Baber Zafar
Operations Management
Project A: Rock’n Bands

Executive Summary

Project objective

The main objective of the project is to prepare an optimized plan for the Rock’n Bands Music Festival to guarantee its completion within ten weeks, two weeks before the start of the festival, while ensuring its maximum efficiency at the minimum possible cost.

Background

- The project is divided into twelve activities, A through K.
- The Rockn’ Bands Festival will begin in twelve (12) weeks.
- Labor is charged at $200 per worker per week for up to four (4) workers. Beyond four workers, one (1) additional worker is available at $300 per week.
- A maximum of two (2) workers may be assigned to any given task.
- Assigning a second worker to an activity will decrease the activity time by one (1) week at an additional cost of $100 over and above the labor cost of $200 per worker per week.
- A maximum of five (5) workers may be employed during any given week.
- Any delays causing the project to extend beyond the ten week completion deadline will be evaluated at a cost of $2000 per week.

The tasks of the project

- Allocate resources to activities such that the project is completed in ten (10) weeks, while keeping costs at a minimum.

Methods Used for Project Management:

- Use the Critical Path Method (CPM) to manage project. CPM assumes fixed time estimates for each activity.
- Identify precedence relationships:
  - Specify immediate predecessors and successors, given a list of projected activities.
  - Specify activity durations
- Arrange the project activities in order of execution.
- Construct an AON (Activity on Node) Project Network Diagram using START and END dummy nodes.
- Use Forward Pass to identify and specify Early Start and Early Finish Times for each activity.
  Use Backward Pass to identify and specify Late Start and Late Finish Times for each activity.
- Calculate Slack Time for each activity.
- Identify critical activities and map critical path. Activities with zero (0) slack time are critical activities. The longest path in terms of duration from START to END

is the critical path and consists of all critical activities. The critical path provides a measure of the duration of time required to complete the project.

- Conduct cost/time-value analysis and proceed to crash activities on the critical path to ensure timely completion of the project. Activities may be crashed one at a time and all paths from START to END are reviewed for duration to check for emergence of a different or another critical path. Continue cost/time-value analysis while crashing activities on one or more critical paths to ensure minimum cost.

Process

CPM assumes fixed time estimates for each activity. The introduction of START and END dummy nodes gives us a concrete beginning and end point to the project. To supplement our understanding of the timeline and duration of the project, we use the Forward Pass to estimate the earliest starting (ES) and earliest finishing (EF) times, and the Backward Pass to approximate the latest starting (LS) and latest finishing (LF) times of the activities of the project. They are calculated as follows:

Activity	Immediate Predecessor	Duration (Weeks)	ES	EF	LS	LF	Slack Time (Weeks)	Critical Activity
A	-	3	0	3	2	5	2	NO
B	C	5	2	7	3	8	1	NO
C	-	2	0	2	1	3	1	NO
D	-	3	0	3	0	3	0	YES
E	A	1	3	4	5	6	2	NO
F	D	4	3	7	3	7	0	YES
G	E	1	4	5	5	6	1	NO
H	C, D	3	3	6	4	7	1	NO
I	F, H	5	7	12	7	12	0	YES
J	E, B, H	4	7	11	8	12	1	NO
K	G	5	5	10	7	12	2	NO
L	F	2	7	9	10	12	3	NO

The Slack Time for an activity may be calculated as either LF-EF or LS-ES, both resulting in the same answer. Activities with zero (0) slack time are identified as critical activities and therefore determine the critical path and the duration of the project.

The above information in combination with the precedence relationships provided may now be used to construct a Project Network Diagram (See Appendix 1). The critical path is highlighted with a red line and the critical activities are highlighted in red.

Paths from START to END, No Crash Scenario:					
Path	**Activity and Duration**				**Total Duration**
A-E-G-K	**A**	**E**	**G**	**K**	
Duration	3	1	1	5	10
A-E-J	**A**	**E**	**J**		
Duration	3	1	4		8
C-B-J	**C**	**B**	**J**		
Duration	2	5	4		11
C-H-I	**C**	**H**	**I**		
Duration	2	3	5		10
D-F-I	**D**	**F**	**I**		Critical Path
Duration	3	4	5		12
D-F-L	**D**	**F**	**L**		
Duration	3	4	2		9

The critical path, currently, consists of the following critical activities:

START – D – F – I – END

and the duration of the project given by the current critical path is 12 weeks. Following the current critical path will result in a delay of two weeks beyond the deadline with an activity cost of $7,600 and an additional delay cost of $4,000 for a total cost of $11,600. A breakdown of the estimated cost is shown in Appendix 2. Since this duration is two weeks longer than the given deadline of ten weeks, we must crash activities, one by one, along the critical path(s) until we are able to complete the project within ten weeks.

Project Crashing

Only activities on the critical path may be crashed in order to effectively shorten the duration of the project. Since the cost of crashing is independent of activity, we may choose to crash any of them as long as the total number of workers hired simultaneously for other activities during a given week does not exceed four (4) when possible and absolutely cannot exceed five (5) and that the number of workers hired for any given activity does not exceed two (2). The cost of crashing an activity, i.e. hiring a second worker for an activity for a given week is $100 per week. However, if the total number of workers exceeds four, the company will incur an additional cost of $300 per week.

The worker allocation schedule for a No-Crashing scenario with a duration of 12 weeks given in Appendix 2 indicates that at the start of activities F and I, there are already four workers allocated during their respective starting weeks. Therefore, crashing either of the two activities by one week would result in incurring an additional direct labor cost of fifth worker of $300 over and above the labor cost of the four workers already allocated plus the cost of allocating a second worker to any activity of $100. The net savings from the allocation of the fifth worker would amount to the decrease in delay cost of $2000 per week minus the allocation cost of the fifth worker of $300 and the cost of allocating a second worker to any activity. The net savings is therefore $2000 - $300 - $100 = $1600. However, since activity D is also on the critical path, and only three workers are allocated to the starting week of activity D, the additional cost of allocating a fourth worker is only $200 plus the cost of allocating a second worker to any activity of $100, while the decrease in delay cost stays the same. Therefore, the net savings from crashing activity D instead of F or I would be $2000 - $200 - $100 = $1700. Since this is greater than the savings achieved from crashing F or I, we proceed to crash activity D by one week.

Crashing activity D on the critical path D-F-I now shortens the critical path to 11 weeks. Since this is still one week longer than the targeted deadline of 10 weeks, we need to continue to crash activities along the critical path while being sensitive to the number of workers allocated during the week in which the activity is to be crashed. We also need to observe for the emergence of new critical paths through the project network. Since the critical path is defined as the longest path through the project network, we notice that another path shares the same duration as our original critical path D-F-I after activity D had been crashed for 1 week. The path C-B-J through the project network has now become critical too. This is outlined in the table below:

Paths from START to END, Crash D by 1 Week					
Path	**Activity and Duration**				**Total Duration**
A-E-G-K	**A**	**E**	**G**	**K**	
Duration	**3**	**1**	**1**	**5**	10
A-E-J	**A**	**E**	**J**		
Duration	3	1	4		8
C-B-J	**C**	**B**	**J**		Critical Path 2
Duration	2	5	4		11
C-H-I	**C**	**H**	**I**		
Duration	2	3	5		10
D-F-I	**D**	**F**	**I**		Critical Path 1
Duration	2	4	5		11
D-F-L	**D**	**F**	**L**		
Duration	3	4	2		9

If both critical paths shared a common activity, it may be to our advantage to examine the costs and benefits of crashing such an activity. However, the two critical paths do not share any activities and a comparative analysis of crashing a common activity versus activities exclusive to a given critical path will not be included in our analysis.

The critical paths now under review are:

START – D – F – I – END
START – C – B – J – END

Crash Analysis of Critical Path: START – D – F – I – END

Activity D cannot be crashed any further since the number of workers allocated to activity D during the 1st week has already reached the maximum allowable quantity of two workers.

Activity F may be crashed during the 3rd, 4th, or 5th weeks since there is an additional 5th worker available beyond the three already allocated to other activities, and activity F has only been allocated one worker, for a total of four workers, leaving room to allocate another worker to activity F. The additional cost of this fifth worker will be $300 in direct labor costs, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity F during the 3rd, 4th, or 5th weeks would be $2000 - $300 - $100 = $1600.

Activity I may be crashed in the 7th, 8th, 9th, or 10th week. Crashing activity I during the 7th or 8th week will result in a direct labor cost of $300, the cost of allocating a 5th worker during the week, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity I during the 7th or 8th week would be $2000 - $300 - $100 = $1600. Crashing activity I during the 9th or 10th week will result in a direct labor cost of $200, the cost of an additional unit of labor given that the total number of units allocated during the week is less than 5, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity I during the 9th or 10th week would be $2000 - $200 - $100 = $1700. Since the savings resulting from crashing activity I during the 9th or 10th week are greater than the savings resulting from crashing activity I during the 7th or 8th week, we would prefer to crash activity I over the 9th or 10th week.

Since the maximum savings over this critical path are obtained when crashing activity I during the 9th or 10th week, we proceed to crash activity I by one week at the beginning of the 9th week.

The critical path START – D – F – I – END now has a duration of 10 weeks.

Crash Analysis of Critical Path: START – C – B – J – END

Activity C may be crashed in the 1st or 2nd week. Crashing activity C during the 1st week will result in a direct labor cost of $300, the cost of allocating a 5th worker during the week, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity C during the 1st week would be $2000 - $300 - $100 = $1600. Crashing activity C during the 2nd week will result in a direct labor cost of $200, the cost of an additional unit of labor given that the total number of units allocated during the week is less than 5, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity C during the 2nd week would be $2000 - $200 - $100 = $1700. Since the savings resulting from crashing activity C during the 2nd week are greater than the savings resulting from crashing activity C during the 1st week, we would prefer to crash activity C over the 2nd week.

Activity B may be crashed during the 3rd, 4th, or 5th weeks since there is an additional 5th worker available beyond the three already allocated to other activities, and activity B has only been allocated one worker, for a total of four workers, leaving room to allocate another worker to activity B. The additional cost of this fifth worker will be $300 in direct labor costs, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity B during the 3rd, 4th, or 5th weeks would be $2000 - $300 - $100 = $1600. However

Activity B may also be crashed in the 6th week. Crashing activity B during the 6th week will result in a direct labor cost of $200, the cost of an additional unit of labor given that the total number of units allocated during the week is less than 5, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity B during the 6th week would be $2000 - $200 - $100 = $1700. Since the savings resulting from crashing activity B during the 6th week are greater than the savings resulting from crashing activity B during the 3rd, 4th, or 5th weeks, we would prefer to crash activity B over the 6th week.

Activity J may be crashed in the 8th, 9th, or 10th week. Crashing activity J during the 8th week will result in a direct labor cost of $300, the cost of allocating a 5th worker during the week, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity J during the 8th week would be $2000 - $300 - $100 = $1600. Crashing activity J during the 9th or 10th week will result in a direct labor cost of $200, the cost of an additional unit of labor given that the total number of units allocated during the week is less than 5, plus the cost of $100 of allocating a second worker to an activity. Therefore the net savings in crashing activity J during the 9th or 10th week would be $2000 - $200 - $100 = $1700. Since the savings resulting from crashing activity J during the 9th or 10th week are greater than the savings resulting from crashing activity J during the 8th week, we would prefer to crash activity J over the 9th or 10th week.

Since the maximum savings over this critical path are obtained either when crashing

activity C over the 2nd week, or

activity J over the 9th or 10th week, or

activity B over the 6th week,

we proceed to crash activity J by one week at the beginning of the 10th week.

The critical path START – C– B – J – END now has a duration of 10 weeks.

Cost

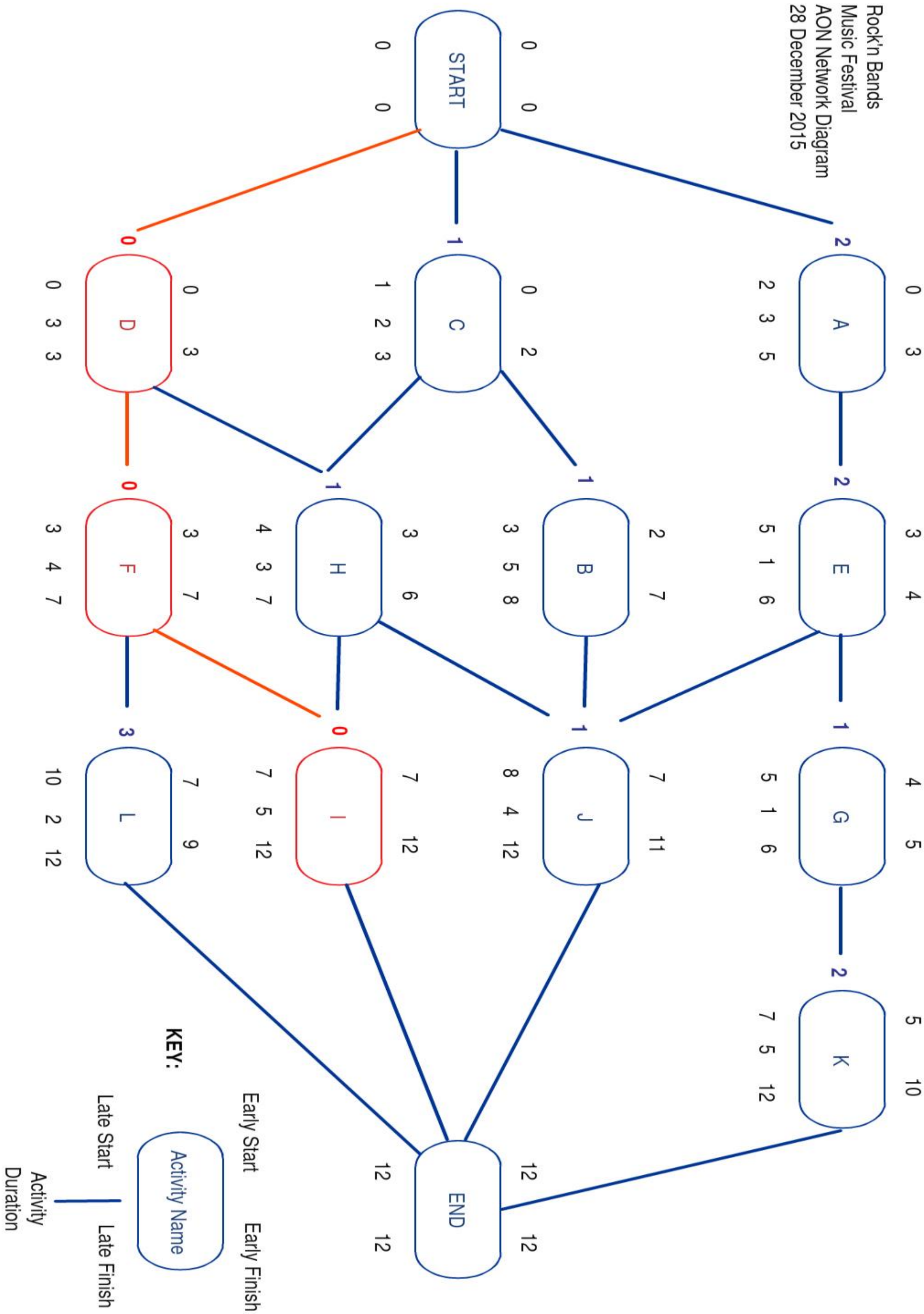
Total cost of the project is given by the sum of the activity costs, additional direct and indirect labor costs, as well as any delay costs incurred if the project duration extends beyond the ten week deadline. A summary of the cost analysis is included in the crashing schedule given in Appendix 2. The results of the analysis are summarized below.

The project cost of $11,600 when no activity is crashed is made up of $7,600 in activity costs, and $4,000 in delay costs.

The project cost of $9,700 when the first activity, activity D, is crashed is made up of $7,700 in activity costs, and $2,000 in delay costs.

The project costs of $7,800 when the second activity, activity I on the critical path D-F-I, and activity J on the critical path C-B-J, is crashed is made up entirely of activity costs since crashing the second activity reduces the duration of the project to within the required framework resulting in no delay costs.

APPENDIX 1


Rock'n Bands
Music Festival
AON Network Diagram
28 December 2015
START
A
B
C
D
E
F
G
H
I
J
K
L
END
KEY:
Early Start
Early Finish
Activity Name
Late Start
Late Finish
Activity
Duration

APPENDIX 2

No Crash Scenario

Activities	Weeks 1	2	3	4	5	6	7	8	9	10	11	12	Activity Costs	
A	1	1	1										3x200	600
B			1	1	1	1	1						5x200	1000
C	1	1											2x200	400
D	1	1	1										3x200	600
E				1									1x200	200
F				1	1	1	1						4x200	800
G					1								1x200	200
H				1	1	1							3x200	600
I								1	1	1	1	1	5x200	1000
J								1	1	1	1		4x200	800
K						1	1	1	1	1			5x200	1000
L								1	1				3x200	400
Total Workes	3	3	3	4	4	4	3	4	4	3	2	1		7600

Waiting for Predecessors	Delay Cost	2x2000	$4,000
Performing Activities	Total Cost		$11,600.00

Crash #1 - Only D

	Weeks													
Activities	1	2	3	4	5	6	7	8	9	10	11	12	Activity Costs	
A	1	1	1										3x200	600
B			1	1	1	1	1						5x200	1000
C	1	1											2x200	400
D	2	1											3x200+1x100	700
E				1									1x200	200
F			1	1	1	1							4x200	800
G					1								1x200	200
H			1	1	1								3x200	600
I							1	1	1	1	1		5x200	1000
J								1	1	1	1		4x200	800
K						1	1	1	1	1			5x200	1000
L							1	1					2x200	400
Total Workes	4	3	4	4	4	3	4	4	3	3	2			7700

(pink)	Waiting for Predecessors	Delay Cost	1x2000	$2,000
(blue)	Performing Activities	Total Cost		$9,700.00

Crash #2 - Crash I From D-F-I

Activities	Weeks 1	2	3	4	5	6	7	8	9	10	11	12	Activity Costs	
A	1	1	1										3x200	600
B			1	1	1	1	1						5x200	1000
C	1	1											2x200	400
D	2	1											3x200+1x100	700
E				1									1x200	200
F			1	1	1	1							4x200	800
G					1								1x200	200
H			1	1	1								3x200	600
I							1	1	2	1			5x200+1x100	1100
J								1	1	1	1		4x200	800
K						1	1	1	1	1			5x200	1000
L							1	1					2x200	400
Total Workes	4	3	4	4	4	3	4	4	4	3				

Waiting for Predecessors

Performing Activities

Delay Cost	0x2000	0
Total Cost		$7,800.00

Crash #2 - Crash J From C-B-J

Activities	Weeks 1	2	3	4	5	6	7	8	9	10	11	12	Activity Costs	
A	1	1	1										3x200	600
B			1	1	1	1	1						5x200	1000
C	1	1											2x200	400
D	2	1											3x200+1x100	700
E				1									1x200	200
F			1	1	1	1							4x200	800
G					1								1x200	200
H			1	1	1								3x200	600
I							1	1	1	1	1		5x200	1000
J								1	1	2			4x200+1x100	900
K						1	1	1	1	1			5x200	1000
L							1	1					2x200	400
Total Workes	4	3	4	4	4	3	4	4	3	4				

Waiting for Predecessors		
Performing Activities		
Delay Cost	0x2000	0
Total Cost		$7,800.00