CHAPTER 10

PROJECT CONTROL

The limited objective of project control deserves emphasis. Project control procedures are primarily intended to identify deviations from the project plan rather than to suggest possible areas for cost savings. This characteristic reflects the advanced stage at which project control becomes important. The time at which major cost savings can be achieved is during planning and design for the project. During the actual construction, changes are likely to delay the project and lead to inordinate cost increases. As a result, the focus of project control is on fulfilling the original design plans or indicating deviations from these plans, rather than on searching for significant improvements and cost savings. It is only when a rescue operation is required that major changes will normally occurring in the construction plan.

10.1 Problems that may Arise During Construction

In construction, no project, almost, is executed as planned. Control needs to be carried-out due to the dynamic nature of the construction process. Controlling after project finish is trivial and updates are usually done periodically. Controlling can be done for project schedule and/or project cost. As the construction stage of project starts, the project mostly will face delays and/or cost overruns. The following is a list of the factors that may cause such problems:

- Change in activity durations and quantities.
- Sudden changes of the availability of resources.
- Change orders.
- Accidents.
- Procurement delays.

10.2 Schedule Updating

Construction typically involves a deadline for work completion, so contractual agreements will force attention to schedules. More generally, delays in construction represent additional costs due to late facility occupancy or other factors. Just as costs incurred are compared to budgeted costs, actual activity durations may be compared to expected durations. In this process, forecasting the time to complete particular activities may be required.

It is important to devise efficient and cost effective methods for gathering information on actual project accomplishments. Generally, observations of work completed are made by inspectors and project managers and then work completed is estimated. Once estimates of work complete and time expended on particular activities are available, deviations from the original duration estimate can be estimated.

For example, Figure 10.1 shows the originally scheduled project progress versus the actual progress on a project. This figure is constructed by summing up the percentage of each activity which is complete at different points in time; this summation can be weighted by the magnitude of effort associated with each activity. In Figure 10.1, the project was ahead of the original schedule for a period including point A, but is now late at point B by an amount equal to the horizontal distance between the planned progress and the actual progress observed to date.

In evaluating schedule progress, it is important to bear in mind that some activities possess float, whereas delays in activities on the critical path will cause project delays. In particular, the delay in planned progress at time t may be soaked up in activities' float (thereby causing no overall delay in the project completion) or may cause a project delay. As a result of this ambiguity, it is preferable to update the project schedule to devise an accurate portrayal of the schedule adherence. After applying a scheduling algorithm, a new project schedule can be obtained.

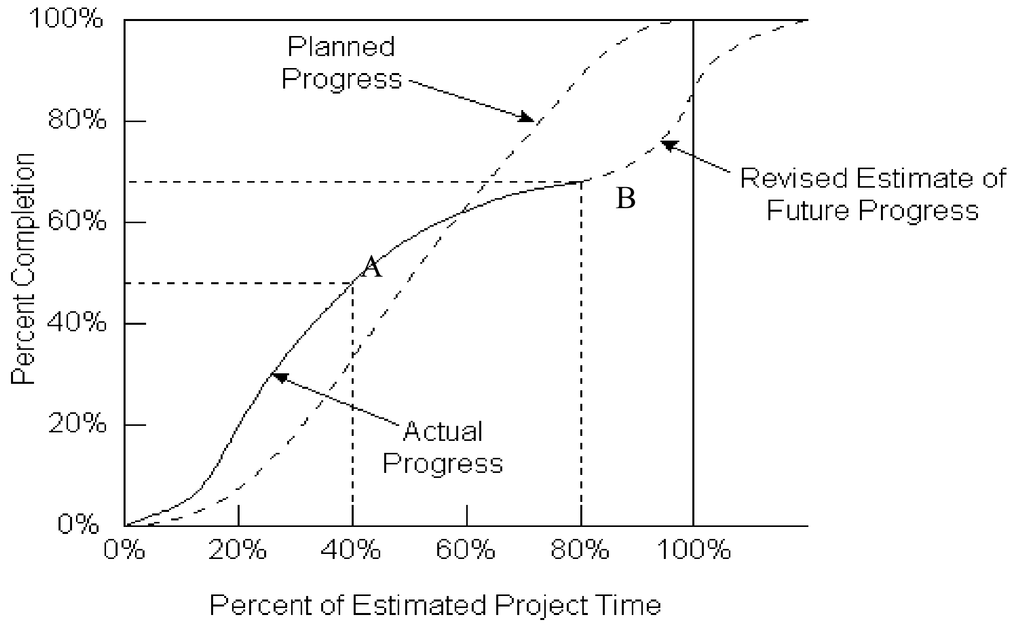

Figure 10.1: Planned versus actual progress over time on a project

It is common that actual durations of activities differ from those estimated. Furthermore, there may be additions or deletions to the scope of the contract that will affect the time at which activities can be started or completed. Schedule updating is a procedure for introducing the latest progress information into the schedule.

Data have to be collected on the actual progress of completed activities and those under execution. A completely new estimate of the amount of work remaining to be done should be made for each activity. The probable output of various resources should be assessed. If the job is found to be behind schedule, corrective actions must be made to retrieve position. A procedure for manual schedule updating can be summarized in the following steps:

-Change the duration of all completed activities to zero.

-Identify all activities on which work is currently processing as Live Activities

-Put early start time of live activities equals the updating date and their durations equal remaining duration.

-Change duration of future activities as given in the update report.

-Carry-out network analysis in the normal way and prepare a new activity schedule.

To illustrate the above hand procedure for schedule updating, consider the following example with the planning data given in Table 10.1. The corresponding precedence network along with time analysis is shown in Figure 10.2. It is evident that initial project duration is 20 weeks and the activities A, B, F, and K comprises the critical path.

Table 10.1: Planning data of the example problem

Activity	Predecessors	Duration (wks)	Overlap (wks)
A	---	2	
B	A	2	
C	A	5	
D	A	3	
E	B	2	
F	B	6	-3
G	C	6	
H	D	6	
I	D	4	-2
J	E, F	2	
K	F, G	8	3 with G
L	H	3	
M	H, I	2	

At the end of the 7th week, new filed data are collected and the project status activities is as follows:

-Activities A, B, D, and E have been completed.

-Remaining Duration of activity C is one week.

-Remaining Duration of activity H is 4 weeks.

-Activity G will not start until beginning of week 10.

-Overlap between activities K and G is one week only

-Volume of work of activity L has been increased by 33%.

-Activity J has been omitted.

The updated precedence network and the corresponding updated schedule are shown in Figure 10.3. It is shown that a new critical path is developed. The new project completion time is 21 weeks which indicates that a delay of one week is encountered. Corrective actions should be taken to improve project performance during the remaining portion.

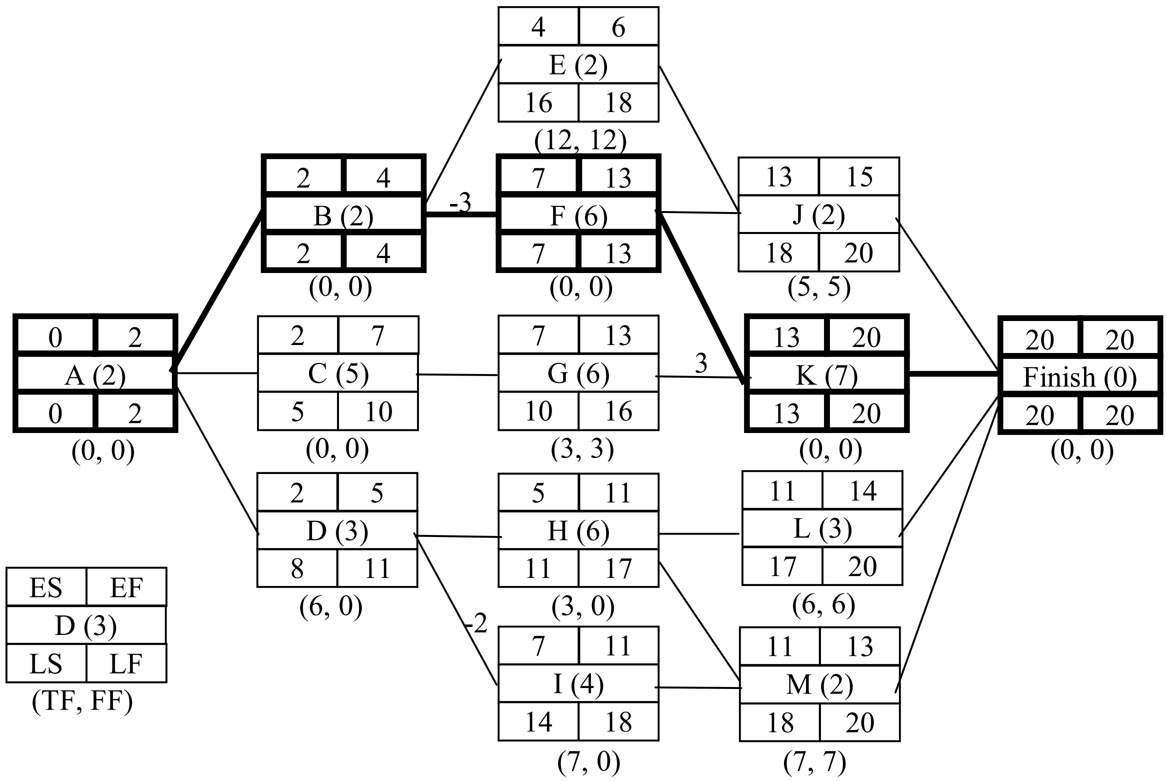

Figure 10.2: Scheduling data of the example problem

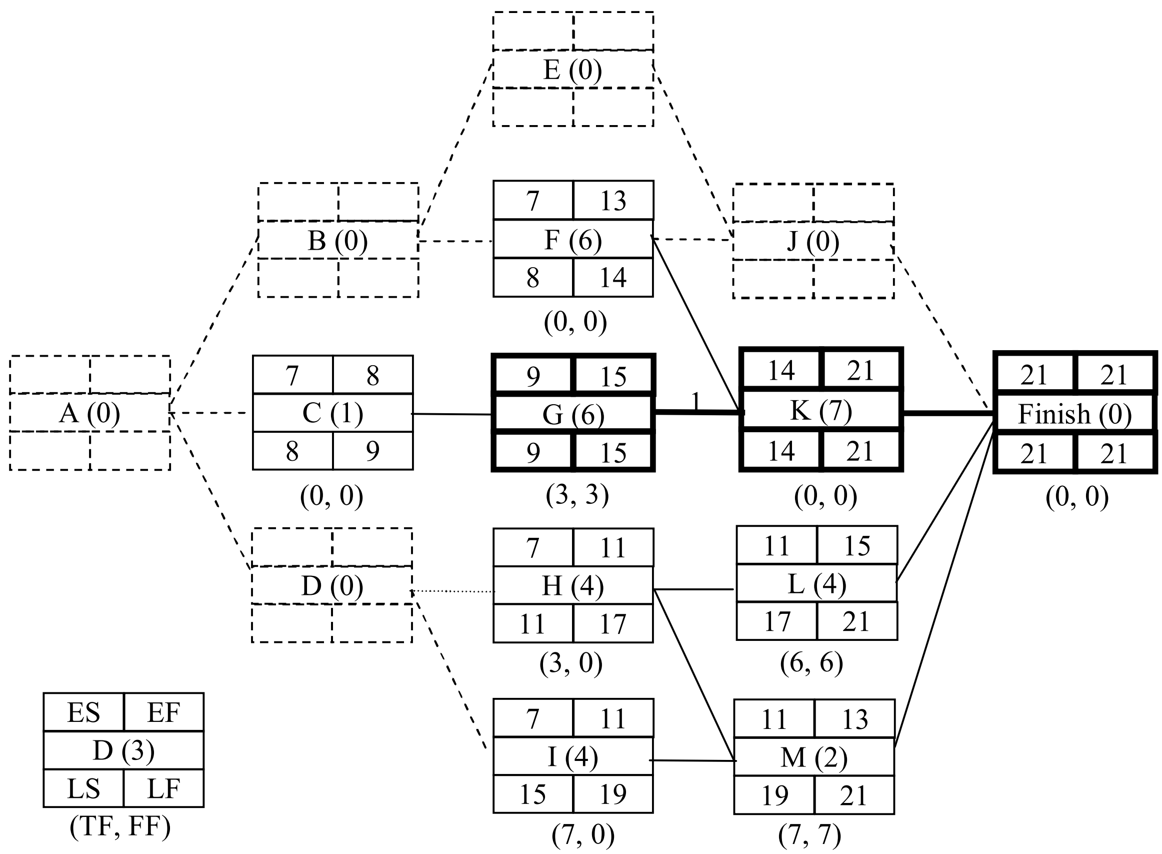

Figure 10.3: Updated network of the example problem

10.3 Delays Analysis

Work changes mean changes in the volume and duration of work to be performed from that envisaged at the start of the contract. Variation in the form of addition and deduction result in more or less cost and time to execute the varied item. On the other hand, omissions mean less cost but not necessarily less time. It might result in wasting resources. For instance, if the quantity of work in a critical activity is increased by x% then the duration of the activity will be extended by x%. The direct cost of the activity should be increased by the same ratio while the indirect cost of the contract might be increased for the extended period.

It is typical for construction contracts to be delayed. A delay that occurred on a non-critical activity does not participate to the delaying completion date of the contract. Therefore, delays on non-critical paths are not considered.

10.3.1 Types of Delays

Delays can be divided into the following categories:

- Those over which the client has control; compensable delays;
- Those over which the contractor has control; non-excusable delays;
- Those over which the neither party has any control; excusable delays; and
- Concurrent delays.

A brief description of each category is given below.

Compensable delays

A delay is deemed compensable to the contractor when it's within the control of, is the fault of, or is due to the negligence of the client. Examples include:

- late possession of site;
- faulty design;
- incomplete drawings and specification;
- changes in scope;
- suspension of work;

- differing site conditions;
- late delivery of client-supplied materials; and
- client's failure to disclose information vital to the contractor.

For this type of delays, the conditions of contract should allow the contractor to be entitled to a time extension and to monetary recompense for extra costs associated with the delay.

Non-excusable delays

In this category, the contractor's own actions or inactions have caused the delay. The contractor is entitled neither time extensions nor monetary recompense from the client. He/she may pay liquidated damages according to the contract.

Excusable delays

These are occurrences over which neither the client nor the contractor has any control. Example includes:

- unforeseen future events which the contractor has not been aware;
- impracticable things which the contractor can only do at an excessive cost;
- events in which the contractor is blameless, such as material shortage beyond what was expected at the time of bidding.

The contractor should declare the excusable delays. The sole relief for these delays is a time extension.

Concurrent delays

Concurrent delays are two or more delays that occur at the same time, either of which, if it occurred alone, would have affected contract completion date. They can be classified as follows:

- excusable delays and non-excusable delays;
- excusable delays and compensable delays;

- excusable delays and compensable delays and non-excusable delays; and
- compensable delays and non-excusable delays.

Concurrent delays with an excusable delay will generally be considered as excusable delays. For these delays, the contractor is entitled to time extension if the delays are on the critical path. This protects him from any resulting liquidated damages. For concurrent compensable and non-excusable delays, the contractor is allowed a time extension for completion with each party suffering his/her own losses. The terms of the contract should declare the method of evaluation of such claims.

10.3.2 The As-Built Schedule

The as-planned schedule of a contract is its initial schedule. The as-built schedule will show the time status of the contract and the causes of all the time changes that happen. Both schedules will be drawn as time-scaled diagrams.

The as-built schedule provides a complete record of the work as-built. It shows all delays encountered and the actual starting and finishing dates of every activity. When compared with the initial schedule, it gives the date for the evaluation of each time delays encountered during construction. The following legend will be used to draw the as-built schedule; "o" to represent compensable delays; "c" to represent non-excusable delays and "n" to represent excusable delays. This schedule will now become the basis for analysis of the effect of different types of delays of the contractor's progress.

<u>Analysis of The As-Built Schedule</u>

If the as-built schedule contains more than one equally delayed critical path, each of them will be examined in turn to determine its net working duration. This is the actual time in which all the activities along a path could have been completed if there had been no work changes or delays affecting the path. This can be found as follows:

A path net working duration = its total duration – all delay times lying on it

The net working duration may be less than the estimated contract duration given by the as-planned schedule. This means that the contractor has performed the contract within the estimated time. On the other hand, it may exceed the contract duration. Then the contractor's original estimates were incorrect. Having examined all apparent critical paths, the scheduler can determine the primary path(s) as that (those) with the longest net working duration. The work could not have been completed in less time than this, even if the delays has not occurred, other parallel apparent critical paths may be classified as secondary as they do not control the contract duration. They have float with respect to the primary path.

If the as-built schedule contains one primary critical path, then the overall effects of all eventualities on the contract will be the difference between the path actual duration and its net working duration. The responsibility of each party for the contract delayed completion is then determined by inspection. If the schedule contains more than one primary critical path with the same net working duration, then it may have concurrent delays. A brief discussion of these delays is provided next.

10.3.3 Analysis of Concurrent Delays

The difference between the as-planned schedule duration and the as-built primary critical path duration can be portioned out as follows:

1. The number of days in which the contractor's and the client's delays are concurrent are those days where the two type of delays occurred; one delay affected a primary critical path and the other affected the other primary critical path on the same day(s).

2. The number of days of concurrent delays with an excusable delay is those days where an excusable delay occurred on any primary critical path and a contractor's delay, a client's delay, or both delays occurred on other primary critical path(s) on the same day(s).
3. Excluding delays number 1 and 2 above, the number of days a contractor should be assessed for liquidate damages is the smallest number of days of inexcusable delays on all primary critical paths.
4. Excluding delays number 1 and 2 above, the number of days a contractor should be reimbursed for additional overhead expense plus a time extension is the smallest number of days of compensable delays on all primary critical paths.
5. Finally, the number of days a contractor should be given a time extension is the difference between the total delay duration and the summation of all the above four delays duration.

Example 10.1

Consider the contract given in the Table 10.2. The delay report given in Table 10.3 was recorded for this contract. Determine how each party is responsible for the contract delayed completion.

Table 10.2: Data for Example 10.1

Activity	Predecessor	Duration (days)
A	-	7
B	-	5
C	A	7
D	B	9
E	B	6
F	C	4
G	D	3
H	E	9
I	F	5
J	H	3

Table 10.3: Recorded delays for Example 10.1

Delay no.	Category	Activity affected	Effective dates	Delay time
1	Neither	A	1	1
2	Contractor	A	2-3	2
3	Contractor	A	7	1
4	Contractor	B	3	1
5	Owner	B	4	1
6	Neither	B	5-7	3
7	Contractor	C	12-14	3
8	Owner	C	15-16	2
9	Owner	E	13-15	3
10	Contractor	E	16	1
11	Neither	E	19-23	5
12	Owner	F	24-25	2
13	Owner	G	22	1
14	Contractor	G	23	1
15	Neither	H	30	1
16	Owner	H	33	1
17	Owner	I	32	1
18	Neither	I	33-34	2
19	Contractor	I	35-36	2
20	Contractor	I	39	1
21	Owner	I	40	1
22	Neither	J	37-38	2

Solution

The as-planned and as-built schedules are drawn in Fig. 10.4. Apparent critical paths are B E H J and A C F I. Each of them has a net working duration = 41 – 18 = 23 days. So, the two apparent critical paths are primary critical paths. The total delay of 18 days can then be divided as follows:

1. Concurrent compensable 7 non-executable = 3 days
2. Concurrent with excusable = 2 days
3. Inexcusable = 1 day

4. Compensable = 2 days
5. Excusable = 18 - (3 + 2 +1 +1) = 10 days

Accordingly, the contractor should be given a time extension of 17 days. He will pay liquidated damages for 4 days and will be reimbursed for overheads of 5 days.

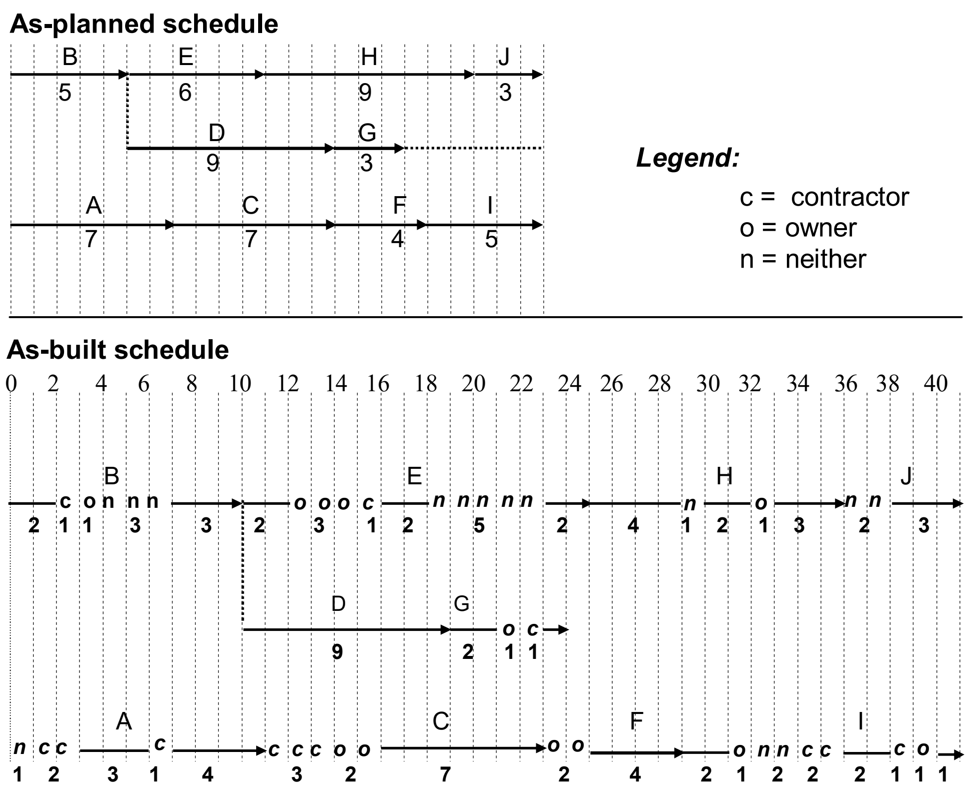

Figure 10.4: Delays analysis for Example 10.1

10.4 Earned Value Management

For cost control on a project, the construction plan and the associated cash flow estimates can provide the baseline reference for subsequent project monitoring and control. The final or detailed cost estimate provides a baseline for the assessment of financial performance during the project. To the extent that costs are within the detailed cost estimate, then the project is thought to be under *financial control*. Overruns in particular cost categories signal the possibility of problems and give an indication of exactly what problems are being encountered.

The key to a profitable project is to keep construction costs within the budget and to know when and where job costs are deviating. The budget determines the amount of cash that will be required over the various periods of the project. Various techniques are usually used for cost control such as S-curve method and earned value technique. Because it is the most widely used method, only earned value technique will be described next. Earned value technique involves a combination of three measures that are needed for the analysis. These measures include:

Budgeted Cost of Work Scheduled (BCWS)

BCWS measures what is planned in terms of budget cost of the work that should to place (i.e., according to the baseline schedule of the project). BCWS curve can be plotted by accumulating the budget cost of the initial schedule.

Budgeted Cost of Work Performed (BCWP) (Earned value – EV)

BCWP measures what is done in terms of the budget cost of work that has actually had been accomplished to date. BCWP curve can be plotted point by point after each reporting period. Here we accumulate the budget cost on the schedule that shows the actual percent complete.

Actual Cost of Work Performed (ACWP)

ACWP measures what is paid in terms of the actual cost of work that has actually been accomplished to date. BCWS curve can also be plotted point by point after each reporting period. Here we accumulate the actual expenditures on the schedule that shows the actual percent complete.

The significance of these three measures is that they directly indicate schedule and cost performances of the project at different reporting periods. This illustrated as shown in Figure 10.5. Using these three measures, different project performance indicators can be calculated. Among these indicators are:

Schedule Variance (SV)

It is the difference between the earned value (BCWP) and the planned budget cost (BCWS).

$SV = BCWP - BCWS$;

$SV > 0$ indicates ahead of schedule while $SV < 0$ indicates behind schedule

Cost Variance (CV)

It is the difference between the actual cost (ACWP) and the earned value or the budget cost (BCWP).

$CV = BCWP - ACWP$;

$CV > 0$ indicates cost saving while $CV < 0$ indicates cost overruns

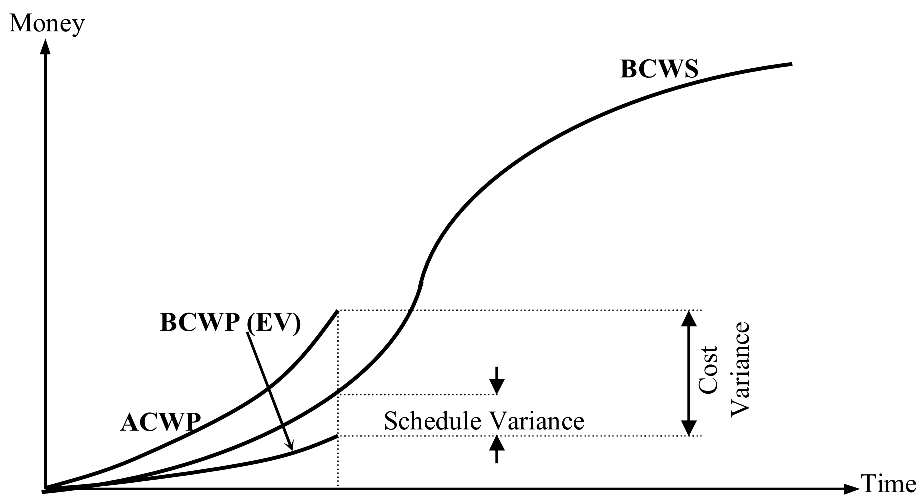

Figure 10.5: Earned value measures and indictors

Schedule Performance Index (SPI)

$SPI = BCWP / BCWS$;

with $SPI > 1$ indicates ahead of schedule, and $SPI < 1$ indicates behind schedule.

Cost Performance Index (CPI)

CPI = BCWP / ACWP;

with CV > 1 indicates cost saving, and *CV* < 1 indicates cost overruns.

Cost Schedule Index (CPI) = CPI × SPI

Estimate at Completion (EAC): What do we currently expect the total project to accomplish? *EAC = BAC / CPI*

Estimate to Completion (ETC): From this point on, how much more do we expect to be at end of the project? *ETC = EAC – BCWP*

Variance at Completion (VAC): How much over or under budget do we expect to be at end of the project? *VAC = BAC - EAC*

These concepts are best illustrated by the example problem with the planning data given in Table 10.1. The price of each activity is given Table 10.4.The schedule of the example problem is given in Figure 10.2. At the end of week number 5, the project status is recorded as given in Table 10.4. Actual costs are also recorded as given in Table 10.5.

Table 10.4: Cost data of the example problem

Activity	A	B	C	D	E	F	G	H	I	J	K	L	M
Price (1000)	36	24	145	84	126	168	126	78	80	216	70	228	120
Actual Start	0	2	2	2	4								
Projected Completion	2	5	7	6	7								

Table 10.5: Actual cost at the end of week 5

Week	1	2	3	4	5	Total
Cost	18	18	72	72	125	305

Figure 10.6 shows the project schedule in bar chart format. The planned expenditure of each activity is assumed to be uniformly distributed over activity duration. The BCWP are calculated as shown in Figure 10.7. The weekly budgets are plotted on a cumulative basis as the BCWS are as shown in Figure 10.8. In Figure 9.8, BCWS as well as BCWP

and ACWP to the end of week 5 are plotted on the same graph. It now possible to calculate schedule and cost control indicators as:

SV = 262 – 294 = -ve which indicates that the project is behind schedule.

CV = 262 – 305 = -ve which indicates that the cost is overrun

Example 10.2

A cost control report of a certain contract gives the following figures as percentages of the contract a-completion budgeted cost:

BCWP = 25% BCWS = 47% ACWP = 72%

Calculate, cost and schedule variances and comment on the status of the contract.

Solution

Cost variance (CV) = BCWP – ACWP = 25 – 72 = -47%

Schedule variance (SV) = BCWP – BCWS = 25 – 47 = -22%

The contract is behind schedule with over cost.

Act.	Budget/w	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	18	18	18																		
B	12			12	12																
C	29			29	29	29	29	29													
D	28			28	28	28															
E	63					63	63														
F	28								28	28	28	28	28	28							
G	21								21	21	21	21	21	21							
H	13						13	13	13	13	13	13									
I	20								20	20	20	20									
J	108														108	108					
K	10														10	10	10	10	10	10	10
L	76												76	76	76						
M	60												60	60							
	Weekly	18	18	69	69	120	105	42	82	82	82	82	185	185	194	118	10	10	10	10	10
	Cumulative	18	36	105	174	294	399	441	523	605	687	769	954	1139	1333	1451	1461	1471	1481	1491	1501

Figure 10.6: Bar chart showing budgeted expenditures (BCWS)

Act.	Budget/w	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	18	18	18																		
B	18			8	8	8															
C	29			29	29	29	29	29													
D	21			21	21	21	21														
E	42					42	42	42													
Weekly		18	18	58	58	100															
Cumulative		18	36	94	152	262															

Figure 10.7: Bar chart updated at end of week 5 (BCWP)

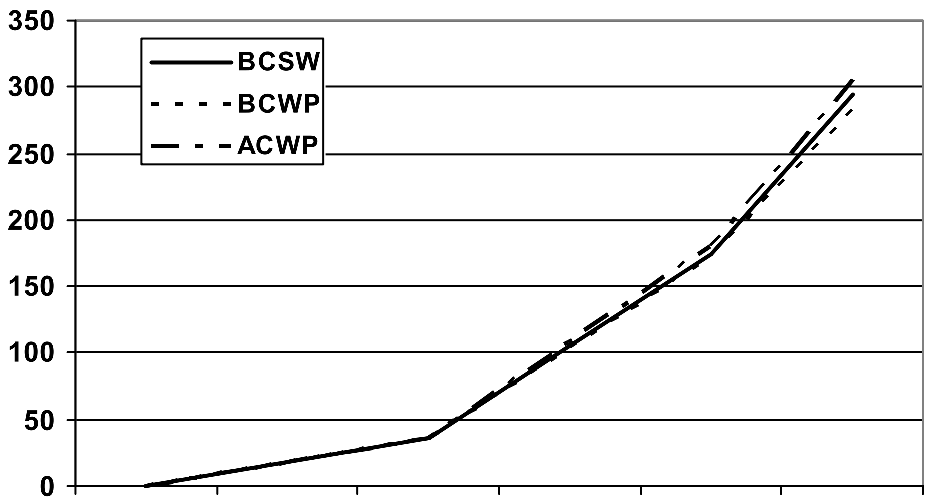

Figure 10.8: Cost curves

Exercises

1. The activities involved in the construction of one kilometer of a pipeline are given together with their estimated durations in the table below. Each of the activities will be done using a separate gang. All of them are sequential except "Excavate trench" and "String pipe" are done concurrently. The project consists of 3 similar kilometers.

Activity name	Duration (days)
(LC) Locate and clear	1
(ET) Excavate trench	5
(SP) String pipe	2
(LP) Lay pipe	6
(PT) Pressure test	1
(BF) Backfill	2

a. Prepare complete plan of the works and determine the activity schedule. Mark the critical path.

b. Assume now that the project is being constructed according to ES timings determined in "a" above. At the end of day 10, the following information is obtained from the project site:

- Activities LC were completed on schedule.
- Duration of the first part of activity ET was prolonged by 1 day but that of the second part will be the same as the original duration.
- Activities SP were completed although ES of the third part had been delayed by 3 days.
- Remaining duration of the first part of activity LP is 3 days.
- The first part of activity PT will not start until beginning of day 16.

Update your network and mark the critical path.

c. If the activities direct cost is listed as below:

Activity	Direct Cost (LE)
LC	400
ET	3000
SP	600
LP	1800
PT	200
BF	1000

The contract site overhead amounts to LE77.777/day and distributed among activities according to their relative direct costs. If the actual cumulative cost at the end of day 10 is LE9270, calculate schedule and cost performance ratios and comment on the progress of the contract.

2. The indirect cost for this contract is LE 250/week. The contract conditions state that the contractor will pay LE 200/week for delays by his own fault. Each of the activities will be done using a separate gang.

Activity	A	B	C	D	E	F	G	H
Predecessors	-	-	A	B	C, D	B	F	E, G
Duration	7	9	8	12	4	9	7	7

Now, consider the project is under construction according to the original schedule and the following table gives the delay report for this contract. Determine how each party is responsible for the contract delayed completion.

Number	Category	Activities affected	Effective dates	Delay time (week)
1	Owner	A	2 – 5	4
2	Contractor	C	14 – 16	3
3	Owner	C	21 – 23	3
4	Owner	D	15 – 18	4
5	Contractor	E	27 – 28	2
6	Neither	F	18 – 19	2
7	Neither	G	26 – 27	2
8	owner	G	28 – 29	2

3. A project with LE200,000 planned value and 12 month duration. At the end of the fourth month, it is found the only 40% of the project is performed with LE75,000 actual cost. Using the Earned Value method, calculate the following: CV, SV, CPI, SPI, ETC, EAC and VAC.

REFERENCES

Awani, Alfred O. (1983). “Project Management Techniques.” Petrocelli Books Inc.

Clough, Richard H. & Sears, Gelen A. (1979). “Construction Project Management.” John Wiley & Sons Inc., NY.

Cormican, David. (1985). “Construction Management: Planning and Finance.” Construction Press, London.

Eldosouky, Adel I. (1996). “Principles of Construction Project Management.” Mansoura University Press, Mansoura, Egypt.

Gould, Frederick E. (1997). “Managing the Construction Process: Estimating, Scheduling, and Project Control.” Prentice-Hall Inc., New Gersy.

Harris, Frank & McCaffer, Ronald. (1983). “Modern Construction Management.” Granada Publishing, Great Britain.

Harris, Robert. (1978). “Precedence and Arrow Networking Techniques for Construction.” John Wiley & Sons Inc., NY.

Hegazy, T. (2002). “Computer-Based Construction Project Management.” Prentice Hall, Upper Saddle River, NJ, USA.

Pilcher, Roy. (1992). “Principles of Construction Management.” Mc-Graw Hill Book company, 3rd ed.

ElgareAllah, Mohamed Ibrahim & Nawara, Jamal Mohamed. (1984). “Edarat Almsharee’ Alhandaseah.” John Wiley & Sons Inc., NY. (This book is available in Arabic).

ابراهيم عبد الرشيد نصير "إدارة مشروعات التشييد" ، دار النشر للجامعات، 2006.