CENG 6101 Construction Economics

Project Cost Control

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Construction Project Management

1. Decision to Bid
2. Project Planning (develop WBS and CMS)
3. Project Estimating and Scheduling
4. Resource Allocation and Leveling
5. Submit Bid (proceed if awarded contract)
6. Estimate then forms basis of budget during construction (both use similar WBS and CBS)
7. Schedule forms basis of execution plan (use similar WBS)
8. Cost control: compare actual to budgeted costs
9. Schedule control: compare actual to planned progress
10. Detect deviations and implement timely corrective actions

Job-based Cost Control

Two types of systems for job cost data collection:

- Financial control system: payroll, accounting, etc.
- Cost control system: man-hours spent on work packages, cost and productivity data, data on labour, material, equipment

Where are Cost Data Initiated?

- Labour: time sheets, foreman's daily work report, company's payroll system
- Labour data collected: craft, level (apprentice, journeyman), hours (regular, overtime), work package(s) worked on
- Equipment: equipment time sheets (similar to labour)
- Material: purchase orders, material delivery slips, material cost records (materials management system)

ATHABASCA OIL SANDS DOWNSTREAM PROJECT

Date : _____

Foreman's Time Card

Foreman: _____

Signature: _____

Approver: _____

Signature: _____

Description of Work	Description of Work	Description of Work	Description of Work	Description of Work
Contract	**Contract**	**Contract**	**Contract**	**Contract**
Area Unit	**Area Unit**	**Area Unit**	**Area Unit**	**Area Unit**
Cost Code	**Cost Code**	**Cost Code**	**Cost Code**	**Cost Code**
Change Order	**Change Order**	**Change Order**	**Change Order**	**Change Order**

Badge	Employee Name	Time IN	Total Hours	ST	OT	DT	ST	OT	DT	ST	OT	DT	ST	OT	DT	ST	OT	DT

Project Control

Monitoring Productivity

- Another component of control is tracking productivity on basis of manhours/unit (i.e., input/output)
- Three methods of measuring output:
  - Estimated % complete
  - Physical measurement
  - Earned value

Estimated % Complete

- Based on observation
- Simple and inexpensive
- Subjective and not sensitive to scope changes
- Estimated quantity complete

  = total quantity * estimated % complete

Project Control

Physical Measurement

- Output based on actually counting or measuring number of work units completed (e.g., diameter inches of pipe welds, m^3 of earthwork)
- Objective, detailed, accounts for scope changes
- Time consuming, expensive

Earned Value

- Actual manhours taken from time sheets
- Actual quantities based on “rules of credit” agreed upon in advance of work being undertaking (for budgeting and payment purposes)
- e.g., 80-20 rule: 20% credit given for commencing activity, 80% credit given for completing activity

Project Control

- Earned Value
- More common is milestone approach: e.g., formwork activity:
  - Fabricate = 60% credit, Erect = 20% credit, Remove forms = 15% credit, Clean forms = 5% credit
- Rules of credit may reflect effort or work involved

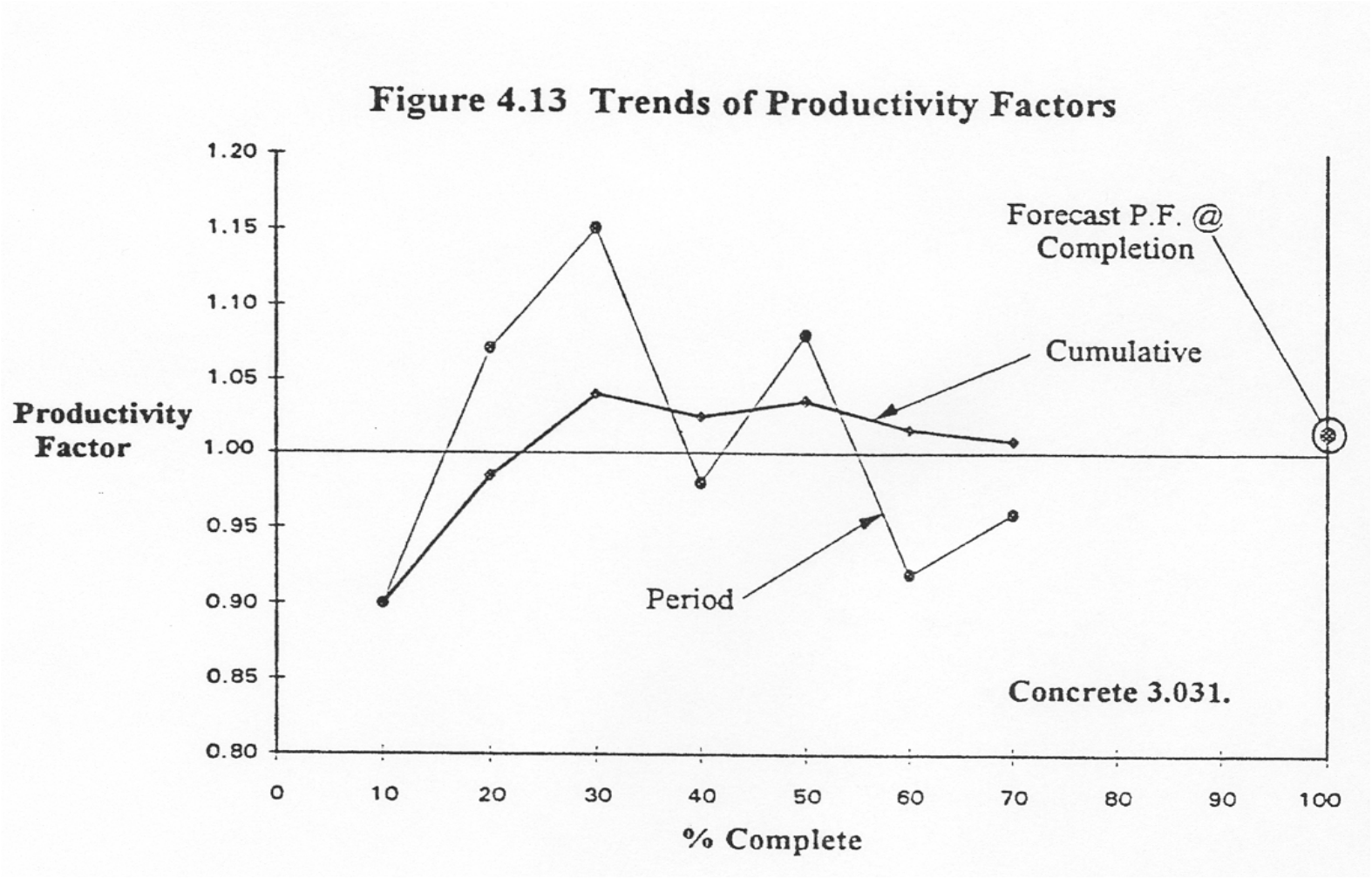
Earned value for manhours

= earned value for quantities * estimated (budgeted) productivity

- EV (mhrs) = EV (m^3) * estimated mhr/m^3
- Performance (Productivity) Factor (PF)

= Earned value mhrs / Actual mhrs

(PF > 1.0 is good in this case)



- Period PF used for immediate control purposes to remedy trends.
- Cumulative PF used to forecast costs at completion.

BETTER SUPERVISION PUMPSTATION PROJECT
PROGRESS AND PERFORMANCE REPORT
AS OF 13-JUNE-94

						5/1380 / 100		7 X 6	7 X 5		10 / 9
	1	2	3	4	5	6	7	8	9	10	11
ID	Description	Dur	Start	Finish	Mhrs	% Value	% Compl	Earned Value	Earned Mnhrs	Spent Mnhrs	Perf. Factor
1	CONTRACT AWARD	0	30-May	30-May	0	0.00	100%	0	0	0	1.00
2	MOBILIZE	4	30-May	2-Jun	32	2.32	80%	1.86	25.6	22	0.86
3	SPOOL DWGS	3	30-May	1-Jun	24	1.74	100%	1.74	24	26	1.08
4	DEL. PIPE & FITTINGS	6	30-May	4-Jun	4	0.29	100%	0.29	4	4	1.00
5	DEL. PUMP & VALVES	10	30-May	8-Jun	2	0.14	100%	0.14	2	2	1.00
6	DEL. PMPHSE BLD'G PKG	7	30-May	5-Jun	2	0.14	0%	0.00	0	0	1.00
7	SURVEY	1	3-Jun	3-Jun	16	1.16	100%	1.16	16	12	0.75
8	FAB. PIPE SPOOLS	6	2-Jun	7-Jun	64	4.64	60%	2.78	38.4	36	0.94
9	DRILL AND CAST PILES	2	4-Jun	5-Jun	64	4.64	100%	4.64	64	72	1.13
10	EXCAVATE FOR FDN'S	3	6-Jun	8-Jun	48	3.48	100%	3.48	48	41	0.85
11	FORM FDN'S & REBAR	5	9-Jun	13-Jun	120	8.70	100%	8.70	120	130	1.08
12	POUR CONC. FDN'S	1	14-Jun	14-Jun	40	2.90	100%	2.90	40	45	1.13
13	STRIP FORMS	2	15-Jun	16-Jun	32	2.32	100%	2.32	32	30	0.94
14	BACKFILL	5	17-Jun	21-Jun	120	8.70	60%	5.22	72	63	0.88
15	INSTALL PUMP	3	17-Jun	19-Jun	48	3.48	0%	0	0		
16	CONC. SLAB	1	22-Jun	22-Jun	48	3.48	0%	0	0		
17	INSTALL PIPING	10	23-Jun	2-Jul	240	17.39	0%	0	0		
18	ERECT PUMPHOUSE	12	30-Jun	11-Jul	300	21.74	0%	0	0		
19	INSTALL INSTRUMENTS	2	3-Jul	4-Jul	32	2.32	0%	0	0		
20	INSTALL DOORS	3	12-Jul	14-Jul	32	2.32	0%	0	0		
21	PULL & TERM. CABLE	4	5-Jul	8-Jul	64	4.64	0%	0	0		
22	DEMOBILIZE SITE	3	15-Jul	17-Jul	48	3.48	0%	0	0		
23	PROJECT COMPLETE	0	17-Jul	17-Jul	0	0.00	0%	0	0		
	Total				**1380**	**100.00**		**35.22**	**486.00**	**483.00**	**0.99**

(PF < 1.0 is good in this case)

Project Control

- Project and Budget Performance
- BCWS (planned value - PV) = budgeted cost of work scheduled
- BCWP (earned value - EV) = budgeted cost of work performed
- ACWP (actual cost - AC) = actual cost of work performed = commitments + payments due + payments made

Project Control

- Cost Performance
- CV = cost variance
  - CV = BCWP–ACWP = EV-AC
- CPI = cost performance index (periodic)
  - CPI = BCWP/ACWP = EV/AC
  - CPI < 1.0 indicates cost overrun
  - CPI > 1.0 indicates cost underrun
- Cumulative cost performance index (CPI^C) (sum of periodic values for each index):
  - $CPI^C = EV^C/AC^C$
  - Used to forecast project costs at completion

Project Control

- Schedule Performance
- SV = schedule variance
  - SV = BCWP–BCWS = EV-PV
- SPI = schedule performance index (periodic)
  - SPI = BCWP/BCWS = EV/PV
  - SPI < 1.0 indicates behind schedule
  - SPI > 1.0 indicates ahead of schedule
- SPI used to predict project completion date, and in conjunction with CPI to forecast costs at completion

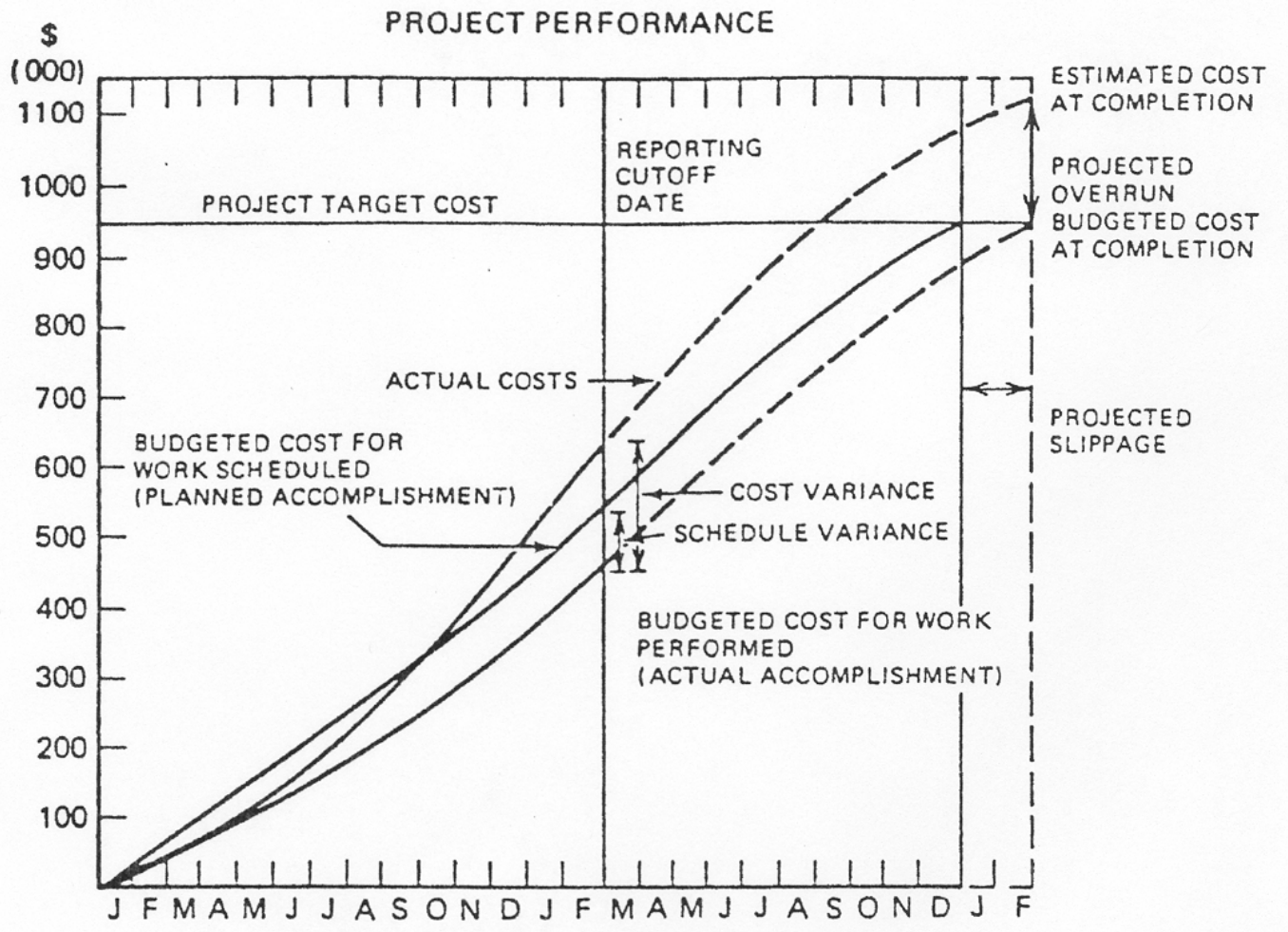


FIGURE 14.18 Performance Curves

Earned Value Technique

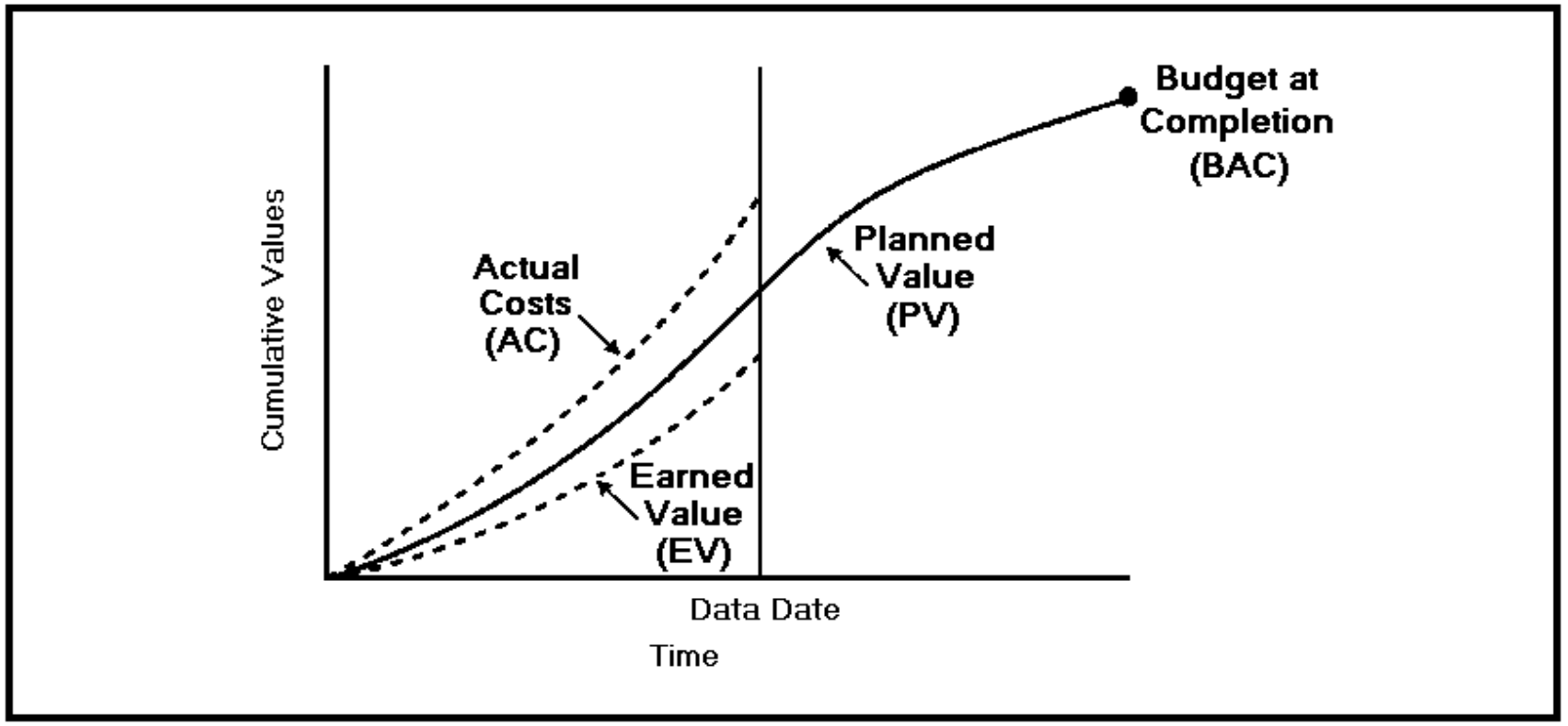


Figure 7-7. Illustrative Graphic Performance Report

Forecasting

- Budget at completion (BAC):
  - BAC = total cumulative PV at completion
- Estimate to complete (ETC): estimate for completing remaining work
- ETC can be calculated based on 3 different scenarios

Scenario 1:

- ETC based on new estimate:
  - Revised estimate for work remaining
  - Original estimate assumptions flawed or no longer relevant

Scenario 2:

- ETC based on atypical variances:
  - ETC = BAC – EV^C
  - Current variances atypical and will not occur in future

Forecasting

Scenario 3:

- ETC based on typical variances:
  - ETC = (BAC – EV^C)/CPI^C
  - Current variances typical of future variances

Estimate at completion (EAC): projected or anticipated total cost when project is completed. Accordingly, EAC can be calculated based on 3 different scenarios

Scenario 1:

- EAC based on new estimate
  - EAC = AC^C + ETC (new estimate)
  - Original estimate assumptions flawed or no longer relevant

Forecasting

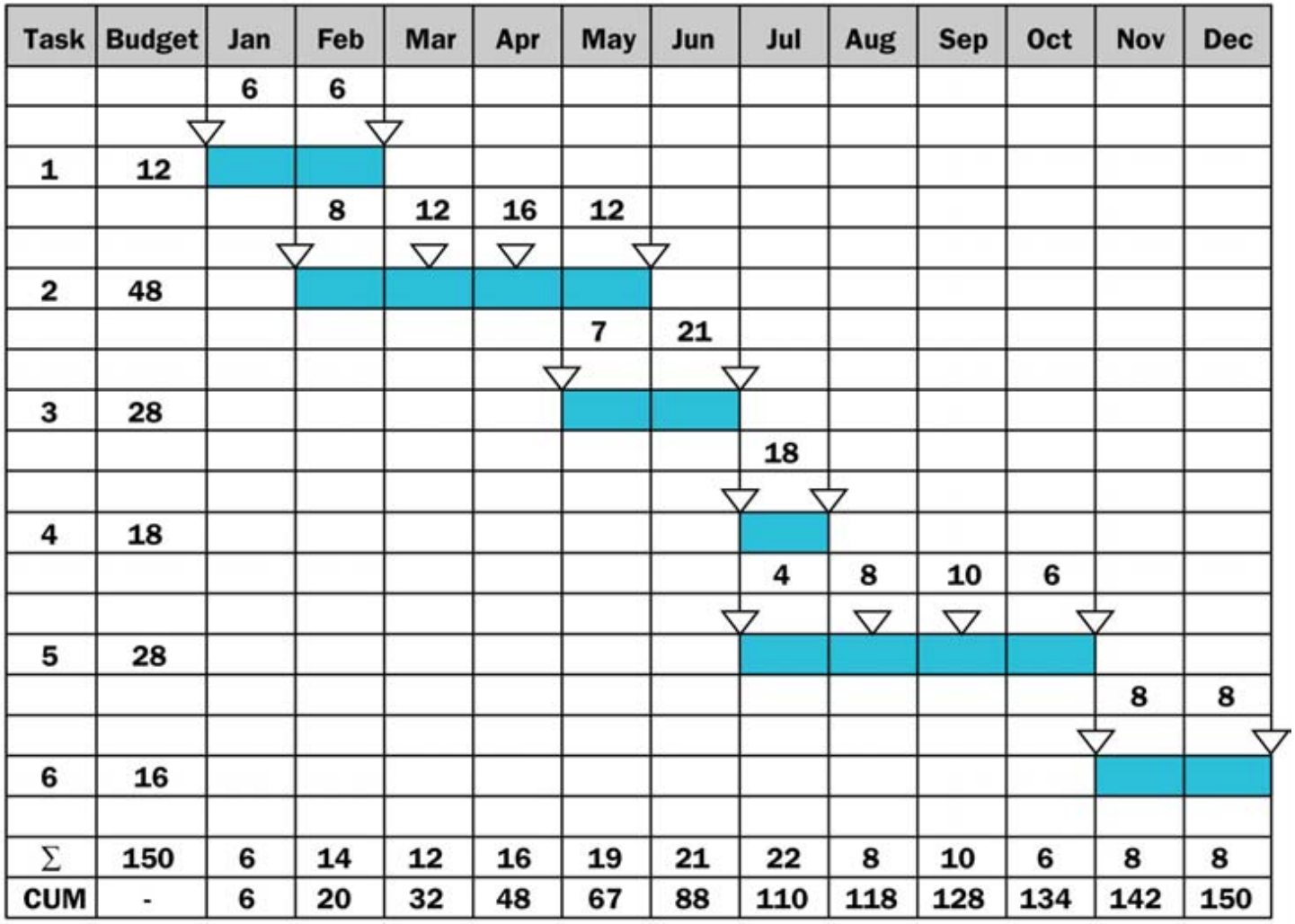
Scenario 2:

- EAC based on atypical variances:
  - $EAC = AC^C + BAC - EV^C$
  - Current variances atypical and will not occur in future

Scenario 3:

- EAC based on typical variances:
  - $EAC = AC^C + ((BAC - EV^C) / CPI^C)$
  - Current variances typical of future variances

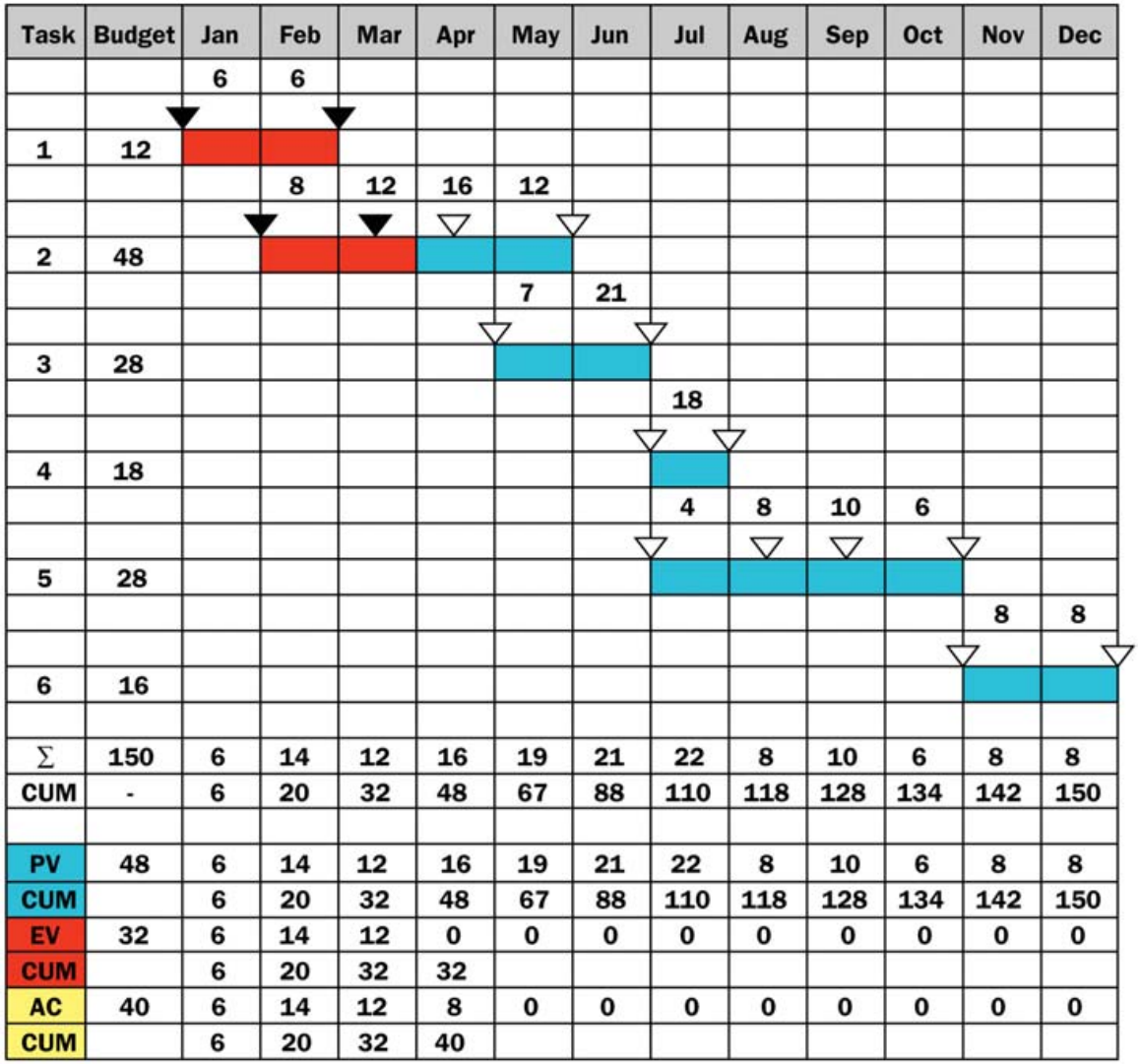
Example



Task	Budget	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		6	6										
1	12												
			8	12	16	12							
2	48												
						7	21						
3	28												
								18					
4	18												
								4	8	10	6		
5	28												
												8	8
6	16												
∑	150	6	14	12	16	19	21	22	8	10	6	8	8
CUM	-	6	20	32	48	67	88	110	118	128	134	142	150

Figure 1-4. Work Plan—Gantt (Bar) Chart

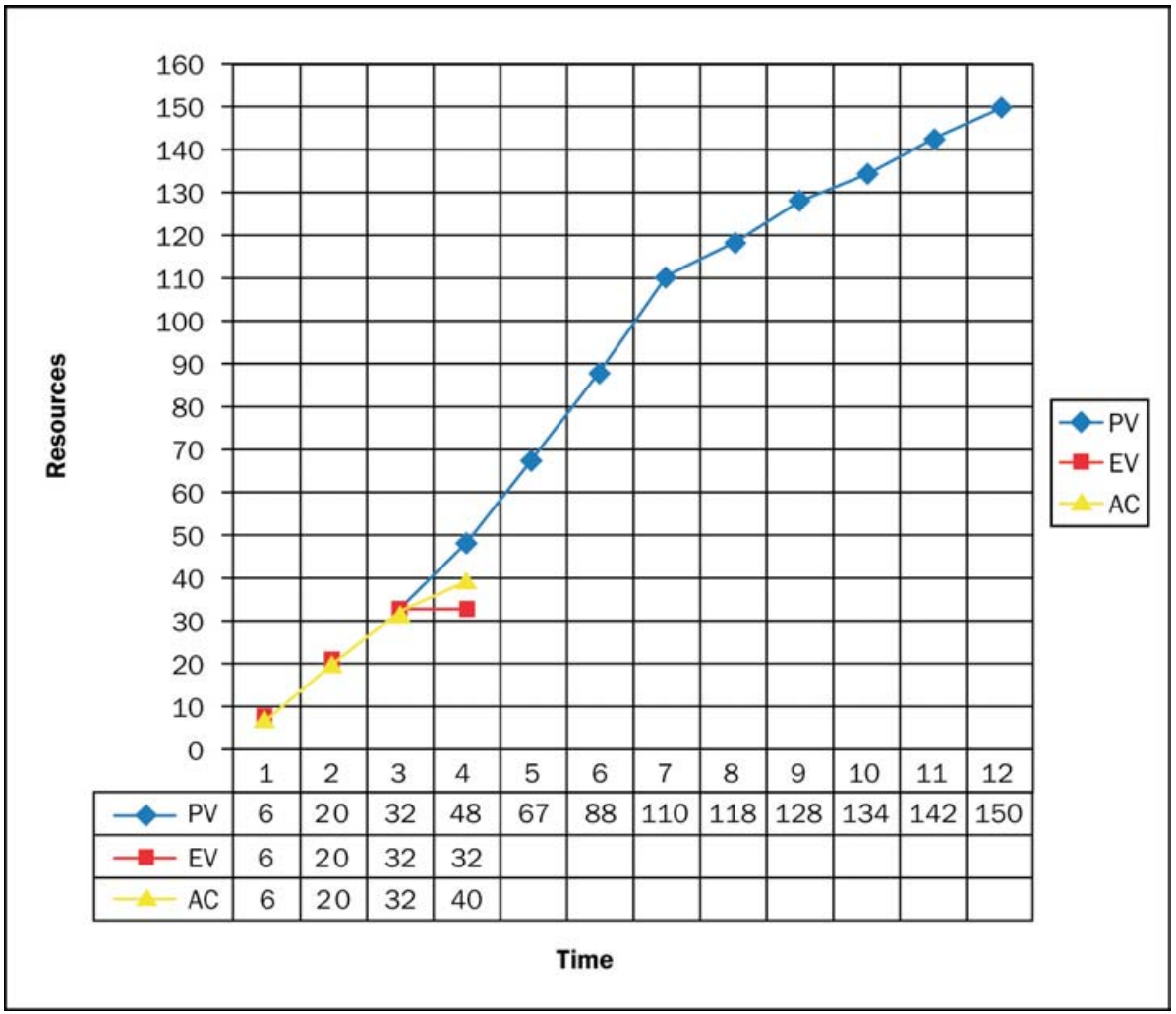
Example



Task	Budget	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		6	6										
1	12												
			8	12	16	12							
2	48												
						7	21						
3	28												
								18					
4	18												
								4	8	10	6		
5	28												
												8	8
6	16												
Σ	150	6	14	12	16	19	21	22	8	10	6	8	8
CUM	-	6	20	32	48	67	88	110	118	128	134	142	150
PV	48	6	14	12	16	19	21	22	8	10	6	8	8
CUM		6	20	32	48	67	88	110	118	128	134	142	150
EV	32	6	14	12	0	0	0	0	0	0	0	0	0
CUM		6	20	32	32								
AC	40	6	14	12	8	0	0	0	0	0	0	0	0
CUM		6	20	32	40								

Figure 2-6. Work Plan and Status for Project EZ (As of April 30)

Example



	1	2	3	4	5	6	7	8	9	10	11	12
PV	6	20	32	48	67	88	110	118	128	134	142	150
EV	6	20	32	32								
AC	6	20	32	40								

Figure 2-7. Cumulative Planned Value, Earned Value, and Actual Cost for Project EZ (As of April 30)

Example

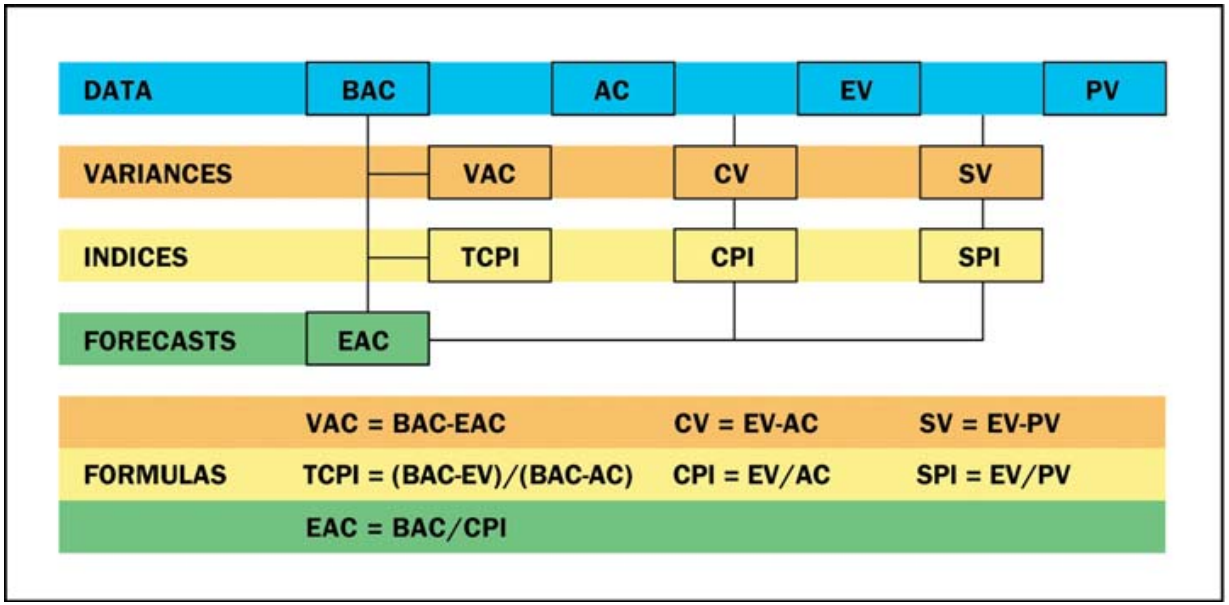


Figure 3-1. EVM Performance Measures

Example

- Schedule Analysis and Forecasting
  - $SV = EV - PV = 32 - 48 = -16\,\{unfavourable\}$
  - $SV\% = \frac{SV}{EV} = -\frac{16}{48} = -33\%\,\{unfavourable\}$
  - $SPI = \frac{EV}{PV} = \frac{32}{48} = 0.67\,\{unfabourable\}$
  - $EAC_t = \frac{(\frac{BAC}{SPI})}{(\frac{BAC}{months})} = \frac{\frac{150}{0.6667}}{\frac{150}{12}} = 18\,months > 12\,months$
- Cost Analysis and Forecasting
  - $CV = EV - AC = 32 - 40 = -8\,\{unfavourable\}$
  - $CV\% = \frac{CV}{EV} = -\frac{8}{32} = -25\%\,\{unfavourable\}$
  - $CPI = \frac{EV}{AC} = \frac{32}{40} = 0.80\,\{unfabourable\}$
  - $EAC = \frac{BAC}{CPI} = \frac{150}{0.80} = 187.50 > 150$
  - $TCPI = \frac{BAC-EV}{BAC-AC} = \frac{150-32}{150-40} = 1.07$ → For the project to achieve the BAC, performance must improve from a CPI of 0.80 to a TCPI (To-Complete PI) of 1.07

Project Cost Control

Factors Influencing Original Plan

- Changes in time or cost objectives for completion
- Changes in operating policies
- Changes in technical specifications
- Changes in construction methods
- Changes in owner's needs
- Revised activity time estimates
- Inaccurate planning of activity relationships
- Failure of suppliers or contractors to deliver on time
- Reassessment of resource requirements and usage
- Unexpected technical difficulties, environmental conditions, market fluctuations

Project Cost Control

Elements of Management Control

- Obtaining feedback from output and comparing it with designed performance levels
- Responding to changing conditions to mitigate their effects
- Implementing corrective actions
- Requires management of change and unexpected conditions

Project Cost Control

Change Control

- Changes required to: (1) correct errors or omissions (2) changes in scope due to economic or functional reasons
- Project manager must establish formal procedure for control of changes
- Authorization of changes required → becomes a change order
- Risky for contractor to implement changes prior to obtaining written authorization

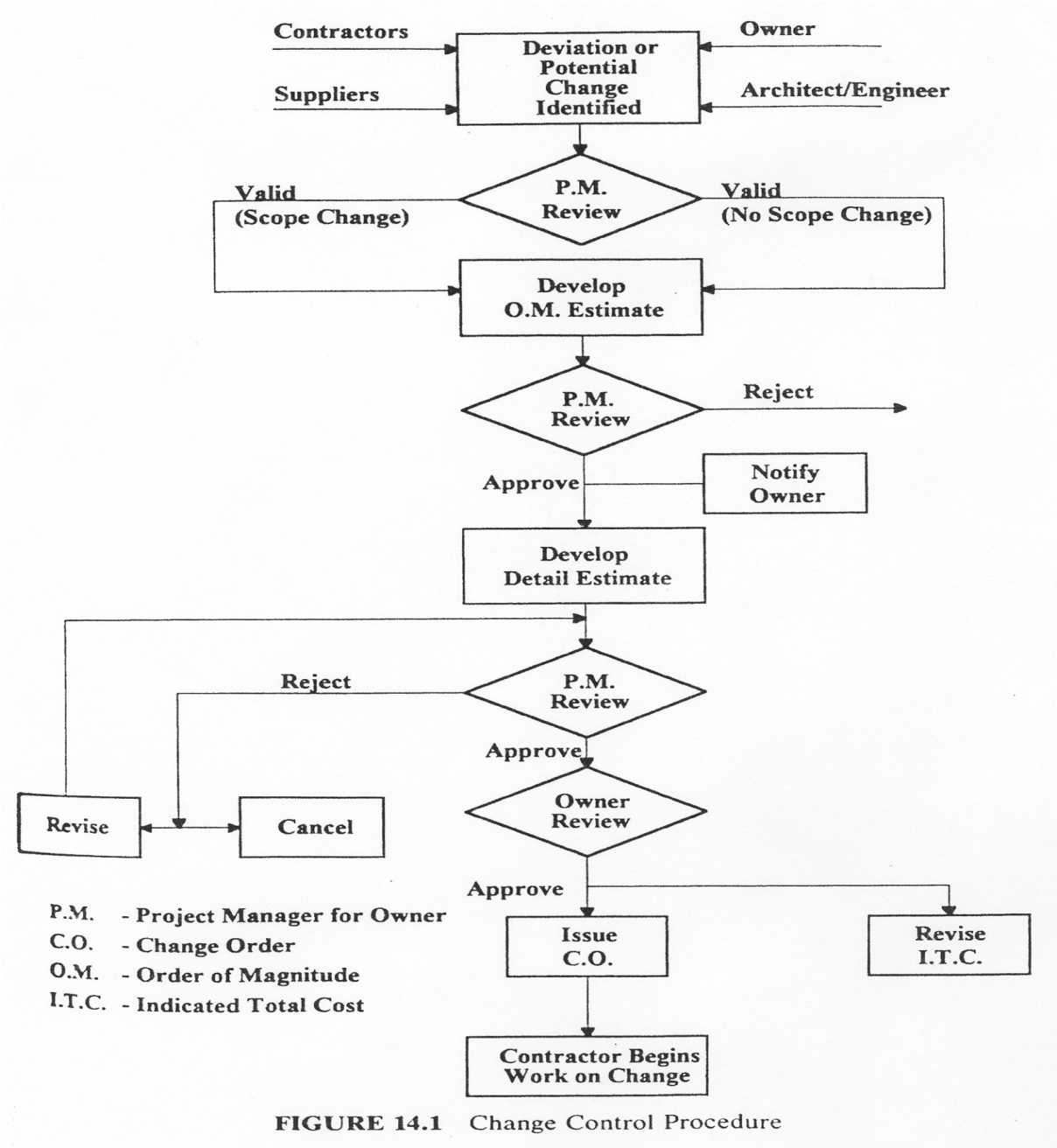


FIGURE 14.1 Change Control Procedure

JONES AND SMITH
PROJECT MANAGERS
GANDER, NFLD.

CONTRACT CHANGE ORDER

Project: *Airport Terminal Building*
For: *Dept. of Transportation*
To: *The Labrador Construction Co., Ltd.*
Churchill, NFLD.

Change Order No. *1*
Date July 27, 19 __

Revised Contract Amount	
Previous contract amount	*5,762,634.00*
Amount of this order ~~(decrease)~~ (increase)	*5,478.00*
Revised Contract Amount	*5,768,112.00*

An ~~(increase)~~ ~~(decrease)~~ (no change) of _____ days in the contract time is hereby authorized.

This order covers the contract modification hereunder described:

Providing and installing 50mm dia. copper pipe as shown and described by Supplemental Drawing GB 25 attached hereto

The work covered by this order shall be performed under the same terms and conditions as included in the original construction contract.

Changes Approved

_____
(Owner)

by _____

_____
(Contractor)

by _____

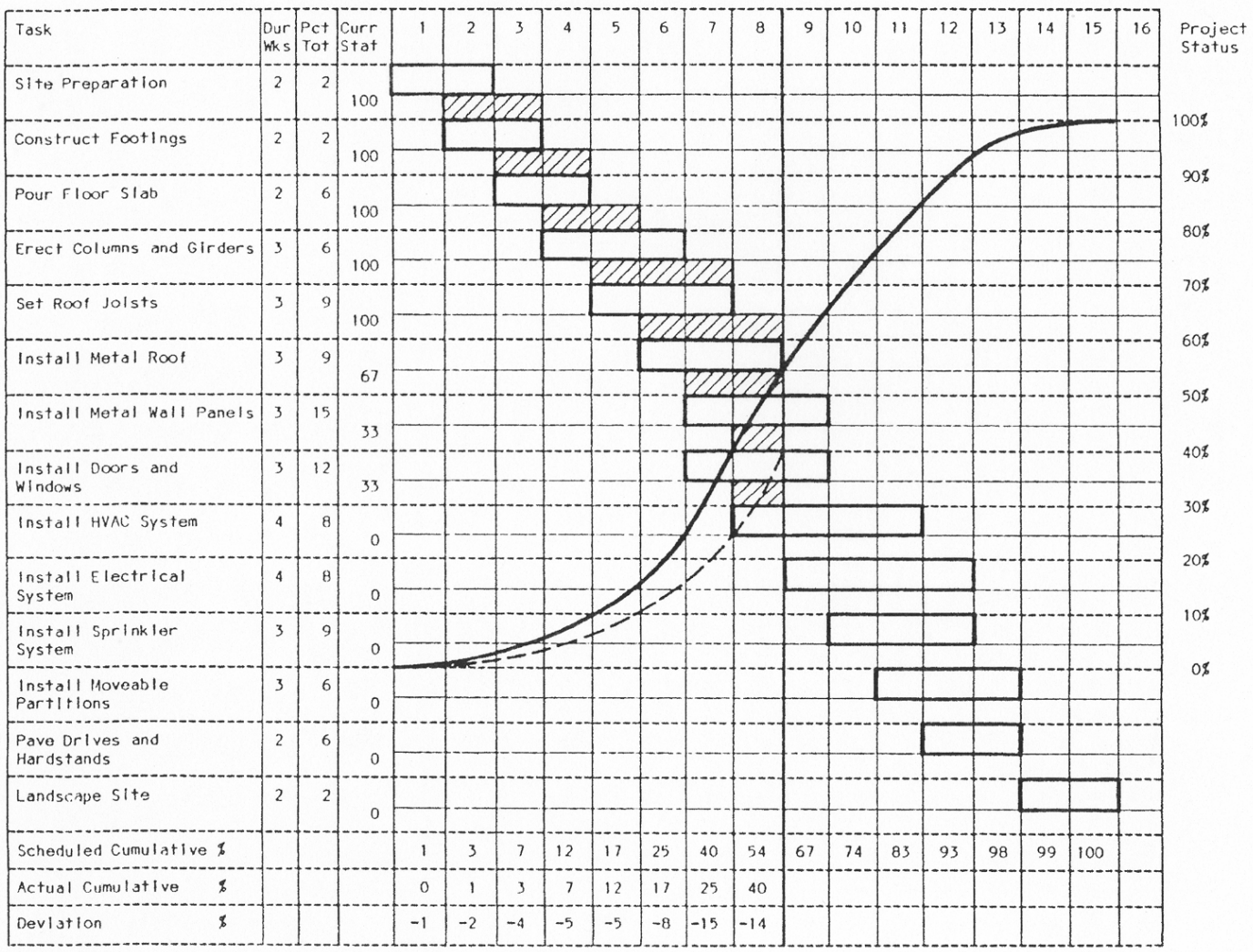
Jones and Smith, Project Managers

by _____

FIGURE 14.2 Contract Change Order

FIGURE 12.3
UPDATED BAR CHART FOR WAREHOUSE PROJECT

PROJECT: ACME Warehouse Project Updated As Of: End of 8 th Week



Task	Dur Wks	Pct Tot	Curr Stat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Site Preparation	2	2	100																
Construct Footings	2	2	100																
Pour Floor Slab	2	6	100																
Erect Columns and Girders	3	6	100																
Set Roof Joists	3	9	100																
Install Metal Roof	3	9	67																
Install Metal Wall Panels	3	15	33																
Install Doors and Windows	3	12	33																
Install HVAC System	4	8	0																
Install Electrical System	4	8	0																
Install Sprinkler System	3	9	0																
Install Moveable Partitions	3	6	0																
Pave Drives and Hardstands	2	6	0																
Landscape Site	2	2	0																
Scheduled Cumulative %				1	3	7	12	17	25	40	54	67	74	83	93	98	99	100	
Actual Cumulative %				0	1	3	7	12	17	25	40								
Deviation %				-1	-2	-4	-5	-5	-8	-15	-14								

Project Closeout

Data to Collect at Project Closeout

- "As-built" CPM network from design to construction
- Crew composition, mhrs per unit measure
- Equipment usage per unit measure
- Materials consumed per unit measure
- Overhead expenditure as % total job cost
- Learning curve effects
- Progress at different stages in project
- Special difficulties, problems encountered
- Effective techniques and corrective actions
- Evaluation of consultants', contractors', subcontractors' performance
- Comparison of sub-element cost in design estimates with actual costs at completion
- Actual vs. estimated contingency and profit

References:

- *CIV E 601: Project Management, Lecture Notes,* Fayek, A. R. University of Alberta, 2013.
- *Project Management: Techniques in Planning and Controlling Construction Projects*, 2nd Edition, Ahuja, Dozzi, and AbouRizk, John Wiley and Sons, 1994.
- Earned Value Management: Practical Guide, PMI, 200?.