Time Value of Money and Optimization Process

Cost Definitions

- Inflation increase in cost of products over time, decrease of purchasing power
- Recurring cost a cost that happens multiple times at regular intervals (ie - rent, car loan repayment, tuition and fees, maintenance)
- Capital cost one time cost (ie construction, permit, machinery purchase)
- Present worth equivalent present value of future or recurring costs

Inflation

Money loses purchasing power over time

- Average price of milk in 1995 = \$2.48
- Average price of milk in 2016 = \$3.17
- Average annual increase = 1%
- Average price of unleaded gasoline in 1976 = \$0.61
- Average price of unleaded gasoline in 2016 = \$2.10
- Average annual increase = 1.7%

Usually estimate average annual inflation = 3%

Capital Expense

- Initial, one-time cost
- Design, excavation, piping, rainwater harvest tank, construction...
- Assumes that components will last a certain period of time
- Already in present worth

Recurring Expense

- A cost that happens multiple times at regular intervals
- Maintenance cleaning pervious pavement, weeding, landscaping, replacing mulch layer of a rain garden, sediment and debri removal
- Inflation means maintenance will get more expensive each year

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Year

Present Worth

- Inflation \rightarrow maintenance cost increases each year
- Geometric gradient increase, 3% inflation not linear
 - $P = A_1\left(\frac{N}{1+i}\right)$
- P = Present value
- A₁ = First annual payment
- N = Number of years
- i = Interest rate or inflation rate

Optimization Routine



Design Constraints

Fixed constraints

- LID can be implemented only in available space
 - Bioretention and disconnection limited by pervious area
 - Greenroofs and rainwater harvesting only on roof area
 - Pervious concrete and pavers only on streets, parking lots, and sidewalk areas
 - Pervious asphalt only on streets and parking lots

Flexible constraints

• Implement a certain amount of LID for other purposes – aesthetics, education, ecosystem services

Regression

• EPA Stormwater Calculator output for different percentages of impervious area treated by each singular LID type





Regression (cont.)

Runoff Depth for Impervious Area Treated by Different LID Types



- DisconnectionGreen Roof
- Infiltration Basin
- Rain Gardens(5%)
- Rain Harvest
- Street Planter
- Rain Gardens(10%)
- Permeable Pavement

Regression (cont.)

LID Type	Regression Equation
Disconnection	$D_{runoff} = -0.035(A) + 25.1$
Green Roof	$D_{runoff} = -0.047(A) + 25.1$
Rain Gardens (drainage area = 5% of treatment area)	$D_{runoff} = -0.069(A) + 25.1$
Rain Harvest	$D_{runoff} = -0.075(A) + 25.1$
Street Planter	$D_{runoff} = -0.085(A) + 25.1$
Rain Gardens (drainage area = 10% of treatment area)	$D_{runoff} = -0.12(A) + 25.1$
Permeable Pavement	$D_{runoff} = -0.21(A) + 25.1$

 D_{runoff} = Depth of runoff generated A = % Impervious area treated

Runoff Calculation

 Calculate runoff with selected amount of impervious area treated

Example

Treat 10% of impervious area with permeable asphalt

$$D_{runoff} = -0.21(10) + 25.1$$

 D_{runoff} = 22.8 inches $D_{reduced}$ = $D_{current} - D_{runoff}$ 2.1 inches = 25.1 inches – 23 inches (8% reduction)

Cost Calculation

 Calculate cost with selected amount of impervious area treated <u>Example</u>

Treat 10% of impervious area with permeable asphalt

$$Present \ Cost(\$/_{ft^2}) = Capital \ Cost(\$/_{ft^2}) + Maintenance \ Cost(\$/_{ft^2}) * \left(\frac{N}{1+i}\right) + 5.47(\$/_{ft^2}) = 1.5(\$/_{ft^2}) + 0.19(\$/_{ft^2}) * \left(\frac{20years}{1.03}\right)$$

10% of impervious area = 8.3 acres

Total Present Value Cost(\$) = 5.47
$$\binom{\$}{ft^2}$$
 * 8.3acres * $\frac{43,560ft^2}{1 acre}$

Total Present Value Cost = \$3.3 million

Minimization Functions

Calculate runoff reduction minimization function: Calculate cost minimization function: LID runoff depth to predevelopment runoff depth 20-yr cost per gallon $pr gallon = \frac{(20yr \$)}{Vol_{reduction}}$ $Runoff\ ratio = \frac{Runoff_{LID}}{Runoff_{Pre}}$ **Calculate multi-objective minimization function:** Runoff reduction and cost per gallon $f_{min} = (Runoff ratio) \times (\$ per gallon)$

Minimization Functions

•
$$Runoff\ ratio = \frac{Runoff_{LID}}{Runoff_{Pre}} = \frac{23\ inches}{11.7\ inches} = 1.97$$

•
$$\$ per gallon = \frac{(20yr \$)}{Vol_{reduction}} = \$0.49$$

•
$$f_{min} = (Runoff \ ratio) \times (\$ \ per \ gallon) = 0.958$$

Back to the flow chart



Are we done?

Guess control variables:

% of impervious area treated by each LID control

Calculate multi-objective minimization function: Runoff reduction and cost per gallon

 $f_{min} = (Runoff \ ratio) \times (\$ \ per \ gallon)$



Minimization Function



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Fairgrounds - Excel

9/20/2016

- Set Objective
- By Changing Variable

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Setting Constraints

- What can be treated by each LID type?
 - Green roof and rain harvesting can only treat roof
 - Permeable asphalt can only treat streets/parking lots
 - Permeable concrete, permeable pavers, and street planters can treat streets/parking lots and sidewalks/other
 - Raingardens, bioretention, and infiltration basins can treat anything
- How much space is available for each LID type?
 - Rain gardens, bioretention, and infiltration basins compete for green space
 - Permeable asphalt, permeable concrete, permeable pavers, and street planters compete for pavement area
 - Green roofs and rain harvesting compete for roof area

Setting Constraints

- "Subject to the
- Constraints"
- Add

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2	% Volume Reduced	68%	5		Streets/Parking Lots	4	17		By Changing Varia	ble Cells:				25.1	8.00	
3	% runoff of pre	0.683	3		Roofs	3	31		SB\$14:5B\$24					82,464,554	26,281,37	/1
4	cost/gal	\$ 0.30			Sidewalks/Other		5		30311130321							
5	f_min =	0.203	}		Total Impervious	8	33		S <u>u</u> bject to the Cor	straints:						
6					Pervious Area	з	88		\$B\$14 <= \$D\$14			*	Add			
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12		Solver Variables	impervi	ous area)		of Ireatment			\$B\$19 > = \$C\$19			-	Load/Save	sent Cost	Equation	
13		Optimum %Impervious Area Treated	Lower Limit	Upper Limit		(ft)			Make Unconst	rained Variabl	es Non-Negative			(\$)	(%area versus runoff)	5
14	Rain Garden (5%)	0.0	0.0	100	Rain Garden (5%)	1.5			S <u>e</u> lect a Solving M	ethod:	GRG Nonlinear	-	Options	-	25.1	
15	Rain Garden (10%)	23.8	0.0	100	Rain Garden (10%)	1.5								1,052,158	22.3	
16	Bioretention	7.2	0.0	100	Bioretention	1.5			Solving Method					355,820	24.2	
17	Green Roof ext	0.0	0.0	38	Green Roof ext	-			Select the GRG N	onlinear engir	ne for Solver Problems	that are smooth nor the Evolutionary en	nlinear. Select the LP	-	25.1	
18	Green Roof int	0.0	0.0	38	Green Roof int	-			problems that ar	e non-smooth	·	the evolutionary en		-	25.1	
19	Perm Asphalt	34.0	0.0	56	Perm Asphalt	2								11,323,299	18.0	
20	Perm Concrete	2.3	0.0	02 62	Perm Concrete	2		1						1,150,539	24.0	
21	Infiltration Rasin	2.5	0.0	100	Infiltration Basin	0.5		[<u>H</u> elp			Solve	Cl <u>o</u> se	1,211,005	24.0	
23	Street Planters	0.0	0.0	62	Street Planters	2.5		L		FIFE			0100		25.1	
24	Rain Harvesting	26.0	0.0	38	Rain Harvesting	-			0.87	0.87	0.04	1.7	1	\$ 1,591.999	19.7	
25	Sum	95	i		5									\$ 16,691,420		
26																
27		Additional Contraint	ts						Oth	ner Costs						
L.,		Sum of Contributing	Solver Cons	straints (% of								410-				
1	 → Regressio 	n Watershed Delinea	tion Storr	nwater Calc Re	sults Solver	+			1010/1		•	10 (A40)				•
RE	ADY															- + 100%

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Optional Constraints

- Aesthetic or educational want at least one green roof or rain garden
- Cost per gallon want cost per gallon below \$0.50/gallon
- Want LID runoff to equal predevelopment runoff -

$$\frac{Runof f_{LID}}{Runof f_{Pre}} = \frac{11.7 \text{ inches}}{11.7 \text{ inches}} = 1$$

• Want to reduce runoff volume by > 60%

$$\frac{Runof f_{LID}}{Runof f_{Current}} = \frac{10 \text{ inches}}{25.1 \text{ inches}} = 0.6$$

Future Optimizations

- Additional optimizations water quality, peak flow reduction, ecosystem services
- Weighted combinations set water quality more important than cost...
- Range of parameters set by user