	1000	14	1400
30	150	16	20	3000	18	2700
40	100	16	20	2000	18	1800
50	100	8	10	1000	9	900
Contract Price				7500		7400

2. Total direct cost = 100 (4 + 8 + 16 + 16 + 8) = 5200
   Indirect cost & mark-up = 6500 - 5200 = 1300 = 25% of direct cost

   a) If completed quantity of activity 20 is increased to 150.
      The calculation of new prices is given in Table 5.7a, then

   - total direct cost = 5200 + 50(8)= 5600

   - indirect cost & mark-up for the balanced bid = 7000 - 5600 = 1400 = 25% of direct cost

   - indirect cost & mark-up for the unbalanced bid = 7200 - 5600 = 1600 = 29% of direct cost

   This increase in indirect cost & mark-up means that the profit of the contractor has been increased. This is a risk to the client.

   b) If completed quantity of activity 30 is increased to 150.
      The calculation of new prices is given in Table 5.7b, then

   - total direct cost = 5200 +50(16)= 6000

   - indirect cost & mark-up for the balanced bid = 7500 - 6000 = 1500 = 25% of direct cost

   - indirect cost & mark-up for the unbalanced bid = 7400 - 6000 = 1400 = 23% of direct cost

   This reduction in indirect cost & mark-up means that the contractor's profit has been eroded.

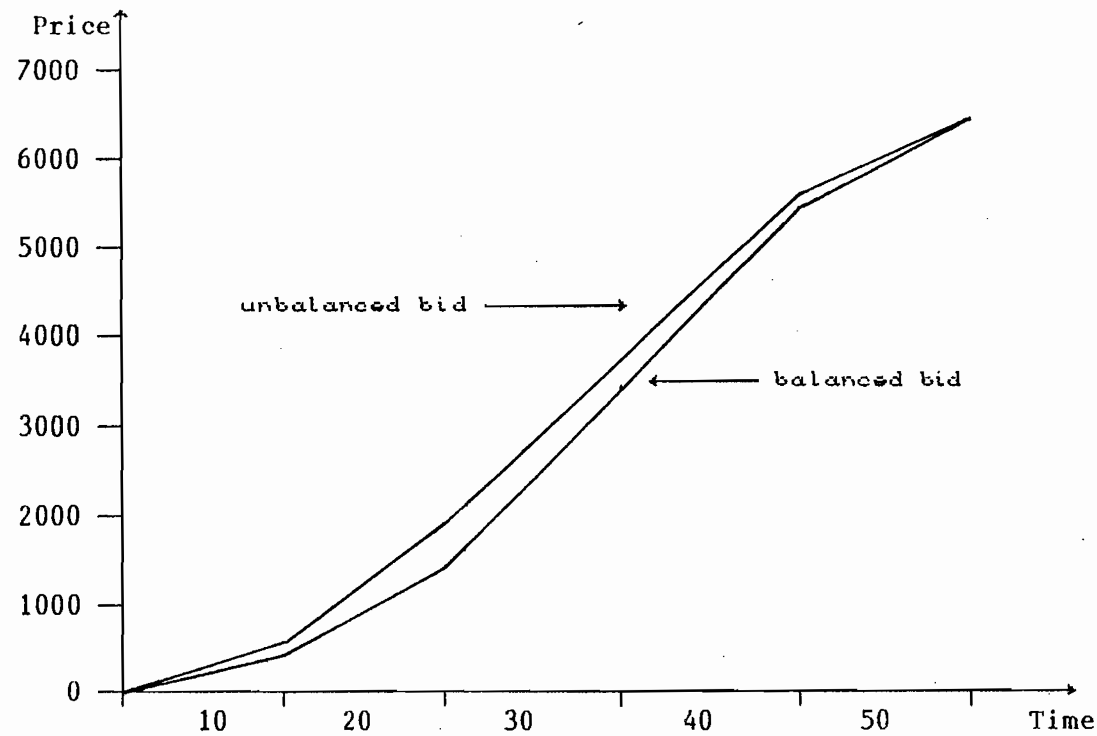


Figure 5.6 Effect of Rate Loading on Cash Flow

Method-Related Charges

It has been demonstrated that the prices entered in the conventional bill of quantities may not represent the real cost of the work defined in the individual items. This is because not all the costs are directly related to the quantity of work completed. Therefore adjustment of the price due to a change in a quantity of a particular item may not represent the real variation in cost. This usually produces unnecessary amount of uncertainty, contention and delay in the financial control of many contracts.

The following example demonstrates the above situation: Site overheads is mainly a time-related charge. Assume that it will be incurred monthly. In the conventional bill of quantities, the cost of site overheads must be recovered by spreading it over the quantity proportional rates and there is an obvious difference in the pattern of expense and income relating to site overheads. If variations occur and the site facilities are required for a longer period, there is no systematic way of adjusting the contract price. If the time-related cost of site overheads could be entered in the bills of quantities as a time-related charge, then the cash flow pattern would be realistic and this item could be adjusted in the event of relevant variation.

The concept of Method-Related Charges was introduced in the U.K. to permit tenderers to enter their own items in the bill of quantities (B.O.Q) for any operation whose cost is not directly linked to the quantities of permanent work. It allows the tenderer to define his own fixed and time-related charges that would cover all charges which are independent of the quantity of completed work. To distinguish these charges, they are called method-related charges. Table 5.8 gives an example of method-related pricing.

The items to be separated as method-related charges should be chosen by consideration of how the price entered in the bills of quantities will be affected if a change is introduced which affects either the billed quantity of work or the duration of the item.

The main advantages of using this method for pricing B.O.Q. are:

- it allows a systematic evaluation of variation and change
- it provides a reasonable payment for work varied in quantity
- it realistically reflects the cost of construction which reduces the effect of inflation and the investment required from the contractor
- loading of the bill rates is unnecessary as the desired improvement in cash flow is achieved.

Table 5.8 Example of Method-Related Pricing

Activity / Resource (1)	Fixed Charge (2)	Time-related Charge (3)	Unit (4)	Tender Price (5)=(2)+(3)
Establish site			sum	
Site overheads			sum	
Steelfixers			sum	
Bulldozers			sum	
Excavators			sum	
Head office overheads			sum	
------			sum	
------			sum	

Example 5.8

Suggest the items to be separated as method-related charges for the contract given in example 5.3.

Solution

The items to be separated as method-related charges are:

- establish site
- carpenters
- steelfixers
- bricklayers
- crane
- batching plant
- trucks
- bulldozers
- site overheads
- head office overheads
- clean site on completion.