



Week 11

Earned Value

457.307 Construction Planning and Management
Department of Civil and Environmental Engineering
Seoul National University

Prof. Seokho Chi

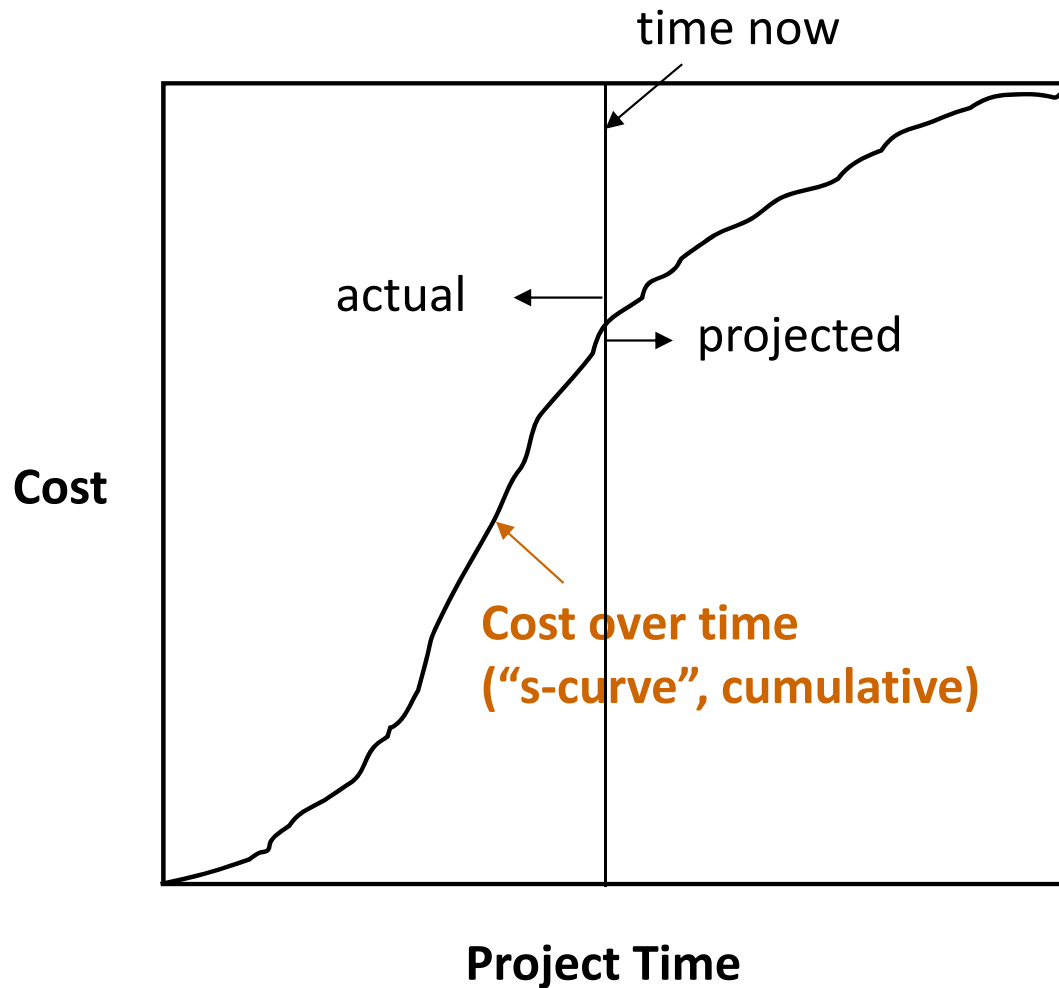
shchi@snu.ac.kr

건설환경공학부 35동 304호

Earned Value Purpose

- Monitor cost and schedule performance and progress in an integrated fashion
- A contractor knows “earned” value: the *budgeted* value of completed work
 - Budgeted: used to report to owner
 - Hence, earned value concept typically used as project control to track progress of those that work for you

Integrate Money and Time

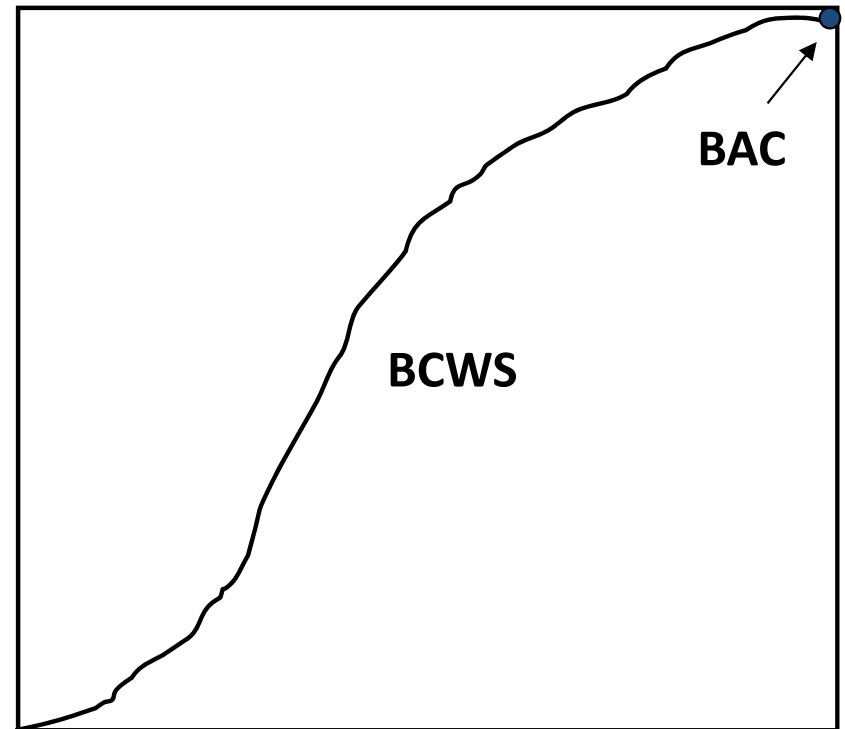


Cost loaded schedule

ID	Task Name	Duration	September				October		
			5	12	19	26	3	10	17
1	Start Date	0 days			9/20				
2	Clear & Grade Lot	4 days							
3	Final Grade Check	0.5 days							
4	Compaction Test	0.5 days							
5	Stake Start	1 day							
6	Plumbing Slab Start	1 day							
7	Plumbing slab complete	1 day							
8	Slab Setup	2 days							
9	Slab Inspection	1 day							
10	Slab pour / Finish	1 day							
11	Frame	10 days							

Definitions (Metrics)

- **BCWS: Budgeted Cost of Work Scheduled**
 - Cost loaded schedule used to generate cumulative cost curve
- **BAC: Budgeted Cost at Completion**
 - Original total estimated cost



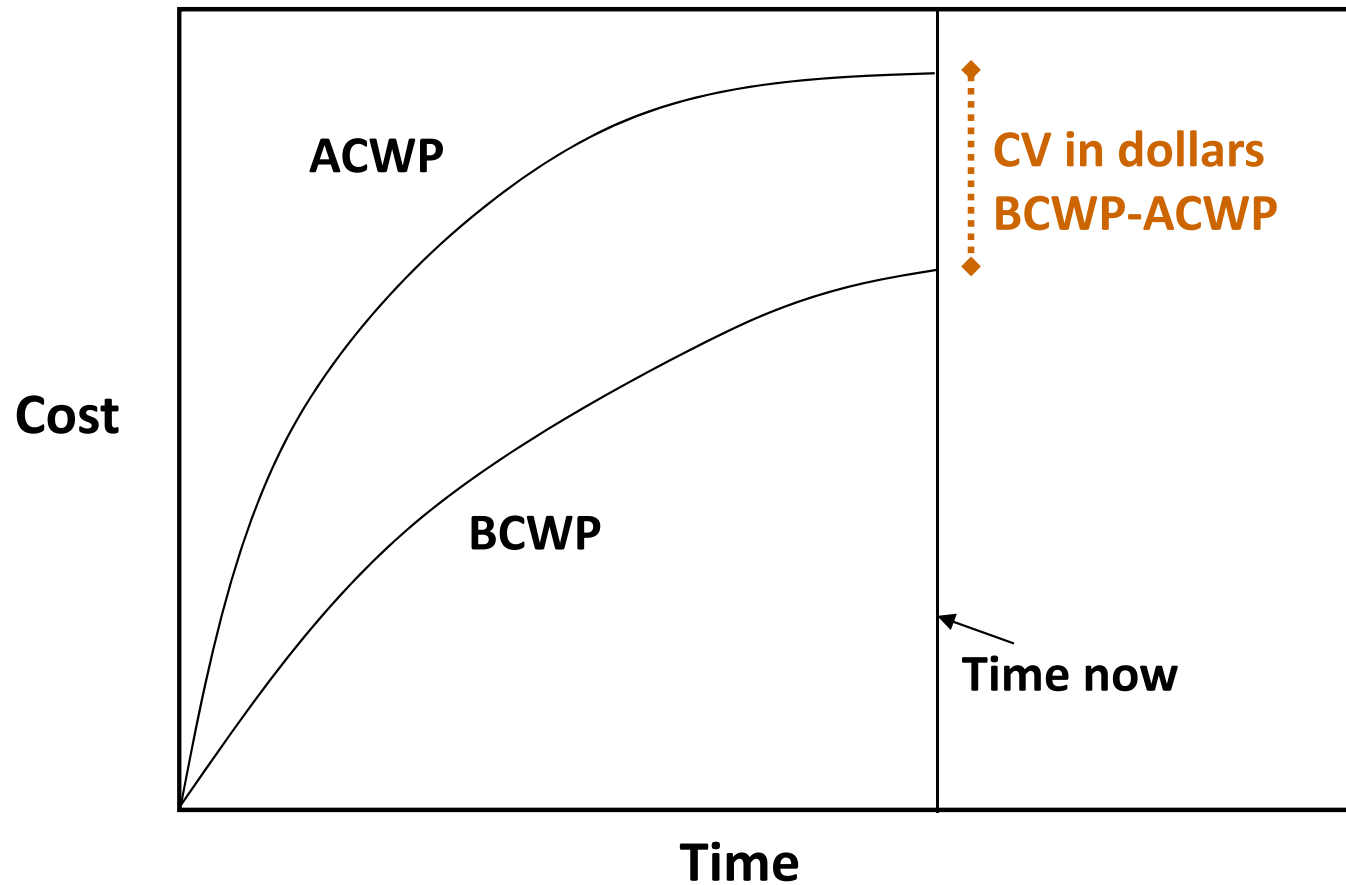
Metrics (2)

- **BCWP: Budgeted Cost of Work Performed**
 - Budgeted (not actual) cost of work performed to-date on project
 - $BCWP = \text{Earned Value}$ (definition)
- **ACWP: Actual Cost of Work Performed**
 - Actual (not budgeted) cost of work performed to-date on project
 - Monitor time and cost

Metrics (3) – CV

- **CV: Cost Variance = BCWP – ACWP**
 - Difference between budgeted and actual cost of work performed
 - Provided project cost status
 - $CV > 0$: project under budget
 - $CV < 0$: project over budget
- **%CV: % Cost Variance**
 - $\%CV = 100 \times CV/BCWP$

Metrics (4) – CV

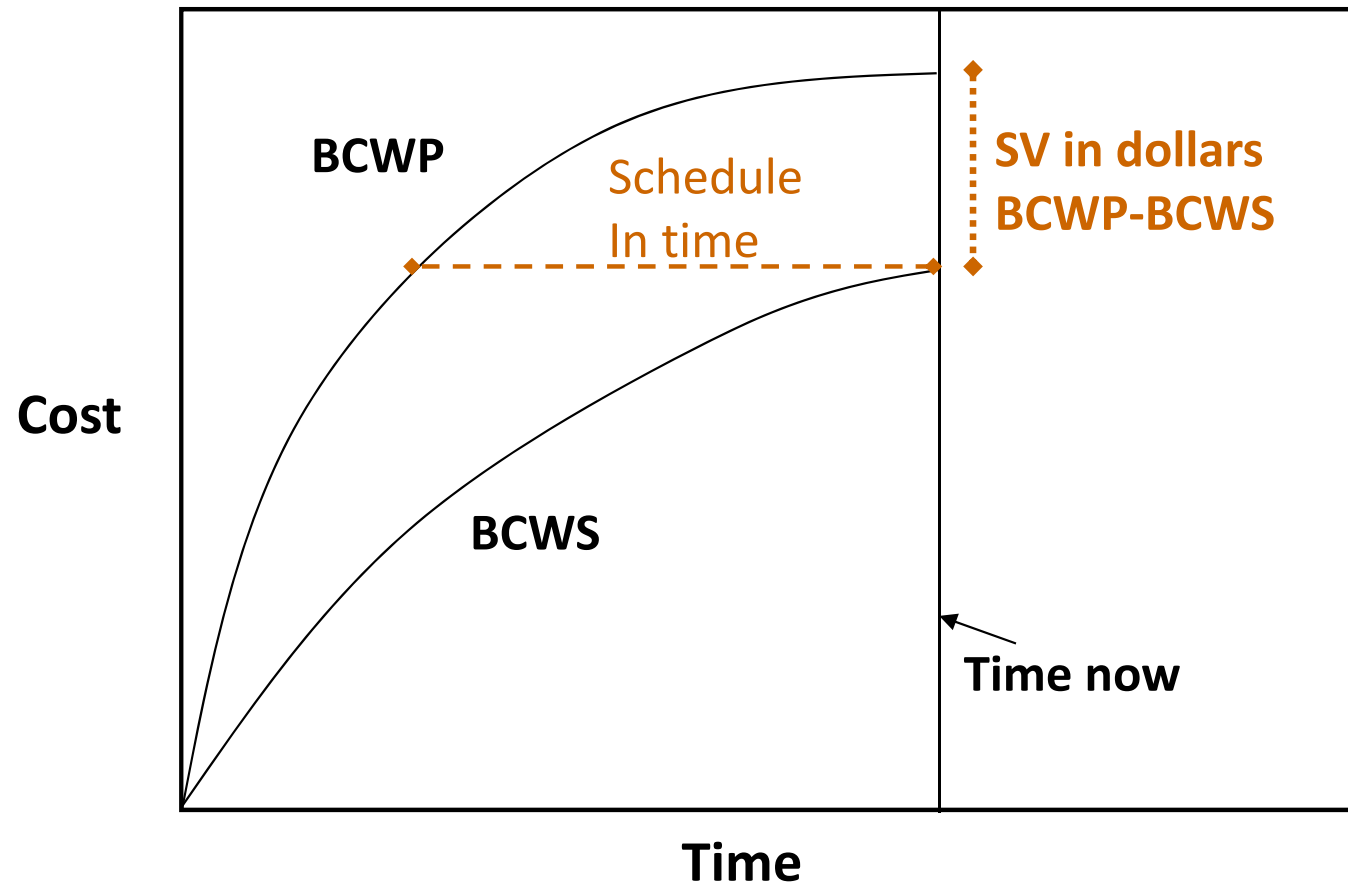


Is this project over or under budgeted cost?

Metrics (5) – SV

- **SV: Schedule Variance = BCWP – BCWS**
 - Use budgeted amount for both, so not looking at cost variance
 - Infer schedule performance from difference
 - $SV > 0$: ahead of schedule *오늘을 기준으로 *schedule*상으로는 *a*라는 예산에 해당하는 일까지 했으면 되는데, 실제로는 더 많은 예산*b*에 해당하는 일만큼 했다.
 - $SV < 0$: behind schedule
- **%SV: % Schedule Variance**
 - $\%SV = 100 \times SV/BCWS$

Metrics (6) - SV



Is this project ahead of or behind schedule?

Metrics (7)

- **Related metrics:**
 - SPI: Schedule Performance Index ($BCWP/BCWS$)
 - $SPI > 1$ – ahead of schedule
 - $SPI < 1$ – behind schedule
 - CPI: Cost Performance Index ($BCWP/ACWP$)
 - $CPI > 1$ – under budget
 - $CPI < 1$ – over budget

Metrics (8)

- **PC: Percent Complete – $BCWP/BAC$**
 - Estimates of PC used to status each activity
- **EAC: Estimated cost at completion**
 - $EAC = ACWP + (BAC - BCWP)$
 - $EAC = BAC + (ACWP - BCWP)$
 - Is it reasonable if $ACWP <> BCWP$?
 - What is the assumption here?
 - What would you want to know to clarify?

Example 1

Six month project
 Current time **3.5 months**
 Current cost: \$152,000
 BAC: \$257,000

Activity status

Sitework 100%

Excavation 100%

Foundation 100%

Fencing 100%

Rough electrical 100%

Framing 50%

Plumbing 75%

Paving 50%

Calculate:

ACWP, BCWP, BCWS,
 SV, %SV, SPI, CV, %CV,
 CPI, PC, EAC

Activity	Budget \$	Mon1	Mon2	Mon3	Mon4	Mon5	Mon6
Sitework	\$22,000						
Fencing	\$10,000						
Paving	\$18,000						
Excavation	\$30,000						
Foundation	\$50,000						
Framing	\$40,000						
Rough Electric	\$ 6,000						
Rough Plumbing	\$16,000						
Drywall	\$13,000						
Suspend Ceiling	\$ 4,000						
Interior Finish	\$34,000						
Carpeting	\$14,000						

Example 1

- $ACWP = \$152,000$ (given)
- $BCWS =$
- $BCWP =$
- $SV =$
- $\%SV =$
- $SPI =$

Example 1

- $ACWP =$
- $BCWS =$
- $BCWP =$

- $CV =$
- $\%CV =$
- $CPI =$

Example 1

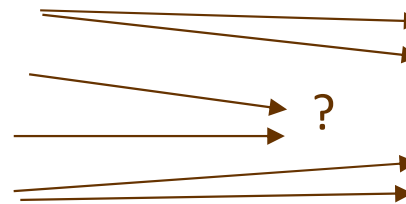
- $ACWP = \$152,000$ (given)
- $BCWS =$
- $BCWP =$
- Percent Complete =
- $EAC =$

**Although the project is slightly behind schedule, it is performing under budget. The project is currently at the 62% completion stage and is estimated to be completed for a revised estimated cost of \$250,000, a decrease from the original estimate.*

Cost Loading

- Conceptually easy: add cost to activities
- Difficult because:
 - Break apart estimates
 - Level of detail

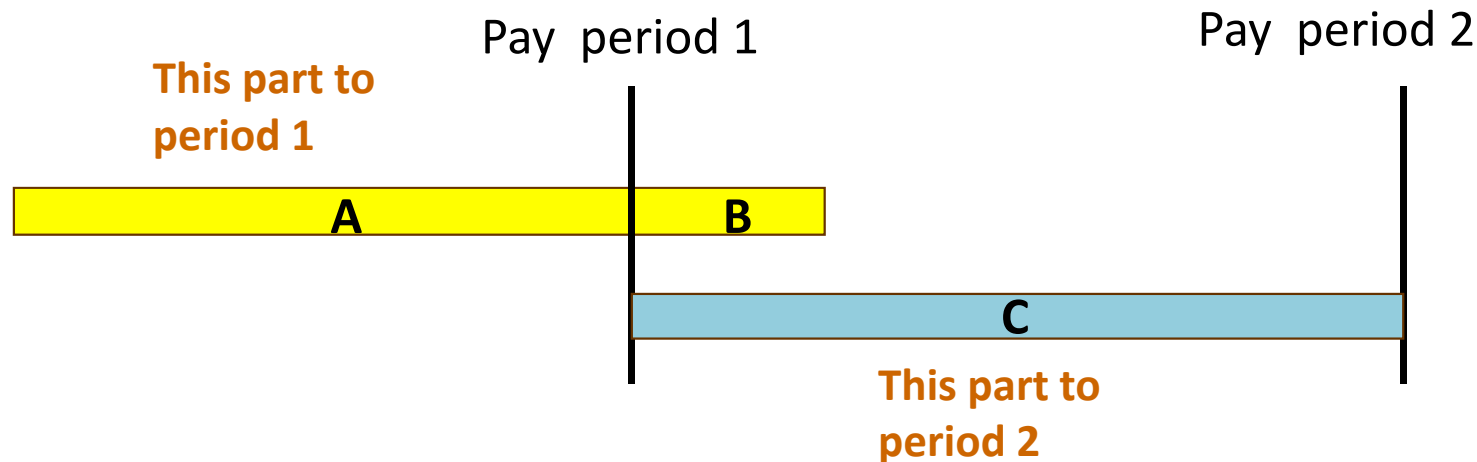
Grading 400 sf, \$5k
 Formwork, \$8k
 Rebar, \$3k
 Concrete, \$12k



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Calculating EV in the Real World

- In the real world, there are periodic payments (month, week)
- To account for these, apportion activity costs to pay period
 - Activity-based = A+B and C
 - Period-based = A and B+C



Key Skills

- Understand concept of Earned Value
- Know definition and use of several metrics related to earned value calculations
- Deploy metrics on project data to calculate values



Week 11

Change Management

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Prof. Seokho Chi

shchi@snu.ac.kr

건설환경공학부 35동 304호

"We commission hundreds of new build and refurbishment projects of various sizes every year. Many of them do not complete on time or within budget. As a result, we suffer significant losses in terms of both higher construction costs and delayed business opening."



"Many serious project delays can be traced to some seemingly insignificant delays that happened sometime ago somewhere upstream in the project delivery process."

<Project Manager>



<Client (Owner)>

Different Perspectives on Changes

<Source: Managing Changes in Construction Projects>

<Contractor>



<Design Consultant>

"In many of our projects, we have to make late changes to the design because the client keeps changing their requirements. This results in a waste of staff time as high as 30% in a typical project."

"We often have to delay the work on-site and even re-do the work because the drawings provided by the designers are either incomplete or inconsistent with the site conditions."

Construction Project Performance

- *‘More than a third of major clients are dissatisfied with contractors’ performance in keeping to the **quoted price** and to **time**, **resolving defects**, and delivering a final product of the **required quality**’*
- **More than 50% of construction projects: delay, over-spending**
- **More than 30% of completed construction projects have quality defects**
- **About 30% of construction is rework**
 - Labor efficiency: 40 – 60%
 - At least 10% of materials are wasted
 - Direct costs caused by rework average 5% of total construction costs.

Reasons for Change and Rework

- **Change in owner's requirements**
 - Owner will add or deduct portions of work (e.g., scope change to the contract)
 - A change order is almost always authorized for this kind of changes
- **Constructive Change**
 - The architect or owner representative causes the contractor to perform work outside the contract
 - Construction document errors, omissions

Reasons for Change and Rework

- **Differing Site Conditions**

- Subsurface soil conditions
- In renovation projects, the designer does not have all of the previous construction details and plans.

- **Jobsite Discovery of Hazardous Materials**

- The contractor would notify the owner of any discovery of hazardous materials
- The owner then needs to decide on the best way of handling the material (owner's responsibility).

Reasons for Change and Rework

- **Code Revisions by the Outside Agencies**

- The local building code authority reviews the project after the construction contract has been awarded and requests code revisions.

**building code: a set of rules that specify the minimum acceptable level of safety for constructed objects*

e.g., code violation: this concrete block wall is penetrated by cable trays and cables. The hole should be firestopped to restore the fire-resistance rating of the wall. Instead it is filled with flammable polyurethane foam.



Changes → Re-sequencing/Rework → More Time and Cost

Change Order

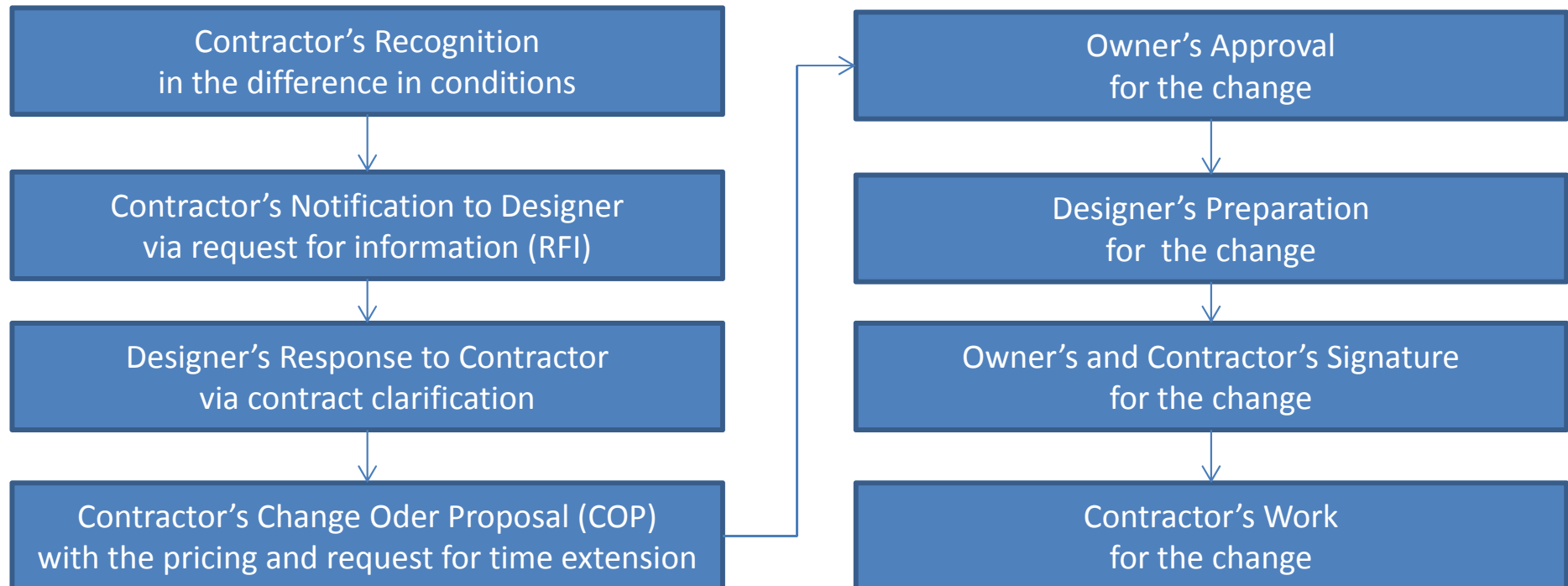
- **Change of scope or addition of work**
 - Construction contracts contain provisions allowing owners to make changes to the work by a written notice
 - Architects, engineers, and owners occasionally direct the contractor to alter the construction plan.

“The contractor’s excavation subcontractor decided on using a Hydraulic Excavator for excavation of a sewer line trench. However, as construction proceeded, the owner requested that the contractor use a smaller piece of excavation equipment to minimize damage to the surrounding existing environment. Because the smaller piece of equipment was not owned by the excavating subcontractor, the rental rate exceeded the rate for the owned piece of equipment. The productivity of the smaller equipment was lower than the Hydraulic Excavator, requiring more time for the activity and resulting in higher labor costs. The excavating subcontractor requested a Change Order for an extra amount for a directed change in means and methods.”

Item	Hydraulic Excavator	Rubber-tired Backhoe
Equipment	16 hrs @ \$80/hr = \$ 1280.	24 hrs @ \$100/hr = \$ 2400.
Labor	16 hrs @ \$30/hr = \$ 480.	24 hrs @ \$ 30/hr = \$ 720.
Equipment	16 hrs @ \$20/hr = <u>\$ 320.</u>	24 hrs @ \$ 20/hr = <u>\$ 480.</u>
Total Cost	\$ 2080.	\$ 3600.
Net Additional Cost		\$ 1520.
Plus: 15% Allowable		\$ 228.
Overhead & Profit		
Additional Cost Impact		<u>\$ 1748.</u>

Change Order Process

- Described in the contract document
- Typical change order process
 - For different site conditions





Change Order Proposal

To: _____ Date: _____
_____ Job No.: _____

Subject: Notification of Change or Claim for: _____

Attn.: _____

Gentlemen:

The following **Request for Information, No. 45** has been determined by FGH Construction Company to be beyond the scope of our contract. You are hereby notified that this problem may create a suspension /delay of the work, increase scheduled time to complete the project, and/or cause additional cost to our work. We reserve the right to request additional time and costs for this work. This work could potentially have an adverse effect on other work being performed or that will be performed.

Description of Occurrence or Request for Information:

Date of Occurrence On: _____
From: _____ To: _____

You are hereby notified of our intention to seek recovery of all extra costs, including but not limited to General Condition Expenses if this delay affects scheduled completion. It is our intent to minimize the effect of this change.

Please issue the appropriate paperwork to complete this change. Thank you.

Sincerely,

Bill Jones

Project Engineer

cc: **Frank Canteen**

Project Manager

File CP - _____

Enclosures: _____

5390 Walnut Avenue, San Francisco,
California, 93422-0027
Phone: (415)555-2346, Fax: (415)555-2300



Change Order Proposal

To: _____ No. _____
_____ Project: _____
_____ Date: _____

From: _____

FGH Construction Co., wishes to submit the following Change Order Proposal for the change in scope of the contract work as described:

Cost of the work:

Description :	Labor	Mat.	Equip.	Other	Sub	Total
Labor Burden _____ %						
Subtotal						
Bond Premium _____ %						
Liability Insurance _____ %						
Subtotal						
Overhead						
Profit						
Grand Total:						
Schedule Extension:						
Calendar Days to be added to the contract time:						
FGH Construction will proceed on this change when authorized by _____ in writing. This information is time sensitive and is valid for 10 days without review.						

Signed: _____

Title: _____

5390 Walnut Avenue, San Francisco,
California, 93422-0027
Phone: (415)555-2346, Fax: (415)555-2300

CO Sample

2000 EDITION

AIA DOCUMENT G701-2000

Change Order

(Instructions on reverse side)

PROJECT:
(Name and address)

Huna Office Building
9301 Glacier Highway
Juneau, Alaska 99801

TO CONTRACTOR:
(Name and address)

Northwest Construction Co.
1242 First Avenue
Cascade, Washington 98202

CHANGE ORDER NUMBER: 1

DATE: November 15, 2000

ARCHITECT'S PROJECT NUMBER: 937

CONTRACT DATE: August 15, 2000

CONTRACT FOR: Construction of office building

OWNER ☒

ARCHITECT ☒

CONTRACTOR ☒

FIELD ☐

OTHER ☐

THE CONTRACT IS CHANGED AS FOLLOWS:

(Include, where applicable, any undisputed amount attributable to previously executed Construction Change Directives.)

Incorporate Change Order Proposals 1, 2, 3, 4, and 5 per attached Change Order Proposal Log

The original (~~Contract Sum~~) (Guaranteed Maximum Price) was \$ 1,760,000.00

The net change by previously authorized Change Orders \$ NA

The (~~Contract Sum~~) (Guaranteed Maximum Price) prior to this Change Order was \$ 1,760,000.00

The (~~Contract Sum~~) (Guaranteed Maximum Price) will be (~~increased~~) (~~decreased~~)

(~~unchanged~~) by this Change Order in the amount of \$ 4,623.00

The new (~~Contract Sum~~) (Guaranteed Maximum Price) including this Change Order will be \$ 1,764,623.00

The Contract Time will be (~~increased~~) (~~decreased~~) (unchanged) by Zero (0) days.

The date of Substantial Completion as of the date of this Change Order therefore is June 3, 2001

NOTE: This Change Order does not include changes in the Contract Sum, Contract Time or Guaranteed Maximum Price which have been authorized by Construction Change Directive for which the cost or time are in dispute as described in Subparagraph 7.3.2 of AIA Document A201.

Not valid until signed by the Architect, Contractor and Owner.

Jensen Yorba Lott
ARCHITECT (Typed name)

Norm Riley
(Signature)

Norm Riley
BY

Nov. 15, 2000
DATE

Northwest Const.
CONTRACTOR (Typed name)

Sam Peters
(Signature)

Sam Peters
BY

Nov. 15, 2000
DATE

Huna Totem
OWNER (Typed name)

Robert Smith
(Signature)

Robert Smith
BY

Nov. 15, 2000
DATE



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AIA DOCUMENT G701-2000
CHANGE ORDER

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The American Institute
of Architects
1735 New York Avenue, N.W.
Washington, D.C. 20006-5292

FIGURE 19-4 Change Order

Change Order Process

- Time is of the essence
 - Usually takes a long time until authorization
 - All paperwork must be executed promptly and accurately
- Changes can be initiated by any party involved
- If the owner and the designer disagree with the change order proposal submitted by the contractor
 - Contractor options:
 - Revise the proposal
 - Withdraw the proposal
 - Pursue the proposal as submitted: Change proposal becomes a claim **But the contractor continuously works and the owner should pay.*

Change Order Process

- **Construction Change Directive (CCD)**
 - Written notice directing work change before a written change order
 - Used to keep work going
 - Clearly describes additional work
 - Specifies a payment method

CONSTRUCTION CHANGE DIRECTIVE CONSTRUCTION MANAGER-ADVISER EDITION AIA DOCUMENT G714/CMa <small>(Instructions on reverse side)</small>		OWNER <input type="checkbox"/> CONSTRUCTION MANAGER <input type="checkbox"/> ARCHITECT <input type="checkbox"/> CONTRACTOR <input type="checkbox"/> FIELD <input type="checkbox"/> OTHER <input type="checkbox"/>
PROJECT: <small>(Name and address)</small>		DIRECTIVE NO.: DATE:
TO CONTRACTOR: <small>(Name and address)</small>		PROJECT NOS.: CONTRACT FOR: CONTRACT DATE:

You are hereby directed to make the following change(s) in this Contract:

PROPOSED ADJUSTMENTS

1. The proposed basis of adjustment to the Contract Sum is Guaranteed Maximum Price is:

☐ Lump Sum (increase) (decrease) of \$ _____

☐ Unit Price of \$ _____ per _____

☐ as provided in Subparagraph 7.3.6 of AIA Document A201/CMa, 1992 edition.

☐ as follows:

2. The Contract Time is proposed to (be adjusted) (remain unchanged). The proposed adjustment, if any, is (an increase of _____ days) (a decrease of _____ days).

Signature by the Contractor indicates the Contractor's agreement with the proposed adjustments in Contract Sum and Contract Time set forth in this Construction Change Directive.

CONTRACTOR _____

Address _____

BY _____

DATE _____

When signed by the Owner, Construction Manager and Architect and received by the Contractor, this document becomes effective IMMEDIATELY as a Construction Change Directive (CCD), and the Contractor shall proceed with the change(s) described above.

OWNER _____	CONSTRUCTION MANAGER _____	ARCHITECT _____
Address _____	Address _____	Address _____
BY _____	BY _____	BY _____
DATE _____	DATE _____	DATE _____

CAUTION: You should use an original AIA document which has this caution printed in red. An original assures that changes will not be obscured as may occur when documents are reproduced.

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- **Files should be established for every change**
 - Defined by COP: Includes all relevant documentation
 - Several change orders may be processing at the same time
 - Important to track proposals and orders
 - Change order log is used for recording

[illegible]

FIGURE 19-3 Change Order Proposal Log



Week 11

Project Closeout

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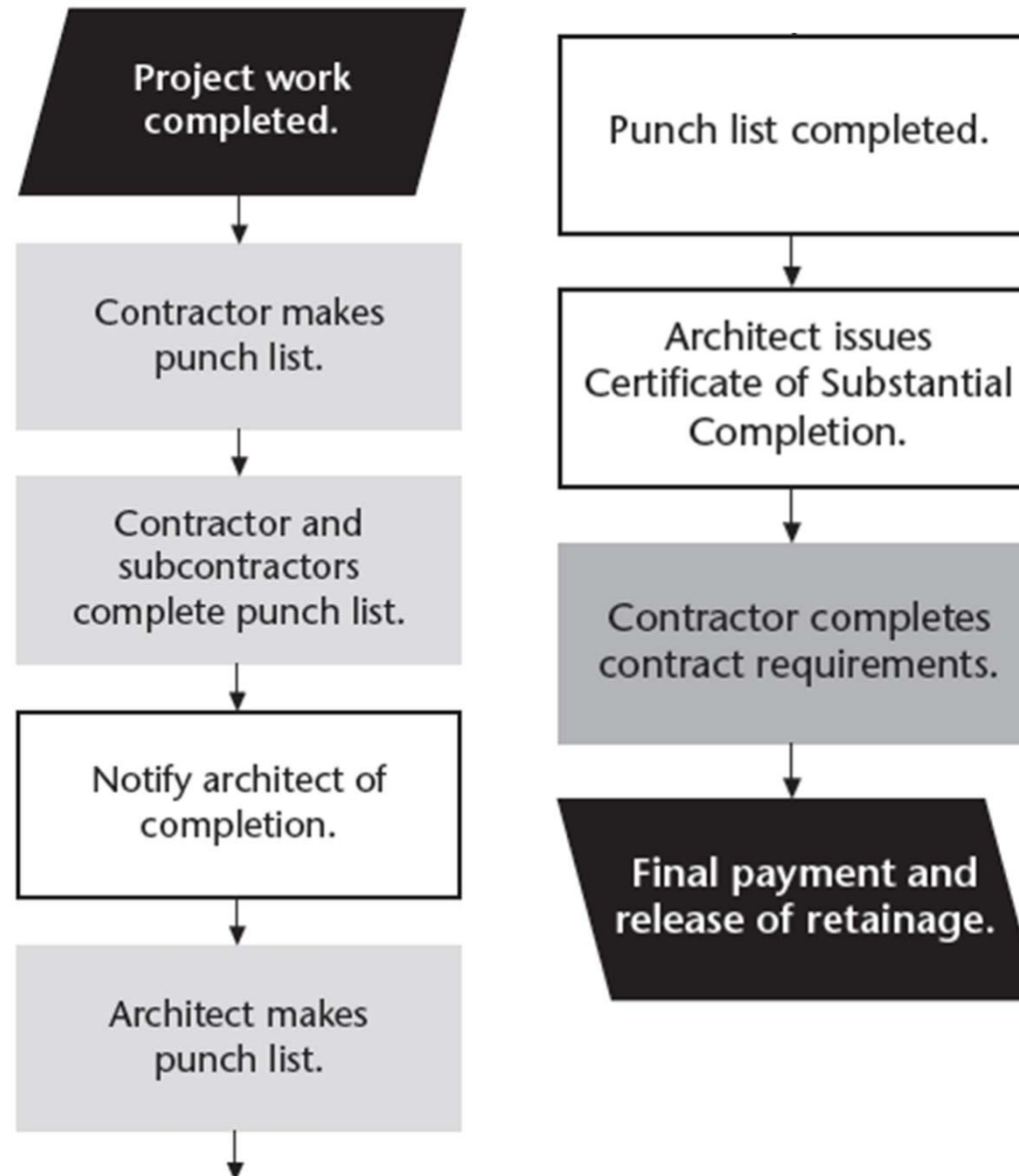
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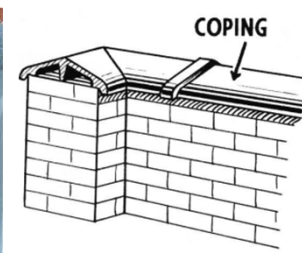
Project Closeout

- **Process of completing a construction project**
 - Contractual requirements, approvals, financial resolution, and documentation
 - Minor details
 - Late material and equipment delivery
 - Replacement of defective materials, equipment, etc.
 - Repairs
 - Testing and approval of building/infrastructure systems

Closeout Process



Punch List



- A sheet of paper posted on each door or in every room
- Managed by a log form

ROOM 1065
OFFICE
POSTED 6/27/10

Item	Gen. Cont. Complete	Architect Approval	Remarks
Rubber base	6/29/10	7/5/10 HDA	
Replace defective faucet @ sink	6/30/10	7/6/10	
Install Folding Door			Delivery scheduled for 7/10/10
Replace cracked outlet plate	6/29/10	7/6/10 JLB	
Touch-up paint, west wall	6/29/10		Not acceptable 7/5/10 HDA

Item #	Location	Item	Response	Completed Date	Init	Approval Date	By	Remarks
I A	General	Final clean	XYZ	7/5/10	RTZ	7/10/10	ALS	
I B	General	New filters	ABC Mech.	7/6/10	RTZ	7/10/10	ALS	
I C	General	Waste Rem.	XYZ	7/6/10	RTZ	7/10/10	ALS	
II A 1	West Ext.	Splash block	XYZ	7/6/10	RTZ	7/10/10	ALS	
II A 2	West Ext.	Caulking	A-1 Sealants	7/9/10	RTZ	7/10/10	ALS	
II B 1	North Ext.	Paint Coping	Steve's Painting	7/9/10	RTZ	7/10/10	ALS	
II C 1	East Ext.	Ovhd. door	Doors, Inc.					Scheduled: 7/13/10

Certificate of Substantial Completion

- *Point when the designer has determined that the facility or a portion of the facility is acceptable for owner use and occupancy*
- **Contents**
 - Project identification
 - Description of the project completed
 - Definition of substantial completion
 - List of remaining responsibilities
 - List of warranty dates
 - Signature
 - List of agreements

Inspection

- Final inspection must be issued prior to the owner occupying the facility
- Inspection agencies
 - Plumbing
 - Electrical
 - HVAC equipment
 - Elevator
 - Public works (for roads)
 - Planning compliance
 - Fire protection systems
 - Fire alarm
 - Environmental/storm water drainage
 - Health department: sewage systems
 - ADA (the American with Disabilities Act) requirements: handicapped access

System Testing and Documentation

- Building systems are tested for compliance to specifications
 - Mechanical and electrical
- Information to be documented
 - Date and location of test
 - System or equipment tested
 - Method of testing
 - Results of the test
 - Witnesses to the test, signed by each
- O&M manuals

Test	System	Date	Method	Results	Tested by	Witnessed
Fire Protect.	Fire Alarm, Fire Sprinkler	6/3/10	Alarm, Smoke	OK	John Smith Fire Marshall	<i>JLS</i>
Plumbing Vents, Drains	Plumbing	3/23/10	Hydrostatic Pressure	OK	Fred Johnson Plumbing Inspector	<i>FJ</i>
Pumps	Plumbing, Fire Sprinkler	5/2/10	Pressure, Flow	OK	Ole Olsen Pump Rep.	<i>OO</i>
Fans	HVAC	5/10/10	Speed, Blade angle	OK	N.T. Jones Fan Rep.	<i>NTA</i>
Temperature Controls	HVAC	5/13/10	Calibration, computer chk	OK	R.T. Andrews Temp. Cont. Rep.	<i>RTA</i>
Elevator	Elevator	4/2/10 5/8/10	Complete	No OK	O. McCarthy State Elevator Inspector	<i>OJM</i>