Lecture 8

Produced by Dr. Worldwide

Welcome to the 305

Integer Programming

- Prior linear programs have decision variables that are naturally integer-valued
- Optimal solutions are commonly not integer-valued
- Simply rounding up or down could lead to non-optimal solutions or could lie in an infeasible region
- Algorithms exist to handle this common problem
- Models where some/all the variables are required to be integer-valued are known as integer programming models

Integer Programming

- Total integer models are linear programming models where all the decision variables must be integer-valued
- 0-1 integer models are linear programming models where all the decision variables must take the values 0 or 1
- Mixed integer models are linear programming models where some of the decision variables must be integer valued while others do not

Total Integer Model

- Decision variables
  - $x_1 = Dollars\ invested\ in\ municipal\ bonds$
  - $x_2 = Dollars\ invested\ in\ CDs$
  - $x_3 = Dollars\ invested\ in\ Treasury\ Bills$
  - $x_4 = Dollars\ invested\ in\ Growth\ Stock$

- Linear program

Maximize $0.085x_1 + 0.05x_2 + 0.065x_3 + 0.13x_4$

Subject to

$$x_1 + x_2 + x_3 + x_4 = 70000$$
$$x_1/(x_1 + x_2 + x_3 + x_4) \leq 0.2$$
$$x_2 \leq x_1 + x_3 + x_4$$
$$(x_2 + x_3)/(x_1 + x_2 + x_3 + x_4) \leq x_1 + x_3 + x_4$$
$$(x_2 + x_3)/(x_1 + x_4) \geq 1.2$$
$$x_1, x_2, x_3, x_4 \geq 0$$

0-1 Integer Model

- Decision variables
  - $x_1 = Dollars\ invested\ in\ municipal\ bonds$
  - $x_2 = Dollars\ invested\ in\ CDs$
  - $x_3 = Dollars\ invested\ in\ Treasury\ Bills$
  - $x_4 = Dollars\ invested\ in\ Growth\ Stock$

- Linear program

Maximize $0.085x_1 + 0.05x_2 + 0.065x_3 + 0.13x_4$

Subject to

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$$x_2 \leq x_1 + x_3 + x_4$$
$$(x_2 + x_3)/(x_1 + x_2 + x_3 + x_4) \leq x_1 + x_3 + x_4$$
$$(x_2 + x_3)/(x_1 + x_4) \geq 1.2$$
$$x_1, x_2, x_3, x_4 \geq 0$$

Mixed Integer Model

- Decision variables
  - $x_1 = Dollars\ invested\ in\ municipal\ bonds$
  - $x_2 = Dollars\ invested\ in\ CDs$
  - $x_3 = Dollars\ invested\ in\ Treasury\ Bills$
  - $x_4 = Dollars\ invested\ in\ Growth\ Stock$

- Linear program

Maximize $\quad 0.085x_1 + 0.05x_2 + 0.065x_3 + 0.13x_4$

Subject to

$$x_1 + x_2 + x_3 + x_4 = 70000$$
$$x_1/(x_1 + x_2 + x_3 + x_4) \leq 0.2$$
$$x_2 \leq x_1 + x_3 + x_4$$
$$(x_2 + x_3)/(x_1 + x_2 + x_3 + x_4) \leq x_1 + x_3 + x_4$$
$$(x_2 + x_3)/(x_1 + x_4) \geq 1.2$$
$$x_1, x_2, x_3, x_4 \geq 0$$

Ex: Investment

- Linear program in standard form

Maximize $0.085x_1 + 0.05x_2 + 0.065x_3 + 0.13x_4$

Subject to

$$
\begin{aligned}
& x_1 + x_2 + x_3 + x_4 = 70000 \\
& 0.8x_1 - 0.2x_2 - 0.2x_3 - 0.2x_4 \leq 0 \\
& -x_1 + x_2 - x_3 - x_4 \leq 0 \\
& 0.3x_1 - 0.7x_2 - 0.7x_3 + 0.3x_4 \leq 0 \\
& 1.2x_1 - x_2 - x_3 + 1.2x_4 \leq 0 \\
& x_1, x_2, x_3, x_4 \geq 0
\end{aligned}
$$

- Download Investment-1.xlsx from course website from link Sheet 1
- Optimal solution $(x_1, x_2, x_3, x_4) = (0,0,38181,3181.18)$

Ex: Investment

- Sensitivity analysis

Variable Cells

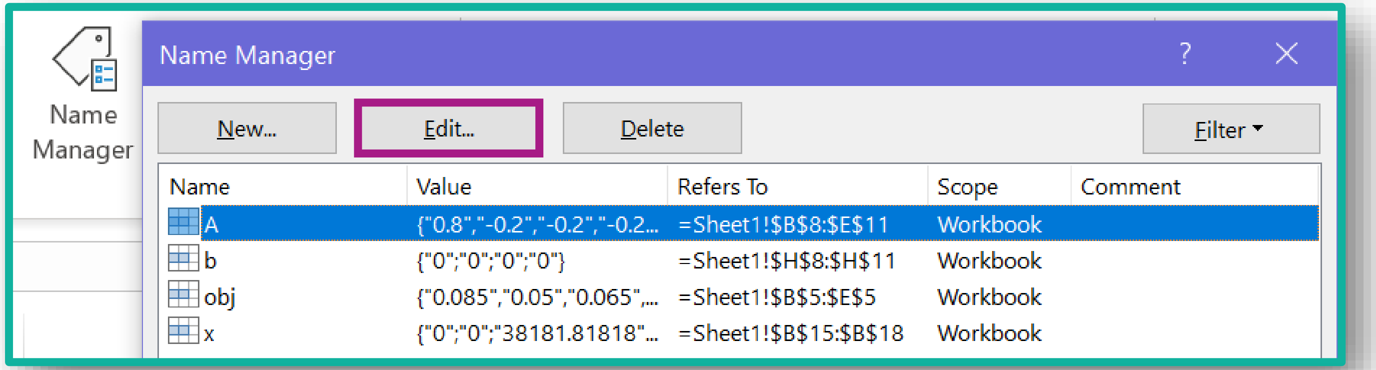
Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B15	Municipal bonds = ($)	0	-0.045	0.085	0.045	1E+30
B16	CDs = ($)	0	-0.015	0.05	0.015	1E+30
B17	Treasury bills = ($)	38181.81818	0	0.065	0.065	0.015
B18	Growth stock = ($)	31818.18182	0	0.13	1E+30	0.045

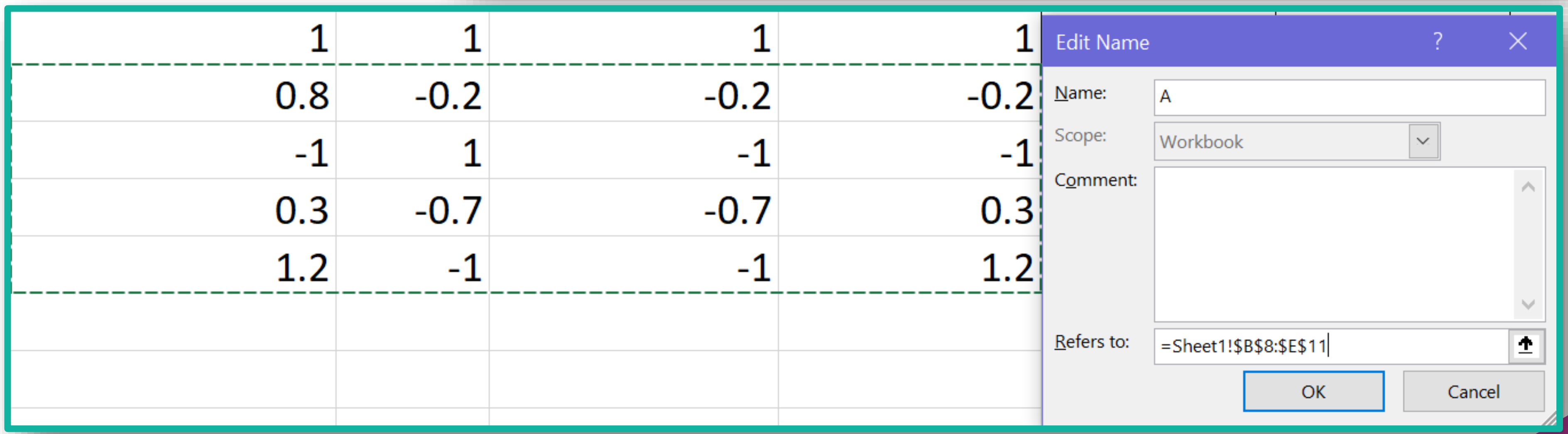
Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
F7	Total investment Usage	70000	0.094545455	70000	1E+30	70000
F8	Constraint 1 Usage	-14000	0	0	1E+30	14000
F9	Constraint 2 Usage	-70000	0	0	1E+30	70000
F10	Constraint 3 Usage	-17181.81818	0	0	1E+30	17181.81818
F11	Constraint 4 Usage	6.54836E-11	0.029545455	0	37800	70000

Ex: Investment

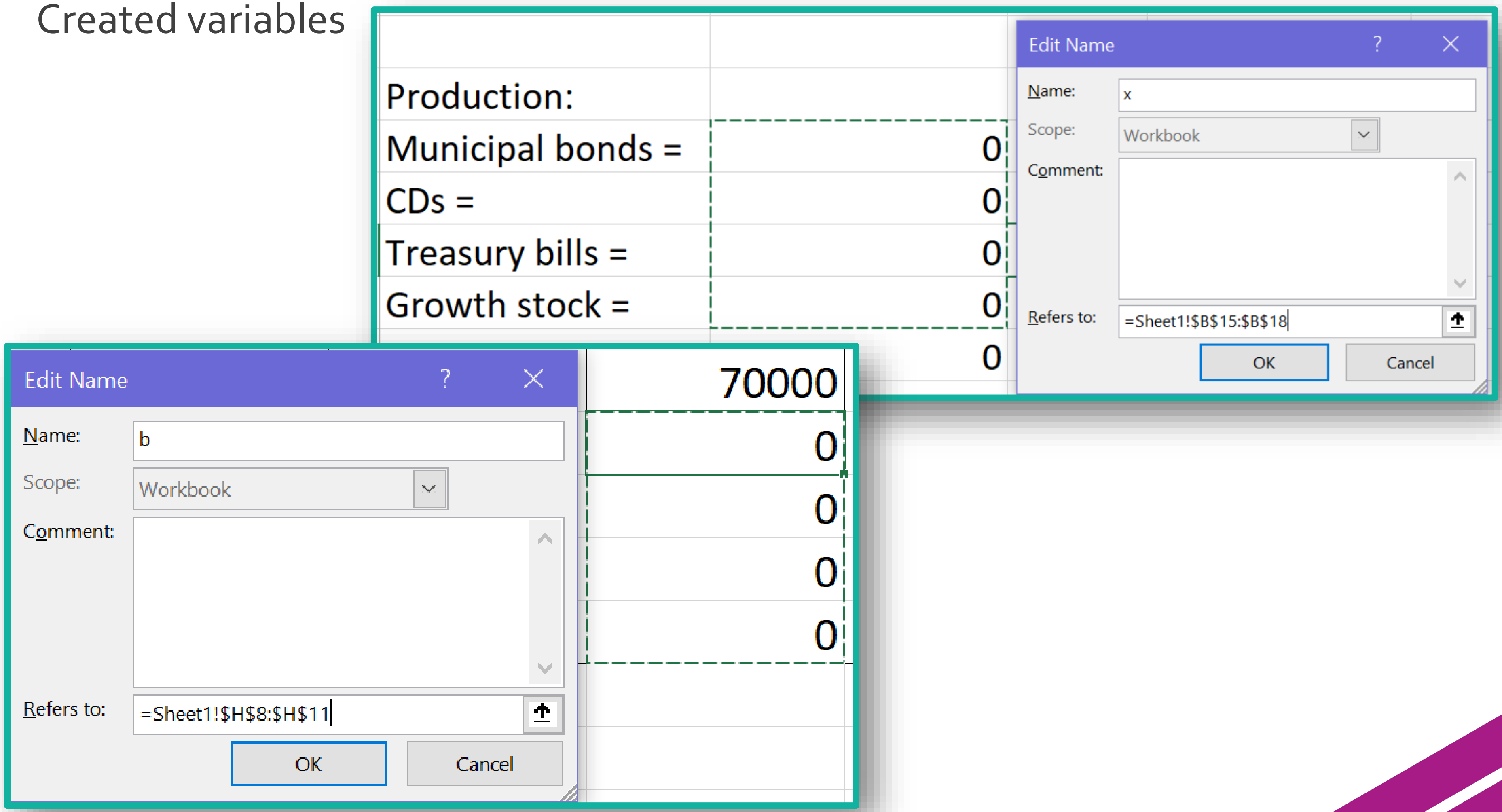
- Created variables





Ex: Investment

- Created variables



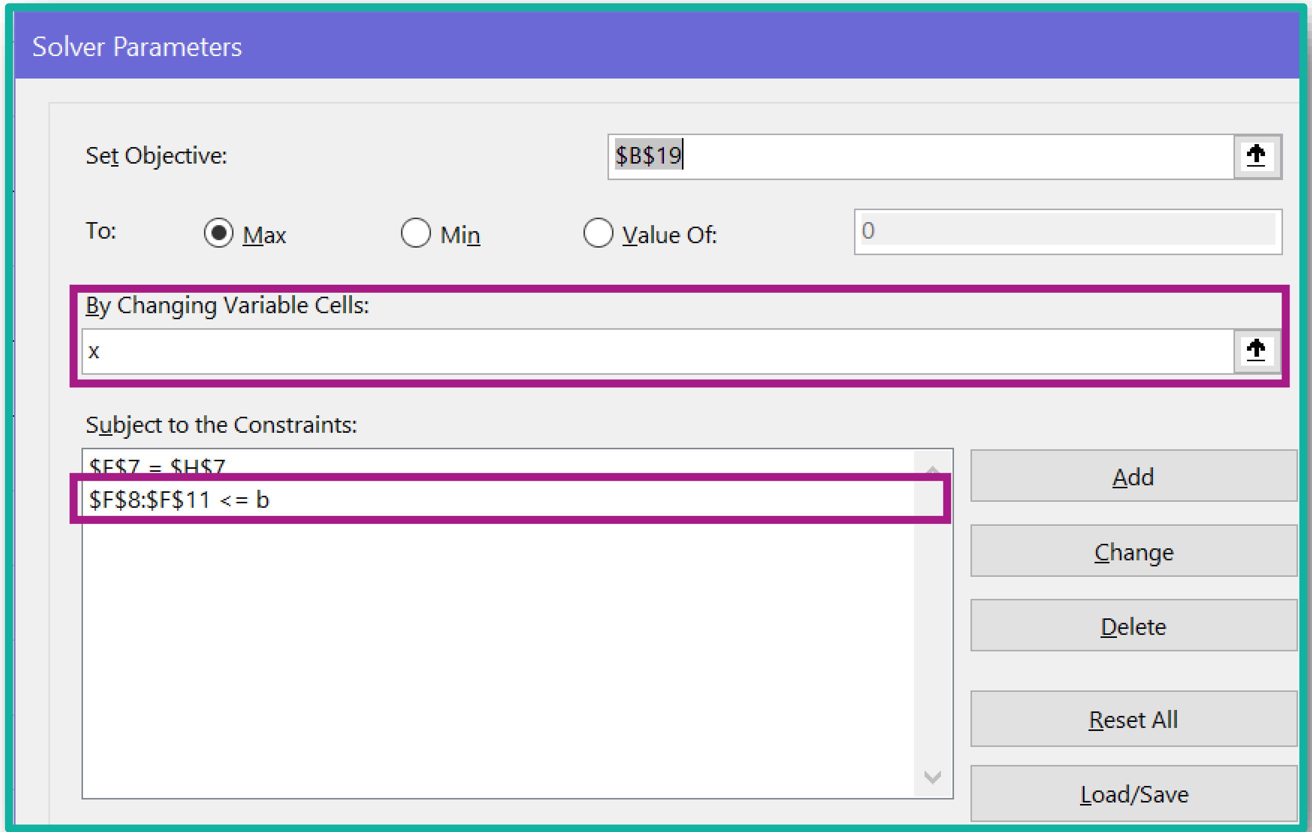
Ex: Investment

- Usage of variables

Products:	Municipal bonds ($)	CDs ($)	Treasury bills ($)	Growth stock ($)			
Return:	0.085	0.05	0.065	0.13			
Constraints:					Usage	Constraint	R.H.S.
Total investment	1	1	1	1	0	=	70000
Constraint 1	0.8	-0.2	-0.2	-0.2	=MMULT(A,x)		0
Constraint 2	-1	1	-1	-1	0	<=	0
Constraint 3	0.3	-0.7	-0.7	0.3	0	<=	0
Constraint 4	1.2	-1	-1	1.2	0	<=	0
Production:							
Municipal bonds =	0						
CDs =	0						
Treasury bills =	0						
Growth stock =	0						
Return =	0						

Ex: Investment

- Usage of variables



- Q: What other variable was created and how is it being used?

Ex: Transportation

- Best Boy retail chain ships televisions from 3 of its distribution warehouses to three of its retail stores monthly

- Each warehouse has a fixed supply per month and fixed demand per month

- Q: How many TVs should be shipped from each warehouse to each store to minimize the total cost of transportation?

- Supply (700 TVs) and Demand (600 TVs)

Warehouse	Supply (TVs)
1. Cincinnati	300
2. Atlanta	200
3. Pittsburgh	200

Store	Demand (TVs)
A. New York	150
B. Dallas	250
C. Detroit	200

Ex: Transportation

- Shipping cost per TV for each route

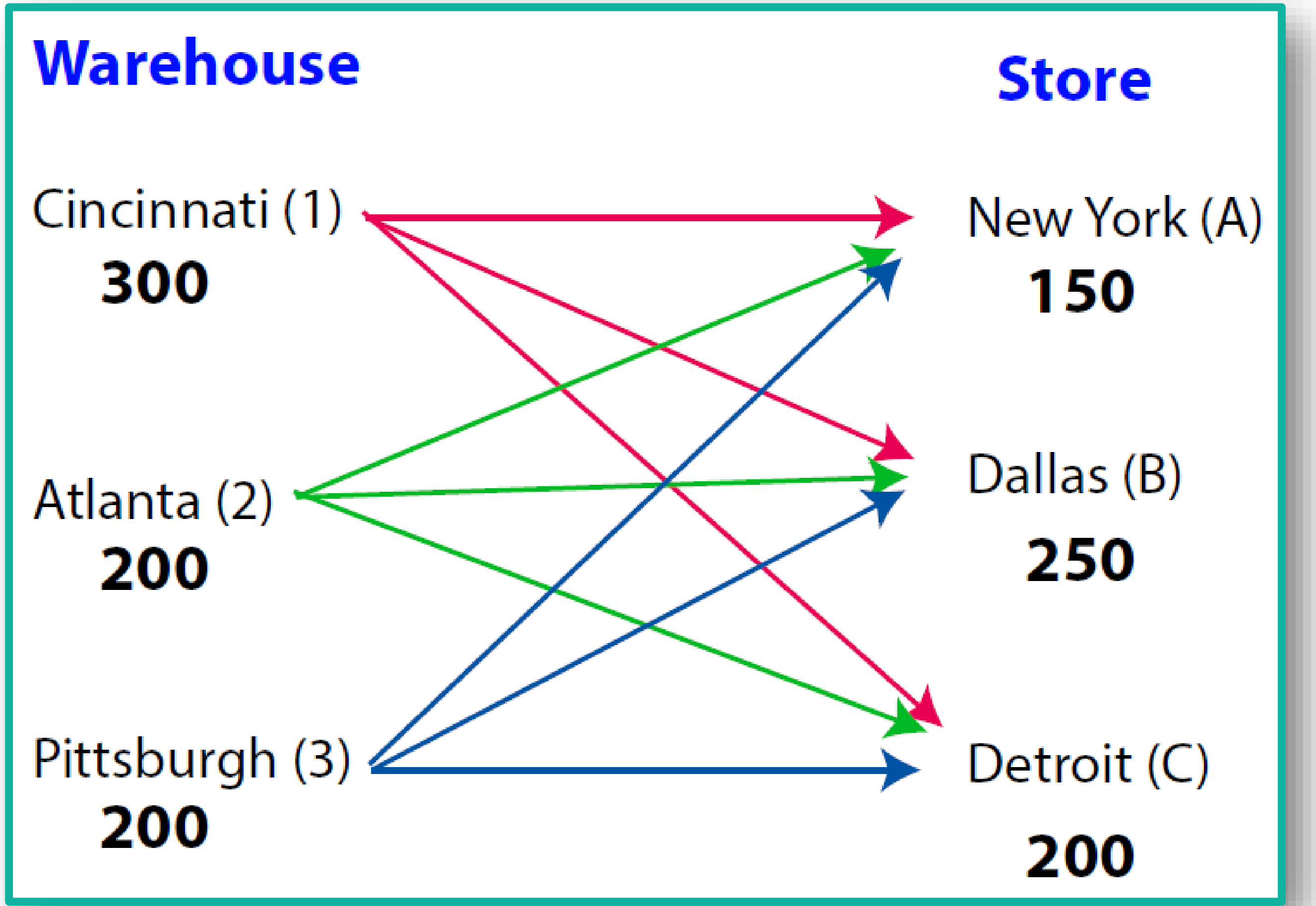
Warehouse
1. Cincinnati
2. Atlanta
3. Pittsburgh

Store
A. New York
B. Dallas
C. Detroit

	To Store		
From Warehouse	A	B	C
1	\$16	\$18	\$11
2	14	12	13
3	13	15	17

Ex: Transportation

- Visual of all routes (supply > demand)



Ex: Transportation

- Decision variables
  - Need to have one for each of the 9 routes
  - x_{ij} = number of televisions from warehouse i to store j
  - $i = 1,2,3 \quad \& \quad j = A, B, C$

- Linear program in standard form

Minimize $\quad 16x_{1A} + 18x_{1B} + 11x_{1C} + 14x_{2A} + 12x_{2B} + 13x_{2C} + 13x_{3A} + 15x_{3B} + 17x_{3C}$

Subject to

$x_{1A} + x_{1B} + x_{1C} \leq 300$ (Cincinnati supply)

$x_{2A} + x_{2B} + x_{2C} \leq 200$ (Atlanta supply)

$x_{3A} + x_{3B} + x_{3C} \leq 200$ (Pittsburgh supply)

$x_{1A} + x_{2A} + x_{3A} \geq 150$ (New York demand)

$x_{1B} + x_{2B} + x_{3B} \geq 250$ (Dallas demand)

$x_{1C} + x_{2C} + x_{3C} \geq 200$ (Detroit demand)

Ex: Transportation

- Download Transportation-1.xlsx from course website from link Sheet 2
- Sheet called Standard contains the standard linear program format and the sheet called Alternative contains a more compact form of the same linear program
- Focus on Alternative sheet

	A	B	C	D	E	F	G
4	***Warehouse***	New York	Dallas	Detroit	***TV sets shipped***	***Constraint***	***Supply***
5	Cincinatti	0	0	200	200	<=	300
6	Altanta	0	200	0	200	<=	200
7	Pittsburgh	150	50	0	200	<=	200
8	***TV sets shipped***	150	250	200			
9	***Constraint***	>=	>=	>=			
10	***Demand***	150	250	200			
11	***Cost ($)***	7300					
12							
13							
14	***Warehouse***	New York	Dallas	Detroit			
15	Cincinatti	16	18	11			
16	Altanta	14	12	13			
17	Pittsburgh	13	15	17			

Ex: Transportation

- Use of SUMPRODUCT in creation of objective function

	A	B	C	D
4	***Warehouse***	New York	Dallas	Detroit
5	Cincinatti	0	0	200
6	Altanta	0	200	0
7	Pittsburgh	150	50	0
8	***TV sets shipped***	150	250	200
9	***Constraint***	>=	>=	>=
10	***Demand***	150	250	200
11	***Cost ($)***	7300		
12		=SUMPRODUCT(B5:D7,B15,D17)		
13				
14	***Warehouse***	New York	Dallas	Detroit
15	Cincinatti	16	18	11
16	Altanta	14	12	13
17	Pittsburgh	13	15	17

Ex: Scheduling

- Download Multischedule-1.xlsx from course website from link Sheet 3

Ex: Quick-Screen Clothing

- Decision Variables
  - $x_1 = Number\ of\ Boxes\ of\ Sweatshirts\ - F$
  - $x_2 = Number\ of\ Boxes\ of\ Sweatshirts - B/F$
  - $x_3 = Number\ of\ Boxes\ of\ T - shirts - F$
  - $x_4 = Number\ of\ Boxes\ of\ T - shirts - B/F$

- Consider the following table showing resource requirements, unit costs, and profit of every dozen (box) of shirts

	Processing time (hr.) per dozen	Cost per dozen	Profit dozen
Sweatshirt - F	0.10	\$36	\$90
Sweatshirt - B/F	0.25	48	125
T-shirt - F	0.08	25	45
T-shirt - B/F	0.21	35	65

Ex: Quick-Screen Clothing

- Objective Function
  - Goal: Maximize profit on shirts
  - $Z = 90x_1 + 125x_2 + 45x_3 + 65x_4$

- Constraints
  - Only have 72 hours of processing time to produce all items: $0.1x_1 + 0.25x_2 + 0.08x_3 + 0.21x_4 \leq 72$
  - Company has a budget of $25,000: $36x_1 + 48x_2 + 25x_3 + 35x_4 \leq 25{,}000$
  - Trailer truck will pick up shirts and can accommodate 1,200 standard-size boxes where each standard-size box holds 12 T-shirts and a box of 12 sweatshirts is 3 times the size of the standard-size box: $3(\mathrm{x}_1 + \mathrm{x}_2) + x_3 + x_4 \leq 1{,}200$
  - They have 500 dozens of blank sweatshirts: $x_1 + x_2 \leq 500$
  - They have 500 dozens of blank T-shirts: $x_3 + x_4 \leq 500$
  - Nonnegativity: $x_1, x_2, x_3, x_4 \geq 0$

Ex: Quick-Screen Clothing

- Download ProductMix.xlsx from website link called Sheet 2
- Before Excel solver

A product mix								
Products:	Sweatshirt-F (dozen)	Sweatshirt-B/F (dozen)	T-shirt-F (dozen)	T-shirt-B/F (dozen)				
Profit per dozen:	90	125	45	65				
Resources:					Usage	Constraint	Available	Left over
Processing time	0.1	0.25	0.08	0.21	0	<=	72	72
Cost	36	48	25	35	0	<=	25000	25000
Truck capacity	3	3	1	1	0	<=	1200	1200
Blank sweatshirts	1	1	0	0	0	<=	500	500
Blank T-shirts	0	0	1	1	0	<=	500	500
Production:								
Sweatshirts-F =	0							
Sweatshirts-B/F =	0							
T-shirt-F =	0							
T-shirt-B/F =	0							
Profit =	0							

Ex: Quick-Screen Clothing

- After Excel solver

A product mix								
Products:	Sweatshirt-F (dozen)	Sweatshirt-B/F (dozen)	T-shirt-F (dozen)	T-shirt-B/F (dozen)				
Profit per dozen:	90	125	45	65				
Resources:					Usage	Constraint	Available	Left over
Processing time	0.1	0.25	0.08	0.21	72	<=	72	0
Cost	36	48	25	35	21593.333	<=	25000	3406.6667
Truck capacity	3	3	1	1	1200	<=	1200	0
Blank sweatshirts	1	1	0	0	233.33333	<=	500	266.66667
Blank T-shirts	0	0	1	1	500	<=	500	0
Production:								
Sweatshirts-F =	175.55556							
Sweatshirts-B/F =	57.777778							
T-shirt-F =	500							
T-shirt-B/F =	0							
Profit =	45522.222							

Ex: Quick-Screen Clothing

- Recommended optimal solution to maximize profit at $45,522.22
  - $x_1 = 175.56$
  - $x_2 = 57.78$
  - $x_3 = 500$
  - $x_4 = 0$

- Sensitivity report for objective function coefficients

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B15	Sweatshirts-F = (dozen)	175.5555556	0	90	11.92307692	40
B16	Sweatshirts-B/F = (dozen)	57.77777778	0	125	13.21428571	11.92307692
B17	T-shirt-F = (dozen)	500	0	45	1E+30	4.111111111
B18	T-shirt-B/F = (dozen)	0	-10.33333333	65	10.33333333	1E+30

Ex: Quick-Screen Clothing

- Sensitivity report for constraint quantities

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
F10	Blank sweatshirts Usage	233.3333333	0	500	1E+30	266.6666667
F11	Blank T-shirts Usage	500	4.111111111	500	185.7142857	500
F7	Processing time Usage	72	233.3333333	72	26.33333333	8.666666667
F8	Cost Usage	21593.33333	0	25000	1E+30	3406.666667
F9	Truck capacity Usage	1200	22.22222222	1200	260	316

Vectors and Matrices

- Linear program with 4 decision variables and 4 constraints requires more time to insert formulas in Excel

- Understanding of linear algebra can make this a more efficient process

- The object $\mathbf{x} = [x_1, x_2, x_3, x_4]$ is a row vector in $\mathbb{R}^4$

- The object $\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$ is a column vector in $\mathbb{R}^4$

- The transpose of a vector $\mathbf{x}$, denoted $\mathbf{x}'$, transforms a row vector into a column vector and vice versa

Vectors and Matrices

- The object $\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \\ a_{41} & a_{42} & a_{43} \end{bmatrix}$ is a matrix in $\mathbb{R}^{4\times 3}$

- The dimension of a matrix, denoted $\dim(\mathbf{A})$, describes its number of rows and number of columns (in that order)

- Based on above example, $\dim(\mathbf{A})$ is 3×4

- A row vector in $\mathbb{R}^m$ is a matrix in $\mathbb{R}^{1\times m}$

- A column vector in $\mathbb{R}^n$ is a matrix in $\mathbb{R}^{n\times 1}$

- Typically, all vectors are by default column vectors

Vectors and Matrices

- For matrices $\mathbf{A} \in \mathbb{R}^{m\times n}$ and $\mathbf{B} \in \mathbb{R}^{n\times p}$, we can define their product $\mathbf{M} = \mathbf{AB}$, which will be a matrix in $\mathbb{R}^{m\times p}$

- For $\mathbf{A} \in \mathbb{R}^{3\times 4}$ and $\mathbf{B} \in \mathbb{R}^{4\times 2}$, matrix $\mathbf{M} = \mathbf{AB}$ can be expressed as

$$\mathbf{M} = \mathbf{AB} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \end{bmatrix} \times \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \\ b_{31} & b_{32} \\ b_{41} & b_{42} \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \\ m_{31} & m_{32} \end{bmatrix}$$

where

$$m_{ij} = a_{i1}b_{1j} + a_{i2}b_{2j} + a_{i3}b_{j3} + a_{i4}b_{4j} \text{ for } i = 1,2,3 \text{ and } j = 1,2$$

- In order to compute, $\mathbf{M} = \mathbf{AB}$, the number of columns in $\mathbf{A}$ must equal the number of rows in $\mathbf{B}$

- In above example, the matrix $\mathbf{M} = \mathbf{BA}$ does not exist

Vectors and Matrices

- If $\mathbf{A}$ and $\mathbf{B}$ are square matrices of the same size, say in $\mathbb{R}^{p\times p}$, we can compute both $\mathbf{AB}$ and $\mathbf{BA}$, but they may not necessarily be equal

- Let $\mathbf{A} = \begin{bmatrix} 1 & 3 \\ -2 & 0 \end{bmatrix}$ and $\mathbf{B} = \begin{bmatrix} 2 & 5 \\ 7 & 1 \end{bmatrix}$

$$\mathbf{AB} = \begin{bmatrix} 1\times 2 + 3\times 7 & 1\times 5 + 3\times 1 \\ -2\times 2 + 0\times 7 & -2\times 5 + 0\times 1 \end{bmatrix} = \begin{bmatrix} 23 & 8 \\ -4 & -10 \end{bmatrix}$$

$$\mathbf{BA} = \begin{bmatrix} 2\times 1 + 5\times -2 & 2\times 3 + 5\times 0 \\ 7\times 1 + 1\times -2 & 7\times 3 + 1\times 0 \end{bmatrix} = \begin{bmatrix} -8 & 6 \\ 5 & 21 \end{bmatrix}$$

- Let $\mathbf{x} = [x_1, x_2, x_3, x_4]'$ and $\mathbf{y} = [y_1, y_2, y_3, y_4]'$ be column vectors in $\mathbb{R}^4$

$$\mathbf{x}'\boldsymbol{y} = x_1y_1 + x_2y_2 + x_3y_3 + x_4y_4 = \mathbf{y}'\mathbf{x}$$

Excel: Matrix Multiplication

- MMULT Function in Excel
  - The MMULT Function in Excel is used to multiply arrays (matrices) that have compatible dimensions and returns an array (matrix)
  - Syntax: MMULT(array1,array2)
  - Example: Vector Multiplication

	A	B	C	D	E	F
1	**Vector a**	1	2	3		**Vector b**
2						3
3						2
4						1
5						
6	MMULT(a,b)	10				
7	MMULT(b,a)	3	6	9		
8		2	4	6		
9		1	2	3		

Excel: Matrix Multiplication

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  - Syntax: MMULT(array1,array2)
  - Example: Vector Multiplication

	A	B	C	D	E	F
1	**Vector a**	1	2	3		**Vector b**
2						3
3						2
4						1
5						
6	MMULT(a,b)	10	=MMULT(B1:D1,F2:F4)			
7	MMULT(b,a)	3	6	9		
8		2	4	6		
9		1	2	3		

Excel: Matrix Multiplication

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  - Syntax: MMULT(array1,array2)
  - Example: Vector Multiplication

	A	B	C	D	E	F
1	**Vector a**	1	2	3		**Vector b**
2						3
3						2
4						1
5						
6	MMULT(a,b)	10				
7	MMULT(b,a)	3	6	9	=MMULT(F2:F4,	
8		2	4	6		B1:D1)
9		1	2	3		

Excel: Matrix Multiplication

- MMULT Function in Excel
  - Example: Matrix Multiplication

	A	B	C	D	E	F	G
1	Matrix A	1	2	3		Matrix B	
2		4	5	6		1	2
3						3	4
4							
5	MMULT(A,B)	#VALUE!					
6	MMULT(B,A)	9	12	15			
7		19	26	33			

Excel: Matrix Multiplication

- MMULT Function in Excel
  - Example: Matrix Multiplication

	A	B	C	D	E	F	G
1	Matrix A	1	2	3		Matrix B	
2		4	5	6		1	2
3						3	4
4							
5	MMULT(A,B)	#VALUE!	=MMULT(B1:D2,F2:G3)				
6	MMULT(B,A)	9	12	15			
7		19	26	33			

Excel: Matrix Multiplication

- MMULT Function in Excel
  - Example: Matrix Multiplication

	A	B	C	D	E	F	G
1	Matrix A	1	2	3		Matrix B	
2		4	5	6		1	2
3						3	4
4							
5	MMULT(A,B)	#VALUE!					
6	MMULT(B,A)	9	12	15	=MMULT(F2:G3,B1:D2)		
7		19	26	33			

Excel: Matrix Multiplication

- SUMPRODUCT Function in Excel
  - The SUMPRODUCT function in Excel is used to multiply arrays (matrices) element-wise and then returns the sum of their products
  - In mathematics, this is often referred to as a cross-product or vector-product when the arrays are vectors
  - Syntax: SUMPRODUCT(array1,array2)
  - Ex: Cross-product

	A	B	C	D	E	F
1	**Vector a**	1	2	3		**Vector c**
2	**Vector b**	3	2	1		4
3						5
4						6
5						
6	SUMPRODUCT(a,b)	10				
7	SUMPRODUCT(a,c)	#VALUE!				

Excel: Matrix Multiplication

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  - Syntax: SUMPRODUCT(array1,array2)
  - Ex: Cross-product

	A	B	C	D	E	F
1	**Vector a**	1	2	3		**Vector c**
2	**Vector b**	3	2	1		4
3						5
4						6
5						
6	SUMPRODUCT(a,b)	10	=SUMPRODUCT(B1:D1,B2:D2)			
7	SUMPRODUCT(a,c)	#VALUE!				

Excel: Matrix Multiplication

- SUMPRODUCT Function in Excel
  - The SUMPRODUCT function in Excel is used to multiply arrays (matrices) element-wise and then returns the sum of their products
  - In mathematics, this is often referred to as a cross-product or vector-product when the arrays are vectors
  - Syntax: SUMPRODUCT(array1,array2)
  - Ex: Cross-product

	A	B	C	D	E	F
1	**Vector a**	1	2	3		**Vector c**
2	**Vector b**	3	2	1		4
3						5
4						6
5						
6	SUMPRODUCT(a,b)	10				
7	SUMPRODUCT(a,c)	#VALUE!	=SUMPRODUCT(B1:D1,F2:F4)			

Excel: Application of Matrices

- Both MMULT and CROSSPRODUCT can be used in Excel to make the creation of formulas and constraints of linear programs considerably easier

- Made up example for practice

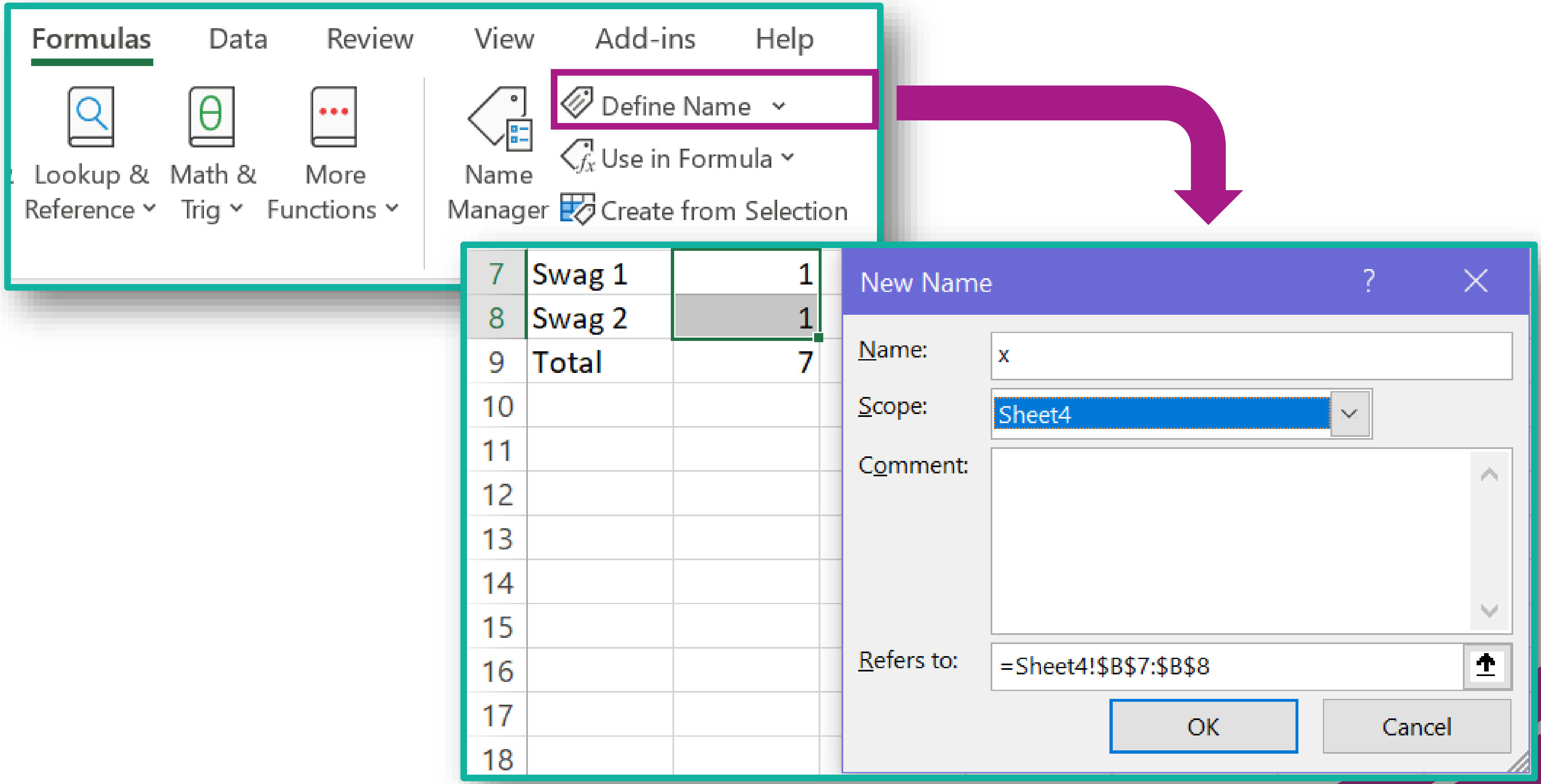
	A	B	C	D	E	F
1	Profit	3	4			
2				Total	Constraint	Max
3	Metal	2	1	3	<=	30
4	Plastic	0	4	4	<=	50
5						
6						
7	Swag 1	1				
8	Swag 2	1				
9	Total	7				

Solver

	A	B	C	D	E	F
1	Profit	3	4			
2				Total	Constraint	Max
3	Metal	2	1	30	<=	30
4	Plastic	0	4	50	<=	50
5						
6						
7	Swag 1	8.75				
8	Swag 2	12.5				
9	Total	76.25				

Excel: Application of Matrices

- Creating EXCEL variable for easy referencing



Excel: Application of Matrices

- Usage of created variable in establishing constraints and objective function

	A	B	C	D	E	F
1	Profit	3	4			
2				Total	Constraint	Max
3	Metal	2	1	30	<=	30
4	Plastic	0	4	50	<=	50
5				=MMULT(B4:C4,x)		
6						
7	Swag 1	8.75				
8	Swag 2	12.5				
9	Total	76.25	=MMULT(B1:C1,x)			

Excel: Application of Matrices

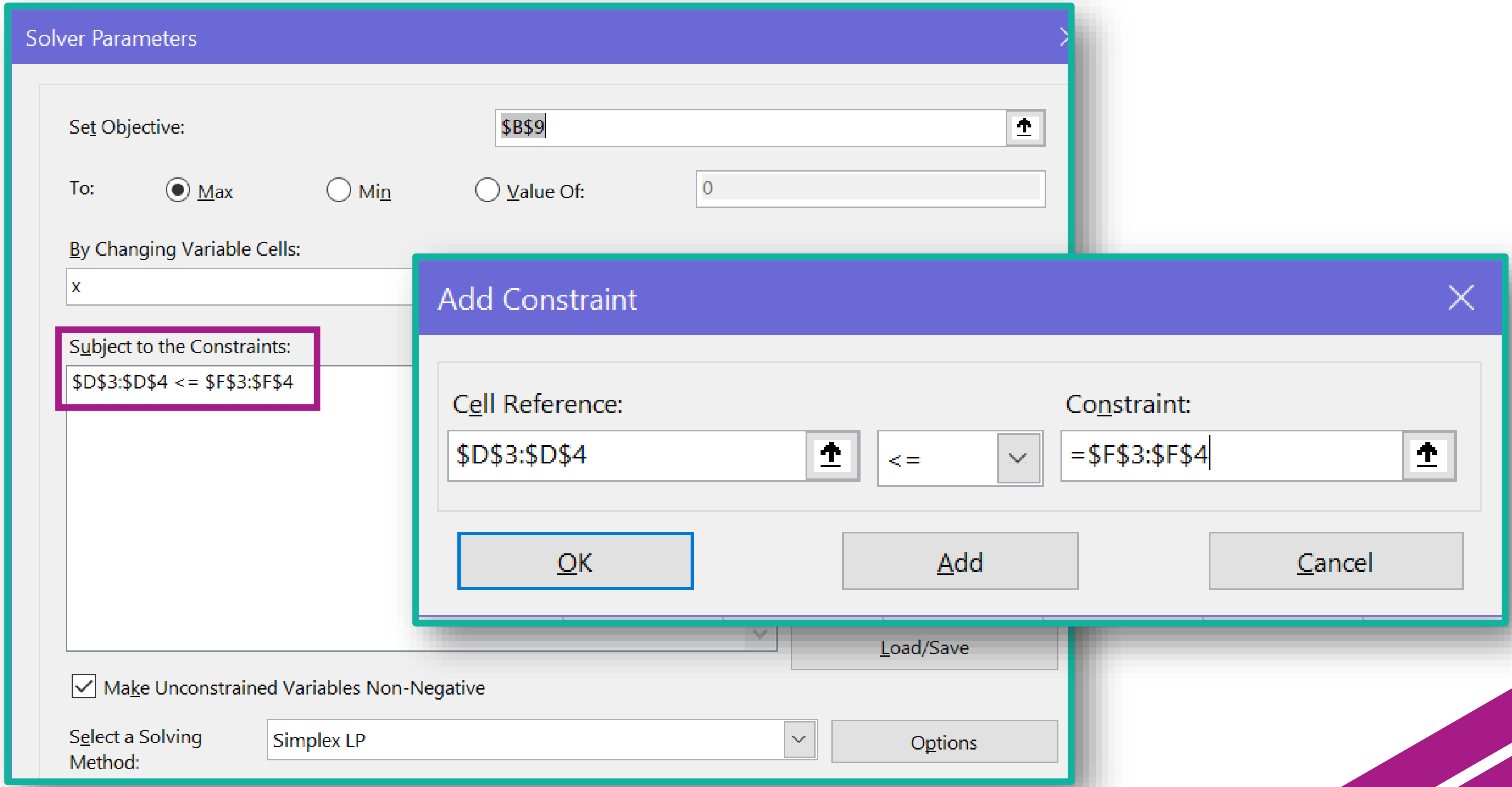
- Another option for specification

SUM =MMULT(B3:C4,B7:B8)

	A	B	C	D	E	F
1	Profit	3	4			
2				Total	Constraint	Max
3	Metal	2	1	B8)	<=	30
4	Plastic	0	4	4	<=	50
5						
6						
7	Swag 1	1				
8	Swag 2	1				
9	Total	7				

Excel: Application of Matrices

- Another option for specification



Excel: Application of Matrices

- Try using MMULT and SUMPRODUCT in cell formulas
- Try using vectors/matrices in specification of constraints
- Download Lecture6WS.xlsx from course website from link Sheet 2 for all examples seen in this lecture

The End

Dale