Decision Modeling: Data Analytics for Stormwater Project Selection and Risk Analysis

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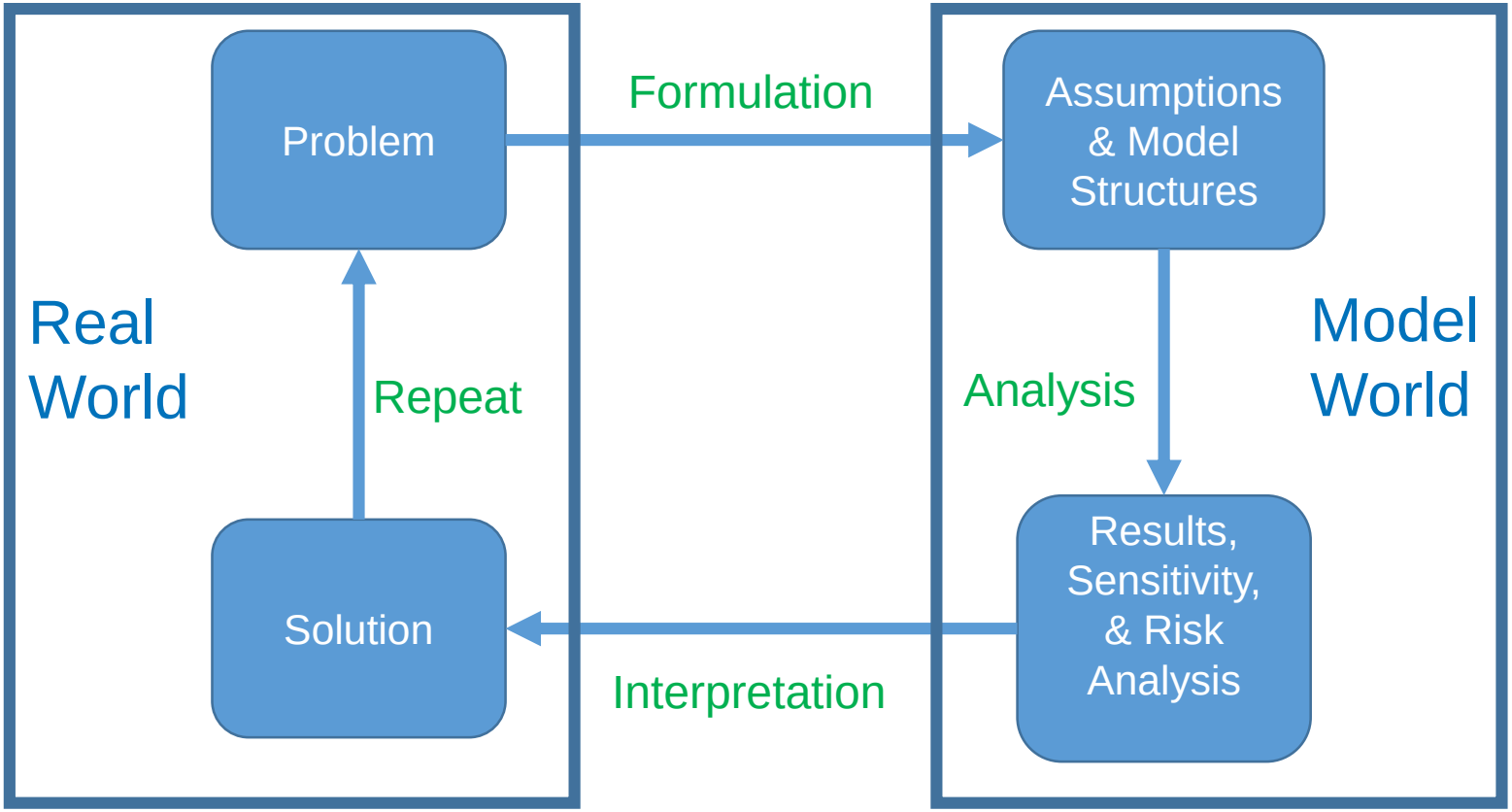
Agenda

- Intro to Decision Modeling
- Modeling Project Selection
- Insights & Takeaways
- Resources and follow-up discussions

Decision Modeling

Model: A simplified representation of reality.



MWRD Stormwater Capital Programs

Phase I Projects
Identified from the DWPs to address overbank flooding “riverine flooding”

Phase II & GI Projects
Working with local communities and agencies to address local drainage problems.

Stormwater Masterplans
Investigate “urban flooding” issues and evaluate potential green and gray infrastructure solutions.

2004 2011 2012 2013 2014 2015 2016 2017 2018

The authority for general supervision of stormwater management in Cook County was conveyed to the District by the Illinois State legislature.

Capital Programs	Projects Selected	Projects Evaluated
Phase I	27	135
Phase II	58	108
GI	39	92
Totals	**124**	**335**

Project Selection MODEL - Linear Optimization, with qualitative factors

Objective: Maximize the NPV of the Capital Plan

Decision Variables: Quantity of the scalable projects across the 3 regions.

Constraints: Region budgets cannot be exceeded, staff hours cannot be exceeded, rain barrels cannot exceed rain barrel eligible structures, property buyouts cannot exceed repetitive loss structures in each region, streetscape total length cannot exceed available length in each region, reservoir expansion total volume cannot exceed available volume in each region, flood reduction benefits cannot exceed flood reduction losses, and quantities must be non-negative.

Color Key	Decision Variables	Cells in Formulation	Constraints	Optimized Cell

Project Title	# of Impacted Households	Construction Costs ($)/Unit	Yearly Maintenance Costs ($/yr)/Unit	Life Cycle (yrs)	Yrly Flood Reduction Benefits ($/yr Region 1)	Yrly Flood Reduction Benefits ($/yr Region 2)	Yrly Flood Reduction Benefits ($/yr Region 3)	Life Cycle Costs ($)	Life Cycle Benefits ($)	NPV for Capital Plan ($)	B/C Ratio	Billable Staff Hours/Unit	Units	Region 1 Quantity	Region 2 Quantity	Region 3 Quantity	Region 1 Capital Plan ($)	Region 2 Capital Plan ($)	Region 3 Capital Plan ($)	Capital Plan Billable Hours	Total Quantity
Rain Barrel Reimbursement Program	80.00	$ 50.00	$ -	30	$ 2,000.00	$ 1,000.00	$ 1,000.00	$4,000.00	$ 73,168.13	$ 69,168.13	18.292	10	Rain Barrels	40	20	20	$ 2,000.00	$ 1,000.00	$ 1,000.00	800	80.00 Rain Barrel(s)
Property Buyouts	6.44	$ 200,000.00	$ 500.00	Inf.	$ 22,005.80	$ 21,950.00	$ 20,450.00	$ 1,368,623.19	$ 1,610,144.93	$ 241,521.74	1.176	100	Res. Structure Equivalents	2.2005797	2.195	2.045	$ 440,115.94	$ 439,000.00	$ 409,000.00	644.057971	6.44 Res. Structure Equivalent(s)
Green Streetscape	2.00	$ 20,000.00	$ 700.00	50	$ 6,900.00	$ 6,900.00	$ 4,600.00	$280,300.23	$ 413,672.20	$ 133,371.96	1.476	150	100ft	3	3	2	$ 60,000.00	$ 60,000.00	$ 40,000.00	1200	800.00 ft
Reservoir Expansion	0.89	$ 55,000.00	$ 500.00	75	$ 6,228.99	$ -	$ -	$118,956.19	$ 153,733.91	$ 34,777.72	1.292	200	1 ac-ft	1.7797101	0	0	$ 97,884.06	$ -	$ -	355.942029	1.78 ac-ft
				SUM	$ 37,134.78	$ 29,850.00	$ 26,050.00		SUM	$478,839.55											
																Sum	$ 600,000.00	$ 500,000.00	$ 450,000.00	3000	

Discount Rate: 4.00%

CONSTRAINTS

	Region 1	Region 2	Region 3
Budget Constraint	$ 600,000.00	$ 500,000.00	$ 450,000.00
Staff Scheduled Hours Budget	3000		
Rain Barrel Eligible Structures	40	20	20
Repetitive Loss	50	200	150
Convertible Street Length (100s of ft)	3	3	2
Available Vol. For Reservoir Expansion(ac-ft)	3	4	5
Avg. Flooding Damages ($)/yr	45000	35000	50000

Increase Amount (All 3 Regions)
$ -

Color Key	Decision Variables	Cells in Formulation	Constraints	Optimized Cell

Decision Variables: Quantity of 4 scalable projects for 3 regions

Project Title	Units	Region 1 Quantity	Region 2 Quantity	Region 3 Quantity
Rain Barrel Reimbursement Program	Rain Barrels	40	20	20
Property Buyouts	Res. Structure Equivalents.	2.20057971	2.195	2.045
Green Streetscape	100ft	3	3	2
Reservoir Expansion	1 ac-ft	1.77971014	0	0

Color Key	Decision Variables	Cells in Formulation	Constraints	Optimized Cell

Objective: Maximize [Net Present Value of Benefits ($) – Costs ($)]

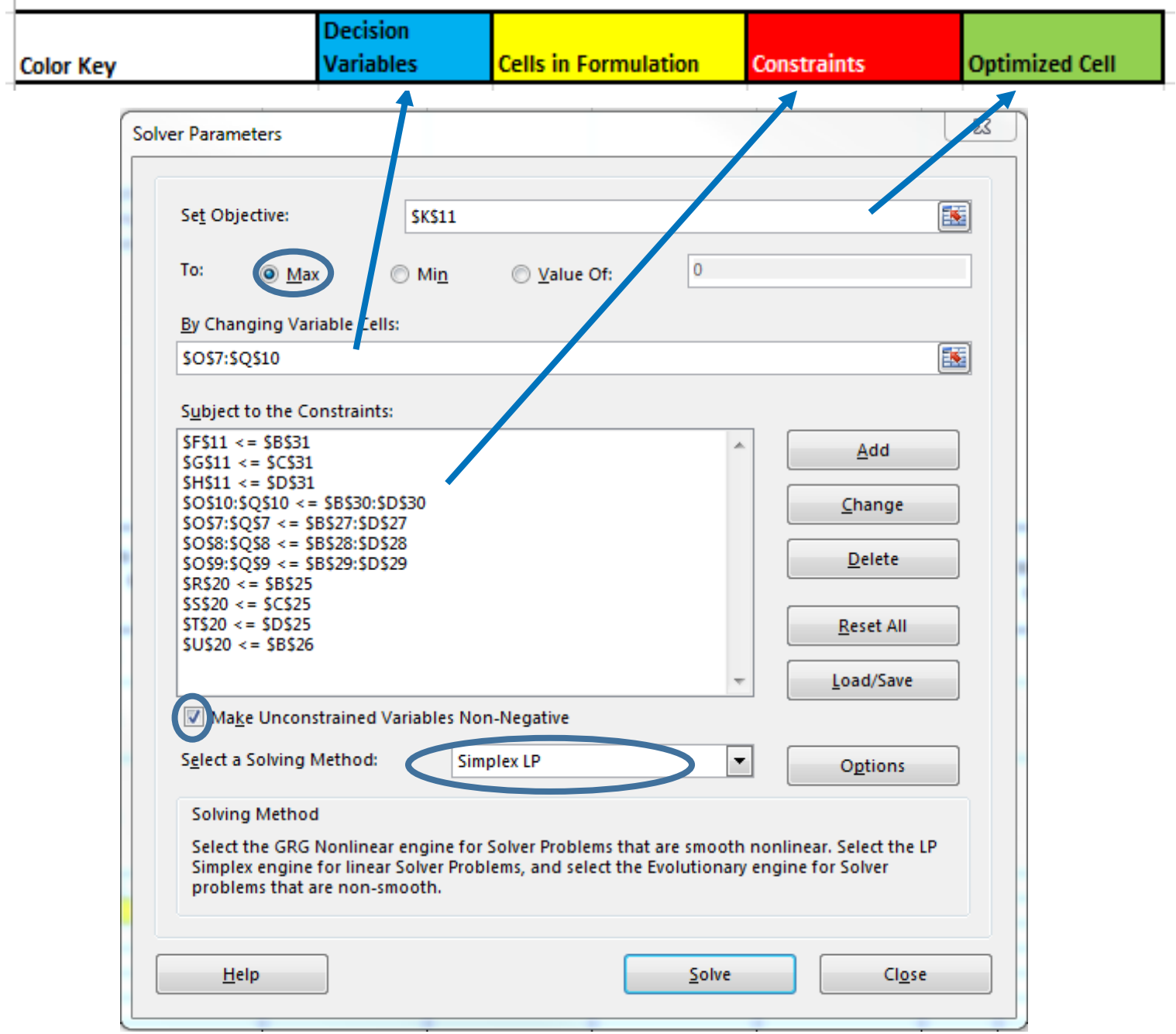
Project Title	Units	NPV for Capital Plan ($)
Rain Barrel Reimbursement Program	Rain Barrels	$ 69,168.13
Property Buyouts	Res. Structure Equivalents.	$ 241,521.74
Green Streetscape	100ft	$ 133,371.96
Reservoir Expansion	1 ac-ft	$ 34,777.72
	Sum →	**$478,839.55**

Color Key	Decision Variables	Cells in Formulation	Constraints	Optimized Cell

Constraints & Formulation Cells

Discount Rate	4.00%		
CONSTRAINTS			
	Region 1	Region 2	Region 3
Budget Constraint	$ 600,000.00	$ 500,000.00	$ 450,000.00
Staff Scheduled Hours Budget	3000		
Rain Barrel Eligible Structures	40	20	20
Repetitive loss Structures	50	300	150
Convertible Street Length (100s of ft)	3	3	2
Available Vol. For Reservoir Expansion(ac-ft)	3	4	5
Avg. Flooding Damages ($)/yr	45000	35000	50000

i.e. Capital Plan ≤ Budget Constraint



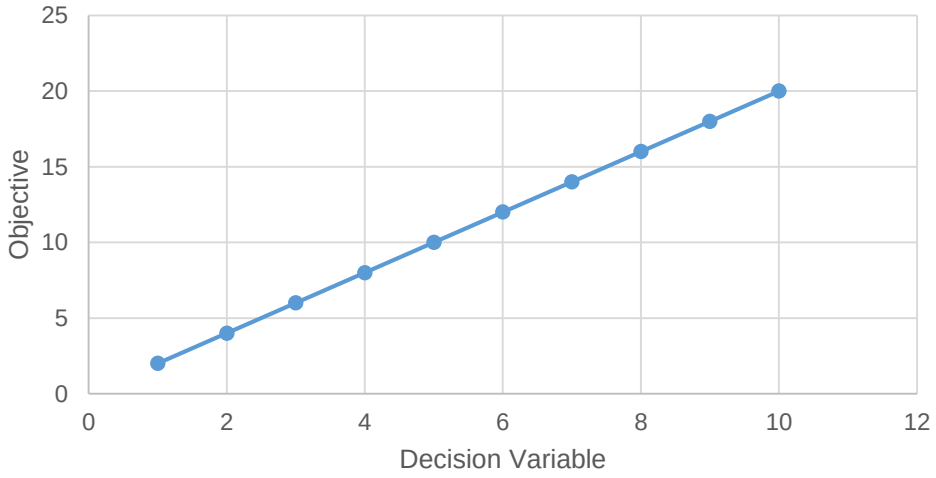
Add-in must be enabled on the Excel add-in settings

Linear Optimization Models

Sample Objective= $\sum$ Decision Variables x (NPV constants)

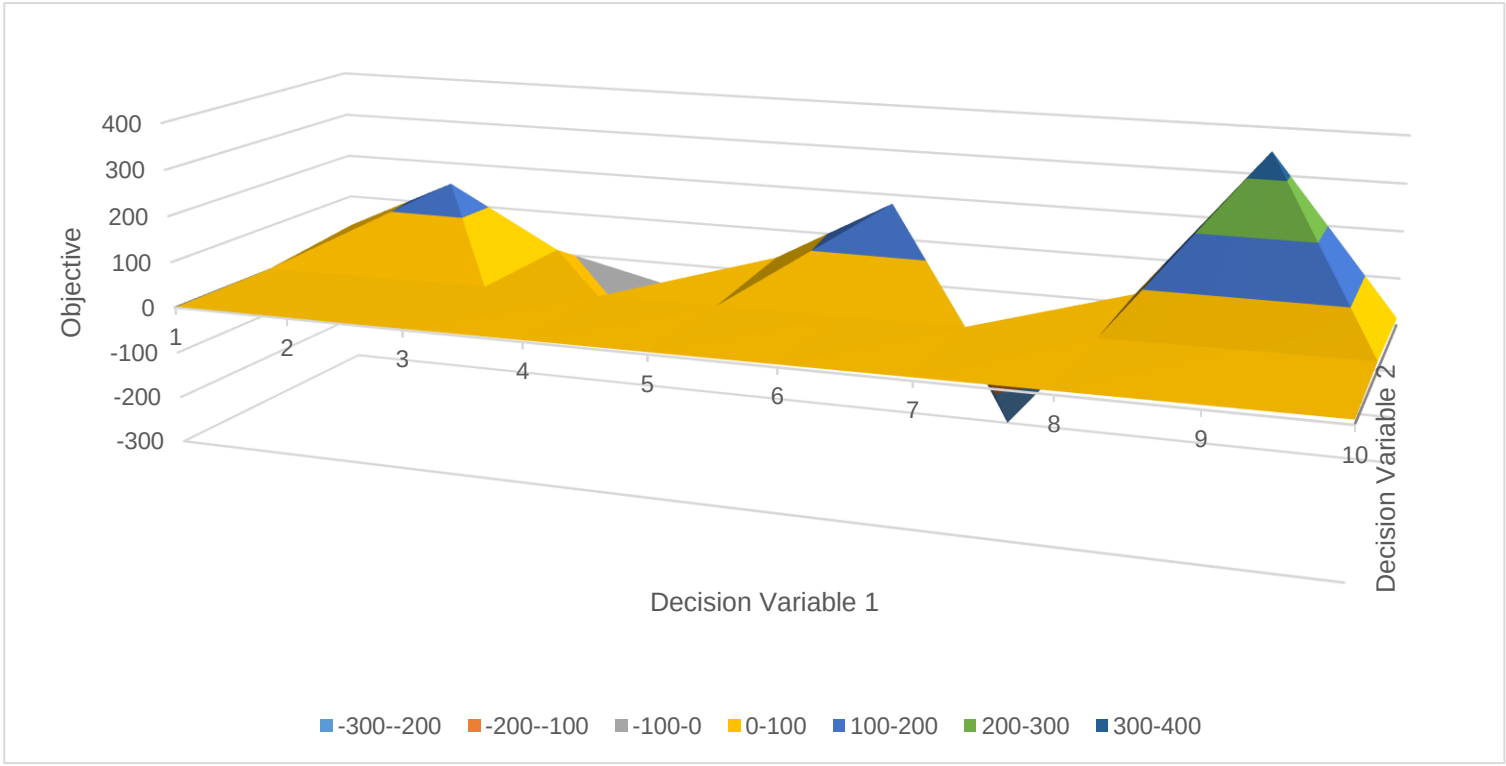
Examples:

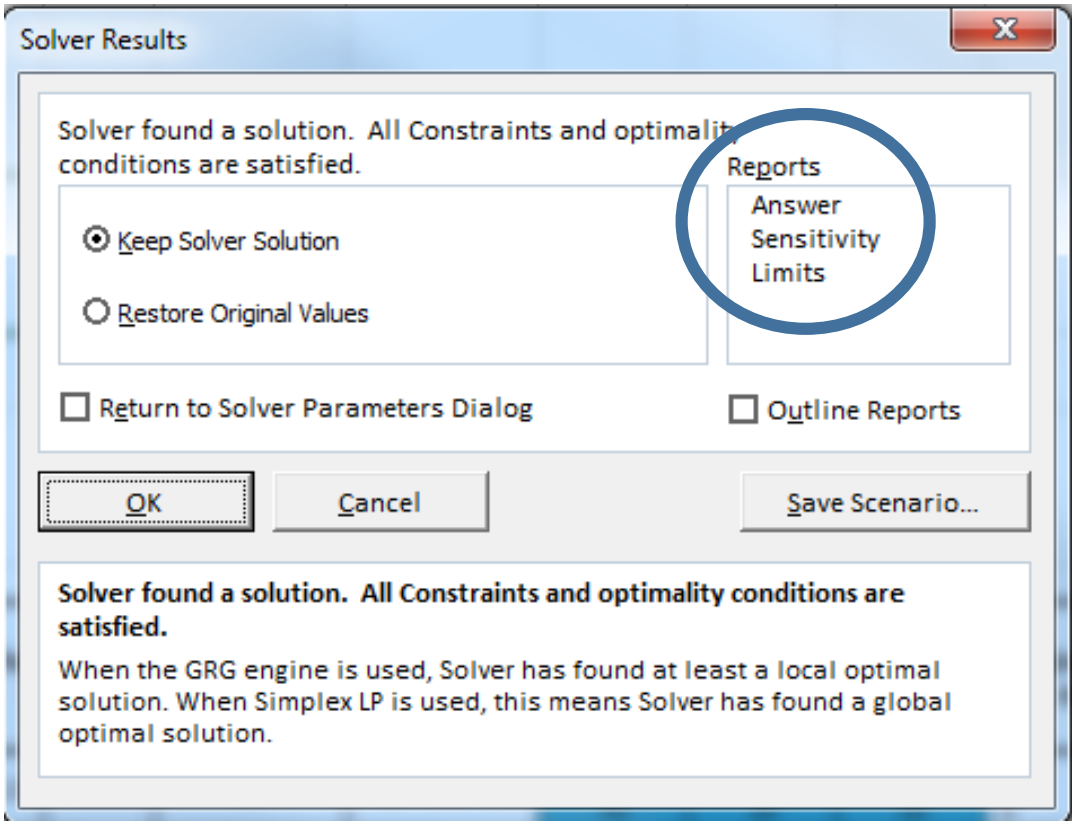
$15x_1 + 10x_2 - 10x_3$	**Linear**
$3x_1x_2 + 10x_3$	**Nonlinear**
$x_1^2 + 10x_3/x_2$	**Nonlinear**



Non-Linear Optimization Algorithms

GRG Nonlinear & Evolutionary





Sensitivity Report

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
F11	SUM Yrly Flood Reduction Benefits ($/yr Region	$37,134.78	0	45000	1E+30	7865.217391
G11	SUM Yrly Flood Reduction Benefits ($/yr Region	$29,850.00	0	35000	1E+30	5150
H11	SUM Yrly Flood Reduction Benefits ($/yr Region	$26,050.00	0	50000	1E+30	23950
R20	Sum Region 1 Capital Plan ($)	$600,000.00	0.160750072	600000	164454.5455	379600
S20	Sum Region 2 Capital Plan ($)	$500,000.00	0.160750072	500000	103000	421000
T20	Sum Region 3 Capital Plan ($)	$450,000.00	0.160750072	450000	479000	409000
U20	Sum Capital Plan Billable Hours	3000	53.49985523	3000	210.5	307

Add-in: Solver Datatable

Oneway analysis for Solver model in Project Selection worksheet

Budget Increase (All 3 Regions) (cell F24) values along side, output cell(s) along top

	K11
$ -	$478,839.55
$ 50,000.00	$502,952.06
$ 100,000.00	$527,064.57
$ 150,000.00	$543,621.83
$ 200,000.00	$557,124.84
$ 250,000.00	$565,162.34
$ 300,000.00	$573,199.84
$ 350,000.00	$581,123.98
$ 400,000.00	$588,915.02
$ 450,000.00	$596,706.07
$ 500,000.00	$601,224.87
$ 550,000.00	$601,224.87
$ 600,000.00	$601,224.87
$ 650,000.00	$601,224.87
$ 700,000.00	$601,224.87
$ 750,000.00	$601,224.87
$ 800,000.00	$601,224.87
$ 850,000.00	$601,224.87
$ 900,000.00	$601,224.87
$ 950,000.00	$601,224.87
$ 1,000,000.00	$601,224.87

Data for cha

K11
478839.6
952.1
064.6
521.8
124.8
162.3
199.8
1124
8915
706.1
224.9
224.9
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601224.9
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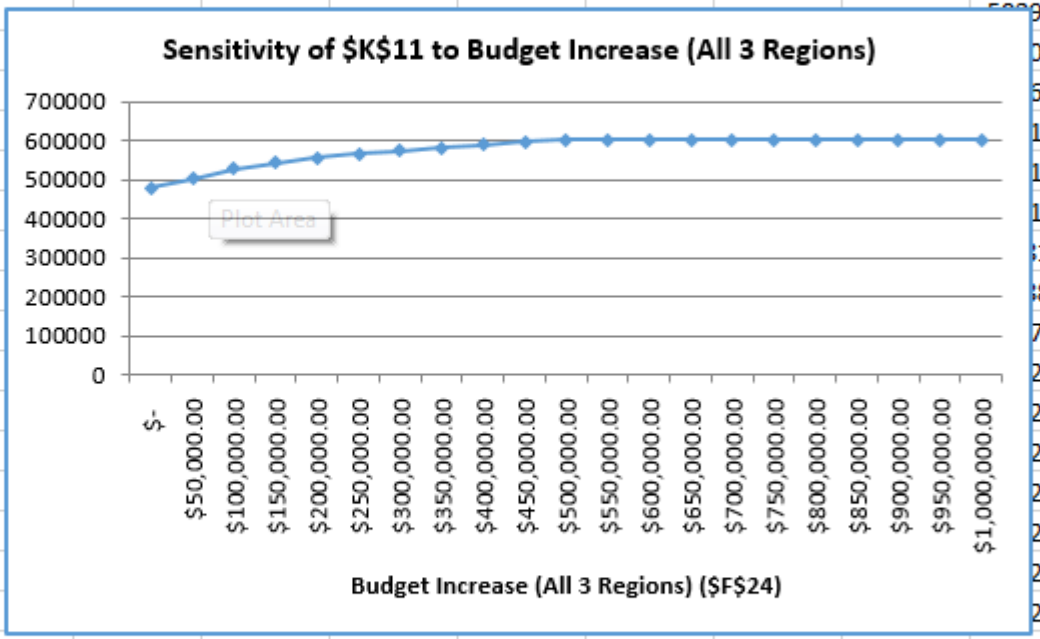

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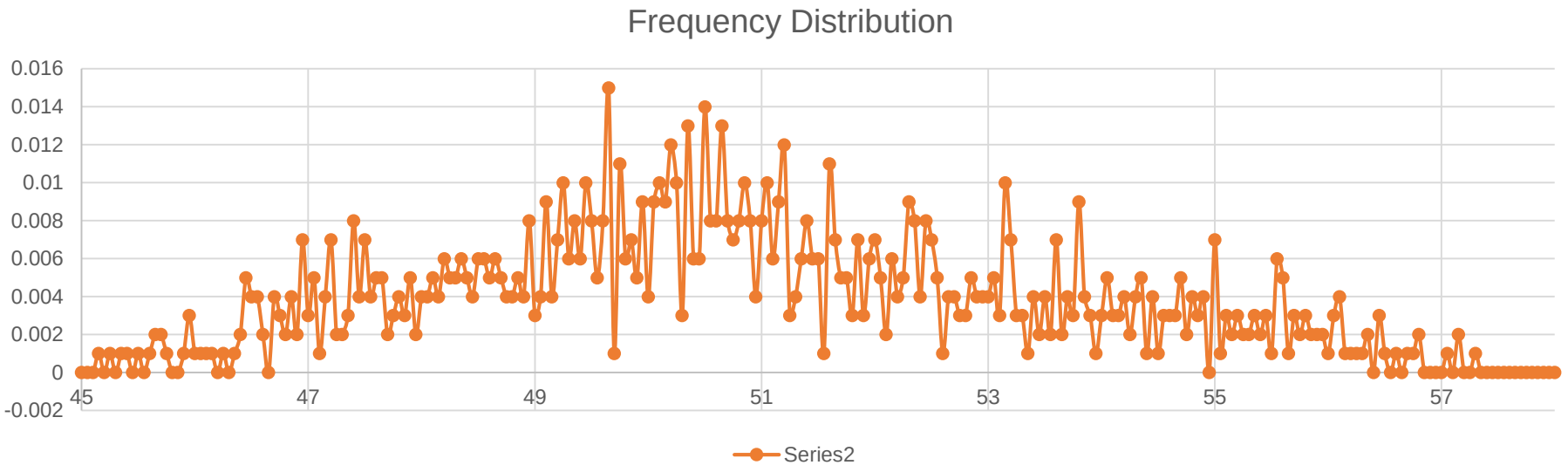
Monte Carlo Simulation: Distribution Functions



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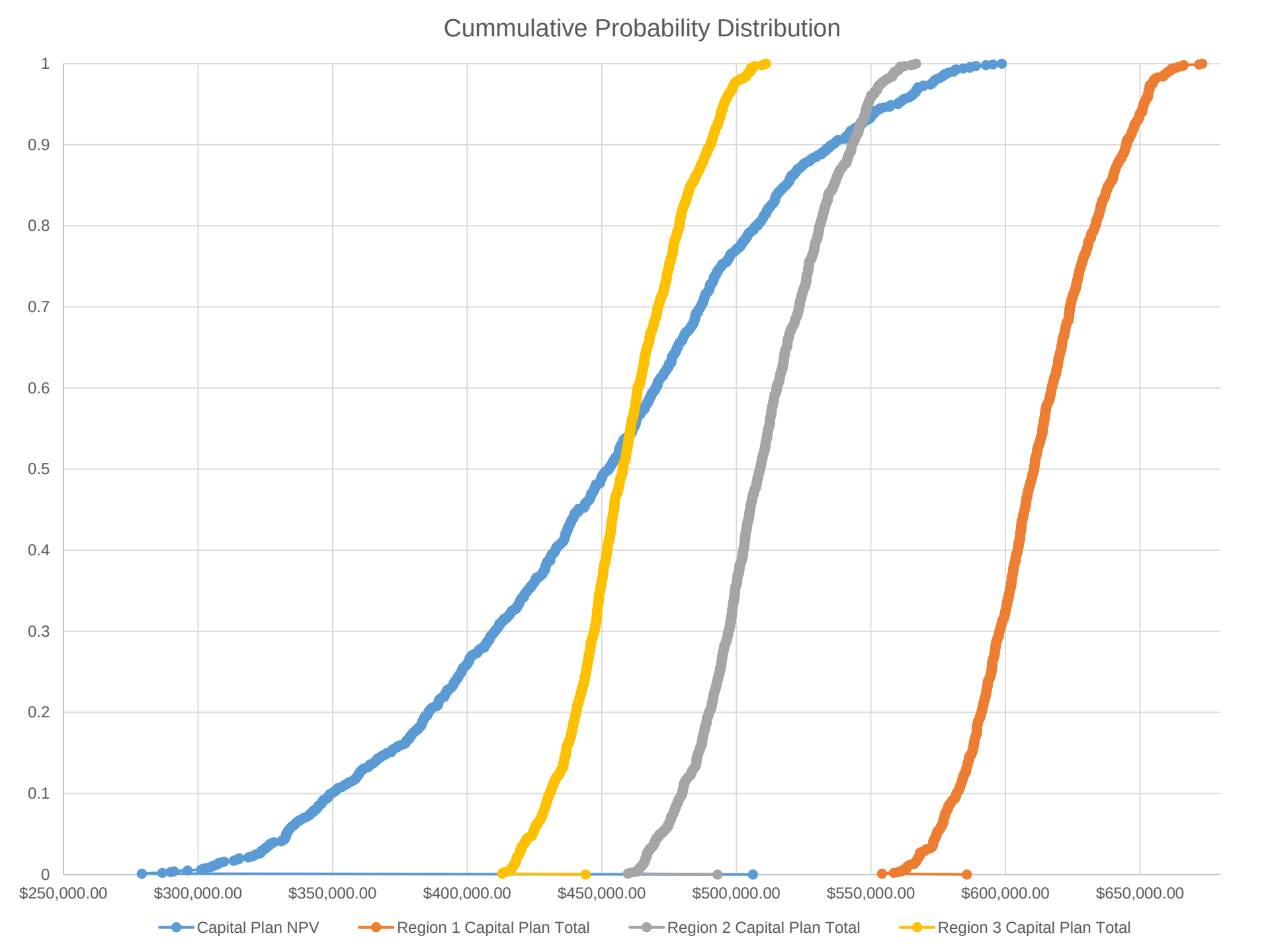

Cummulative Probability Distribution
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$250,000.00
$300,000.00
$350,000.00
$400,000.00
$450,000.00
$500,000.00
$550,000.00
$600,000.00
$650,000.00
Capital Plan NPV
Region 1 Capital Plan Total
Region 2 Capital Plan Total
Region 3 Capital Plan Total

Modeling what to order for dinner: Decision Variables

Local Restaurant | Menu - Massachusetts ...
kellysroastbeef.com

Bacon Truck Café in Charle...
bostonmagazine.com

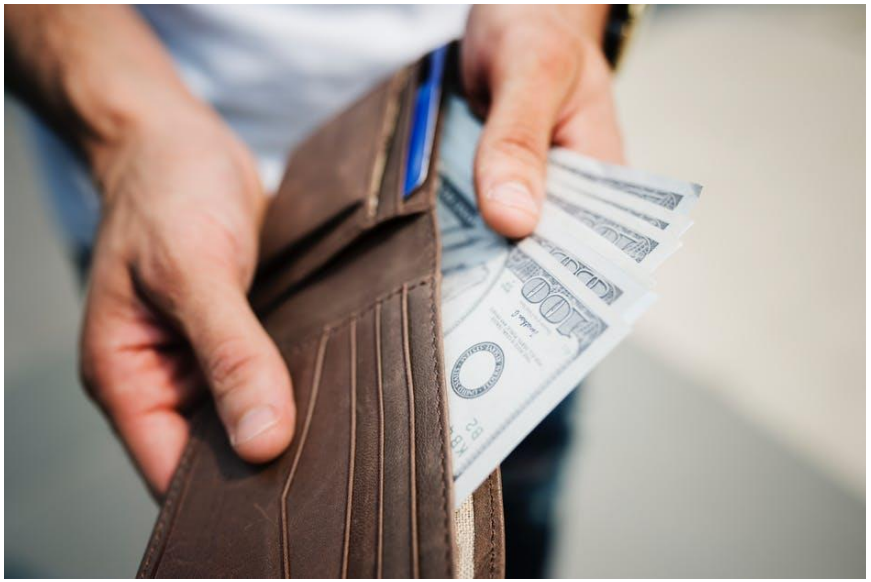
Menu - 18481848 ‹ A busin...
sfuo.ca

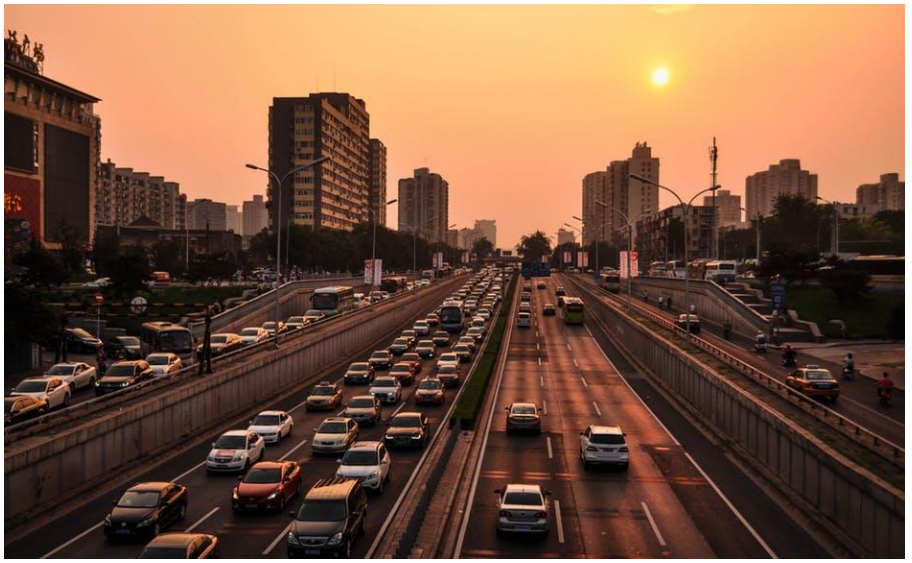
Red Border Chinese Menu - ...
canva.com

Customize 2,221+ Menu te...
canva.com

Java Moose, Fairplay CO - ...
javamoosesouthpark.com

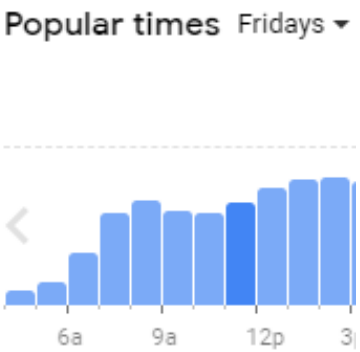
Modeling what to order for dinner: Constraints





Modeling what to order for dinner: Objective Function Formulation

yelp = Facts



$	$$
$$$	$$$$

(Ratings ✖ Popularity − Costs) ✖ Preference Weights = **Menu Option Score**

Modeling what to order for dinner: Results

Resource Allocation Applications

1. Project Selection
2. Workforce Scheduling
3. Budget & Revenue
4. Materials Procurement

Important Personal Decisions:

1. Home purchase
2. Job Search
3. Investing
4. Grad School Applications
5. Wedding Services Procurement

Insights & Takeaways

1. Align the model formulation with your organizations goals.
2. Careful with bias in the data.
3. Expand the plan outlook (5, 10, or 15 years).
4. Use life cycle costs and benefits.
5. Compare projects against other initiatives.
6. Don’t forget the “do-nothing” project.

Insights & Takeaways cont.

7. Coordinate with other organizations.
8. Use economic data if available but don't shy away from qualitative data.
9. Consider equitable distribution of resources.
10. Maintain good records for future use.
11. Incorporate transparency and feedback mechanism into your programs
12. Don't leave your business decisions to intuition.

Questions?

Contact Information:

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Resources and Follow-up Discussions:

OSDesignGuide.com

Design Community Survey:
https://goo.gl/forms/dmp4ayFbKmsNMLtI3

Images in this presentation: www.pexels.com & maps.google.com