EVALUATION OF ALTERNATIVE CONTINGENCY PLANS FOR THE COLLAPSE OF A BRIDGE

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INTRODUCTION

This paper describes how pay-off matrices [1] were used to evaluate contingency plans to cope with the possible collapse of a bridge. The problem was to decide whether to spend money on precautionary measures (and, if so, on which of several possible measures) in advance of any collapse, or to wait until it occurred. The bridge consisted of a number of spans, and it was not certain whether failure of one span or pier would lead to progressive collapse of the whole structure. Partial collapse could be repaired relatively quickly and cheaply, but complete collapse would require a new bridge, temporary or permanent, or a traffic diversion of about 16 km. A temporary bridge could be built alongside the existing structure, either in advance or if collapse occurred; alternatively the foundations alone could be built in advance, and this would take about half as long as complete construction. Plans existed for a new bridge as part of a by-pass scheme to relieve traffic congestion, but this could not be completed before 1980. The probability and consequences of collapse of the existing structure were factors influencing the timing of construction of the by-pass, which could therefore be considered a decision variable.

Thus the cost variables to be considered were:

i. the cost of repairing a partial collapse, and the time taken (the time would be shorter if materials were stockpiled in advance);
ii. the cost of building the foundations and superstructure of a temporary bridge and the time taken;
iii. the cost and date of the by-pass bridge;
iv. the cost of traffic diversion.

In the pay-off matrices the rows represented alternative courses of action (options) and the columns represented different possible sequences of events (outcomes). The elements of the matrices consisted of discounted costs associated with each option and outcome, and they were multiplied by probabilities estimated for each outcome, to give a probability table of expected values. The sum of the products for each row then provided an index for ranking the options.

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SEQUENCES OF EVENTS

In defining the possible outcomes, three main possibilities for the bridge fabric were considered:

(a) complete (progressive) collapse;
(b) partial collapse;
(c) no collapse.

Over a series of time periods, (c) could be followed by (a) or (b), but (b) or (c) could not follow (a). If a partial collapse was repaired, it could be followed by any of (a), (b) or (c). Over four time periods, for example, the possibilities were therefore as shown in Figure 1, a total of 31 possible chains of events. This total applies to each option; therefore the number of options and (especially) time periods had to be kept to a minimum. (It should be noted that Figure 1 does not represent a "decision tree", because the nodes are events rather than actions).

The costs incurred in these chains of events would be affected by the date of completion of the by-pass, because a collapse at the time of completion of the by-pass, or later, would be irrelevant from a traffic viewpoint. For this reason the four-period scheme shown in Figure 1 also needs a fifth period to be specified, in which the by-pass could be completed. Where the by-pass was assumed to be completed earlier than period 5, the number of periods (and therefore outcomes) was reduced accordingly; e.g., if the system finished in period 2, there were only seven possible outcomes. In the present case a planning period of at least ten years was needed, and to restrict the time periods to a manageable number they were defined as two years each, as shown in Table 1.

COURSES OF ACTION

Five options were selected, summarised as follows:

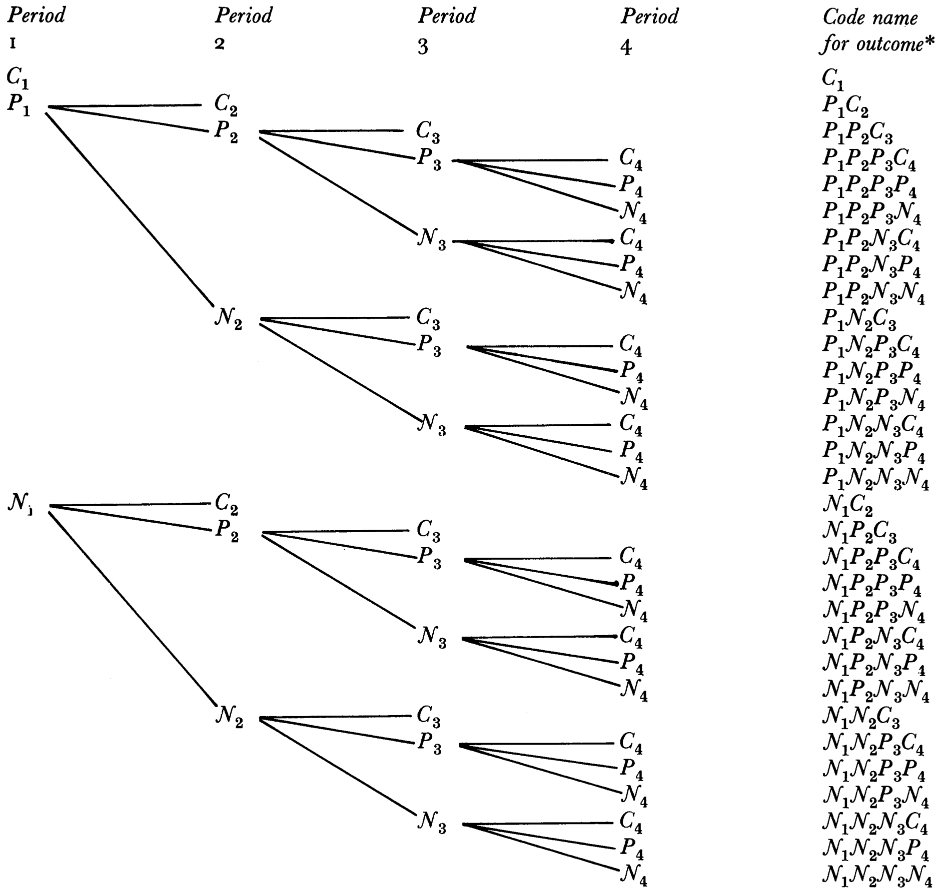
(1) Build temporary bridge now, to cover both complete and partial collapses.
(2) Build temporary bridge at complete collapse, unless within 2 years of completion of by-pass; repair any partial collapse.
(3) Do not build a temporary bridge but repair any partial collapse.

TABLE I

Time Periods and Discounting Factors

Period	1	2	3	4	5*
Years	1976-77	1978-79	1980-81	1982-83	1984-85
Year nos	1-2	3-4	5-6	7-8	9-10
Mid-point (years)	1.5	3.5	5.5	7.5	9.5
Discount factor	0.867	0.716	0.592	0.489	
Annuity factor	1.33	2.84	4.08	5.11	5.96

*Applicable only to by-pass construction.



Key: C = Complete collapse
P = partial collapse
N = no collapse
Subscripts are time periods

*Additional code names apply where the by-pass is completed earlier than period 5. See Appendix I.

FIGURE 1
Possible Sequences of Events

(4) Build the foundations for a temporary bridge now, to be completed if and when complete collapse occurs; repair any partial collapse.

(5) Build temporary bridge at partial or complete collapse, unless within two years of completion of by-pass: repair any partial collapse.

With each of these options there were three possible dates for completion of the

TABLE 2
Matrix Form with By-pass Completion in Period 3

Option \ Outcome	C_1	P_1C_2	P_1P_2	P_1N_2	N_1C_2	N_1P_2	N_1N_2
1							
2							
3							
4							
5							

TABLE 3
Costs and Times for Repair

	Cost (*£000*)	*Approximate Time*
Construction of temporary foundations	95	12 months
Erection of bridge on foundations	161	12 months
Repair of partial collapse:		
Labour	10	20 days*
Stock piling materials	26	—

*Assuming materials are stockpiled.

by-pass, (a) 1980-81, (b) 1982-83, and (c) 1984-85, and the matrix size varied according to the by-pass completion date. For 1980-81 it was 5 × 7, and for 1982-83 it was 5 × 15. The 1980-81 matrix is listed for illustration in Table 2, using the notation for outcomes as in Figure 1; three of the outcomes in Table 2 also appear in Figure 1.

COSTS

Estimated costs (at mid-1974 prices) and times for remedial action are shown in Table 3. Diversion costs are the sum of the time and operating costs incurred by the longer travel distance. The formula used was that incorporated in the official method of evaluating inter-urban road schemes [2]. This takes into account the current costs of fuel, adjusted to allow for the "net tax" payable: that is, the difference between the fuel tax and the average rate of indirect tax on other goods and services. The value of time of vehicle occupants is varied according to the type of vehicle and the average occupancy rate. No allowance was made for reduction in traffic flow following on the longer travel distances, but on the other hand there was also no allowance for additional road maintenance costs, which were not known. At £8,500 per day, the diversion costs for the construction and repair periods were therefore: for 12 months, £3,102,000; for 20 days, £170,000.

These costs were discounted according to the time period and the particular situation. For example, a partial collapse in period 1 was assumed to be at the mid-point of the period, and therefore the discount factor for period 1 was applied (see Table 1). But a complete collapse in period 1, for options by which the temporary bridge was constructed immediately (options 1 and 4), only involved 12 months' diversion costs, in year 2, because the temporary bridge should be complete by the end of the first period.

The cost of the by-pass bridge was estimated to be £2.3 million, and this was divided equally over a 4-year construction period, giving annual costs of £575,000. These and the other cost items incurred in different time periods were brought to a common (present) value, using a discount rate of 10 per cent. The discount and annuity factors applicable to the time periods are included in Table 1, where 1976 = year 1[3]. For example, the cost of the by-pass bridge was treated as a deferred annuity over 4 years. The materials needed for repairing a partial collapse were assumed to be stockpiled in advance, with restocking, after a partial collapse in which they were used, at a cost discounted according to the time period. Some examples of calculations of discounted costs are given in Appendix I.

RESULTS

The result of these calculations was three tables of discounted costs, with the columns representing the outcomes and the rows the five options. To obtain a ranking of options it was necessary to select probabilities for each possible event in each time period. Referring to Figure 1, every C, P and N must be given a probability, and for each vertical set of three (eg $C_2P_2N_2$) the probabilities must add to 1.0. Suppose a sequence of values is as follows:

P_1	0.1	followed by:
N_2	0.9	followed by:
P_3	0.08	followed by:
N_4	0.93	

(This is outcome 13 on Figure 1). Then the joint probability for this outcome is $0.1 \times 0.9 \times 0.08 \times 0.93 = 0.0067$.

As already mentioned, a sequence of events covering four time periods was relevant only if the by-pass had not been built within these periods. For example, if it was assumed to be completed in 1980-81 (period 3), only sequences such as $P_1 N_2$ were relevant; and, using the values shown above, the probability in this case was $0.1 \times 0.9 = 0.09$. For the three alternative completion dates for the by-pass, the relevant time periods were as follows:

	By-pass completion date	*Time periods*
(a)	1980-81	1 and 2
(b)	1982-83	1 to 3
(c)	1984-85	1 to 4

Thus, because the length of sequence effectively varied between (a), (b) and (c) above, the joint probability for each of the 31 outcomes listed in Figure 1 differed

TABLE 4
Sums of Discounted Costs Adjusted for Probabilities
(£000 × probability)

Period of completion of by-pass	*Low probability*			*High probability*		
	(*a*) *3*	(*b*) *4*	(*c*) *5*	(*a*) *3*	(*b*) *4*	(*c*) *5*
Option						
1	1898.2	1622.1	1403.3	2138.9	1863.0	1639.2
2	1820.3	1622.7	1467.2	2511.2	2472.0	2277.2
3	1819.1	1765.6	1755.6	2553.8	3150.5	3697.2
4	1822.8	1590.1	1409.0	2221.2	2078.8	1945.7
5	1831.0	1633.6	1671.0	2499.1	2396.2	2643.4

according to whether (a), (b) or (c) was being considered, even though the individual probability values within sequences remained the same. In addition, the individual values could also be varied, corresponding to (say) high and low probabilities of partial or complete collapse.

Two sets of individual probabilities for the events listed in Figure 1 were drawn up, in consultation with the engineers responsible for the bridge, and are shown in Appendix II. The first set corresponds to a generally low expectation of collapse of the bridge, and was regarded by the engineers as the more reasonable; the second set corresponds to a much higher expectation of collapse, and was included for sensitivity analysis. An assumption incorporated in these probabilities is that after repair of a partial collapse the bridge would be stronger (in that span or spans) than before. The individual probabilities when multiplied together in sequence, as described above, yielded joint probabilities for each outcome; these are listed in Appendix III.

Each discounted cost was multiplied by the corresponding joint probability (Appendix III) to give a table of values showing costs adjusted for probabilities. The sum of the values in each row (option) then provided an index of the cost of each option, from which they could be ranked. The products of discounted costs and probabilities (two sets) are shown in Appendix IV, and the sums of the rows obtained from all the three matrices are given in Table 4.

CONCLUSIONS

The figures in Table 4 are graphed in Figures 2 and 3, and it can be seen that for most options it is cheaper to defer completion of the by-pass until period 5 (1984-85), and possibly later, although this was not tested. Taking the low probability of collapse, and by-pass completion in period 5, there is little to choose between options 1, 2 and 4. Options 1 and 4 involve building either the temporary bridge or its foundations immediately, whereas option 2 waits for complete collapse to occur before taking any action of this kind. Therefore, on these probabilities,

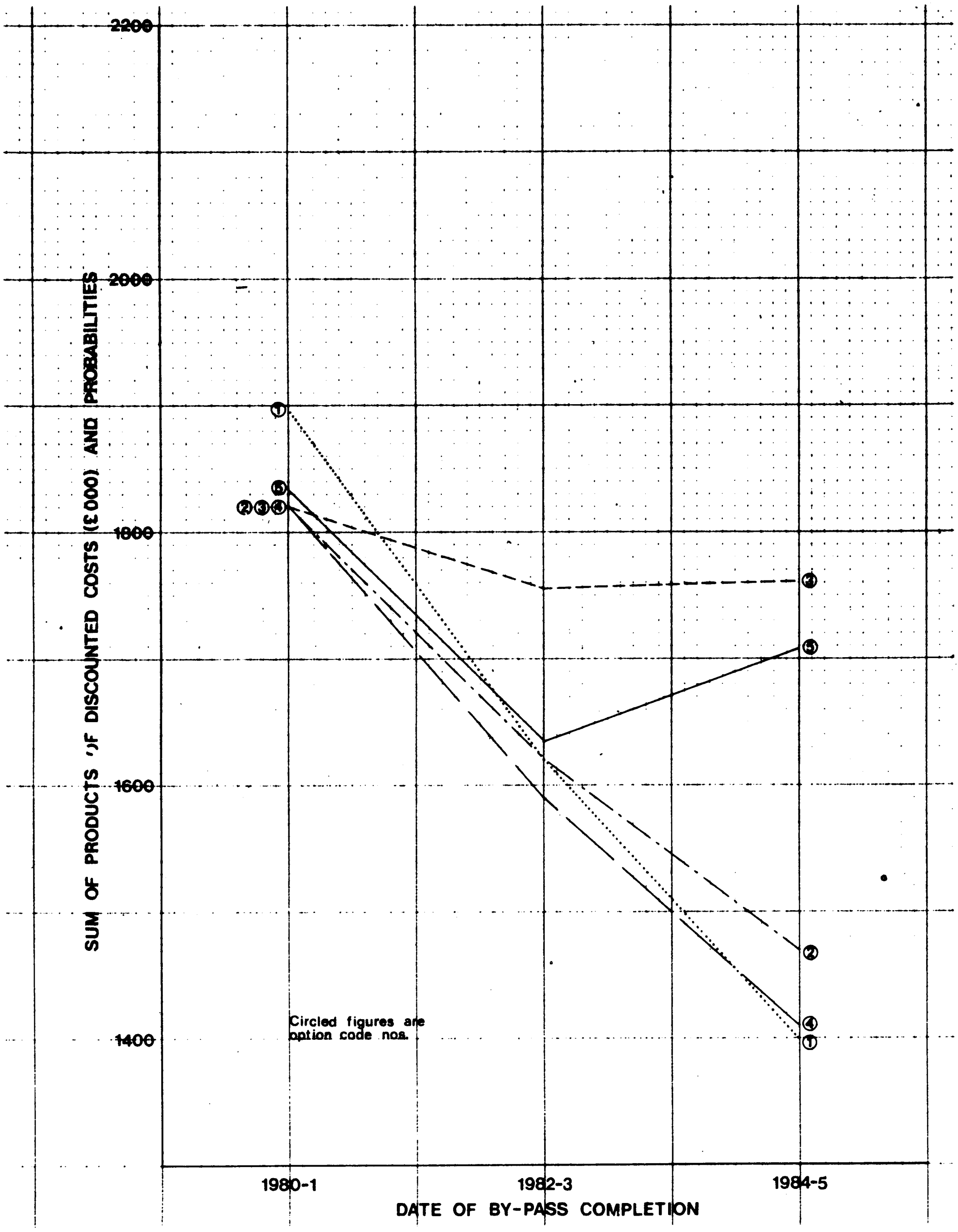


FIGURE 2
Ranking of Options—Low Probability of Collapse

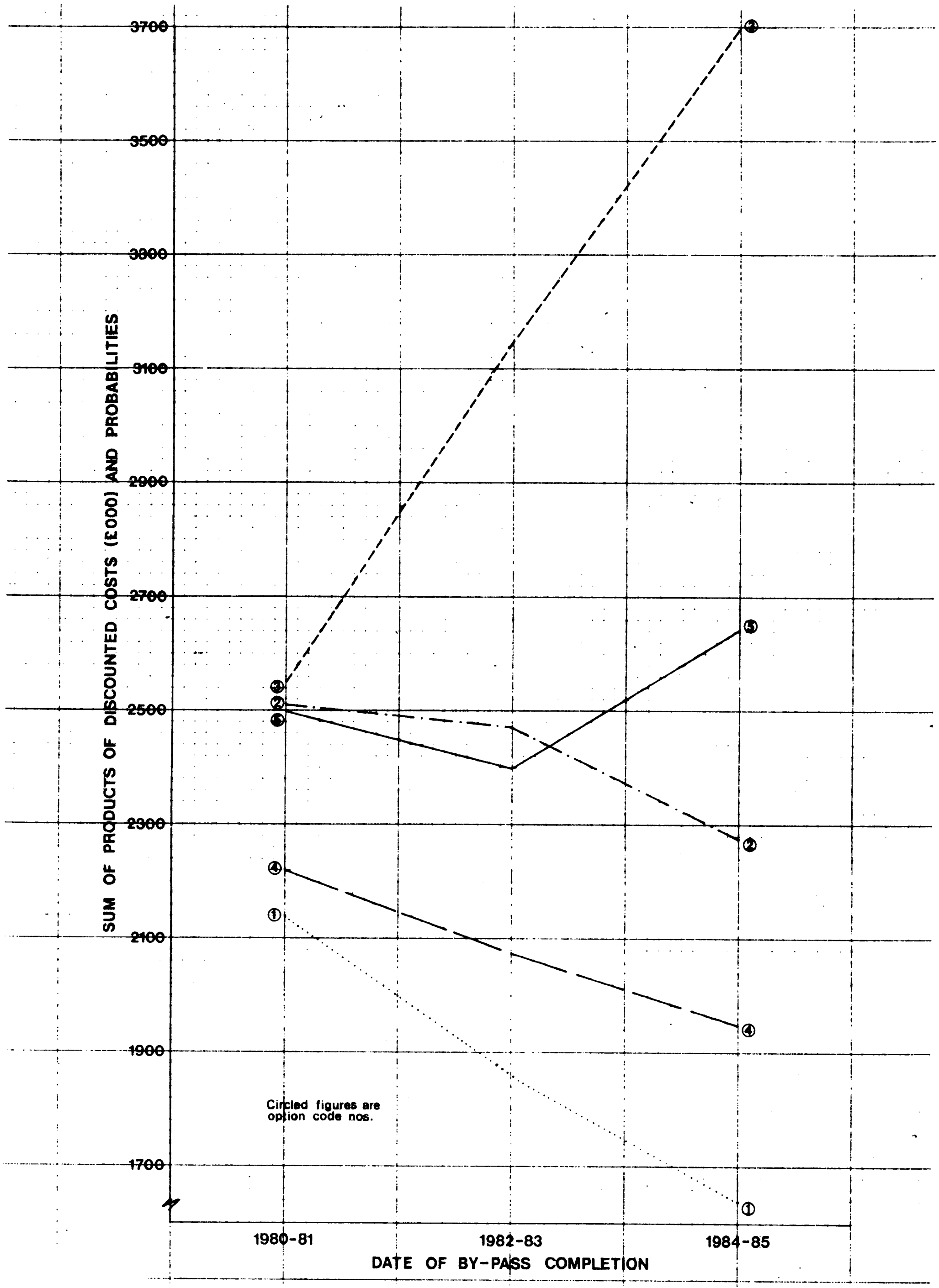


FIGURE 3
Ranking of Options—High Probability of Collapse

there is little to choose between action and inaction. With the higher probabilities of collapse, however, it is not surprising that immediate action appears the cheapest alternative; thus option 1 is appreciably cheaper than option 4, which itself is cheaper than option 2. The final conclusion therefore depends on the view taken of the probabilities of collapse.

Appendix I

Examples of Calculations of Discounted Costs

		£000 discounted
Option 1a, Outcome P_1C_2		
Cost of temp. bridge, period 1	256 × 0.867 =	222
Stockpile materials	26 × 1.0 =	26
Repair partial collapse, period 1 (labour)	10 × 0.867 =	9
Restockpile materials	26 × 0.867 =	23
Diversion costs, period 1	170 × 0.867 =	147
Bypass costs (completed period 3)	575 × (4.08 − 1.33) =	1581
		2008
Option 2b, Outcome $N_1P_2C_3$		
Stockpile materials, period 1	26 × 1.0 =	26
Repair partial collapse, period 2 (labour)	10 × 0.716 =	7
Diversion costs, period 2	170 × 0.716 =	122
Restockpile materials, period 2	26 × 0.716 =	19
Bypass costs (completed period 4)	575 × (5.11 − 2.84) =	1305
Diversion costs until bypass*	3102 (0.564 + 0.513) =	3341
		4820
Option 3c, Outcome $N_1P_2N_3P_4$		
Stockpile materials, period 1	26 × 1.0 =	26
Repair partial collapse, period 2 (labour)	10 × 0.716 =	7
Repair partial collapse, period 4 (labour)	10 × 0.489 =	5
Diversion costs, period 2	170 × 0.716 =	122
Diversion costs, period 4	170 × 0.489 =	83
Restockpile materials, period 2	26 × 0.716 =	19
Restockpile materials, period 4	26 × 0.489 =	13
Bypass costs (completed period 5)	575 × (5.96 − 4.08) =	1081
		1356
Option 4a, Outcome C_1		
Foundations and bridge, period 1	265 × 0.867 =	222
Stockpile materials	26 × 1.0 =	26
Diversion costs (1977)	3102 × 0.826 =	2562
Bypass costs (completed period 3)	575 × (4.08 − 1.33) =	1581
		4391

*These are in years 6 and 7, so the discount factors for these years are applied to the *annual* diversion cost.

Option 3c, Outcome $P_1N_2P_3C_4$

Repair partial collapse, period 1 (labour)	10 × 0.867	=	9
Repair partial collapse, period 3 (labour)	10 × 0.592	=	6
Stockpile materials	26 × 1.0	=	26
Restockpile materials, period 1	26 × 0.867	=	23
Restockpile materials, period 3	26 × 0.592	=	15
Diversion costs, period 1	170 × 0.867	=	147
Diversion costs, period 3	170 × 0.592	=	101
Diversion costs, years 8 and 9	3102 × (0.467 + 0.424)	=	2764
Bypass costs (completed period 5)	575 × (5.96 − 4.08)	=	1081
			4172

Appendix II
Assumed Probabilities of Events

Period	*Probability*		*Period*	*Probability*		*Period*	*Probability*		*Period*	*Probability*	
1	*Low*	*High*	*2*	*Low*	*High*	*3*	*Low*	*High*	*4*	*Low*	*High*
C_1	0.02	0.1									
P_1	0.1	0.3	C_2	0.02	0.05						
			P_2	0.08	0.25	C_3	0.01	0.05			
						P_3	0.06	0.15	C_4	0.01	0.05
									P_4	0.04	0.1
									N_4	0.95	0.85
						N_3	0.93	0.8	C_4	0.01	0.05
									P_4	0.06	0.15
									N_4	0.93	0.8
			N_2	0.9	0.7	C_3	0.02	0.05			
						P_3	0.08	0.25	C_4	0.01	0.05
									P_4	0.06	0.15
									N_4	0.93	0.8
						N_3	0.9	0.7	C_4	0.02	0.05
									P_4	0.1	0.2
									N_4	0.88	0.75
N_1	0.88	0.6	C_2	0.02	0.1						
			P_2	0.1	0.3	C_3	0.02	0.05			
						P_3	0.08	0.25	C_4	0.01	0.05
									P_4	0.06	0.15
									N_4	0.93	0.8
						N_3	0.9	0.7	C_4	0.02	0.05
									P_4	0.08	0.2
									N_4	0.9	0.75
			N_2	0.88	0.6	C_3	0.02	0.1			
						P_3	0.1	0.3	C_4	0.02	0.05
									P_4	0.08	0.15
									N_4	0.9	0.8
						N_3	0.88	0.6	C_4	0.02	0.1
									P_4	0.1	0.3
									N_4	0.88	0.6

Key: C = complete collapse
P = partial collapse
N = no collapse
Subscripts are time periods

APPENDIX III
Joint Probabilities

Outcome	Probability Low	Probability High	Bypass Completion Periods to which relevant
C_1	0.02	0.1	3, 4, 5
P_1C_2	0.002	0.015	3, 4, 5
P_1P_1	0.008	0.075	3
P_1N_2	0.09	0.21	3
N_1C_2	0.0176	0.06	3, 4, 5
N_1P_2	0.088	0.18	3
N_1N_2	0.7744	0.36	3
$P_1P_2C_3$	0.00008	0.00375	4, 5
$P_1P_2P_3$	0.00048	0.01125	4
$P_1P_2N_3$	0.00744	0.06	4
$P_1N_2C_3$	0.0018	0.0105	4, 5
$P_1N_2P_3$	0.0072	0.0525	4
$P_1N_2N_3$	0.081	0.147	4
$N_1P_2C_3$	0.00176	0.009	4, 5
$N_1P_2P_3$	0.00704	0.045	4
$N_1P_2N_3$	0.0792	0.126	4
$N_1N_2C_3$	0.01549	0.036	4, 5
$N_1N_2P_3$	0.07744	0.108	4
$N_1N_2N_3$	0.68147	0.216	4
$P_1P_2P_3C_4$	0	0.0006	5
$P_1P_2P_3P_4$	0	0.0011	5
$P_1P_2P_3N_4$	0.000456	0.0096	5
$P_1P_2N_3C_4$	0.0000744	0.003	5
$P_1P_2N_3P_4$	0.000446	0.009	5
$P_1P_2N_3N_4$	0.00692	0.048	5
$P_1N_2P_3C_4$	0	0.0026	5
$P_1N_2P_3P_4$	0	0.0079	5
$P_1N_2P_3N_4$	0.0067	0.042	5
$P_1N_2N_3C_4$	0.00162	0.0074	5
$P_1N_2N_3P_4$	0.0081	0.0274	5
$P_1N_2N_3N_4$	0.7126	0.1103	5
$N_1P_2P_3C_4$	0.00007	0.0023	5
$N_1P_2P_3P_4$	0.000422	0.0068	5
$N_1P_2P_3N_4$	0.00655	0.036	5
$N_1P_2N_3C_4$	0.00158	0.0063	5
$N_1P_2N_3P_4$	0.00634	0.0252	5
$N_1P_2N_3N_4$	0.07128	0.0945	5
$N_1N_2P_3C_4$	0.001549	0.0054	5
$N_1N_2P_3P_4$	0.0062	0.0162	5
$N_1N_2P_3N_4$	0.0697	0.0864	5
$N_1N_2N_3C_4$	0.01363	0.0216	5
$N_1N_2N_3P_4$	0.06815	0.0648	5
$N_1N_2N_3N_4$	0.5997	0.1296	5

Appendix IV

Products of Discounted Costs and Probabilities
(£000 × Probability)

(a) Outcomes where bypass completed in period 3

Option	C_1	P_1C_2	P_1P_2	P_1N_2	N_1C_2	N_1P_2	N_1N_2
Low prob							
1	87.8	4.0	16.1	180.7	32.2	161.0	1416.4
2	134.0	11.7	15.5	160.7	99.5	154.4	1244.5
3	172.4	7.8	15.3	160.7	65.6	152.8	1244.5
4	87.8	8.2	16.2	168.5	69.0	162.0	1311.1
5	134.0	4.0	15.9	178.7	99.5	154.4	1244.5
High prob							
1	439.2	30.1	150.6	421.7	109.7	392.2	658.4
2	669.9	87.5	145.1	375.1	339.2	315.9	578.5
3	861.9	58.6	143.6	375.1	223.6	312.5	578.5
4	438.9	61.5	151.5	393.1	235.3	331.4	609.5
5	669.9	29.8	148.9	416.9	339.2	315.9	578.5

(b) Outcomes where bypass completed in period 4

Option	C_1	P_1C_2	$P_1P_2C_3$	$P_1P_2P_3$	$P_1P_2N_3$	$P_1N_2C_3$	$P_1N_2P_3$
Low prob							
1	82.3	3.5	0.1	0.8	12.9	3.1	12.5
2	128.5	11.4	0.4	0.9	12.3	8.7	11.8
3	240.4	14.6	0.4	0.9	12.3	8.7	11.8
4	82.3	7.7	0.3	0.9	13.0	6.2	12.4
5	128.5	3.4	0.1	0.8	12.7	3.1	12.3
High prob							
1	411.6	26.0	6.5	19.5	103.9	18.2	90.9
2	642.3	85.8	18.8	20.0	99.5	50.9	85.7
3	1202.0	109.6	18.8	20.0	99.5	50.9	85.7
4	411.3	57.4	13.5	21.0	104.8	36.1	90.2
5	642.4	25.6	6.4	19.2	102.5	17.9	89.7

Option	$P_1N_2N_3$	N_1C_2	$N_1P_2C_3$	$N_1P_2P_3$	$N_1P_2N_3$	$N_1N_2C_3$	$N_1N_2P_3$	$N_1N_2N_3$
Low prob								
1	140.3	27.3	2.7	10.9	123.0	24.1	120.3	1058.3
2	122.3	97.6	8.5	11.3	117.1	72.4	112.5	907.0
3	122.3	125.4	8.5	11.3	117.1	72.4	112.5	907.0
4	129.3	64.1	6.0	11.9	123.8	50.4	118.9	962.9
5	138.4	97.6	2.9	11.6	130.3	72.4	112.5	907.0
High prob								
1	254.6	93.2	14.0	69.9	195.7	55.9	167.7	335.4
2	222.0	333.6	43.4	72.0	186.4	168.2	156.9	287.5
3	222.0	427.6	43.4	72.0	186.4	168.2	156.9	287.5
4	234.6	218.5	30.6	75.8	196.9	117.1	165.8	305.2
5	251.2	332.6	14.8	74.0	207.3	168.2	156.9	287.5

(c) *Outcomes where bypass completed in period 5*

Option	C_1	P_1C_2	P_1P_2 C_3	P_1P_2 P_3C_4	P_1P_2 P_3P_4	P_1P_2 P_3N_4	P_1P_2 N_3C_4	P_1P_2 N_3P_4
Low prob								
1	77.8	3.0	0.1	0	0	6.8	0.1	0.7
2	124.0	11.0	0.4	0	0	7.1	0.3	0.7
3	296.7	20.2	0.5	0	0	7.1	0.3	0.7
4	77.8	7.2	0.3	0	0	7.5	0.2	0.7
5	124.0	3.0	0.1	0	0	6.8	0.1	0.7
High prob								
1	389.2	22.6	5.7	0.9	1.7	14.5	4.5	13.6
2	619.9	82.5	18.7	2.6	1.8	14.9	12.6	13.8
3	1483.7	151.8	23.7	2.6	1.8	14.9	12.6	13.8
4	388.9	54.0	12.8	1.9	1.9	15.8	9.1	14.6
5	620.0	22.3	5.6	0.9	1.6	14.3	4.5	13.4

Option	P_1P_2 N_3N_4	P_1N_2 C_3	P_1N_2 P_3C_4	P_1N_2 P_3P_4	P_1N_2 P_3N_4	P_1N_2 N_3C_4	P_1N_2 N_3P_4	P_1N_2 N_3N_4
Low prob								
1	10.4	2.7	0	0	10.1	2.4	12.2	107.5
2	9.9	8.6	0	0	9.4	6.6	11.2	91.6
3	9.9	10.9	0	0	9.4	6.6	11.2	91.6
4	10.5	5.8	0	0	10.0	4.7	11.9	97.8
5	10.3	2.7	0	0	9.9	2.4	12.0	105.8
High prob								
1	72.4	15.8	3.9	11.9	63.3	11.2	44.3	166.3
2	68.8	50.0	10.8	11.9	59.1	30.0	40.8	141.8
3	68.8	63.8	10.8	11.9	59.1	30.0	40.8	141.8
4	73.0	33.7	7.8	12.6	62.7	21.4	43.3	151.3
5	71.3	15.6	3.9	11.7	62.4	11.0	43.7	163.8

Option	N_1C_2	N_1P_2 C_3	N_1P_2 P_3C_4	N_1P_2 P_3P_4	N_1P_2 P_3N_4	N_1P_2 N_3C_4	N_1P_2 N_3P_4	N_1P_2 N_3N_4
Low prob								
1	23.4	2.3	0.1	0.6	8.7	2.1	8.4	94.7
2	93.6	8.3	0.3	0.6	9.0	6.4	8.6	89.5
3	175.0	10.6	0.3	0.6	9.0	6.4	8.6	89.5
4	60.2	5.6	0.2	0.7	9.6	4.5	9.1	95.3
5	111.2	4.3	0.2	1.0	15.9	3.8	15.3	172.6
High prob								
1	79.7	12.0	3.1	9.0	47.8	8.4	33.5	125.6
2	319.1	42.6	8.5	10.1	49.6	25.3	34.2	118.6
3	596.6	54.4	9.5	10.1	49.6	25.3	34.2	118.6
4	205.1	28.6	6.7	10.6	52.5	18.0	36.2	126.3
5	379.1	21.8	5.6	16.5	87.2	15.3	61.0	228.8

(*c*) *Outcomes where bypass completed in period* 5 (cont.)

Option	N_1N_2 C_3	N_1N_2 P_3C_4	N_1N_2 P_3P_4	N_1N_2 P_3N_4	N_1N_2 N_3C_4	N_1N_2 N_3P_4	N_1N_2 N_3N_4
High prob							
1	47.8	7.2	21.5	114.8	28.7	86.1	172.2
2	165.1	21.6	21.5	106.2	83.6	78.3	143.5
3	212.3	21.6	21.5	106.2	83.6	78.3	143.5
4	109.1	15.3	22.9	113.3	58.6	83.6	154.1
5	201.1	12.8	38.3	204.5	83.6	78.3	143.5
Low prob							
1	20.6	2.1	8.2	92.6	18.1	90.6	797.0
2	71.0	6.2	8.2	85.7	52.8	82.3	663.9
3	91.4	6.2	8.2	85.7	52.8	82.3	663.9
4	46.9	4.4	8.8	91.4	37.0	87.9	713.0
5	86.5	3.7	14.7	165.0	52.8	82.3	663.9

REFERENCES

[1] Pearce, D. W.: *Cost-Benefit Analysis*. Macmillan, 1971.
[2] Department of the Environment: *COBA, A method of economic appraisal of highway schemes*, 1972.
[3] Merrett, A. J., and Sykes, Allen: *Capital Budgeting and Company Finance*. Longmans, 1966.