Business Case
2 Stage Stochastic Programming Approach for R&D Project Selection

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Hypothetical Business Problem in a Pharmaceutical Company

- 5 Drug Development Projects set to begin Phase III trials in 2005
  - Can be possibly delayed by a year
  - Assume they have no scientific uncertainty

- 2 Licensing Candidates-“now or never” opportunities
  - Both will complete Phase II trials at the end of 2005 and possibly enter Phase III trials
  - All uncertainty resides in their Phase II trials only

Potential optimization problem

Project	Phase	Phase POS	PTRS	2005 OOP ($MM)	2006 OOP ($MM)	NPV ($MM)	ENPV ($MM)
A	III	100%	100%	$50	$45	**$400**	**$400**
B	III	100%	100%	$60	$45	**$400**	**$400**
C	III	100%	100%	$85	$65	**$900**	**$900**
D	III	100%	100%	$45	$35	**$550**	**$550**
E	III	100%	100%	$60	$60	**$300**	**$300**
Licensing Candidate #1	II	50%	50%	$150	$150	**$1000**	**$425**
Licensing Candidate #2	II	70%	70%	$150	$250	**$1000**	**$625**

Potential optimization problem

Delayed scenario valuations for the 5 Phase III Projects

Project	2005 OOP ($MM)	2006 OOP ($MM)	**NPV ($MM)**	**ENPV ($MM)**
A (Delayed)	-	$50	**$200**	**$200**
B (Delayed)	-	$60	**$300**	**$300**
C (Delayed)	-	$85	**$850**	**$850**
D (Delayed)	-	$45	**$450**	**$450**
E (Delayed)	-	$60	**$150**	**$150**

2005-2006 R&D Budget

- Budget for 2005 - $350 MM
- Budget for 2006 - $450MM
- For the rest of the discussion, let us assume that these are hard constraints that cannot be violated under any circumstances

Project Selection Problem

- Objective: Maximize Portfolio's Expected Net Present Value
- Problem: Which of the "on the table" projects should be funded/delayed in 2005?
- Which of the 2 Licensing candidates should be selected in 2005?

Solution within Deterministic Framework

- The problem has 2 classes of stochastic parameters
  - 2006 costs for the 2 licensing candidates
  - NPV for the 2 licensing candidates

- Replace stochastic elements by their *expected* values
- Solve as a Binary Integer Problem

Solution within the Deterministic Framework

Decisions in 2005

Project	Decision
A	Fund in 2005
B	Delay in 2005
C	Fund in 2005
D	Delay in 2005
E	Fund in 2005
LC #1	Drop
LC #2	Fund in 2005

Decisions in 2006

Project	Decision
B (Delayed)	Fund
D (Delayed)	Fund

Results in Portfolio ENPV = $3.005 B

Consequence of Implementing Solution

Decisions in 2005

Project	Decision
A	Fund in 2005
B	Delay in 2005
C	Fund in 2005
D	Delay in 2005
E	Fund in 2005
LC #1	Drop
LC #2	Fund in 2005

Resolution of LC#2's Phase II trial uncertainty

Licensing Candidate #2 Succeeds

Scenario 1: Decisions in 2006

Project	Decision
B (Delayed)	Drop
D (Delayed)	Drop

Licensing Candidate #2 Fails

Scenario 2: Decisions in 2006

Project	Decision
B (Delayed)	Fund
D (Delayed)	Fund

Simulated Portfolio ENPV will be .7*2600 + .3*2200 = $2.480 B

Not $3.005 B

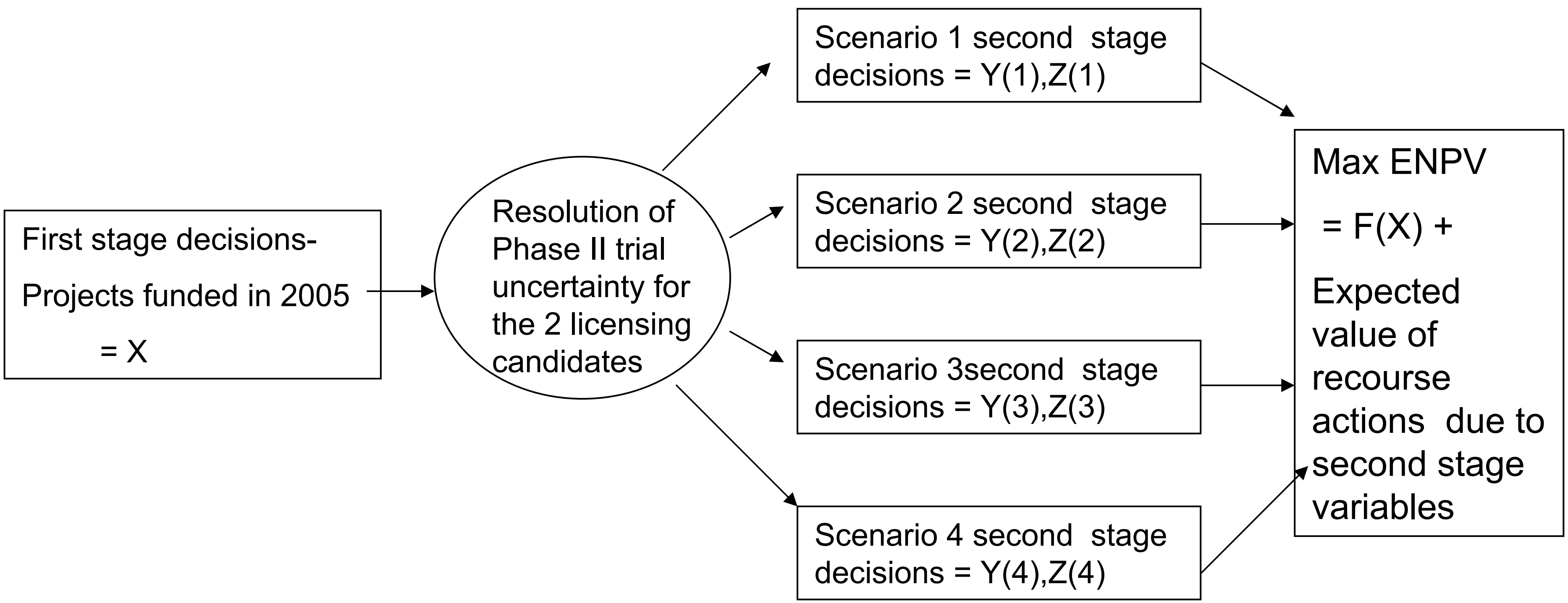
Solving as a 2 Stage Stochastic Integer Problem

- Based on projects succeeding or failing, second stage decisions taken in 2006

- Second stage decisions constrained by values of first stage decisions

- Make first stage decisions non anticipatively such that *expected* value of all possible second stage decisions is also maximized

Solving as a 2 Stage Stochastic Integer Program



Solution from the 2 Stage Approach

Decisions in 2005

Project	Decision
A	Fund in 2005
B	Fund in 2005
C	Fund in 2005
D	Delay in 2005
E	Delay in 2005
LC #1	Drop
LC #2	Fund in 2005

Resolution of LC#2's Phase II trial uncertainty

Licensing Candidate #2 Succeeds

Scenario 1: Decisions in 2006

Project	Decision
D (Delayed)	Fund
E (Delayed)	Drop

Licensing Candidate #2 Fails

Scenario 2: Decisions in 2006

Project	Decision
D (Delayed)	Fund
E (Delayed)	Fund

Simulated Portfolio ENPV will be = $2.850 B

Concluding Remarks

- Implementation of this solution results in a portfolio ENPV = \$2.850 B vs. \$2.480 B using Deterministic approach
- We get a better ENPV because we have incorporated the expected consequences of all possible corrective actions in 2006 into the objective function
- The 2 stage or multi-stage formulation can be used for trade-off analysis within small portfolios (not more than 10 projects)

Appendix I

Deterministic Problem

Optimization problem – delayed scenarios

Project	Decision variables
A	X1
B	X2
C	X3
D	X4
E	X5
Licensing candidate #1	X6
Licensing candidate #2	X7

X(i) = 1 implies that a project is funded in 2004

A (delayed)	Y1
B (delayed)	Y2
C (delayed)	Y3
D (delayed)	Y4
E (delayed)	Y5

Yi = 1 implies that a project is delayed and funded in 2005 instead

Formulating the problem as a deterministic optimization problem

Maximize the portfolio ENPV =

X1*400 + X2*400 + X3*900 +X4*550 +X5*300

+

X6*(1000*.5 –150*.5) + X7*(1000*.7 – 150*.3)

+

Y1*200 + Y2*300 + Y3*850 + Y4*450 + Y5*150

2004 Budgetary constraints:

X1*50 + X2*60 + X3*85 + X4*45 + X5*60 +X6*150 + X7*150 $\leq$ 350

2005 Budgetary constraint

X1*45 + X2*45 + X3*65 + X4*35 + X5*60

+ X6*(150*.5) + X7*(250*.7)+

Y1*50 + Y2*60 + Y3*85 + Y4*45 + Y5*60 $\leq$ 450

Formulating the problem as a deterministic optimization problem

- "Mutual exclusivity" constraints:

  $Xi + Yi \leq 1$ for all i

- Binary Constraints:

  $Xi, Yi \in [0,1]$ for all i

Solution within the deterministic framework

Project	Decision variables	Values
A	X1	1
B	X2	0
C	X3	1
D	X4	0
E	X5	1
LC #1	X6	0
LC #2	X7	1
A delayed	Y1	0
B delayed	Y2	1
C delayed	Y3	0
D delayed	Y4	1
E delayed	Y5	0
	Objective value= $3005	

- The solution:
  - Forego Licensing candidate # 1
  - Delay B,D and fund them in 2005 instead

- However, such a solution cannot always be implemented in totality
  - Specifically, in 2005, both B and D cannot be funded if Licensing candidate #2's Phase II trials succeed

- Consequently, implementing this solution will result in a Portfolio ENPV that is different from $3005 MM

Appendix II

Stochastic Problem

2 stage stochastic integer problem- continued

- First stage decision variables

Project	Decision variable
A	X1
B	X2
C	X3
D	X4
E	X5
LC #1	X6
LC #2	X7

2 stage stochastic integer problem- continued

Second stage decision variables for 4 mutually exclusive scenarios

Description	Scenario 1 LC# 1, LC#2 fail	Scenario 2 LC#1, LC#2 succeed	Scenario 3 LC#1 succeeds, LC #2 fails	Scenario 4 LC#1 fails, LC#2 succeeds
A (delayed)	Y1(1)	Y1(2)	Y1(3)	Y1(4)
B (delayed)	Y2(1)	Y2(2)	Y2(3)	Y2(4)
C (delayed)	Y3(1)	Y3(2)	Y3(3)	Y3(4)
D (delayed)	Y4(1)	Y4(2)	Y4(3)	Y4(4)
E (delayed)	Y5(1)	Y5(2)	Y5(3)	Y5(4)
Corrective action I	Z6(1)	Z6(2)	Z6(3)	Z6(4)
Corrective action II	Z7(1)	Z7(2)	Z7(3)	Z7(4)

Continued

- Main problem

Max X1*400 + X2*400 + X3*900 +X4*550 +X5*300 + X6*1000 + X7*1000 + Expected value of the “recourse” actions

such that

X1*50 + X2*60 + X3*85 + X4*45 + X5*60 +X6*150 + X7*150 $\leq$ 350

(2004 budgetary constraint)

2 stage stochastic integer problem- continued

Scenario 1 – Both licensing projects fail (occurs with a 15% probability)

- Sub-problem: **Max** Y1(1)*200 + Y2(1)*300 + Y3(1)*850 + Y4(1)*450 + Y5(1)*150 -Z6(1)*(1000+150) –Z7(1)*(1000+150)

Corrective action to the portfolio's NPV

- 2005 budgetary constraint:
  X1*45 + X2*45 + X3*65 + X4*35 + X5*60 + X6*(0) + X7*(0) +Y1(1)*50+Y2(1)*60 + Y3(1)*85 + Y4(1)*45 + Y5(1)*60 $\leq$ 450

- Z6(1) = X6; Z7(1) = X7
  Ensures that the a particular corrective action to the portfolio NPV will be made only if the licensing candidates were chosen in the first stage to begin with

2 stage stochastic integer problem- continued

- Scenario 2– Both licensing projects succeed (occurs with a 35% probability)

- Sub-problem: **Max** Y1(2)*200 + Y2(2)*300 + Y3(2)*850 + Y4(2)*450 + Y5(2)*150 -Z6(2)*(0) –Z7(2)*(0)

Corrective action to the portfolio's NPV

- 2005 budgetary constraint:

X1*45 + X2*45 + X3*65 + X4*35 + X5*60 + X6*(150) + X7*(250) +Y1(2)*50+Y2(2)*60 + Y3(2)*85 + Y4(2)*45 + Y5(2)*60 $\leq$ 450

- Z6(2) = X6; Z7(2) = X7

  Ensures that the a particular corrective action to the portfolio NPV will be made only if the licensing candidates were chosen in the first stage to begin with

- "Mutual exclusivity" and binary constraints

2 stage stochastic integer problem- continued

Scenario 3 – LC #1 succeeds, LC #2 fails (occurs with a 15% probability)

- Sub-problem: **Max** Y1(3)*200 + Y2(3)*300 + Y3(3)*850 + Y4(3)*450 + Y5(3)*150 -Z6(3)*(0) –Z7(3)*(1000+150)

Corrective action to the portfolio's NPV

- 2005 budgetary constraint:

X1*45 + X2*45 + X3*65 + X4*35 + X5*60 + X6*(150) + X7*(0) +Y1(3)*50+Y2(3)*60 + Y3(3)*85 + Y4(3)*45 + Y5(3)*60 $\leq$ 450

- Z6(3) = X6; Z7(3) = X7

- Mutual Exclusivity and binary constraints

2 stage stochastic integer problem- continued

Scenario 4 – LC #1 fails, LC #2 succeeds (occurs with a 35% probability)

- Sub-problem: **Max** Y1(4)*200 + Y2(4)*300 + Y3(4)*850 + Y4(4)*450 +

  Y5(4)*150 -Z6(4)*(1000+150) –Z7(4)*(0)

Corrective action to the portfolio's NPV

- 2005 budgetary constraint:

  X1*45 + X2*45 + X3*65 + X4*35 + X5*60 + X6*(0) + X7*(250)
  +Y1(4)*50+Y2(4)*60 + Y3(4)*85 + Y4(4)*45 + Y5(4)*60 $\leq$ 450

- Z6(4) = X6; Z7(4) = X7

- Mutual Exclusivity and binary constraints

Complete formulation reduces to a large linear integer program

Max

X1*400 + X2*400 + X3*900 +X4*550 +X5*300 + X6*1000 + X7*1000

+

Y1(1)*200 + Y2(1)*300 + Y3(1)*850 + Y4(1)*450 +Y5(1)*150 - Z6(1)*(1000+150) - Z7(1)*(1000+150) *.15

+

Y1(2)*200 + Y2(2)*300 + Y3(2)*850 + Y4(2)*450 +Y5(2)*150 -Z6(2)*(0) –Z7(2)*(0) *.35

+

Y1(3)*200 + Y2(3)*300 + Y3(3)*850 + Y4(3)*450 +Y5(3)*150 -Z6(3)*(0) –Z7(3)*(1000+150) *.15

+

Y1(4)*200 + Y2(4)*300 + Y3(4)*850 + Y4(4)*450 +Y5(4)*150-Z6(4)*(1000+150) –Z7(4)*(0) *.15

Constraints

X1*50 + X2*60 + X3*85 + X4*45 + X5*60 +X6*150 + X7*150 $\leq$ 350
(2004 budgetary constraint)

All the sub problem constraints