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### Lab 8: Review of Linear Programming and Introduction to Excel Solver

Long He Dept of Industrial Engineering & Operations Research Fall 2013



## Linear Programming

• Primal and dual in canonical forms

$$\begin{array}{ll} Max \ \sum_{j \in J} c_{j} X_{j} & Min \ \sum_{i \in I} b_{i} W_{i} \\ s.t. \ \sum_{j \in J} a_{ij} X_{j} \leq b_{i} \quad \forall i \in I & s.t. \ \sum_{i \in I} a_{ij} W_{i} \geq c_{j} \quad \forall j \in J \\ X_{j} \geq 0 & \forall j \in J & W_{i} \geq 0 & \forall i \in I \end{array}$$

## Example in Textbook 2.5.2

- Consider a problem of deciding how to allocate a budget for municipal services between police and fire protection. In the simple model, each police patrol costs \$200,000 per year and each fire truck costs \$1,000,000 per year including the cost of the fire station. The city has only \$5,350,000 to allocate to the combined police and fire budgets. In addition, contracts with the unions representing the two city services stipulate that there must be at least 1.5 times as many police patrol units as there are fire trucks and that there cannot be more than 7.5 times as many police units as there are fire units.
- The goal is to maximize the number of lives saved over a year. We expect 0.2 lives saved per year per police patrol unit and 0.65 lives saved per fire truck.

## 2.5.2 Formulation

 $\begin{array}{ll} Max \ 0.2 \cdot Police + 0.65 \cdot Fire \\ s.t. & 200 \cdot Police + 1000 \cdot Fire \leq 5350 \\ & -1.0 \cdot Police + 1.5 \cdot Fire \leq 0 \\ & 1.0 \cdot Police - 7.5 \cdot Fire \leq 0 \\ & Police \geq 0 \\ & Fire \geq 0 \end{array}$ 

### • Build model in Excel

	A	В	С	D	E	F
1			100			
2		Inputs				
3						
4		Cost/Police	2	in \$100,000		
5		Cost/Fire	10	in \$100,000		
6		Budget	53.5	in \$100,000		
7		Min Police/Fire	1.5			
8		Max Police/Fire	7.5			
9						
10		Lives/Police	0.2			
11		Live/Fire	0.65			
12						
13		Decision Vari	ables			
14						
15			Police	Fire		
16						
17						
18		Objectiv	e			
19			1 · · · · · ·			
20		Objective	0.2	0.65		
21			1	1.1		
22		Mazimize Lives Saved	0	· · · · · · · · · · · · · · · · · · ·		
23						
24		Constrain	its			
25						
26		Police >= Min Police/Fire*Fire				
27			1 8			
28			0	>=	0	
29			1			
30		Police <= Max Police/Fire*Fire				
31			6			
32			0	<=	0	
33			5 8	· · · · · · · · · · · · · · · · · · ·		
34		Budget				
35			1 8	-	- Corner	
36			0	<=	53.5	
37			1 C C			

#### Name the cells

Formulas -> Create from Selection

1 A	A	В	С	D	E	F	G	Н	1	J	K	L	M
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4		Cost/Police	2	in \$100,000			Cre	ate nam	es from	values	in the:		
5		Cost/Fire	10	in \$100,000									
6		Budget	53.5	in \$100,000				Top ro	w				
7		Min Police/Fire	1.5					Z					
8		Max Police/Fire	7.5						biumn				
9								Bottor	n row				
10		Lives/Police	0.2										
11		Live/Fire	0.65					Right	column				
12													
13		Decision \	/ariables			1				OK		Cance	
14										UN		Carries	
15			Police	Fire			. L.		_	-	-	-	

• Edit the cells with formulas (using names)

# Solving the Problem in Excel Setup solver (File->Options->Add-Ins->Solver Add-In)

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Formulas							
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	PDFComplete	C:\cepdf.dll	COM Add-in	Euro Cu	rency Tools		
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			OK Cancel				

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### • Setup solver

rmulas Data Review	View Developer A	dd-Ins Acrobat		◆ Show Deta	il 💫 Solver
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		1 A	A	В	C	D	E	
		1						
		2		Input	s			
		3						
		4		Cost/Police	2	in \$100,000		
		5		Cost/Fire	10	in \$100,000		
		6		Budget	53.5	in \$100,000		
		7		Min Police/Fire	1.5	1 38 39 gr		
		8		Max Police/Fire	7.5			
olver found a solution. All Constraints and o	ptimality	9						
onditions are satisfied.	Reports	10		Lives/Police	0.2			
	Answer	11		Live/Fire	0.65			
Koop Solver Solution	Sensitivity	12						
Keep Solver Solution     Sensitivity				Decision Variables				
O Prostere Original Values		14						
O <u>R</u> estore Original Values		15			Police	Fire		
		16			16.05	2.14		
Batura to Solver Parameters Dialog		17						
Return to solver Parameters Dialog	U Outline Reports	18		Objecti	ve			
		19		Object				
OK Cancel	Save Scenario	20		Ohiective	0.2	0.65		
		- 21						
		22		Maximize Lives Saved	4,601	1		
olver found a solution. All Constraints and op	timality conditions are	23				1.1		
tisfied. <b>Q</b>		24		Constra	inte			
hen the GRG engine is used. Solver has foun	d at least a local optimal	24		Constra	incs			
olution. When Simplex LP is used, this means	Solver has found a global	20		Police v Min Police/Eire*Eire			_	
ptimal solution.		20		Folice >= Min FolicerFife Fife				
		20		-	10.05		2.2	
		20			16.00	/=	3.2	
		20		Police / May Police/Fire*Fire	-			
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		22		-	10.05	1-	16.01	
		22			16.00	N-	16.03	
		34		Budget	-	-		
		35		Dudget				
		36			52.5	/-	521	
		27				N		
		31						

#### Answer report

	A B	С	D	E	F	G
1	Microsof	t Excel 12.0 Answer Report				
2	Workshe	et: [Lab1.xlsx]Sheet1				
3	Report C	reated: 9/1/2011 4:23:15 PM				
4						
5						
6	Target Ce	ell (Max)				
7	Cell	Name	<b>Original Value</b>	Final Value		
8	\$C\$22	Maximize Lives Saved Police	4.601	4.601		
9						
10						
11	Adjustab	le Cells				
12	Cell	Name	<b>Original Value</b>	<b>Final Value</b>		
13	\$C\$16	Police	16.05	16.05		
14	\$D\$16	Fire	2.14	2.14		
15						
16						
17	Constrair	its				
18	Cell	Name	Cell Value	Formula	Status	Slack
19	\$C\$28	Police	16.05	\$C\$28>=\$E\$28	Not Binding	12.84
20	\$C\$32	Police	16.05	\$C\$32<=\$E\$32	Binding	0
21	\$C\$36	Police	53.5	\$C\$36<=\$E\$36	Binding	0
22						

### • Sensitivity report

4	A B	С	D	E	F	G	Н
1	Microsof	t Excel 1	L2.0 Ser	nsitivity Re	port		
2	Workshe	et: [Lab	1.xlsx]	Sheet1			
3	Report C	reated:	9/1/201	1 4:22:59	PM		
4							
5							
6	Adjustab	le Cells					
7			Final	Reduced	Objective	Allowable	Allowable
8	Cell	Name	Value	Cost	Coefficient	Increase	Decrease
9	\$C\$16	Police	16.05	0	0.2	1E+30	0.07
10	\$D\$16	Fire	2.14	0	0.65	0.35	2.15
11							
12	Constrair	nts					
13	2		Final	Shadow	Constraint	Allowable	Allowable
14	Cell	Name	Value	Price	R.H. Side	Increase	Decrease
15	\$C\$28	Police	16.05	0	0	12.84	1E+30
16	\$C\$32	Police	16.05	0.028	0	26.75	24.69230769
17	\$C\$36	Police	53.5	0.086	53.5	1E+30	53.5
10							

## 2.5.2 Mixed Integer Program

Max  $0.2 \cdot Police + 0.65 \cdot Fire$  $200 \cdot Police + 1000 \cdot Fire \le 5350$ s.t.  $-1.0 \cdot Police + 1.5 \cdot Fire \leq 0$  $1.0 \cdot Police - 7.5 \cdot Fire \leq 0$ *Police* integer *Fire* integer Police > 0 $Fire \geq 0$ 

