Final: Total 200 points (3-hour exam)

[Engineering Economics]

IRR Calculation [15 points]

One alternative for improving a company's operations is to do nothing for the next 2 years and then spend $10,000 on operations. If this course of action is followed, the following cash flow will result:

End of Year	Cash Flow
0	+ $3000
1	$0
2	- $10,000
3	+ $2000
4	+ $2000
5	+ $2000
6	+ $2000

What rate of return can be expected from this cash flow? And under what condition would this proposal be attractive?

Solution:

IRR	Net Present Worth
0%	+ $1000
9.4%	$0
10%	- $25
20%	- $350
30%	- $353
40%	- $215
50%	- $2
51%	$0

According to the results of mathematical calculation, the proposal is attractive when the external rate of return is below 9.4% or above 51%. However, 51% of interest rate is not realistic. This means that IRR method has flaw of having more than one rate in some cases and this flaw should be considered in making decisions.

[Project Evaluation and Selection]

Challenger-Defender Method (Incremental Method) [20points]

You have three alternative plans of operation for the next 6 years. All transactions occur in the beginning of the year. (Interest Tables and Formulas are attached at the end.)

1) Plan A: Do nothing for first 2 years and invest $10,000 in the third year. This will yield an annuity of $3,200 starting in the 4th year until the 7th year.
2) Plan B: Do nothing this year and invest $7,000 next year. The annuity will be $1,800 from the 3rd year to the 7th year.
3) Plan C: Invest $8,000 now and earn an annuity of $1,200 starting in the 2nd year.

The minimum attractive rate of return is 8%. Which plan would you choose?

Answers:

Year	**Transaction Point on Cash Flow Diagram**	**Cash Flow**		
		Plan A	**Plan B**	**Plan C**
1st	0	0	0	- 8,000
2nd	1	0	- 7,000	+ 1,200
3rd	2	- 10,000	+ 1,800	+ 1,200
4th	3	+ 3,200	+ 1,800	+ 1,200
5th	4	+ 3,200	+ 1,800	+ 1,200
6th	5	+ 3,200	+ 1,800	+ 1,200
7th	6	+ 3,200	+ 1,800	+ 1,200

Step 1:

PV (Plan A) = – 10,000 (P/F, 8%, 2) + 3,200 (P/A, 8%, 4)(P/F, 8%, 2)
= – 10,000 * 0.8573 + 3,200 * 3.3121 * 0.8573 = $513 → OK

PV (Plan B) = – 7,000 (P/F, 8%, 1) + 1,800 (P/A, 8%, 5)(P/F, 8%, 1)
= – 7,000 * 0.9259 + 1,800 * 3.9927 * 0.9259 = $173 → OK

PV (Plan C) = - 8,000 + 1,200 (P/A, 8%, 6) = - 8,000 + 1,200 * 4.6229 = - $2452 → Reject!

Step 2:

Compare the amount of investment (ignore the different timing of investment): B < A

Year	**Transaction Point on Cash Flow Diagram**	**Cash Flow**
		B→A (A – B)
1st	0	0
2nd	1	+ 7,000
3rd	2	- 11,800
4th	3	+ 1,400
5th	4	+ 1,400
6th	5	+ 1,400
7th	6	+ 1,400
PV		**340**
Decision		**A**

PV (B→A) = 7,000 (P/F, 8%, 1) – 11,800 (P/F, 8%, 2) + 1,400 (P/A, 8%, 4) (P/F, 8%, 2)
= 7,000 * 0.9259 – 11,800 * 0.8573 + 1,400 * 3.3121 * 0.8573 = $340

→ Going from B to A is good, **Choose A**

Final Choice is A

Decision Tree [20 points]

A project manager is planning an activity that requires use of a crane. He has two alternatives; a medium size crane or a large size crane. The rent is $10,000 for the medium sized one and $15,000 for the large one. Because of its greater capacity, the large crane can accomplish the activity faster, therefore the probability of the work being delayed is lower.

Type of Crane to Choose	Rent	Probability of being delayed
Medium	$10,000	0.3
Large	$15,000	0.2

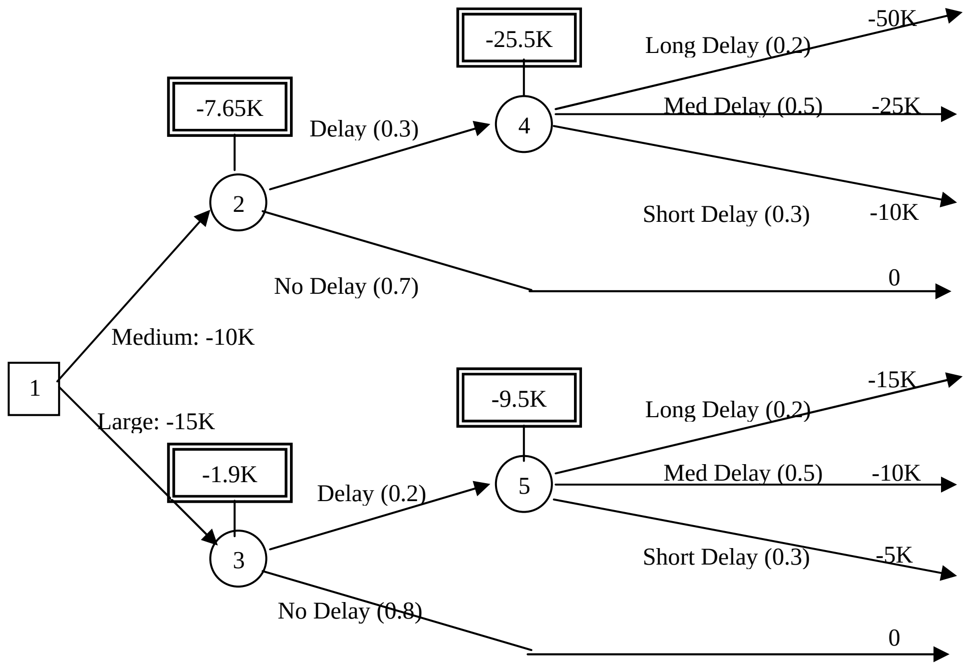
Once the work is delayed, no matter which crane is used, the probability that the delay becomes ‘long delay’ is 20%. The probabilities that the delay becomes ‘medium delay’ and ‘short delay’ are 50% and 30%, respectively. The costs of delay are different for the types of cranes. The costs of the delay will also vary depending on the types of the delay. This information is tabulated below.

Crane Type	Type of Delay	Probability	Cost of Delay
Medium	Long Delay	0.2	$50,000
	Medium Delay	0.5	$25,000
	Short Delay	0.3	$10,000
Large	Long Delay	0.2	$15,000
	Medium Delay	0.5	$10,000
	Short Delay	0.3	$5,000

(a) Which crane size should the project manager choose? Develop the decision tree and calculate the EV (Expected Value) for each crane. Please make it clear what are the decision nodes and chance nodes.

(b) Discuss your solution; which variable, when changed, is most likely to lead to the opposite result or decision? Limit your answer to 2-3 sentences.

Decision Tree Diagram:



Calculation:

EMV	Calculation	Choice
Chance Node 4	- 50 * 0.2 – 25 * 0.5 – 10 * 0.3 = - 25.5K	Total Cost for Medium: $17,650 Total Cost for Large: $16,900 **→ Choose Large Crane!**
Chance Node 5	- 15 * 0.2 – 10 * 0.5 – 5 * 0.3 = - 9.5K	
Chance Node 2	- 25.5 * 0.3 + 0 * 0.7 = - 7.65K	
Chance Node 3	- 9.5 * 0.2 + 0 * 0.8 = - 1.9K	
Decision Node 1	Medium: -10K – 7.65K = - 17.65K	
	Large: -15K –1.9K = - 16.9K	

EV of Perfect Information [20 points]

You are planning to construct a vacation house on land you've recently purchased. You are expecting to make profits by renting the house.

Then you learned that there would be a 10 % chance of a mudslide in that area within five years after construction. In case of a mudslide, you are responsible for fixing any damage to the property.

You have two choices to make; (1) you spend extra $ to harden the ground around the house and reduce the damage in case of a mudslide or (2) just ignore the chance of a mudslide. The damage will be greater in the latter case.

The profits for the alternatives are tabulated below.

	Mudslide (0.1)	No mudslide (0.9)
(1) Extra ground work in addition to house	$40,000	$50,000
(2) No extra ground work, only house	- $20,000	$70,000

(a) Which alternative would you choose?

(b) Suppose you can get perfect information about whether there will be a mudslide within five years, by going to a consultant. But there is a consulting fee of $ 5,000. Would you pay the consultant to get the perfect information?

Answers:

(a) Calculate EV's for each option and compare them.

EV(Alt.1) = 40,000 * 0.1 + 50,000 * 0.9 = 49,000
EV(Alt.2) = -20,000 * 0.1 + 70,000 * 0.9 = 61,000

Choose the one that gives the bigger EV. → **Alternative 2**

(b) Calculate the EV when you have the perfect information. If you know there will be a mudslide for sure, you will choose the option (1). If you know there will be no mudslide for sure, you will choose the option (2).

EV (Perfect Info) = 40,000 * 0.1 + 70,000 * 0.9 – 5,000 = 67,000 – 5,000 = 62,000

Compare this EV with the EV when you have no perfect information;

EV (No Info) = 61,000 < EV (Perfect Info) = 62,000 → **Pay the consultant!**

[Scheduling]

CPM with Lead-Lag Relationships [15 points]

(a) For the following activities, draw AON and find the ES, EF, LS, LF, TF, and FF. Record your answers neatly in a table. Identify critical paths. [5 points]

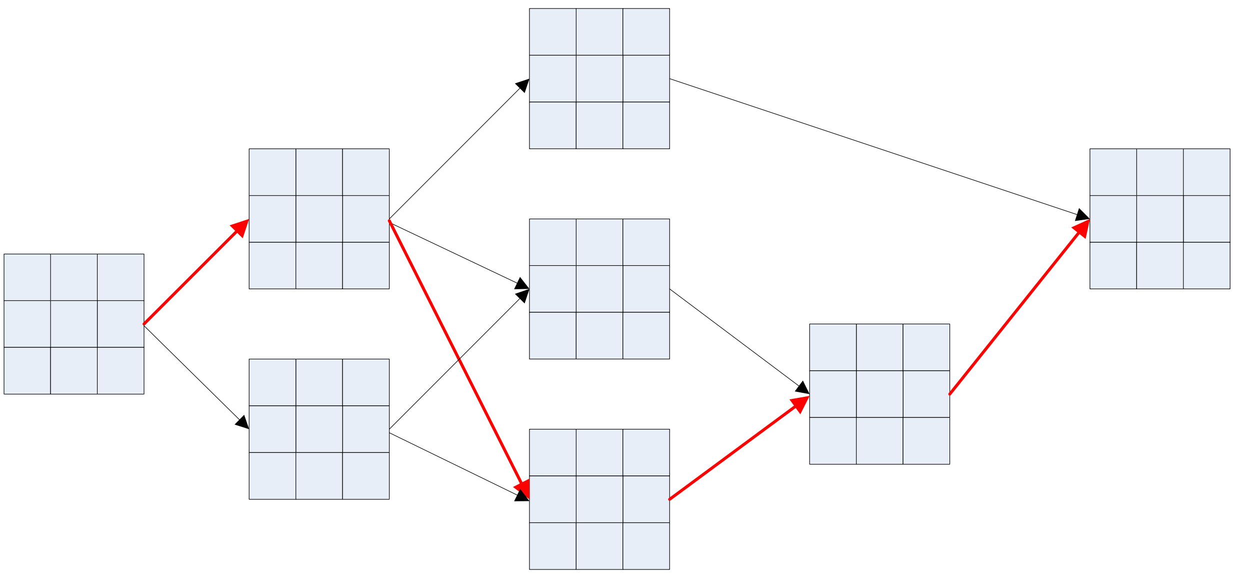
Activity	Predecessor	Duration
A	-	3
B	A	5
C	B	10
D	A	4
E	B, D	5
F	B, D	7
G	E, F	6
H	C, G	2

(b) The contractor reviewed the schedule of (a) and added following lead-lag relationships: (1) Activity E still follows B and D but needs to wait 2 days after D finishes to be able to begin, (2) G can start as soon as 5 days after F's start allowing concurrency, and (3) C needs to be completed at least 3 days before H finishes.

Draw AON and find the ES, EF, LS, LF, TF, and FF and record them neatly in a table. Identify critical paths. Describe the differences specifically and concisely. What is the managerial implication of the changes resulting from the lead-lag relationships? [10 points]

Answers:

(A) AON



CP: A-B-F-G-H

Activity	ES	EF	LS	LF	TF	FF
A	1	4	1	4	0	0
B	4	9	4	9	0	0
C	9	19	12	22	3	3
D	4	8	5	9	1	1
E	9	14	11	16	2	2
F	9	16	9	16	0	0
G	16	22	16	22	0	0
H	22	24	22	24	0	0

9

3 C

12 10

4 9

0 B 0

9

4 5 9

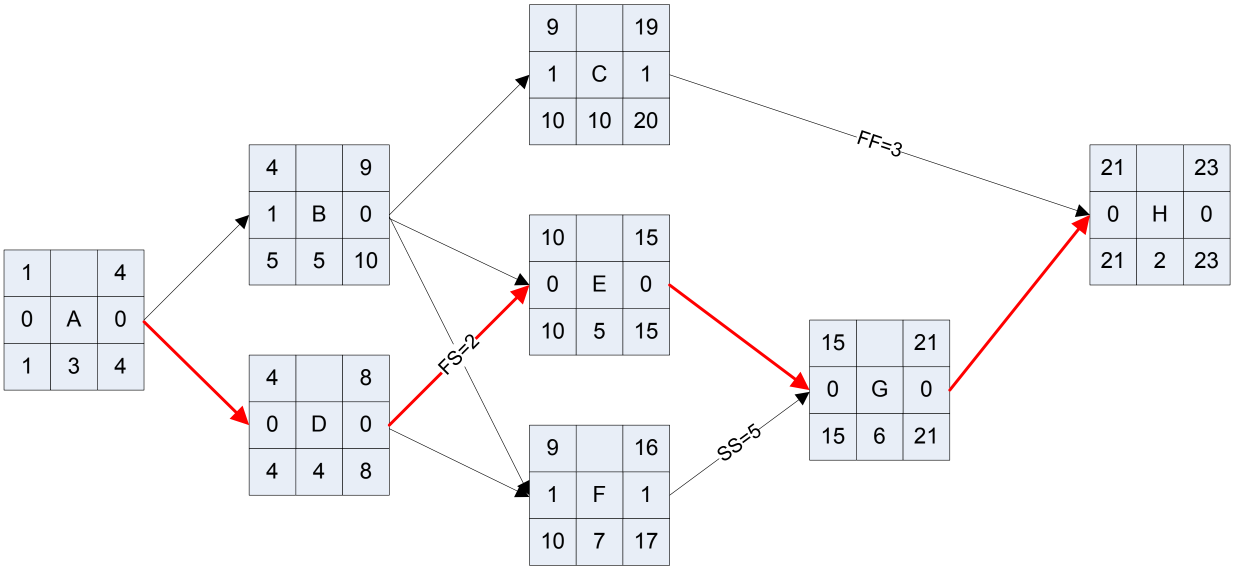
1 4

2 E

0 A 0

11 5

(b) AON



CP: A-D-E-G-H

Activity	ES	EF	LS	LF	TF	FF
A	1	4	1	4	0	0
B	4	9	5	10	1	0
C	4	8	4	8	0	0
D	9	19	10	20	1	1
E	10	15	10	15	0	0
F	9	16	10	17	1	1
G	15	21	15	21	0	0
H	21	23	21	23	0	0

Discussion:

CP has changed from ABFGH to ADEGH. Total duration has reduced from 23 days (finishing date is 24) to 22 days (finishing date is 23). This reduction was mainly because the SS relationship between F and G allowed overlapping of 2 days although FS=2 between D and E canceled out the possible full 2 day reduction. Now the new schedule has less flexibility; total floats of all paths have decreased. All paths are now near critical. C also became critical due to the FF relationship. More attention and care should be taken by management to stay on time.

[Estimating the Durations of Activities]

Learning Curve Effect [20 points]

A task is to be repeated 6 times in a project. Its duration is estimated to be 100 work-hours for the first time if performed by a single worker. The task has a 90% learning curve. Indicate the work-hours by one decimal number.

(a) What is the estimated duration of the task considering the effect of the learning curve?

(b) What if the task is done by two workers? What would be the estimate of their total duration?

(c) Now consider the single worker case. You've just acquired some information that the task might have to be stopped after the 3rd repetition of the work. The work can be resumed after 30 work-hours. However, because of this stoppage, the worker will lose job rhythm. Therefore when he comes back to the site and starts 4th repetition, he will only have the productivity equal to having finished the first repetition.
Knowing this condition, what would be your estimate of duration for this task?

(d) How many hours can be accounted for by the loss of productivity due to stoppage of work in situation (c)?

Formulas:

$$\beta = \log_{10} L / \log_{10} 2$$

$$T_N = T_1 \times N^{\beta}$$

Answers:

$L = 0.9$ and $T_1 = 100$
$\beta = \log_{10} 0.9 / \log_{10} 2 =$ **-0.152**
$T_N = T_1 \times N^{-0.152}$

# of Repetition	Question (a)		Question (b)		Question (c)	
	Equation	Work Hours	Equation	Work Hours	Equation	Work Hours
1st	-	100	*(Worker 1)*	100	-	100
2nd	$100 * 2^{-0.152}$	90	$100 * 2^{-0.152}$	90	$100 * 2^{-0.152}$	90
3rd	$100 * 3^{-0.152}$	84.6	$100 * 3^{-0.152}$	84.6	$100 * 3^{-0.152}$	84.6
		Ø		Ø		30
4th	$100 * 4^{-0.152}$	81	*(Worker 2)*	100	$100 * 2^{-0.152}$	90
5th	$100 * 5^{-0.152}$	78.3	$100 * 2^{-0.152}$	90	$100 * 3^{-0.152}$	84.6
6th	$100 * 6^{-0.152}$	76.2	$100 * 3^{-0.152}$	84.6	$100 * 4^{-0.152}$	81
Total		**510.1**		**549.2**		**560.2**

(d) Lost Hours due to Loss of Productivity = 560.2 – 510.1 – 30 = **20.1 work-hours**

Learning Curve Effect Concept [5 points]

Why is the concept of ‘Learning Curve Effect’ important to Contractors?

Either one of these will get full credit:

- For better planning and scheduling
- For proper resource leveling
- For measuring Impacts of Changes (Disruptions) to (1) re-plan the work when there is disruption and (2) to measure the loss of productivity (impact of changes) and get compensation for that from owner.

[Project Control]

Earned Value Analysis [35 points]

Using the data below, evaluate his project’s earned value status as of the beginning of day 16 and the beginning of day 25. All dates represent the beginning of the day.

(a) Depict the project status graphically. How is this project trending? Do you think the project will finish on budget? Discuss your analysis. All dates represent the beginning of the day. [30 points]

(b) Calculate FAC (EAC) using the data from the day 16. There are two different methods for FAC calculation. Apply both of them and compare the results. [5 points]

Activity	Planned Dates		Total Cost	Budgeted Unit Cost
	Start	Finish		
A	1	10	$18,000	$2,000/day
B	8	18	$15,000	$1,500/day
C	12	28	$40,000	$2,500/day
D	16	30	$28,000	$2,000/day
Total	1	30	$101,000	

As of Beginning of Day 16

Activity	Actual or Forecasted* Dates		Actual Cost Spend-to-Date	% Complete
	Start	Finish		
A	1	9	$20,000	100%
B	7	17*	$13,000	90%
C	11	23*	$22,000	50%
D	16	28*	$0	0%
Total	1	28*	$55,000	

As of Beginning of Day 25

Activity	Actual or Forecasted* Dates		Actual Cost Spend-to-Date	% Complete
	Start	Finish		
A	1	9	$20,000	100%
B	7	18	$15,000	100%
C	11	29*	$35,000	80%
D	16	31*	$18,000	60%
Total	1	31*	$88,000	

Answers:

Part (a)

SV = BCWP – BCWS   CV = BCWP – ACWP

As of Beginning of Day 16

Activity	BCWS	ACWP	BCWP	SV	CV
A	$18,000	$20,000	$18,000	$0	- $2,000
B	$12,000	$13,000	$13,500	+ $1,500	+ $500
C	$10,000	$22,000	$20,000	+ $10,000	- $2,000
D	$0	$0	$0	$0	$0
Total	$40,000	$55,000	$51,500	+ 11,500	- $3,500

SI = BCWP / BCWS = $51,500 / $40,000 = 1.29 → Ahead of Schedule
CI = BCWP / ACWP = $51,500 / $55,000 = 0.94 → Over Budget

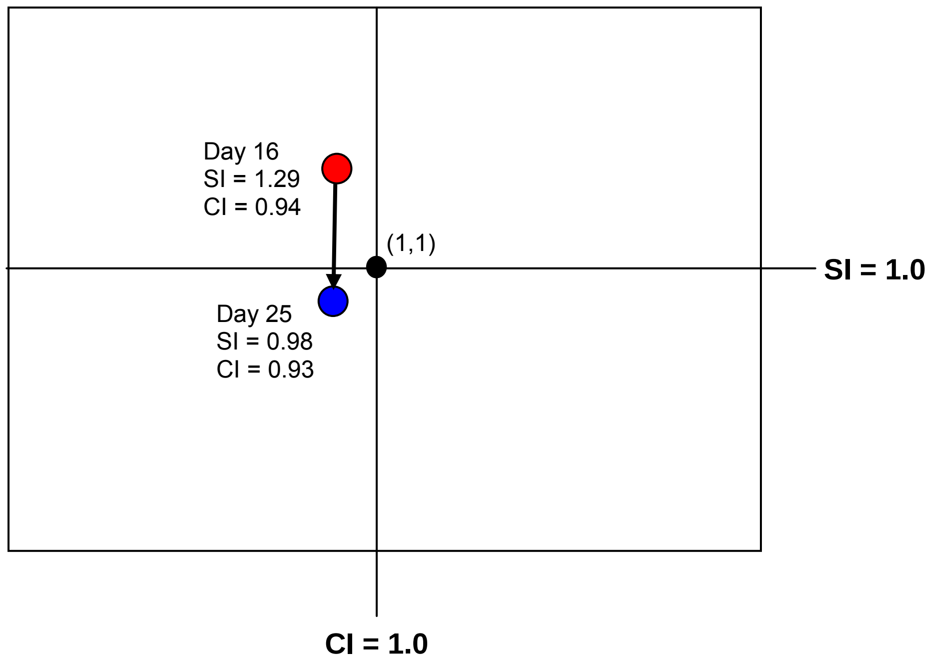
As of Beginning of Day 25

Activity	BCWS	ACWP	BCWP	SV	CV
A	$18,000	$20,000	$18,000	$0	-$2,000
B	$15,000	$15,000	$15,000	$0	$0
C	$32,500	$35,000	$32,000	-$500	-$3,000
D	$18,000	$18,000	$16,800	-$1,200	-$1,200
Total	$83,500	$88,000	$81,800	-$1,700	-$6,200

SI = BCWP / BCWS = $81,800 / $83,500 = 0.98 → Slightly Behind Schedule (Almost on Time)
CI = BCWP / ACWP = $81,800 / $88,000 = 0.93→ Over Budget

Discussion:

The project goes from being over-budget but ahead of schedule to being still over-budget and slightly behind schedule. In overall, the project status got worse. There was no big change in the cost status. Unless special measures or managerial actions are taken, the project will be completed over budget.



*Another type of graph can be used, which was introduced both in class and the review session.

Part (b)

BAC (Budget at Completion) = Original Budget for the Project = $101,000

Method #1: FAC = ACWP + (BAC – BCWP) = 55,000 + (101,000 – 51,500) = **$104,500**
Method #2: FAC = ACWP + (BAC – BCWP)/CI = 55,000 + 49,500/0.94 = **$107,660**

Reflecting the relative deviation of cost of work completed, method #2 shows the result of higher total cost prediction. In other words, when using method #2, we assume that the past cost performance (deviations) is a good predictor of the cost deviations in the remaining work.

[Changes and Disputes]

Pricing of Changes [10 points]

(a) What is forward pricing?
(b) What is force account?

**** For all descriptive answers, you will get the full credits if you describe the main ideas and issues correctly. That is, the answers don't need to be exactly same as the answers provided here.***

According to Bartholomew;

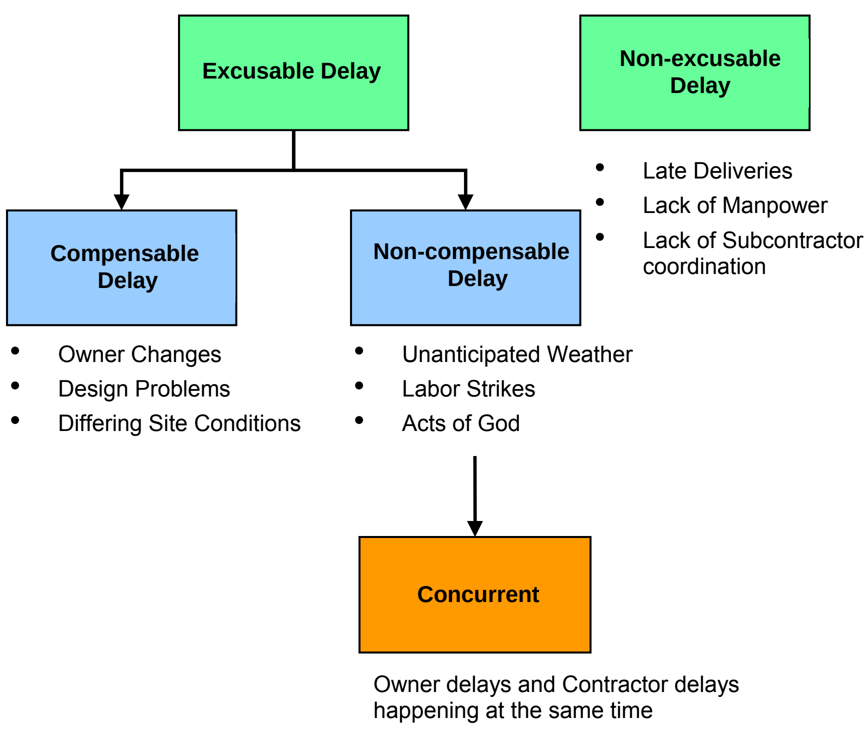
(a) If the contractor and owner agree on the price and time requirement for the changed or additional work before starting performance of the change, the change is said to be forward priced. Under fixed-price contracts, the contractor assumes the full financial risk of performance in the same manner as for the original contract when changes are forward priced.

(b) Force account is a particular form of retrospective pricing in which the contract spells out a specific procedure for arriving at the price adjustment when the contractor and the owner fail to agree on the price by forward pricing. When force account is used, daily records are kept of labor, material, and equipment usage expended on the changed work by the general contractor and all subcontractors involved. The records are agreed upon daily and signed by representatives of both owner and contractor.

Types of Delay [15 points]

List the types of delay and describe the conditions that determine the types.

Answer:



Answer can be narrative.

Constructive Changes [15 points]

(a) What is a constructive change? When it occurs?
(b) What is a contractor supposed to do in this situation?
(c) What are the two elements that must be proved to establish a constructive change?

According to Bartholomew;

(a) A constructive change is a change that is not acknowledged by the owner as such when it occurs, but which nonetheless is a change. In this situation, the owner takes the position that whatever the contractor is directed to do or is prevented from doing is not a change, but rather is required or prohibited by the original contract, as the case may be.

(b) In these situations, the contractor is required to proceed according to the owner's instructions but is free to assert and later attempt to prove that the owner's instructions constituted a change order. If the contractor is correct, court will deem that a constructive change has occurred, and the contractor will be awarded the costs incurred plus a reasonable profit thereon.

(c) First the change element must be proved. The court must be convinced that a true change occurred in the work or requirements of the contract. Second, the order element must be proved. This is established entirely by the owner's acts or words, either written or oral. There must have been an actual order or directive to the contractor or a course of conduct by the owner that had the practical effect of such an order or directive.

[Insurance and Bonds]

Bid Bond and Performance Bond [10 points]

(a) What is bid bond? Who provides it and why?
(b) What is performance bond? Who buys it? And whom does it protect from what?

According to Bartholomew;

(a) Owners want the assurance that the bidding contractor who is awarded the contract will accept and sign it and will furnish all insurance policies and additional surety bonds required by the bid documents. If the successful bidder refuses to sign the contract, the owner must accept a higher price or re-bid the project. Neither alternative is desirable. The bid bond protects the interests of the owner against this potential loss. Contractors must provide the bid bond when they bid for the project.

(b) Owners naturally want assurance that, once they have awarded a contract, the contractor will perform according to the contract's terms. Therefore, owners require contractors buy the bond to protect themselves.