Determining the Optimal Location for a Municipal Solid Waste Facility

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Outline of Presentation

- Waste disposal as a public policy issue
- Waste disposal as a public finance/economic issue for municipalities
- The geography of waste disposal: the case of San Jose, California
- Optimal waste disposal – waste disposal as a Linear Programming (LP) Problem
  - The Primal LP Problem
  - The Dual LP Problem
  - Interpreting the dual solution values – "shadow" prices
  - The geography of the optimal solution
  - Comparing the optimal solution with the actual solution
  - Sensitivity analysis

Waste Disposal as a Public Policy Issue

- Background: How waste disposal is handled by public sector authorities in California
  - Role of state regulation
  - Role of municipalities
  - Role of waste haulers
  - Role of landfill owners
- The Capacity Constraint of Landfills
  - Economic determinants
  - Physical (topographical) determinants
  - Regulatory determinants

Waste Disposal as a Public Policy Issue

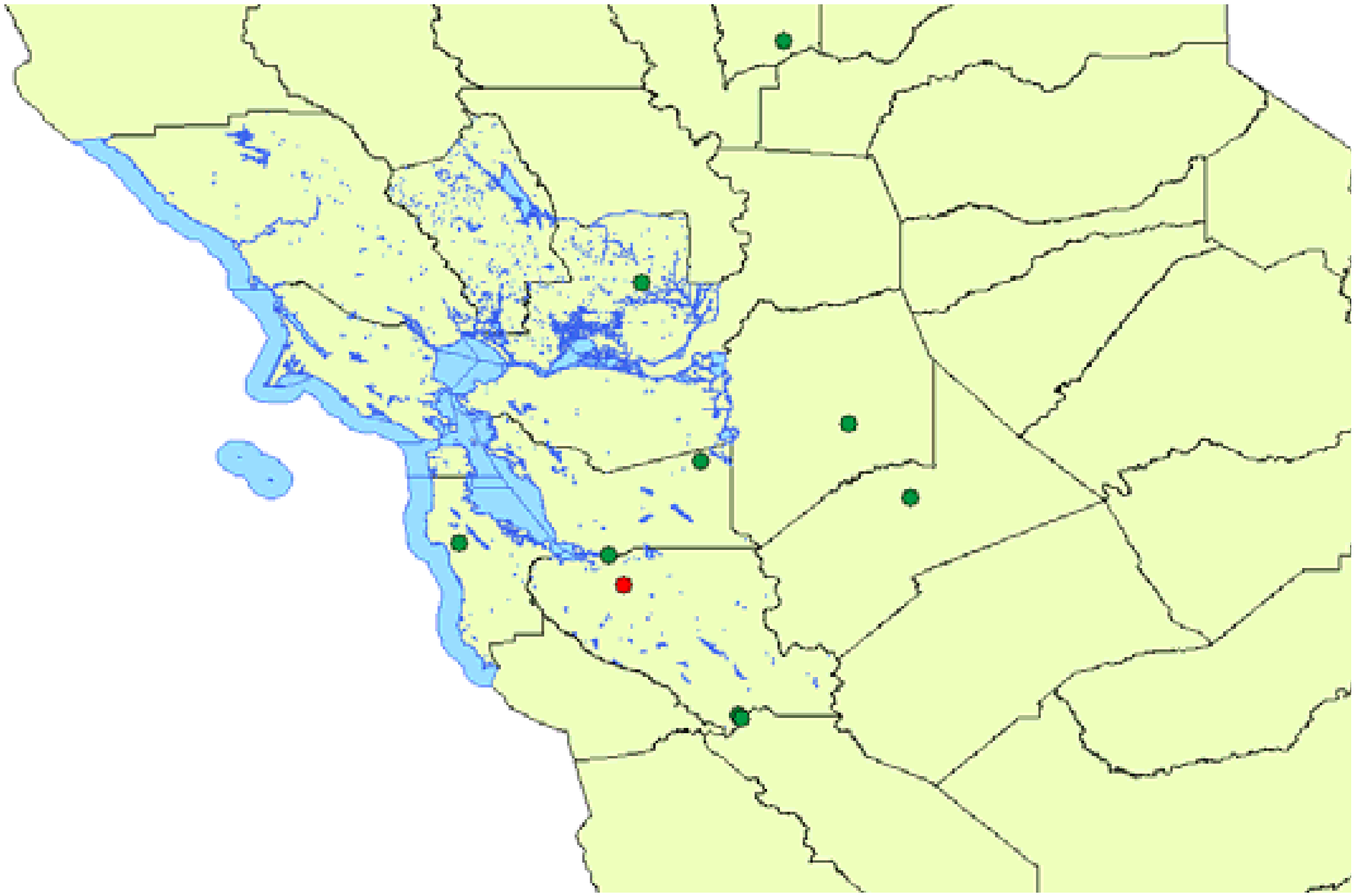
- Mandates of California Integrated Waste Management Act of 1989 - AB 939

- Zero Waste (ZW) policies

Waste Disposal as a Public Finance/Economic Issue for Municipalities

- Types of Solid Waste
  - Garbage
  - Recycling
  - Compost
- Different landfills have **different capacities** for accepting different types of solid waste
- Different landfills have different **tipping fees** for different types of solid waste – under some circumstances the tipping fees may be negative (revenue enhancing)
- Some municipalities are **both demanders and suppliers** of landfill capacity – so they may be net beneficiaries of greater streams of some types of solid waste

The Geography of Solid Waste



Optimal Waste Disposal

The municipality’s waste disposal problem as a Linear Programming (LP) Problem

Elements of a Linear Programming Problem

- Linear objective function
- Linear inequality constraints
- Non-negativity constraints

Optimal Waste Disposal

General formulation of the Waste Disposal LP Problem

- The municipality's objective: minimize total *net* spending on waste disposal
  - Net spending is the tipping fee plus the transportation cost
- The municipality's constraints
  - Given levels of three streams of waste (garbag, recycling, compost) to be disposed of
  - In some cases, *contracted limits* for certain landfills applicable to certain streams of waste

Notes on the Optimal Waste Disposal Problem

Municipality is interested *in the long run* in the optimal solution even if, at the moment, it has an advantageous contract with a hauler. If the hauler's profits are limited, the costs will rise when the next contract is negotiated. So the municipality is interested in the cost including the transportation cost even if that has been included in the hauler's contract.

Per mile transportation costs most affected by whether truck or rail is used

The Solid Waste (Primal) Linear Programming Problem

- The Objective Function

- The Linear Inequality Constraints

- The Non-negativity Constraints

Optimal Waste Disposal Notation

G_f is garbage sent to facility f

R_f is recycling sent to facility f

C_f is compost sent to facility f

m_f is distance in miles to facility f

G = total volume of solid waste to be sent

R = total amount of recycling to be sent

C = total amount of compostable to be sent

k_{tf} = cost (per ton) of sending type t waste to site f

t_{tf} = cost per ton per mile (transportation charge) of sending one ton to waste of type t one mile to facility f

$ncpt_{tf}$ = net cost per ton of sending type t waste to facility f where $ncpt_{tf} = (k_{tf} + m_f{*}t_{tf})$

Solving the Solid Waste (Primal) Linear Programming Problem

- The Simplex Algorithm

- Using Excel Solver

- Using R

Excel Implementation of the Solid Waste (Primal) Linear Programming Problem

(PROTOTYPE MODEL)

STREAMS (tpd)			LANDFILLS	Altamont Landfill	Newby Island	Ox Mountain Landfill	[illegible] Road Landfill	Forward Landfill	Jepson Prairie Organics	Grower Composting Fac	Z-Best Composting	
Garbage	G	1000	G_i	0	0	0	0	0	0	0	0	0
Recycling	R	1000	R_i	0	0	0	0	0	0	0	0	0
Compost	C	1200	C_i	0	0	0	0	0	0	0	0	0
			s_g	33	37	33	42	19	100	63	75	
			s_R	90	90	49.5	37.8	33.1	90	58.5	67.5	
TOTAL NET COST		0	s_C	100	100	55	42	19	100	65	75	
			t_g	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	
			t_R	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	
			t_C	0.3	0.5	0.3	0.5	0.3	0.5	0.3	0.3	
			m_i	36	30	40	130	73	90	83	37	
			K_{ig}	11500	4000	1598	3000	4338	0	0	0	
			K_{iR}	10000	2000	10000	10000	10000	0	0	0	
			K_{iC}	3000	500	0	0	0	750	125	1200	
			$ncpf_{ig}$	61	42	75	117	76.5	137.5	102.5	112.5	
			$ncpf_{iR}$	116	95	49.5	112.8	72.6	127.5	96	105	
			$ncpf_{iC}$	118	105	75	117	78.5	137.5	102.5	112.5	

Excel Solution to the Primal Solid Waste Linear Programming Problem

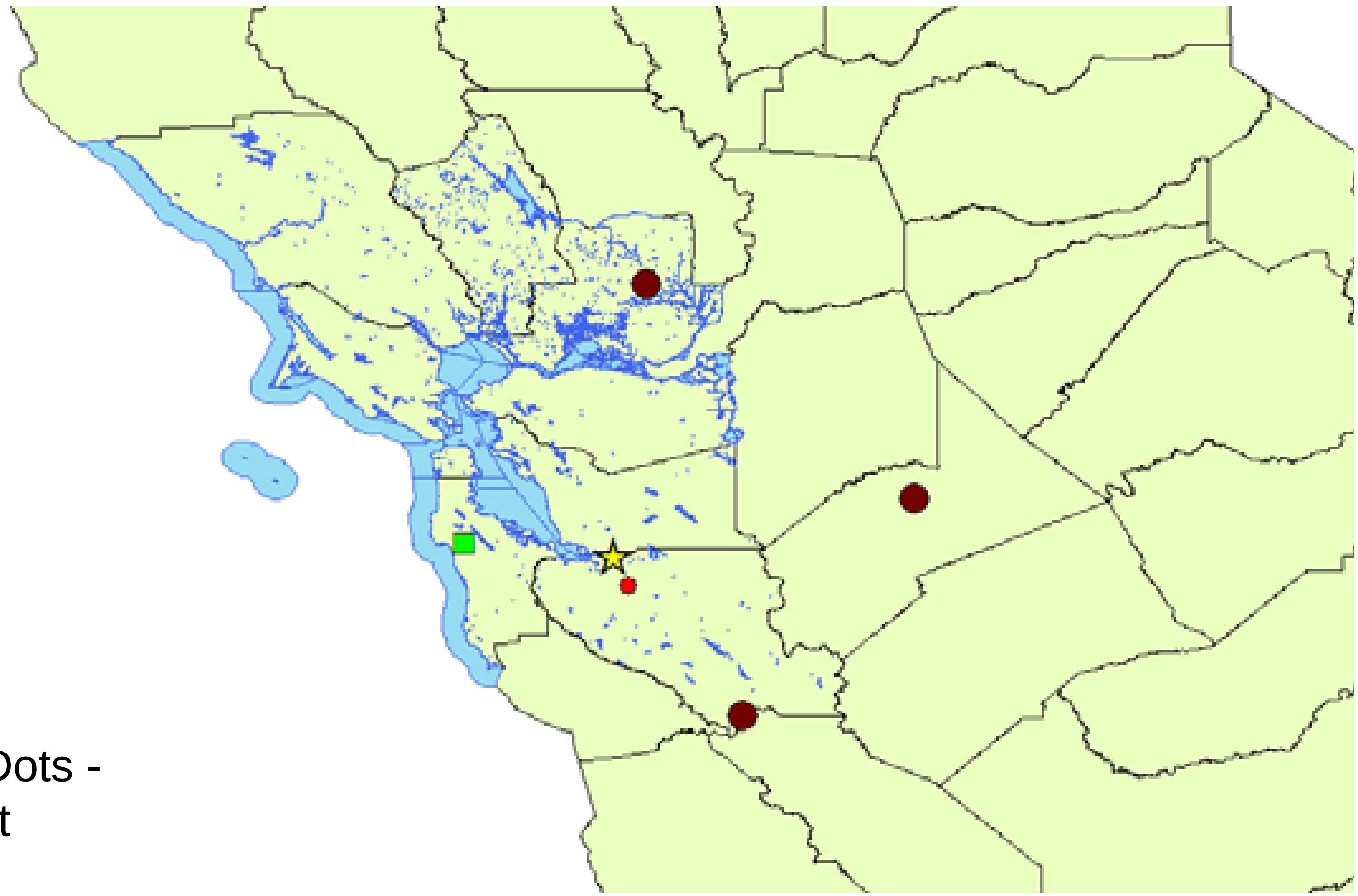
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	STREAMS (tpd)			LANDFILLS	Altamont Landfill	Newby Island	Ox Mountain Landfill	Ozcom Road Landfill	Forward Landfill	Jepson Prairie Organics	Grover Composting Fac	Z-Best Composting	
2	Garbage	G	1800	G_i	0	1800	0	0	0	0	0	0	1800
3	Recycling	R	3000	R_i	0	0	3000	2.84217E-14	0	0	0	0	3000
4	Compost	L	2200	C_i	0	0	0	0	0	750	125	1325	2200
5				a_G	33	37	15	42	39	100	65	75	
6				a_R	90	90	49.5	57.8	15.1	90	58.5	67.5	
7	TOTAL NET COST		275780	a_C	100	100	15	42	39	100	65	75	
8				t_G	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
9				t_R	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
10				t_C	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
11				m_i	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	65	87	
12				k_G	11300	4000	2080	3000	4320	0	0	0	
13				k_R	10000	2000	10000	10000	10000	0	0	0	
14				k_C	3000	[illegible]	0	0	0	750	125	1500	
15				$ncpt_G$	41	42	75	117	78.5	137.5	103.5	112.5	
16				$ncpt_R$	138	95	69.2	112.8	73.6	127.5	90	165	
17				$ncpt_C$	128	105	75	117	78.5	137.5	103.5	112.5	

The Geography of the Optimal Solution for the City of San Jose

Yellow Star – all garbage

Green Square – all recycling

Brown Dots - compost



The Dual Linear Programming Problem

- The Fundamental Theorem of Linear Programming
- What is the Dual Linear Programming Problem?
- How does it relate to the Primal Linear Programming Problem?

The Dual Linear Programming Problem

- Duality in Linear Programming

- Duality in a broader mathematical context

Policy Analysis Based on the Linear Programming Approach

- The significance of “shadow prices”
- Other perturbations of the Primal LP Problem
- The LP Problem and Cost-Benefit Analysis

Questions or Comments?

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