Kim Building Construction Project—Critical Path Modeling, Crashing, Sensitivity Analysis, and Time-Cost Curve

ENCE360
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Overview

- Introduction
- Objectives
- Course Concepts
- Description of Project
- Problems Encountered
- Future Considerations

Introduction

- Jeong H. Kim Engineering Building
  - 155,000 square foot project
  - 16 research labs
  - 6 educational labs
  - 12,000 square foot clean room.

    =
  - One of the most advanced engineering facilities in the entire nation!

Objectives

- Critical Path Modeling
- Crash Analysis
- Sensitivity Analysis
- Create Time-Cost Curve

Using linear programming software

- Lindo
- Microsoft Excel

Course Concepts

- Project Networks
  - AOA
  - AON
- Critical Path
  - Activities with 0 slack
- Time-Cost Tradeoff
- Minimizing Project Duration
  - x_f-x_i

What did we do?

- Acquired data from similar building from UCLA
- Created AOA schedule
- Solved for Critical Path in Lindo
- Analyzed Effects of Crashing
- Analyzed Sensitivity in Excel
- Created Time-Cost Curve

Data

Letter	Activity	Duration (months)	Preceding Activities	Cost ($millions)	Crash Time (months)	Crash Cost ($Million/Month)
A	Preliminary Plans	10	None	2	2	0.3
B	SPWB Review	2	A	0.25	0.25	0.2
C	Working Drawings	16	B	1.5	3	1.4
PHASE 1						
D	Agency Review 1	2	A,B	0.5	0	N/A
E	DOF WD Review 1	1	D	1	0	N/A
F	Bid/Award 1	3	E	0.5	1	0.5
G	Construction 1	24	F	17	5	1.1
H	Closeout 1	2	G	1.75	0.25	2
PHASE 2						
I	Agency Review 2	2	F	0.25	0	N/A
J	DOF WD Review 2	1	I	0.75	0	N/A
K	Bid/Award 2	3	J	0.5	0.5	0.5
L	Construction 2	28	K	21	7	1.3
M	Closeout 2	2	L	3	0.5	2

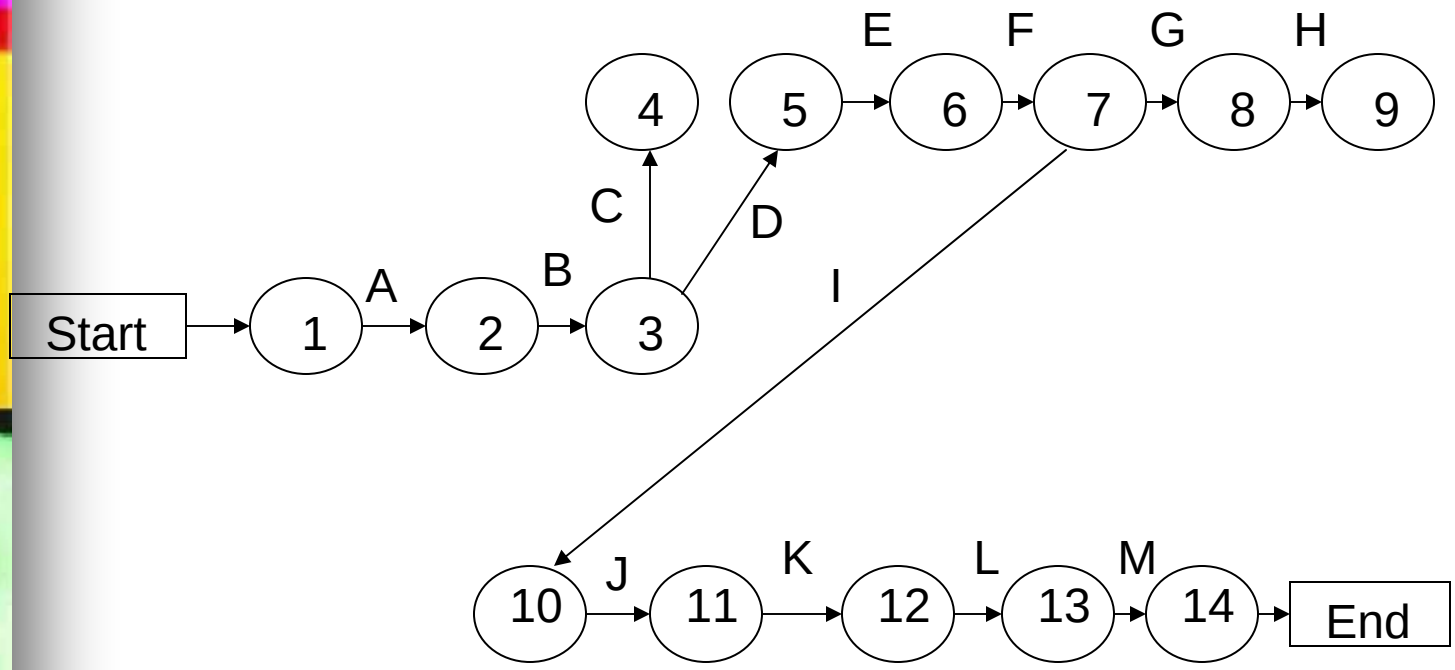
Bar Chart

ACTIVITY	NO OF MONTHS	FY 2004-05	FY 2005-06	FY 2006-07	FY 2007-08	FY 2008-09	FY 2009-10	FY 2010-11
Preliminary Plans	10							
SPWB Review	2							
Working Drawings	16							
PHASE 1 Construction								
Agency Review	2							
DOF WD Review	1							
Bid/Award	3							
Construction	24							
PHASE 2 Construction								
Agency Review	2							
DOF WD Review	1							
Bid/Award	3							
Construction	24							
Cumulative Calendar Months	58							

Prepared by: _____

Title: Natalie Shivers, Director

AOA Schedule



Lindo Code

```
min = x14-x1;
x2-x1>=10;
x3-x2>=2;
x4-x3>=16;
x5-x3>=2;
x6-x5>=1;
x7-x6>=3;
x8-x7>=24;
x9-x8>=2;
x10-x7>=2;
x11-x10>=1;
x12-x11>=3;
x13-x12>=28;
x14-x13>=2;
end
```

LP Objective-Minimize the time from the end of the last activity to the start of the first activity

Time constraints for each activity.

Lindo Output

Objective value:	54.00000	
Total solver iterations:	0	
Variable	Value	Reduced Cost
X14	54.00000	0.000000
X1	0.000000	0.000000
X2	10.00000	0.000000
X3	12.00000	0.000000
X4	28.00000	0.000000
X5	14.00000	0.000000
X6	15.00000	0.000000
X7	18.00000	0.000000
X8	42.00000	0.000000
X9	44.00000	0.000000
X10	20.00000	0.000000
X11	21.00000	0.000000
X12	24.00000	0.000000
X13	52.00000	0.000000
Row	Slack or Surplus	Dual Price
1	54.00000	-1.000000
2	0.000000	-1.000000
3	0.000000	-1.000000
4	0.000000	0.000000
5	0.000000	-1.000000
6	0.000000	-1.000000
7	0.000000	-1.000000
8	0.000000	0.000000
9	0.000000	0.000000
10	0.000000	-1.000000
11	0.000000	-1.000000
12	0.000000	-1.000000
13	0.000000	-1.000000
14	0.000000	-1.000000

The project will take 54 months!

Thus, Activities A, B, D, E, F, J, K, L, M are on the critical path

(Dual Price=-1)

Crashing the Project

- Change constraint
  - $x_f - x_i < 54$ months
  - Decrease one month each cycle
- Determine cost at each cycle

Lindo Code

The objective function includes coefficients that refer to the cost to crash an activity by one time unit and a letter that corresponds to an activity.

```
min = .3*A + 0.2*B + 1.4*C + 0.5*F + 1.1*G + 2*H + 0.5*K + 1.3*L + 2*M;
A<=2;
B<=0.25;
C<=3;
D<=0;
E<=0;
F<=1;
G<=5;
H<=0.25;
I<=0;
J<=0;
K<=0.5;
L<=7;
M<=0.5;
x2-x1+A>=10;
x3-x2+B>=2;
x4-x3+C>=16;
x5-x3+D>=2;
x6-x5+E>=1;
x7-x6+F>=3;
x8-x7+G>=24;
x9-x8+H>=2;
x10-x7+I>=2;
x11-x10+J>=1;
x12-x11+K>=3;
x13-x12+L>=28;
x14-x13+M>=2;
x14-x1<=53;
end
```

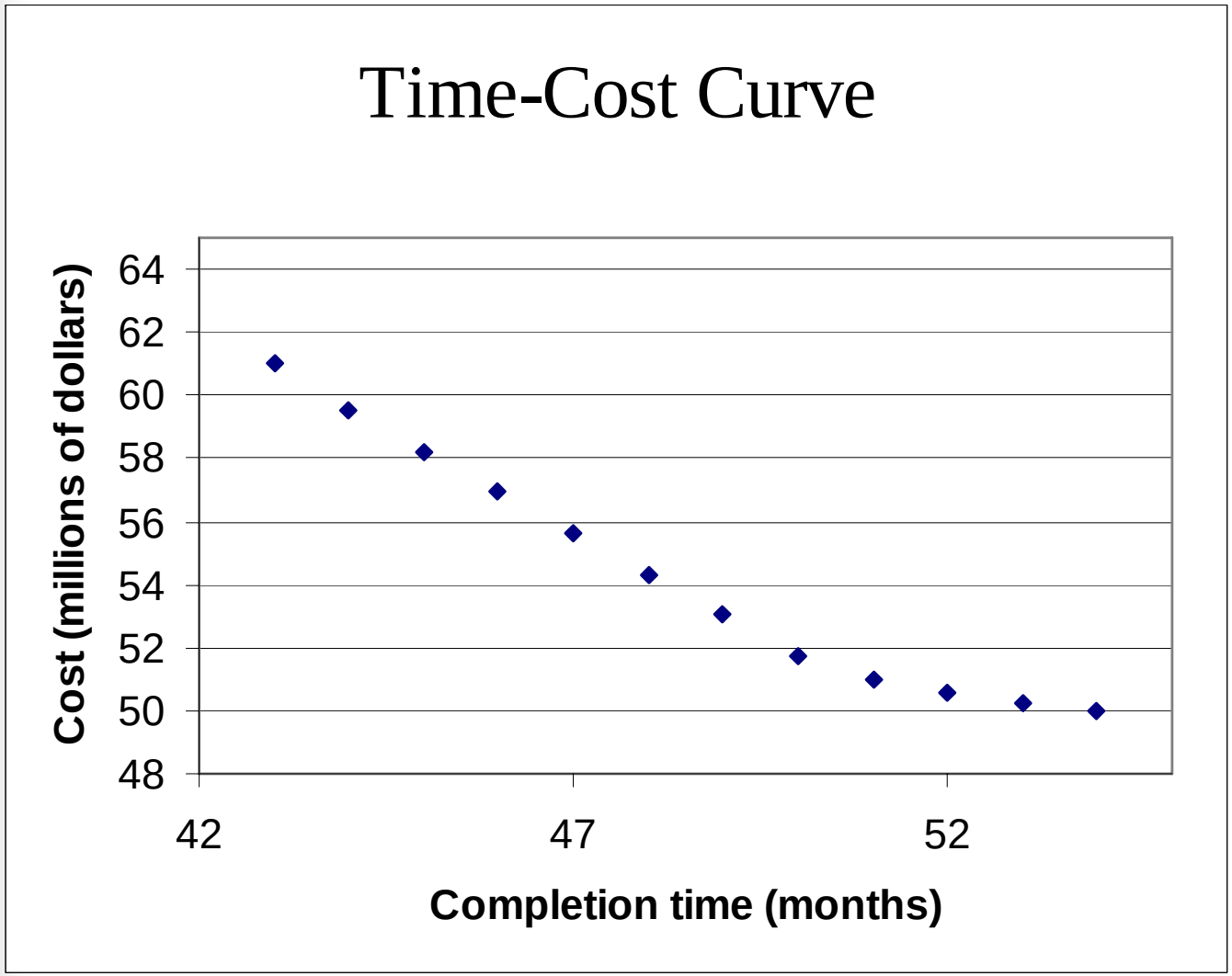
The activity crash time will be less than the maximum time it is allowed to be crashed.

(Final time-Initial time+Activity Crash Time) must be greater than or equal to the time that an activity can take.

The project must occur in 53 time units or less.

This code will output the minimum cost. After many cycles, the time-cost curve could be created!

Time-Cost Curve



Sensitivity Analysis

Activity	Current RHS (months)	Optimal Use (months)	Allowable Decrease (months)	Allowable Increase (months)	Shadow Price (months)
Preliminary Plans	10	10	2	Infinite	1
SPWB Review	2	2	0.25	Infinite	1
Working Drawings	16	16	3	Infinite	0
Agency Review 1	2	2	0	Infinite	1
DOF WD Review 1	1	1	0	Infinite	1
Bid/Award 1	3	3	1	Infinite	1
Construction 1	24	24	5	Infinite	0
Closeout 1	2	2	0.25	Infinite	0
Agency Review 2	2	2	0	Infinite	1
DOF WD Review 2	1	1	0	Infinite	1
Bid/Award 2	3	3	0.5	Infinite	1
Construction 2	28	28	7	Infinite	1
Closeout 2	2	2	0.5	Infinite	1

Conclusions

- Project will take 54 months, pending delay
- Crashing
  - Time-cost curve shows it is advantageous to keep crashing at only 3 months (< $1 million)
  - After 3 months crashed, price goes to over $1 million/month

Problems Encountered

- The data was difficult to find
  - Economic and schedule confidentiality in private projects
  - Found data from building in UCLA to make realistic predictions
- Started doing project in Excel
  - Lindo proved to be much easier to use for this project

Future Considerations

- Shorten project duration by examining resources?
  - You may find it possible to reduce the project cost by rearranging and balancing the use of workers, supplies, or equipment.
- Breakdown the crash costs into equipment and human resource costs
  - Some workers may be able to perform multiple tasks

Questions?