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The Economics Of Bidding In Project Management

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ABSTRACT

This article develops strategic decision tables to be used by management in bidding based on optimal duration costs. In addition, a process is proposed to find the optimal economic duration of the project using crashing techniques, the simplex method of linear programming, and game theory. Standardized software packages for Decision Support Systems (DSS) are used in facilitating the calculations.

Keywords: Bidding, Project Management, Linear Programming, Decision Support Systems

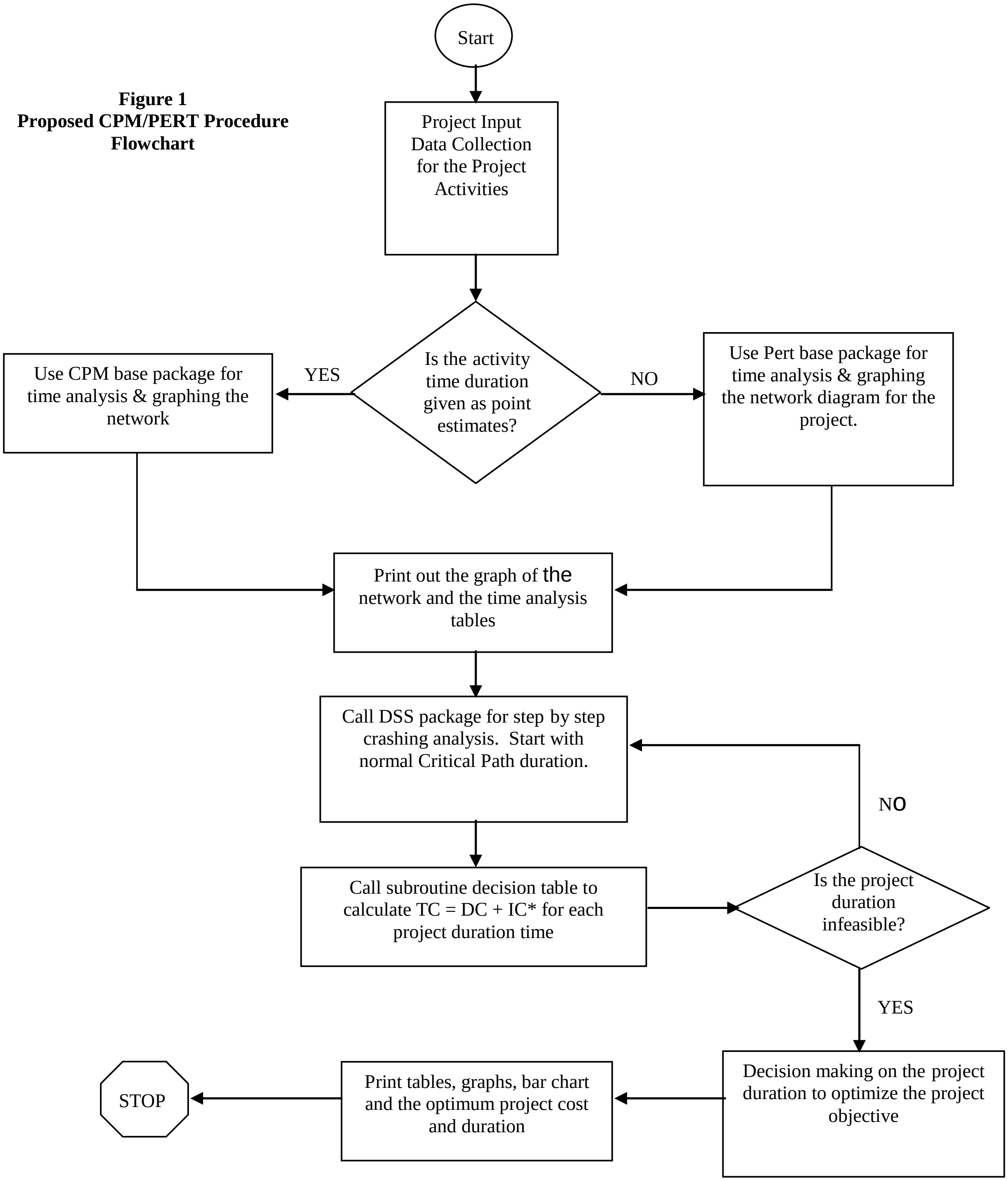
INTRODUCTION

Project Management is a very useful tool to plan, schedule and control projects. Projects can be configured as networks with a start, intermediate activities with dependencies among the activities, and an end. The Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) are two methods to analyze the networks. CPM and PERT are the basis on which software packages, called Decision Support Systems (DSS), are developed. The software packages are generally used to identify the critical path and its duration. In addition, the DSS will calculate the earliest start and finish times, the latest start and finish times, and the slack time for each given activity in the project. If the DSS has graphical capability, it can draw the program's network. Some DSS offer accounting sheets, which summarize cost information. Functionality of any given DSS is dependent upon its design features. All DSS will generally facilitate scheduling of the activities and identifying the duration of project completion time. Through the use of Program Management software and the simplex method of Linear Programming, the cost of the project, as a function of its duration, can be calculated using individual activity duration crashing techniques.

Our premise is that by using time analysis and crashing to the project duration lower limit with DSS packages, the decision maker is able to add the burden cost to the direct cost. The decision-maker can then choose the total minimum cost duration rather than critical path duration in scheduling the activities of the project. This paper deals with this phase of the analysis using software packages Quantitative Management (QM) and Decision Support Systems for Management Science/Operations Research (DSS_MSOR). In addition, the decision maker is able to prepare the total cost decision table from which the cost is a function of project duration, including the burden cost plus crashing cost and normal costs. The developed decision tables in this article are useful tools in bidding on competitive projects in different sectors of the market and they are the focus of this article. Game theory is used at this phase of the analysis to find the bidding strategies.

Shown below is a flowchart (Figure 1) and a procedure to be followed to build the strategic decision tables, the project activity schedule, the bar chart of the project activities, and the cost analysis. A new DSS package is proposed with this functionality. The illustration given in this paper will demonstrate the input data required for the proposed package. The output of the illustration was run on different packages as subroutines in the proposed package.

Figure 1
Proposed CPM/PERT Procedure Flowchart


Start
Project Input Data Collection for the Project Activities
Is the activity time duration given as point estimates?
YES
Use CPM base package for time analysis & graphing the network
NO
Use Pert base package for time analysis & graphing the network diagram for the project.
Print out the graph of the network and the time analysis tables
Call DSS package for step by step crashing analysis. Start with normal Critical Path duration.
NO
Call subroutine decision table to calculate TC = DC + IC* for each project duration time
Is the project duration infeasible?
YES
Decision making on the project duration to optimize the project objective
Print tables, graphs, bar chart and the optimum project cost and duration
STOP

* Total Cost = Direct Cost + Indirect Cost

PROPOSED PROJECT MANAGEMENT PROCEDURE

1 – List the activities that make up the project.

2 – List the immediate predecessors for each activity in the project.

3 – List the duration time(s) of each activity in the project.

- If the activity's duration time is given as point estimate, it goes directly to CPM time analysis routine.
- If the activity's duration times are given as t_o, t_m, t_p

Where: t_o = optimistic time
t_m = most likely time
t_p =pessimistic time

They should be converted to expected time, t_e, and variance, □□□ of the activity package using the formulas below before using the time analysis.

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$\sigma^2 = \left(\frac{t_p - t_o}{6} \right)^2$$

The shape of the activity's time distribution is assumed to be normal.

4 – Draw the project network diagram depicting the activities and their immediate predecessors listed in steps (1) and (2).

5 – Use the project network package to determine the total time required to complete the project, the activities' earliest start and finish times, the activities' latest start and finish time, and the activities' slack times, if any.

6 – Define the project critical path and its duration from those project activities with zero slack times where they form a continuous chain form the starting node to the project's ending node.

7 – Develop the project activities schedule using the information prepared in step (5).

8 – Using the listed information about the activities' normal and crash times and normal and crash costs given in step (3), calculate the duration project costs by reducing the normal critical path by a known decrement of time, $-\Delta t$. Start with the normal project duration calculated in step (6) and stop when the reduced project duration becomes infeasible to obtain. This would be done using a developed simplex model of Linear Programming for the project.

9 – Prepare a total cost-duration table containing direct total cost, indirect total cost, and the combined total cost with reference to the project duration time.

10 – Decide on the optimum total cost project duration with reference to the project objective function given in step (8).

STRATEGIC TABLES DEVELOPMENT

Let:

DDP/L(i, j) = Duration differential Profit / Loss at row i planned project duration and column j contract's project duration
PPD(i) = Planned project duration of row i
CPD(j) = Contract's project duration of column j
PPDC(i) = Planned project duration cost of row i
CPDC(j) = Contract's project duration of column j

Then:

DDP/L(i , j) = CPDC (J) – PPDC (i) i = 1,2,3,…..m, J = 1,2,3,….n

Where m= No. of rows , & n = No. of columns in DDP/L (i,j) matrix.

The positive DDP/L (i, j) are benefit to the bidder if the CPD (j) shifted to PPD (i). The negative DDP/L (i, j) are losses to the bidder if the CPD (j) shifted to PPL (i) (see Table 1). DDP/L (i, j) is the maximum amount the bidder is willing to pay to shift the CPD (j) to PPD (i). The negative DDP/L (i, j) will not be considered (see Table 2), due to the fact that there are losses that will be deducted from the markup profit. Table 3 gives the priorities in descending order of the positive DDP/L (i j). These three tables play a vital role in the bidding game.

According to game theory, Table 4 shows the payoff value, DDP/L (i,j), if the bidder chooses PPD (i) and the contract 's owner prefers CPD (j). Assuming Table 1 is known to both parties, the optimal strategy is that the contract's owner chooses the minmax CPD (j) value according to:

CPD (j) = Min_j. {Max_i. DDP/L(i,j) } where i = 1,2,….m, j = 1,2…..n.
and the bidder chooses the maxmin PPD (i) value according to:

PPD(i,j) = Max_i. {$\text{Min}_{j.}$ (DDP/L (i,j) } where i = 1,2,…m , j =1,…n.

Game theory is used to determine the best strategy for both parties depending on whether the game is a mixed or a pure strategy game. By submitting Table 4 (seen on page 9 following the computer's game theory package), the output will show the best combination of PPD(i), & CPD(j) and the game value DDP/L(i,j) if it is pure strategy game, or it shows the percentages of playing the project's duration strategies for both parties and the corresponding expected DDP/L(i,j) values.

ILLUSTRATION OF A PROJECT

a. Consider the following simple project:

Table 1

Activity	Immediate Predecessor
A	--
B	--
C	A
D	A
E	C,B
F	C,B
G	D,E

Table 2

Activity	Time (months)
A	4
B	6
C	2
D	6
E	3
F	3
G	5

Tables 1 and 2 show a 7-activity project. The activities A through G are preceded by a start point and culminate with an end after steps F and G are complete. Table 1 shows the precedence of the activities and Table 2 shows the normal duration time in months. We have just completed steps 1 and 2 of the Proposed Project Management Procedure.

b. Next, we move to step 3. In step 3, we identify the crash times and the costs for normal and crashed activity times. These are outlined in Table 3. These times are given as a point estimate, so we go directly to CPM. No calculation is required for expected time or the variance. This completes step (3).

Table 3

	Time (months)		**Total Cost ($000s)**	
Activity	**Normal**	**Crash**	**Normal**	**Crash**
A	4	2	50	70
B	6	3	40	55
C	2	1	20	24
D	6	4	100	130
E	3	2	50	60
F	3	3	25	25
G	5	3	60	75

c. Now we move to step 4, drawing the network diagram. This can be accomplished using 1 of 2 methods; i.e. arrow activity oriented network diagram (Figure 2) or node oriented network diagram (Figure 3). Either method is acceptable depending upon your personal preference.

Figure 2 - Activity Oriented Network Diagram

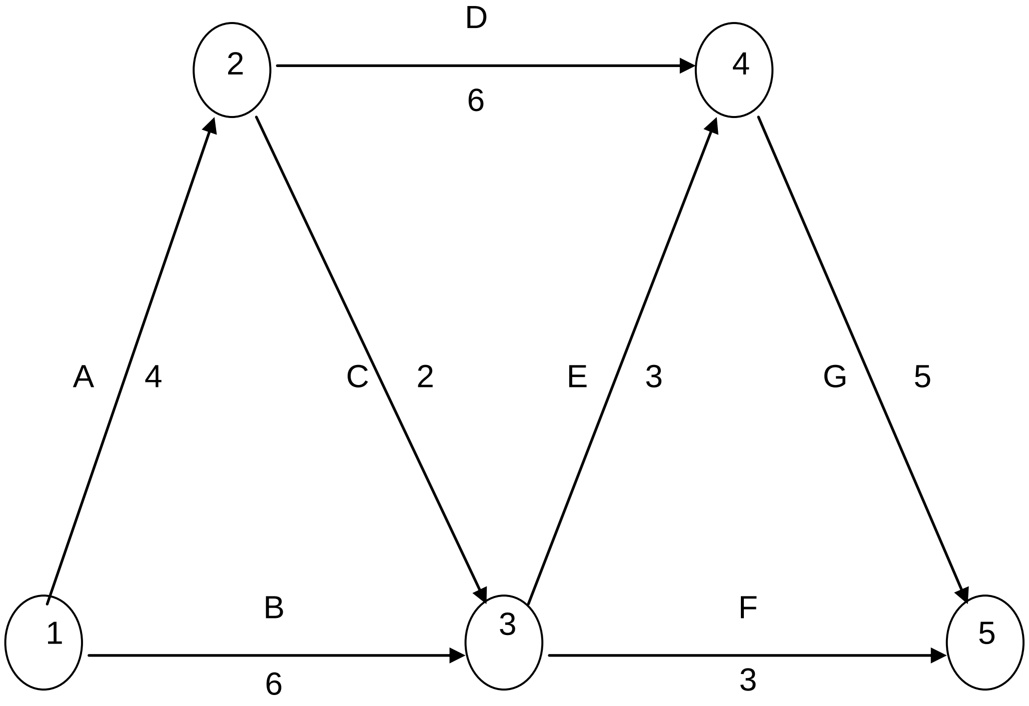
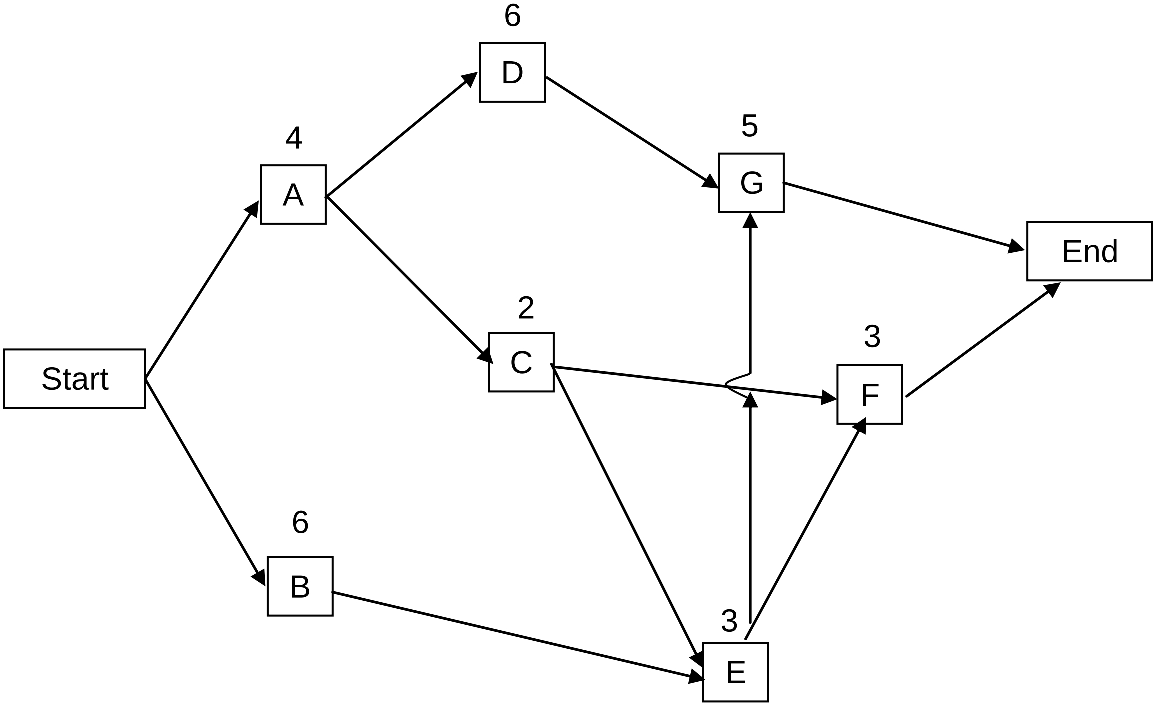


Figure 3 - Node Oriented Network Diagram



The dependencies and time for each stage of the activity oriented network diagram (CPM) or node oriented network diagram node (PERT) are available on either diagram.

c. Next are steps 5, 6, and 7. First, we must utilize a software package to compute the total time to complete the project, as well as the early and late start, early and late finish, and possible slack time for each of the activities. The DSS package "QM" was used for these computations. The input data is listed followed by the output. Activities A, B, C, D, E, F, G are activities 1, 2, 3, 4, 5, 6, and 7, respectively. Under normal conditions, the total time to complete the project is 15 months. Activities B, C, E, and F have slack time. The critical path, identified by asterisks in the output table is A D F. The QM output, or activity schedule, and critical path on the network are shown in Chart 1:

Chart 1

```
Program:  CPM/PERT / CPM
Problem Title:  Illustration without Crashing

***** Input Data *****
----------------------------------------
Activity   Start    End        Time
----------------------------------------
1       1                2        4.000
2       1                3        6.000
3       2                3        2.000
4       2                4        6.000
5       3                4        3.000
6       3                5        3.000
7       4                5        5.000
----------------------------------------
```

Chart 1 (continued)

```
***** Program Output *****
-----------------------------------------------------------------------------
         Earliest    Earliest   Latest     Latest      Slack
Activity Start(EF)  Finish(EF) Start(LF)  Finish(LF)  (LS-ES)
-----------------------------------------------------------------------------
1 *       0.000      4.000      0.000      4.000       0.000
2         0.000      6.000      1.000      7.000       1.000
3         4.000      6.000      5.000      7.000       1.000
4 *       4.000     10.000      4.000     10.000       0.000
5         6.000      9.000      7.000     10.000       1.000
6         6.000      9.000     12.000     15.000       6.000
7 *     1 0.000     15.000     10.000     15.000       0.000
-----------------------------------------------------------------------------
(* : Critical Path Activities)
Expected Completion Time :    15.000
***** End of Output *****
```

e. Now we are ready to start crashing the project. This is step 8. First, we must set up the network in the QM program, CPM With Crashing. This is a repeat of the networks illustrated above in Figures 2 and 3. The QM output, or activity schedule, and critical path on the network follow in Chart 2:

Chart 2

```
Program:  CPM/PERT / CPM With Crashing
Problem Title:  Crashing, O Months Crashed
***** Input Data *****
------------------------------------------------------------------------------
                    TIME               COST
                    -----------------  ------------------
Activity  Start   End    Normal     Crash    Normal    Crash
------------------------------------------------------------------------------
1           1      2     4.000      2.000    50.000    70.000
2           1      3     6.000      3.000    40.000    55.000
3           2      3     2.000      1.000    20.000    24.000
 4          2      4     6.000      4.000   100.000   130.000
5           3      4     3.000      2.000    50.000    60.000
6           3      5     3.000      3.000    25.000    25.000
7           4      5     5.000      3.000    60.000    75.000
------------------------------------------------------------------------------
***** Program Output *****
------------------------------------------------------------------------------
                              Crashing    Activity  Activity
Activity  Activity Nodes   Crash by    Cost       Time      Cost
------------------------------------------------------------------------------
1           1 -->  2          0.000      0.000      4.000    50.000
2           1 -->  3          0.000      0.000      6.000    40.000
3           2 -->  3          0.000      0.000      2.000    20.000
4           2 -->  4          0.000      0.000      6.000   100.000
5           3 -->  4          0.000      0.000      3.000    50.000
6           3 -->  5          0.000      0.000      3.000    25.000
7           4 -->  5          0.000      0.000      5.000    60.000
------------------------------------------------------------------------------
(* : Critical Path Activities)        0.000                        345.000
Expected Normal Completion Time:      15.000
Expected Crashed Completion Time:      15.000
***** End of Output *****
```

This is the first step in crashing. Note that the normal time is 15 months and the requested crash time is also 15 months. There are no activities that were crashed and the total cost is $345,000. This established the time and cost baseline for the project under normal conditions.

Now we start crashing, beginning with a 14-month time period. Chart 3 below shows this input and output.

Chart 3

```
Program:  CPM/PERT / CPM with Crashing
Problem Title:  Crashing, 1 Month Crashed
***** Input Data *****
---------------------------------------------------------------------
                        TIME                COST
                   -----------------   ------------------
Activity  Start   End    Normal     Crash   Normal      Crash
---------------------------------------------------------------------
1          1       2     4.000       2.000    50.000     70.000
2          1       3     6.000       3.000    40.000     55.000
3          2       3     2.000       1.000    20.000     24.000
4          2       4     6.000       4.000   100.000    130.000
5          3       4     3.000       2.000    50.000     60.000
6          3       5     3.000       3.000    25.000     25.000
7          4       5     5.000       3.000    60.000     75.000
---------------------------------------------------------------------

***** Program Output *****
------------------------------------------------------------------------------
                                Crashing    Activity    Activity
Activity  Activity Nodes        Crash by    Cost        Time         Cost
------------------------------------------------------------------------------
1 *          1 -->  2           0.000        0.000       4.000        50.000
2            1 -->  3           0.000        0.000       6.000        40.000
3            2 -->  3           0.000        0.000       2.000        20.000
4 *          2 -->  4           0.000        0.000       6.000       100.000
5            3 -->  4           0.000        0.000       3.000        50.000
6            3 -->  5           0.000        0.000       3.000        25.000
7 *          4 -->  5           1.000        7.500       4.000        67.500
------------------------------------------------------------------------------
(* : Critical Path Activities)          7.500                        352.500
Expected Normal Completion Time  :      15.000
Expected Crashed Completion Time :   14.000
***** End of Output *****
```

Note that the normal time above is 15 months and the requested crash time is 14 months. The program has identified activity 7 for crashing. The total cost has risen to $352,500, which is $7,500 greater than the non-crashed cost. Activity 7 was chosen for this example. Why is this true? It is because activity 7 has the lowest cost per month of activities on the critical path.

Using the information provided in Table 4 below, we begin next by crashing to 13 months.

Table 4

Act.	Beg	End	Normal Months	Crash Months	Normal $	Crash $	Months Available to Crash	Total Crash Delta	Crash Cost Per Month
1*	1	2	4	2	$50	$70	2	$20	$10.0
2	1	3	6	3	$40	$55	3	$15	$5.0
3	2	3	2	1	$20	$24	1	$4	$4.0
4*	2	4	6	4	$100	$130	2	$30	$15.0
5	3	4	3	2	$50	$60	1	$10	$10.0
6	3	5	3	3	$25	$25	0	$0	N/A
7*	4	5	5	3	$60	$75	2	$15	$7.5

Chart 4

```
Program:  CPM/PERT / CPM with Crashing
Problem Title: Crashing, 2 Months Crashed

***** Input Data *****
-----------------------------------------------------------------
                     TIME              COST
               -----------------   ------------------
Activity  Start   End    Normal    Crash    Normal     Crash
-----------------------------------------------------------------------
1            1     2    4.000      2.000    50.000    70.000
2            1     3    6.000      3.000    40.000    55.000
3            2     3    2.000      1.000    20.000    24.000
4            2     4    6.000      4.000   100.000   130.000
5            3     4    3.000      2.000    50.000    60.000
6            3     5    3.000      3.000    25.000    25.000
7            4     5    5.000      3.000    60.000    75.000
-----------------------------------------------------------------------

***** Program Output *****
---------------------------------------------------------------------------
                           Crashing   Activity    Activity
Activity  Activity Nodes   Crash by   Cost        Time       Cost
---------------------------------------------------------------------------
1 *        1 -->  2        0.000      0.000       4.000      50.000
2          1 -->  3        0.000      0.000       6.000      40.000
3          2 -->  3        0.000      0.000       2.000      20.000
4 *        2 -->  4        0.000      0.000       6.000     100.000
5          3 -->  4        0.000      0.000       3.000      50.000
6          3 -->  5        0.000      0.000       3.000     25.000
7 *        4 -->  5        2.000     15.000       3.000      75.000
---------------------------------------------------------------------------
(* : Critical Path Activities)        15.000                  360.000
Expected Normal Completion Time:      15.000
Expected Crashed Completion Time:  13.000
***** End of Output *****
```

As seen in Chart 4 above, the program has identified activity 7 again for crashing at a total cost of $360,000. The critical path has not changed and activity 7 has the lowest per month cost on the critical path. Now repeat the process till we reach the infeasible solution.

Now we move to 8 months and look below at Chart 5 for software output.

Chart 5

```
Program:  CPM/PERT / CPM with Crashing
Problem Title:  Crashing, 7 Months Crashed

***** Input Data *****
-----------------------------------------------------------------------
                        TIME                COST
                   -----------------   ------------------
Activity  Start   End    Normal    Crash    Normal       Crash
-----------------------------------------------------------------------
   1         1      2     4.000     2.000      50.000    70.000
   2         1      3     6.000     3.000      40.000    55.000
   3         2      3     2.000     1.000      20.000    24.000
   4         2      4     6.000     4.000     100.000   130.000
   5         3      4     3.000     2.000      50.000    60.000
   6         3      5     3.000     3.000      25.000    25.000
   7         4      5     5.000     3.000      60.000    75.000
-----------------------------------------------------------------------

***** Program Output *****
ERROR ! - illegal expected project time
  Expected project time must be less than or equal to the project time
  without crashing and greater than or equal to the minimum possible
  project time.
  Project time without crashing       =         15
  Minimum possible project time       =          9
  Input value of expected project time =         8

***** End of Output *****
```

This is the final step in crashing. The solution is 9 months because 8 months is not feasible as a requested possible solution for the given conditions.

There is one last point to analyze. Suppose we run crash times through the CPM without crashing the program in QM, we get the following output as seen in Chart 6.

Chart 6

```
Program:  CPM/PERT / CPM
Problem Title:  Illustration without Crashing

***** Input Data *****
-------------------------------------
Activity   Start    End     Time
-------------------------------------
   1          1       2      2.000
   2          1       3      3.000
   3          2       3      1.000
   4          2       4      4.000
   5          3       4      2.000
   6          3       5      3.000
   7          4       5      3.000
-------------------------------------
```

Chart 6 (continued)

```
***** Program Output *****
---------------------------------------------------------------------------
         Earliest   Earliest    Latest    Latest      Slack
Activity Start(EF)  Finish(EF)  Start(LF) Finish(LF)  (LS-ES)
---------------------------------------------------------------------------
  1 *    0.000      2.000       0.000     2.000       0.000
  2      0.000      3.000       1.000     4.000       1.000
  3      2.000      3.000       3.000     4.000       1.000
  4 *    2.000      6.000       2.000     6.000       0.000
  5      3.000      5.000       4.000     6.000       1.000
  6      3.000      6.000       6.000     9.000       3.000
  7 *    6.000      9.000       6.000     9.000       0.000
---------------------------------------------------------------------------
(* : Critical Path Activities)
Expected Completion Time :     9.000
***** End of Output *****
```

Note that we again get 9 months as the optimal solution, but we crashed one additional month in activity 5, which was unnecessary. If we would have used the given activity's fully crashed times, we would have incurred an additional $10,000 in cost. You must be sure to analyze crashing properly to determine if crashing all activities is necessary (see Table 5 below).

Table 5

Activity	Normal Months	Crash Months	Crash $	9 Month Optimal Solution Months	9 Month Optimal Solution $
1	4	2	$70	2	$70
2	6	3	$55	3	$55
3	2	1	$24	1	$24
4	6	4	$130	4	$130
5	**3**	**2**	**$60**	**3**	**$50**
6	3	3	$25	3	$25
7	5	3	$75	3	$75
Total Cost			$439		$429

This completes step 8 of the Proposed Project Management Procedure.

f. Next is step 9 - preparation of the strategic decision table (Table 6).

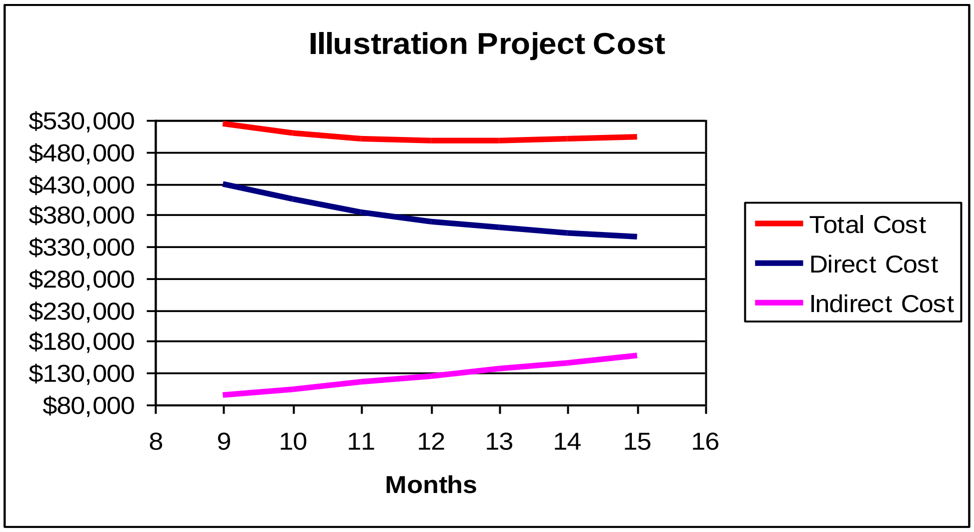
Table 6

Illustration Strategic Decision Table

Time	Direct Cost	Indirect Cost	Total Cost
15	$345,000	$157,500	$502,500
14	$352,000	$147,000	$499,000
13	$360,000	$136,500	$496,500
12	$370,000	$126,000	$496,000
11	$385,000	$115,500	$500,500
10	$405,000	$105,000	$510,000
9	$429,000	$94,500	$523,500

Indirect cost is related to the amount of time to administer the project and overhead spread to the number of project months. Indirect costs will get lower as the project time lessens. We know from the crashing analysis that direct cost will rise as the project time shrinks. This gives us a "U" shaped total cost curve (Figure 4).

Figure 4



g. Finally step (10) - the decision. Let's assume the following situation:

- Our firm is responding to a request for proposal (RFP) for a project.
- The RFP states that the project shall be completed in a minimum of 15 months, with alternate proposals accepted for a smaller amount of time.
- Our bid markup on total cost is 10%.
- We are not the only bidder.

Consider the decision table with profit information added (Table 7).

Table 7

Strategic Decision Table with Profit Information Added

Time	Direct Cost	Indirect Cost	Total Cost	Profit @ 10%	Bid Price	Alternate Bid Price	Additional Profit
15	$345,000	$157,500	$502,500	$50,250	$552,750	$552,750	$0
14	$352,000	$147,000	$499,000	$49,900	$548,900	$552,750	$3,850
13	$360,000	$136,500	$496,500	$49,650	$546,150	$552,750	$6,600
12	$370,000	$126,000	$496,000	$49,600	$545,600	$552,750	$7,150
11	$385,000	$115,500	$500,500	$50,050	$550,550	$552,750	$2,200
10	$405,000	$105,000	$510,000	$51,000	$561,000	$561,000	$0
9	$429,000	$94,500	$523,500	$52,350	$575,850	$575,850	$0

Our firm has a couple of options. If the firm is confident it would not be underbid, it could propose the alternate bid price for completion periods 11-15 and bid the higher prices for months 10 and 11. The firm would reap additional profits if the buyer accepted the proposal for months 11, 12, 13, or 14. If competition is tight and our firm needed the work, we could propose the bid price of $545,600 (the month 12 bid price) for months 12, 13, 14, and 15 and the higher bid prices for months 9, 10, and 11. If award was made at month 14, we would complete the project in 12 months in order to minimize our total cost and maximize our profit. We would have a happy customer, assuming the project was completed two months early and would have built in two months of slack. If the project takes 14 months to complete, our penalty would not be under a formal contract penalty clause with an exorbitant cost. Our "informal" penalty would be $3,000 for the increased costs (direct and indirect). There are other bid possibilities depending on the competitive situation and any unique capabilities possessed by our firm. The strategic tables (8, 9 and 10) show the other possibilities along with priorities to help the decision-makers respond favorably according to the market competitors and other contingencies. However, these tables are known only to the bidder to give them an edge over project owners and market's competitors.

Looking at Table 8 below, DDP/L(4,1) tells the decision-maker that he is willing to reduce his project cost up to $27,500 if the contract owner is willing to relax the project duration from nine months to 12 months. Table 9 is Table 8 without losses. That is, negative values of DDP/L(i,j) are dropped from Table 9 due to the fact that the strategies would reduce the mark-up profit by the shown amount. Table 8 shows the priorities of the project's duration bidding strategies in descending order of DDP/L(i,j). According to Table 5, DDP/L(4,1) has a value of $27,500. Since this value is the highest in the table, it is given priority #1. The bidder has a wide range of extra profits over and above the mark-up profit to deal with in bidding.

Table 8

Contact's Project Time,
CPT (j)

Planned Duration Time, PDT (i)	.	j	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Duration Differential Profit/Loss DDP / L (i , j)**
	i	Project Time	9	10	11	12	13	14	15	
	1	9	0	-13500	-23000	-27500	-27000	-24500	-21000	
	2	10	13500	0	-9500	-14000	-13500	-11000	-7500	
	3	11	23000	9500	0	-3500	-4000	-1500	2000	
	4	12	27500	14000	4500	0	500	3000	6500	
	5	13	27000	13500	4000	-500	0	2500	6000	
	6	14	24500	11000	1500	-3000	-2500	0	3500	
	7	15	21000	-7500	-2000	-6500	-6000	-3500	0	

Duration Differntial Profit /Loss
DD P/L (i , j)

-

Submit Table 8 to the DSS's theory of games sub-routine and the output shows that the table is a pure strategy game; it is a zero-sum game - the best combination of PPD(i), CPD(j) and the game value DDP/L(i,j). If it is not a pure strategy game, it shows the percentages of playing the project's duration strategies for both parties and the corresponding expected DDP/L(i,j) values.

The above illustration results for optimal strategies for both parties are:

PDT(12),CPT(12), & DDP/L(12,12)=0

Table 9

Contact's Project Time,
CPT (j)

Planned Duration Time, PDT (i)		j	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Duration Differential Profit/Loss DDP / L (i , j)**
	i	Project Time	9	10	11	12	13	14	15	
	1	9	0							
	2	10	13500	0						
	3	11	23000	9500	0				2000	
	4	12	27500	14000	4500	0	500	3000	6500	
	5	13	27000	13500	4000		0	2500	6000	
	6	14	24500	11000	1500				3500	
	7	15	21000						0	

Duration Differntial Profit /Loss
DD P/L (i , j)

Table 10

Contact's Project Time,
CPT (j)

Planned Duration Time, PDT (i)		j	**1**	**2**	**3**	**4**	**5**	**6**	**7**	Duration Differential Profit/Loss DDP / L (i , j)
	i	Project Time	9	10	11	12	13	14	15	
	1	9	**20**							
	2	10	**7**	**20**						
	3	11	**4**	**9**	**20**				**17**	
	4	12	**1**	**6**	**12**	**20**	**19**	**15**	**10**	
	5	13	**2**	**7**	**13**		**20**	**16**	**11**	
	6	14	**3**	**8**	**18**			**20**	**14**	
	7	15	**5**						**20**	

Duration Differntial Profit /Loss
DD P/L (i , j)

CONCLUSION

The illustrations demonstrate that the optimal solution for Project Management is not necessarily the shortest amount of time of the least "direct" project cost solution. There are possible hidden costs to consider, such as unnecessarily crashing activities or unallocated indirect costs that must be considered to identify the total project cost. These data can provide a wealth of information to managers and should be utilized to determine the project duration strategic decision table. This technique can be utilized on projects internal to the firm or in the bidding process.

AUTHOR INFORMATION

Dr. Ali Alli specializes in production and quality control, optimization techniques of distribution, project management and managerial decision making. He has worked in area recreational facilities in southeast Texas, optimization of workforce personnel at the King Abdulaziz Airport in Saudi Arabia and in projects related to controlling labor costs at CMI in Oklahoma. Professor Alli is a registered professional engineer. His teaching and research activities span a period of over 35 years. He is Professor Emeriti at Oklahoma City University

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