The Dolphin Bay Development: Optimum Strategy using Network Analysis

Prof. Malcolm Smith
Professor of Accounting
School of Accounting, Finance & Economics
Edith Cowan University, Australia
malcolm.smith@ecu.edu.au

Abstract

This case study provides the opportunity to demonstrate the usefulness of network analysis in relieving bottlenecks and reducing levels of uncertainty in complex projects with interdependent events.

The Context

The regular visits of wild dolphins to the beaches of the far north-west of Western Australia, has made Dolphin Bay a tourist focus within the area. Up to now most tourists have stayed in a beach-side caravan and camping area which has a limited number of static chalets with basic amenities. The local Shire has repeatedly voiced concern over the environmental impact of such a development on the shore line — waterborne pollution would endanger the dolphin population, and therefore tourism.

The Shire has therefore determined to build a new development, nestling behind adjacent sand dunes, and to eliminate the possibility of future pollution (particularly sewage seepage) with the construction of a hard-core base. The existing development will eventually be phased out and the site rehabilitated, but this process will not start until completion dates have been firmly established on the new development and siteworks have commenced. The Shire planning authority has accepted final plans from Murchison Contractors, completed the formalities for rezoning the required parcel of land and identified ten distinct activities which need to be completed before the new development can commence trading:

A. Site clearance and levelling.

B. Surveying and drainage.

C. Channels for pipework and foundations.

D. Transportation of equipment and raw materials to the site.

E. Marketing planning and demand targeting.

F. Promotional activities for the new complex.

G. Assembly of prefabricated buildings.

H. Human resource planning based on local conditions.

I. Recruitment and staffing of the new complex.

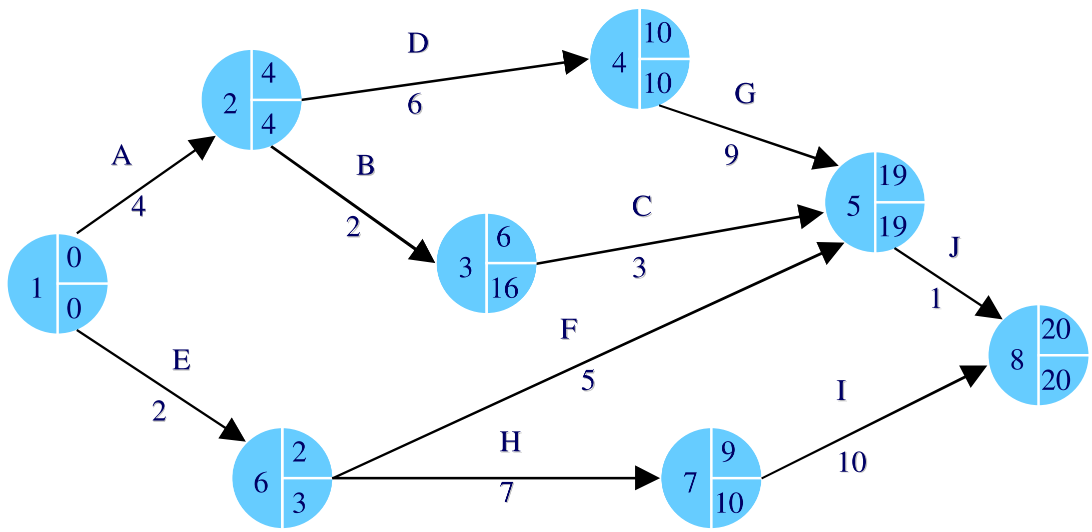
J. Final inspection prior to handover.

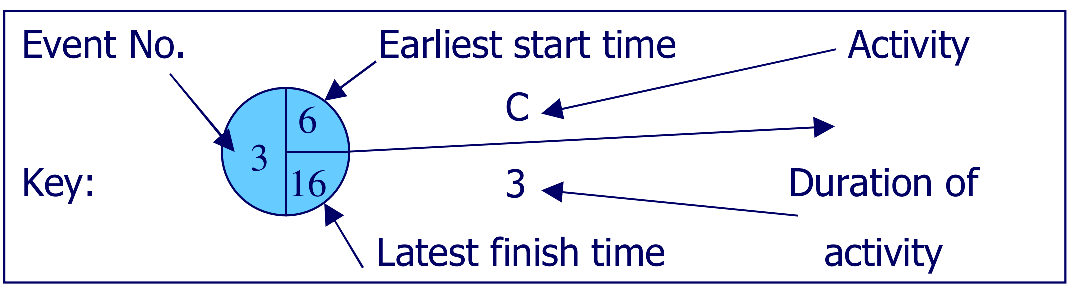
The relationship between these activities and their relative ordering is represented in Figure 1.The Shire has set a target time for completion of 20 weeks and a budget of $800,000. It will exact a penalty from the contractors of $20,000 a week for overruns. Anything greater than a four-week overrun will not be tolerated, since this will throw bookings into total disarray and threaten the credibility and future viability of the site. The contractors will receive an ‘early finish’ bonus of $25,000 a week for completion within the 20 week target.

The expected completion time and cost, together with the estimated variance for each of the activities, is detailed in Table 1. Also shown is the time that the contractors might save on each activity by ‘crashing’ (i.e., using overtime and shift working) together with the additional cost of such endeavours.

Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au
Case ID 030203

Figure 1: Network of Activities in Dolphin Bay development





Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au

Table 1: Target Costs and Completion

Activity	Expected Time (Weeks)		Expected Cost ($000)	Crash Time	
	Normal	Variance		Weeks	Extra Cost ($000)
A	4	1	50	3	20
B	2	1	30	2	0
C	3	1	40	2	20
D	6	2	90	4	25
E	2	1	20	1	20
F	5	1	120	4	10
G	9	5	200	7	25
H	7	8	70	5	30
I	10	16	140	7	40
J	1	1	40	1	0
			$800,000		$180,000

You are required to examine the alternative approaches that the contractors might take in reaching a compromise between cost of contract and time to completion and to recommend an optimum strategy.

Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au

TEACHING NOTE

The network of Figure 1, which establishes the sequencing of the activities, generates a critical path of A-D-G-J. For these activities, `earliest start time' = `latest finish time', and any possible reduction in the length of the project's duration will depend on the degree of variability of activities A, D, G, J.

The contractors earn a bonus of $25,000 per week for finishing early, but incur a $20,000 per week penalty for finishing late. An overrun in excess of 4 weeks is likely to result in expensive litigation.

The summary table of activities and durations, Table 1, details the maximum time reduction possible.

By "crashing" the activities on the critical path the project time can be reduced from:

	A		D		G		J		
	4	+	6	+	9	+	1	=	20 weeks
to,	3	+	4	+	7	+	1	=	15 weeks

A 20-week duration has been budgeted for and incurs neither bonuses nor penalty costs. By examining the costs and benefits, associated with bonuses earned and costs incurred, the contractors can establish which activities it makes sense to crash.

However, a simple crashing of activities on the critical path (A, D, G only, since J cannot be crashed) will be insufficient. Changes in these durations will alter the position of the critical path (e.g. route A-E-H-I has a 19-day duration). We must, therefore, consider the optimum manner of reducing the project duration from between 1 and 5 weeks. In order to accomplish this calculation some assumption needs to be made about the divisibility of the crash time. (e.g. does the $25,000 cost of saving 2 weeks in Activity G equivalent to a $12,500 cost of saving only one week?). This is arguable, but a proportional costing resulting from divisibility has been adopted here.

Step 1: Specify alternative activity sequences and identify those with durations which exceed 15 weeks:

ABCGJ	10 weeks
AEFI	8 weeks
AEHI	19 weeks*

A-E-H-I and, the original, A-D-G-J are, therefore, the focus of attention. If the latter is to be cut to 15 weeks then so must the former.

Step 2: Identify those activities which can be "crashed" to save time:

A	from	4	to	3 weeks, saving 1 week
D	from	6	to	4 weeks, saving 2 weeks
E	from	2	to	1 week, saving 1 week
G	from	9	to	7 weeks, saving 2 weeks
H	from	7	to	5 weeks, saving 2 weeks
I	from	10	to	7 weeks, saving 3 weeks

Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au
Case ID 030203

Step 3: Determine the optimum means of crashing activities in order to reduce project time to, respectively, 19, 18, 17, 16 and 15 weeks, and the corresponding benefits resulting (i.e.,bonuses earned-costs incurred). The 'Cost Slope' is a useful intermediary in this process,

Where

Cost Slope = (Crash Cost *minus* Normal Cost) / (Normal Time *minus* Crash Time)

We should "attack" those activities with the *lowest* cost slopes (e.g. here, activity D = (115 - 90)/(6 - 4) = 12.5) on those paths with the largest time reduction. Table 2 illustrates the iterative procedure.

Table 2: Project Crashing Strategy

Activity	Time Reduction Paths		Cost Slope	Maximum Time Reduction (weeks)	Iterations					
	ADGJ	AEHI			1	2	3	4	5	6
A	1		20	1					X	
D	2		12.5	2	X	X				
G		1	20	1						X
H	2		12.5	2			X	X		
I		1	15	1					X	
		3	13.3	3		X	X	X		
		Resultant Project Time (Weeks)			19	18	17	16	15	

Step 4: At Iteration 1 target Activity D -lowest cost slope (12.5) in longest path (ADGJ).

A one-week "crash" will reduce the total project length to 19 weeks.

Cost : $12,500

Bonus : $25,000 **Net Benefit $12,500**

Step 5: Complete the 2 week "crash" possible on Activity D, cutting ADGJ to 18 weeks. AEHI is then the longest path (19 weeks) and Activity I has the lowest cost slope (13.3) in this path. At Iteration 2 crash Activity I for 3 weeks.

A 1 week "crash" will reduce the total project length to 18 weeks.

Cost : D ($25,000); I ($13,300); Total: $38,300

Bonus : $50,000 **Net Benefit $11,700**

Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au
Case ID 030203

Step 6: Complete the second week of the possible "crash" on Activity I, cutting AEHI to 17 weeks. ADGJ is then the longest path again (18 weeks) and Activity G is lowest cost slope (12.5). At iteration 3 "crash" Activity G. A 1 week "crash" will reduce the total project length to 17 weeks.

Cost : D ($25,000); I ($26,600); G ($12,500); Total $73,500

Bonus : $75,000 **Net Benefit $1,500**

Step 7: Complete the third week of the "crash" on Activity I and the second week of the "crash" on Activity G, making both path lengths 16 weeks at Iteration 4.

Cost : D ($25,000); I ($40,000); G ($25,000); Total $90,000

Bonus : $100,000 **Net Benefit $10,000**

Step 8: Activity H now has the lowest cost slope and crashing on this activity will reduce AEHI path to 15 weeks at Iteration 5. To reduce the total project length to 15 weeks also target Activity A in the ADGJ path for crashing.

Cost : D ($25,000); I ($40,000); G ($25,000)

H ($15,000); A ($20,000) Total $125,000

Benefit: $125,000 **Net Benefit $0**

The minimum project length has now been achieved so no further iterations are required. Iteration 6 and the crashing of Activity E are, therefore, unnecessary.

A summary of costs and benefits reveals that it is not in the contractor's interests to reduce the project length by more than 1 week. A 19 week project term is the only one which yields a positive bonus payment:

20 weeks	-	Bonus	$0
19 weeks	-	Bonus	$12,500
18 weeks	-	Bonus	$11,700
17 weeks	-	Bonus	$1,500
16 weeks	-	Bonus	$10,000
15 weeks	-	Bonus	$0

A one-week crash of either Activity D or Activity G will accomplish the required reduction at minimum cost and maximum bonus earning. However, this analysis ignores the variability of the project length, the *expected* project duration and the contractors' potential vulnerability to a penalty for a time overrun.

Table 1 provides the mean and variance of the anticipated completion time for each project activity. If we assume a normal distribution of project completion times we can quantify the risk of overruns. The level of acceptable risk will be a management decision, but it is unlikely that the contractors will countenance the possibility of an overrun exceeding four weeks.

Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au

There will be a 5% chance of an activity taking an extra 1.645 standard deviations longer than the normal time. Where standard deviation = square root (variance) this additional time can be computed for each activity, as can the likelihood of a blow-out exceeding four weeks:

Activity	5% Bound	Probability of Blow-out >4 weeks
A	1.645 weeks	.000
B	1.645 weeks	.000
C	1.645 weeks	.000
D	2.326 weeks	.002
E	1.645 weeks	.000
F	1.645 weeks	.000
G	3.678 weeks	.036
H	4.652 weeks	.078
I	6.580 weeks	.159
J	1.645 weeks	.000

The focus is, once again, on those activities in the ADGJ and AEHI paths, and particularly on activities D, G, H and I which present the risk of a significant blow-out in costs.

If 19 weeks is the target completion time, then the additional risk attaching to activity G suggests that this activity should be the first to be crashed. However, this does not completely address the problem, since the risk associated with activity I is still, arguably, too high.

If activity G is crashed by one week, the issue of major concern is a blow-out of either H or I by in excess of five weeks, with probability of .038 and .105 respectively.

If the risk with respect to activity I is still judged to be too high, then it will necessitate a modification of the optimum bonus-earning strategy. Target completion times of 19, 18 and 16 weeks currently result in bonuses of $12,500, $11,700 and $10,000 respectively. None of these alternatives involve a crash of activity H, but both of the latter cases include a crash of activity I - by one week (for $11,700 option) and by three weeks (for $10,000 option).

A 16-week target completion duration will earn a sub-optimum bonus of $10,000, but will substantially eliminate the risks of penalty resulting from cost overrun. This may well, therefore, be the preferred strategy from amongst the alternatives.

Prof. Malcolm Smith, School of Accounting, Finance & Economics, Edith Cowan University, Australia
malcolm.smith@ecu.edu.au