Introduction to Decision Analysis

Decisions Under Certainty

- State of nature is certain (one state)
- Select decision that yields the highest return

Examples:

- Product Mix
- Diet Problem
- Distribution
- Scheduling

Decisions Under Uncertainty (or Risk)

• State of nature is uncertain (several possible states)

Examples:

- Drilling for Oil
- Developing a New Product
- Newsvendor Problem
- Producing a Movie

Oil Drilling Problem

Consider the problem faced by an oil company that is trying to decide whether to drill an exploratory oil well on a given site. Drilling costs \$200,000. If oil is found, it is worth \$800,000. If the well is dry, it is worth nothing. However, the \$200,000 cost of drilling is incurred, regardless of the outcome of the drilling.

	State of	Nature
Decision		

Payoff Table

Which decision is best?

"Optimist":

"Pessimist":

"Second-Guesser":

"Joe Average":

Bayes' Decision Rule

Suppose that the oil company estimates that the probability that the site is "Wet" is 40%.

Payoff Table and Probabilities:

	State of	Nature
Decision	Wet	Dry
Drill	600	-200
Do not drill	0	0
Prior Probability	0.4	0.6

All payoffs are in thousands of dollars

Expected value of payoff (Drill) =

Expected value of payoff (Do not drill) =

Features of Bayes' Decision Rule

- Accounts not only for the set of outcomes, but also their probabilities.
- Represents the average monetary outcome if the situation were repeated indefinitely.
- Can handle complicated situations involving multiple and related risks.

Using a Decision Tree to Analyze Oil Drilling Problem

	State of	Nature
Decision	Wet	Dry
Drill	600	-200
Do not drill	0	0
Prior Probability	0.4	0.6

Payoff Table and Probabilities:

All payoffs are in thousands of dollars

Decision Tree:



Folding back:

- At each event node (circle): calculate expected value (SUMPRODUCT of payoffs and probabilities for each branch).
- At each decision node (square): choose "best" branch (maximum value).

Using TreePlan to Analyze Oil Drilling Problem

- 1. Choose Decision Tree under the Tools menu.
- 2. Click on "New Tree" and it will draw a default tree with a single decision node and two branches, as shown below.

	А	В	С	D	E	F	G
1							
2				Decision 1			
3							0
4				0	0		
5		1	K				
6	0		1				
7				Decision 2			
8							0
9				0	0		

- 3. Label each branch. Replace "Decision 1" with "Drill" (cell D2). Replace "Decision 2" with "Do not drill" (cell D7).
- 4. To replace the terminal node of the drill branch with an event node, click on the terminal node (cell F3) and then choose Decision Tree under the Tools menu. Click on "Change to event node," choose two branches, then click OK. TreePlan draws the tree below.

	А	В	С	D	E	F	G	Н		J	К
1								0.5			
2	-							Event 3			
3											0
4	-			Drill				0	0		
5						О					
6	-			0	0			0.5			
7								Event 4			
8	-						1				0
9		1	K					0	0		
10	0										
11											
12				Do not drill							
13											0
14				0	0						

- 5. Change the labels "Event 3" and "Event 4" to "Wet" and "Dry", respectively.
- 6. Change the default probabilities (cells H1 and H6) from 0.5 and 0.5 to the correct values of 0.4 and 0.6.
- 7. Enter the partial payoffs under each branch: (-200) for "Drill" (D6), 0 for "Do not Drill" (D14), 800 for "Wet" (H4), and 0 for "Dry" (H9). The terminal value cash flows are calculated automatically from the partial cash flows.

	А	В	С	D	E	F	G	Н	I	J	К
1								0.4			
2								Wet			
3											600
4				Drill				800	600		
5						С	(
6				-200	120			0.6			
7								Dry			
8			/				1				-200
9		1	<u> </u>					0	-200		
10	120										
11											
12				Do not drill							
13											0
14				0	0						

Final Decision Tree

Features of TreePlan

- Terminal values (payoff) are calculated automatically from the partial payoffs (K3=D6+H4, K8=D6+H9, K13=D14). Alternatively, they can be entered directly (in which case the partial payoffs are ignored).
- Foldback values are calculated automatically (I4=K3, I9=K8, E6=H1*I4+H6*I9, E14=K13, A10=Max(D6,D14)).
- Optimal decisions are indicated inside decision node squares (labeled by branch number from top to bottom, e.g., branch #1 = Drill, branch #2 = Do not drill).
- Changes in the tree can be made by clicking on a node, and choosing Decision Tree under the Tools menu (change type of node, # of branches, etc.)
- Clicking "Options..." in the Decision Tree dialogue box allows the choice of Maximize Profit or Minimize Cost.

Making Sequential Decisions

Consider a pharmaceutical company that is considering developing an anticlotting drug. They are considering two approaches. A biochemical approach would require less R&D and would be more likely to meet with at least some success. Some, however, are pushing for a more radical, biogenetic approach. The R&D would be higher, and the probability of success lower. However, if a biogenetic approach were to succeed, they would likely capture a much larger portion of the market, and generate much more profit. Some initial data estimates are given below.

			Profit	
R&D Choice	Investment	Outcomes	(excluding R&D)	Probability
			K	
Biochemical	\$10 million	Large success	\$90 million	0.7
		Small success	\$50 million	0.3
Biogenetic	\$20 million	Success	\$200 million	0.2
-		Failure	\$0 million	0.8

	А	В	С	D	E	F	G	Н	I	J	Κ
1								0.7			
2								Large Success	;		
3											80
4				Biochemical				90	80		
5						С	χ				
6	-			-10	68		$\boldsymbol{1}$	0.3			
7								Small Success	;		
8							'				40
9	-							50	40		
10		1									
11	68							0.2			
12								Success			
13											180
14				Biogenetic				200	180		
15						C	Χ				
16				-20	20			0.8			
17								Failure			
18											-20
19								0	-20		

	А	В	С	D	E	F	G	Н	I	J	К	L	М	Ν	0	Р	Q	R	S
1																			
2																Biochem	ical		
3												0.2							60
4												Biogen	(S)			90	60		
5														2	K				
6											1	0	170		$\left \right\rangle$				
7																Biogene	tic		
8								0.7			7				 /				170
9								Biochem	(LS)		7					200	170		
10									· /	\mathbb{C}	(
11								0	82										
12											\uparrow					Biochem	ical		
13												0.8							60
14												Biogen(F)		1	90	60		
15							\top							1	\mathbf{k}				
16												0	60		Í\				
17															\uparrow	Biogene	tic		
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19				Simultar	POUS		f_{-}									0	-30		
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21	72 4			-30	72 4														
22							1									Biochem	ical		
23												0.2				Dioonon			20
24							+					Biogen	(S)		-/	50	20		
25												Biogen	(0)	2	\checkmark	50	20		
26							+				\dashv	0	170	-	\wedge				
27							+				+	0	170		\uparrow	Riogene	tic		
28								03			+					Diogenie			170
29								Biochem	(22)	-	+					200	170		170
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33											\rightarrow	0.8			\vdash	50	20		20
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33													20	\vdash	\wedge			\vdash	
30												0	20		$\left \right\rangle$	Diagram	hia.		
31															\vdash	ыogene			
38																		\vdash	-30
39																0	-30		

Simultaneous Development

Biochemical First

2 Biochemical		
		80
4 / 90 80 /		
5		
6		
7 0.7 / Bir	Biochemical	
8 Large Success / 0.2		60
9 Success /	90 60	
	N	
	siogenetic	170
	200 170	170
14 Pursue Biogeneuc //	200 170	
	Piochomical	
	siochemical	60
	90 60	00
20 Biochemical First	50 00	
22 72 4 -10 72 4 Bit	Biogentic	
		-30
24	0 -30	
26		
27 Biochemical		
28		40
30		
31		
32 0.3 / Bir	Biochemical	
33 Small Success 0.2		20
34 2 Success /	50 20	
35 0 50 2		
36 / 0 170		
	Biogenetic	
		170
39 Pursue Biogenetic	200 170	
	Piechomical	
	siochemical	20
	50 20	20
	30 20	
	Biogentic	
		-30
49 49 49 40 40 40 40 40 40 40 40 40 40 40 40 40	0 -30	

Biogenetic First

	А	в	С	D	E	F	G	Н	Ι	J	к	L	м	N	0	Р	Q	R	S	Т	U	V	W
1						1																	
2		t																		Biochem	ical		
3																0.7							60
4		t														Large Succe	ess		7	90	60		
5		t														g= ====		2	\mathbf{K}^{-}				
6																0	170		\mathbf{h}				
7															1					Biogenet	tic		
8		t													1								170
9		T										Pursue Bioc	hemical		1					200	170		
10														C	$(\neg$								
11		t										-10	170		\mathbf{T}								
12		t													1					Biochem	ical		
13											\square				1	0.3							20
14								0.2			17					Small Succe	ess		7	50	20		
15		t						Success			1/							2	\mathbf{K}^{-}				
16		t								2	ť –					0	170		\mathbf{h}				
17								0	180		Ν									Biogenet	tic		
18		T									11												170
19		t									T									200	170		
20																							
21																							
22		t										Biogenetic											
23							\square																180
24												200	180										
25																							
26							1																
27				Biogenetic	: First															Biochem	ical		
28		1		Ŭ		С	1									0.7							60
29	74.4	Γ		-20	74.4											Large Succe	ess		7	90	60	Π	
30																		1	K				
31															1	0	60		\setminus				
32															7					Biogenet	tic		
33															/								-30
34												Pursue Bioc	hemical		/					0	-30		
35														С	(
36												-10	48										
37																				Biochem	ical		
38																0.3							20
39								0.8								Small Succe	ess			50	20		
40								Failure			V							1	<u> </u>				
41										1						0	20		$\boldsymbol{\lambda}$				
42								0	48		1									Biogenet	tic		
43						_					11	-											-30
44																				0	-30		
45																							
46						1																	
47						-	<u> </u>					Biogenetic		_									
48						_								1									-20
49												0	-20	1									

Whole Decision Tree

		A	в	С	D	E	F	G	н	1	J	к	L	м	N	0	Р	Q	R	s	Т	U	v	w
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7				_					0.7			1			F				-	_	Biochemical			60
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10			Π	_					0	82		I			F	Ε,	/	170	2	(=				
12				-								1				H	0	170		7	Biogenetic			
13				_				H				-/	Pursue Bionen	tic	-	1/			-		200	170		170
15												-	Fuisde blogen		t	¥-					200	170		
16				_				11					-20	82	-	N-			-		Biochemical			
18								1								$ \rangle$	0.8				Diodricifical			60
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24								1													0	-30		
25	-		Н	-			\vdash	Η-			H	-			⊢	-			+	_			+	
27													Biochemical											10
29			H	-			\vdash	H			H		50	40					-				+	40
30				_				1				7												
32			H				\vdash	H	0.3			+			⊢	-			+		Biochemical		+	
33									Small Success		2	/					0.2		_	-/	50	20		20
35									0	50	-						Success		2	_	50	20		
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60													Pulsue biocrie	lical	c	¥ –				_	200	170		
61				-								-/	-10	170	F	V			-	_	Biochemical		-	
63												1			t	Ľ	0.3			_	Diodrictificat			20
64	-		H				\vdash	-	0.2 Success			/			+	1	Small Success		21	7	50	20		
66											2						0	170	-	/				
67			H	+			\vdash	\square	0	180		+			┢	-			+	-	Biogenetic			170
69								1				1									200	170		
71								1				1												
72			H				\vdash	H)	Biogenetic		+				-				+	180
74								17					200	180										
75			H	-			\vdash	₩-			H	-			+	-			+				+	
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80				7				1				_			-	\vdash	0	60	1				-	
82			2					1								17	-		1	7	Biogenetic			
84		/4.4	Н				\vdash	H				-	Pursue Biocher	nical	┢	1/-			+	-	0	-30		-30
85								1				_	40	40	р	X								
87			H				\vdash	+				-/	-10	48	-	h			+		Biochemical			
88									0.0			1				$ \rangle$	0.3			1		20		20
90									Failure			/			t	1	Sinal Success		1	6	50	20		
91			Н				\vdash		0	48	1	\vdash			⊢	-	0	20	-	\mathcal{F}	Biogenetic		+	
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96			Ħ	F			F				П	1	Piccon-ti-		F									
98			Ħ	t			t				H	Ξ,	Siogenetic			E							H	-20
99	-	_	П	F			F	F			П	-	0	-20	F	F			1	-			H	
101							L																	
102	1		H	1			H	F			Н	-	0.2		f	1	Biochemical		-				H	60
104			П	#			Г				Ц		Biogen (S)		-	V	90	60	1					
105			H	\parallel			H	L			Н	-	0	170	12	K				_			H	
107			П	#			Г				П	7				Ľ	Biogenetic							470
108			H				t		0.7 Biochem (LS)		H	L			t	t	200	170	Ĵ				H	170
110			П	T			F	1			p	(-			F	F	-		1	_			H	
112			Ħ	#			t			82	Ħ	1			t	t	Biochemical			_				
113	-		H	-ff			F	H			H	1	0.8 Biogen (F)		F	17		60	Ŧ				H	60
115			П	11			F	17			Ħ	<u> </u>			1	K			1					
117	L	_	H				H	⊬			Н	_	0	60	1	£∖	Biogenetic		+	_			Н	
118			П		Simultanoour		F	V			F				F	Ľ	-		ł				Ħ	-30
120			L		Cimulaneous		b	Ľ			Ľ				L	L	0	-30	_	_			H	
121	-		П	Ŧ	-30	72.4	É	1		_	H	-			F	1	Biochemical		Ŧ				H	
123			Ħ	+			Þ	1			Ľ		0.2		t	Þ			+				Ħ	20
124			H				H	H			Н		ыogen (S)		2	ᡟ	50	20		_			H	
126			П	+			Г	1			П	7	0	170	Ē	\setminus	Riogon-ti-							
128			H				t		0.3		H	1			t	Ľ	Biogenetic		_				H	170
129			П	1			F	H	Biochem (SS)		П	F			F	F	200	170	1	-			H	
131			Ħ				t		0	50	Н	1			t	L							H	
132	-		П	1			F	F			F	L	0.0		F	F	Biochemical		1				H	20
134							t				Ħ		U.8 Biogen (F)		t	tZ	50	20					╘	20
135	-		H	-			H	-			H	-	0	20	1	K			┦	_			Н	
137			П				F				Ц			20	t	$ \rangle$	Biogenetic		1				Ħ	
138	L		H				H	-			Н				+	t i	0	-30	+				Η	-30
140			П				Г				П												H	
141			H		Don't Invest		H	L			Н				+	L				_			H	
	-		П	-			E								+	1			+				-	0
143	-			_			_				-	_			+	-			_	-			+	

	Α	В	С	D	E
1 Data		ata			
2		BC Investment	10		
3		BC Large Success Profit	90		
4		BC Small Success Profit	50		
5		BC Large Success Probability	0.7		
6		BG Investment	20		
7		BG Success Profit	200		
8		BG Failure Profit	0		
9		BG Probability of Success	0.2		
10					
11	11 Results				
12		Action:	Biogenetic First		
13			If Success Then (Commercialize Bioge	netic
14			If Failure Then Pu	rsue Biochemical	
15		Expected Payoff (millions):	\$74.400		

Decision Support System

- Data cells in "decision tree" spreadsheet (partial payoffs, probabilities) refer to data cells in "front end" spreadsheet.
- Results in "front end" spreadsheet refer to result cells in "decision tree" spreadsheet (decision node branch #'s, payoff values)

	В	С
12	Action:	=IF(Tree!B82=1,"Biochemical First",IF(Tree!B82=2,"Biogenetic First",IF(Tree!B82=3,"Simultaneous","Don't Invest")))
		Biochemical"," If Large Success then Pursue
		Biogenetic"),IF(Tree!B82=2,IF(Tree!J66=1," If Success Then Pursue
13		Biochemical"," If Success Then Commercialize Biogenetic")))
		Biochemical"," If Small Success then Pursue
		Biogenetic"),IF(Tree!B82=2,IF(Tree!J91=1," If Failure Then Pursue
14		Biochemical"," If Failure Then Don't Pursue Biochemical")))
15	Expected Payoff (millions):	=Tree!A83



Using Data Tables to Plot Payoff vs. Probability of BG Success

A "Data Table" can be used to generate Payoff vs. BG Success Probability.

In the first line of the table (H4), put an equation referring to the output cell of interest (in this case, =C15 for expected payoff).

In the first column of the table (G5:G15), enter the data for the input cells (in this case, the probabilities, ranging from 0 to 1).

Select the whole table (G4:H15), and then choose Table from the Data menu.

Specify the column input cell as the input cell in the spreadsheet that will be changing (as represented by the data in the first column of the table). In this case, this is the BG probability of success, in cell C9.