Closing the loop on supply chains…

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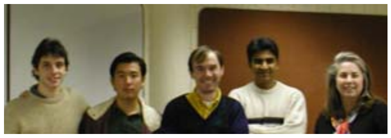
Objectives for today's class

- Understand how efficient closed loop supply chains
  - Benefit the environment
  - Provide economic development opportunity ($, jobs)
- Conceptualize effective infrastructure
  - Collection, transportation, processing
  - Sufficient volumes are critical for economic viability
- See how industrial engineers have the creativity and good analysis tools to design and operate closed loop supply chains
  - Must address uncertainty
  - Must capture perspective



Research Team

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- Wuthichai Wongthatsanekorn, David Newton
- Juan Martín Vannícola (ITBS Argentina)
- Devon Oudit (Fulbright program)
- Ken Gilliam (Army)

Industrial Collaborators

- CARE (Carpet Recovery America Effort)
- Reboot, Zentech, Molam
- Carpet and electronics manufacturers

State& Federal Government

- CCACTI
- Georgia DNR, P2AD
- NSF under grant Grants # DMI-0200162, SBE-0123532, DMI-0620191
- EPA

Research team in action

Used Carpet

- **4.7 billion lbs** of carpet are disposed of in the US each year
- Landfill costs ~ **$100 Million**
- Value of material ~ **$2.8 Billion/yr**

Opportunity

Dalton Landfill

Carpet Manufacturing Waste Monofill Area

Used Electronics

- 300 million personal computers have been “retired” to storage in basements, closets, warehouses, etc.
- 315 – 680 million will be obsolete in next few years

Opportunity !!!!

Used Electronics

- Environmental concerns
  – Lead, arsenic, cadmium, mercury, cobalt
  – Landfill space
  – Export to developing countries where processing may cause problems

Some background

PBS – FRONTLINE –World Stories from a Small Planet

Ghana: Digital Dumping Ground

June 23, 2009

http://www.pbs.org/frontlineworld/stories/ghana804/video/video_index.html

Drivers for Reverse Systems

- 6-7 x World GDP growth in the next 50 years (in constant dollars)
- 5-6 x production capacity for commodities
- 3.5 x increase in world energy demand
- 33% of world energy demand is used in industrial production

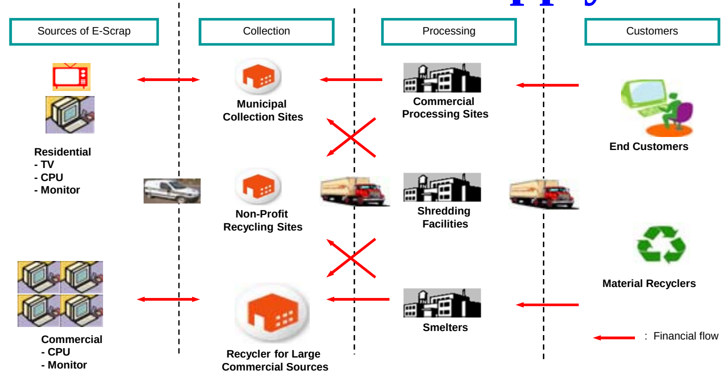
How will we provide these materials and energy?

(The U.S. Consumes 26% of world oil production but has only 2% of its known reserves. The next highest consumer is Japan with 7%.)

Will we continue to meet our material needs through extraction?

Regulatory and disposal costs are additional drivers.

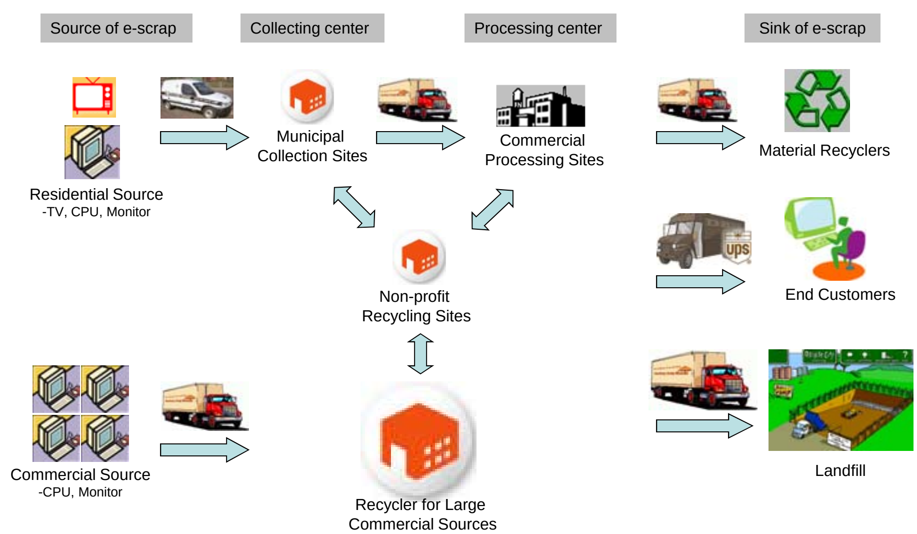
Differences between Reverse and Forward Supply Chains



In the reverse supply chain,

- The network has many sources upstream and narrows to a few customers downstream.
- Diverse materials are produced by disassembly and physicochemical processes.
- The final materials are low volume compared to the forward production system.
- Pricing scheme is different from the forward supply chain.
- Uncertainty in *supply – amounts, condition, content* - is at the beginning of the chain.

RPS Infrastructure



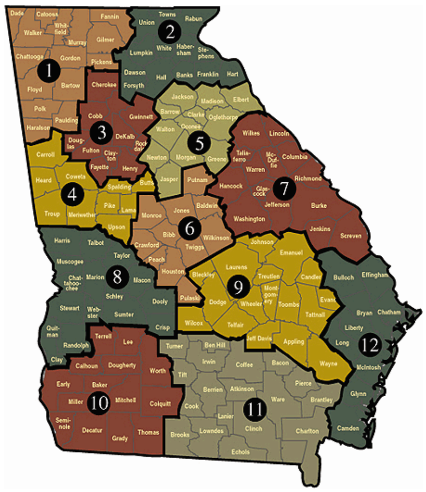
RPS Infrastructure Decisions

- Location, number and size of collection sites and processing sites
- Allocation of functions in the reverse chain to geographic locations
- Modes of transportation connecting sites
- Flows for products and materials through potential task network
- Amount of material allocation to each potential end-use

Georgia's Computer Equipment Disposal and Recycling Council

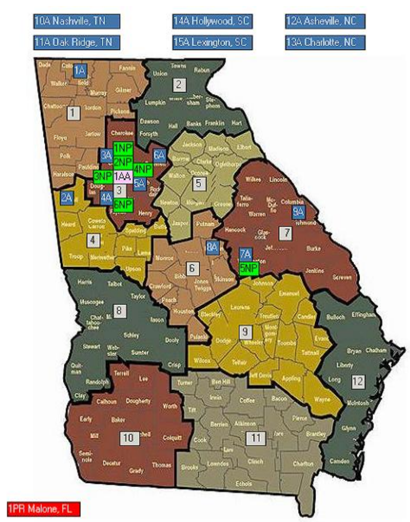
- Created by the Georgia legislature in 2002 for a 5 year term
- Mandate to investigate and advise legislature and governor on E-scrap policy
- Uses operations research models to evaluate potential alternatives
- Monthly hearings

12 DCA Regions in State of Georgia



Service regions are defined by Georgia's Department of Community Affairs (DCA)

Locations of Alternative Sites
(Georgia Case Study)



- 12 Municipal collection sites
- 6 Non-profit collection & processing sites (NP)
- 15 Commercial processing sites (A)
- 1 Prison processing site (PR)
- 1 Processing site for products from large business (AA)

Georgia e-scrap Supply Estimates

Region	Supply for TVs (lbs)	Supply for Monitors (lbs)	Supply for CPUs (lbs)
1	133,610	216,400	272,720
2	87,236	141,290	178,060
3	657,000	1,064,130	1,341,040
4	77,388	125,340	157,960
5	83,970	136,000	171,400
6	84,318	136,570	172,110
7	83,339	134,980	170,110
8	67,680	109,620	138,150
9	52,283	84,680	106,720
10	67,605	109,500	137,990
11	69,912	113,240	142,700
12	104,024	168,480	212,330
13*	0	90,000	90,000
14*	0	90,000	90,000
Total (lbs)	**1,568,365**	**2,720,230**	**3,381,290**

* Outside Georgia

RPS Infrastructure Determination Model (RPS)

Maximize: ***Net Profit*** (Revenues – Operating and Fixed Costs)

Subject to*:*

Supply and Demand
based on supply and demand at each source and sink point.

Flow balances between sites
based on material consumed and produced by the tasks located at those sites.

Upper and lower bounds
on storage, transportation and processing of material at sites.

Logical constraints on sites, such as the need to open a site before allowing tasks to be located there.

Experimental Design

- Four factors and two levels for each factor
  - Participation rate
    - Levels: 20% and 30%
  - CRT recycler option
    - Levels: with all CRT recyclers and with only OH CRT recycler
  - TV usability rate
    - Levels: 10% and 30%
  - CPU & monitor usability rate
    - Levels: (CPU 40%, monitor 40%) and (CPU 20%, monitor 20%)
- Total scenarios conducted: 2 × 2 × 2 × 2 = 16

Model Scenarios

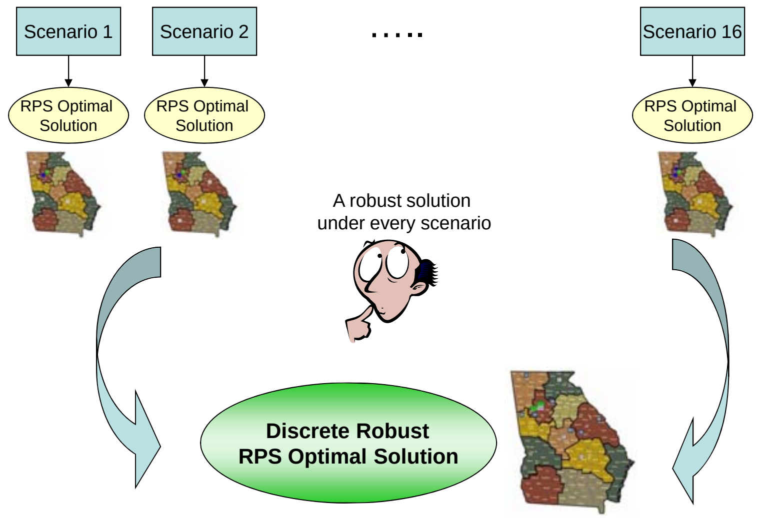
Useable %: TV: 30% CPU: 40% Monitor: 40%		CRT Recyclers	
		With all CRT Recyclers	With only CRT recycler in OH
Percent Participation	*20%*	***Sc 1***	***Sc 2***
	30%	***Sc 3***	***Sc 4***

Useable %: TV: 10% CPU: 40% Monitor: 40%		CRT Recyclers	
		With all CRT Recyclers	With only CRT recycler in OH
Percent Participation	*20%*	***Sc 5***	***Sc 6***
	30%	***Sc 7***	***Sc 8***

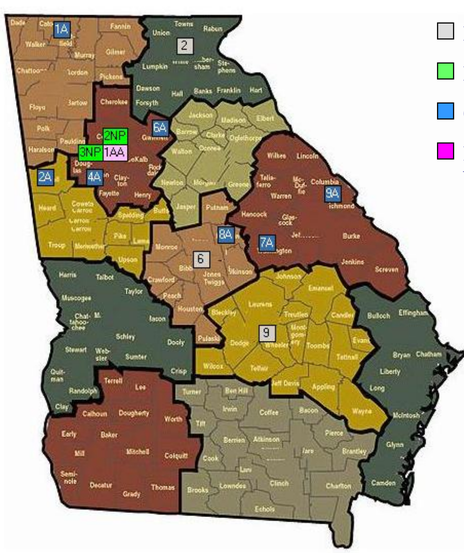
Useable %: TV: 30% CPU: 20% Monitor: 20%		CRT Recyclers	
		With all CRT Recyclers	With only CRT recycler in OH
Percent Participation	*20%*	***Sc 9***	***Sc 10***
	30%	***Sc 11***	***Sc 12***

Useable %: TV: 10% CPU: 20% Monitor: 20%		CRT Recyclers	
		With all CRT Recyclers	With only CRT recycler in OH
Percent Participation	*20%*	***Sc 13***	***Sc 14***
	30%	***Sc 15***	***Sc 16***

Robust Decisions in the Case Study



Robust Solution for 16 Scenarios



- Municipal collection sites
- Non-profit collection & processing sites (NP)
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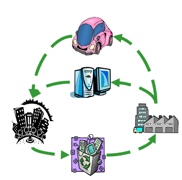
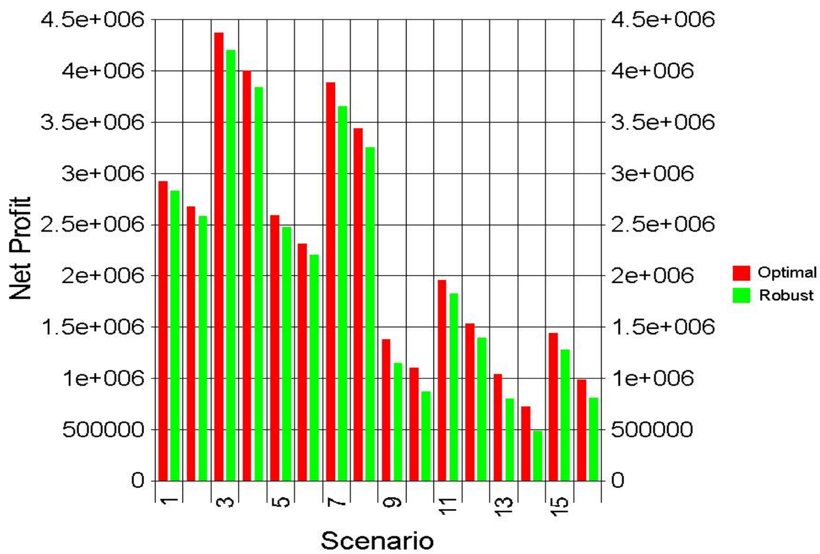
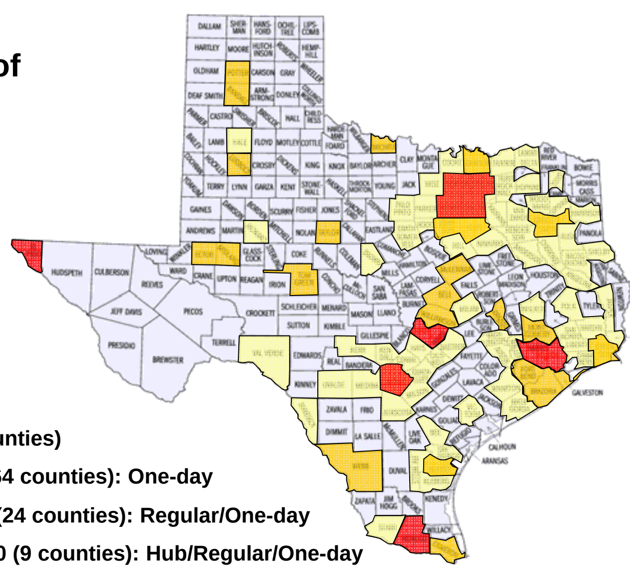


Net Profit of Scenario 1 ~ 16



Texas case study by Assavapokee's student, Pantanat Wayuparb

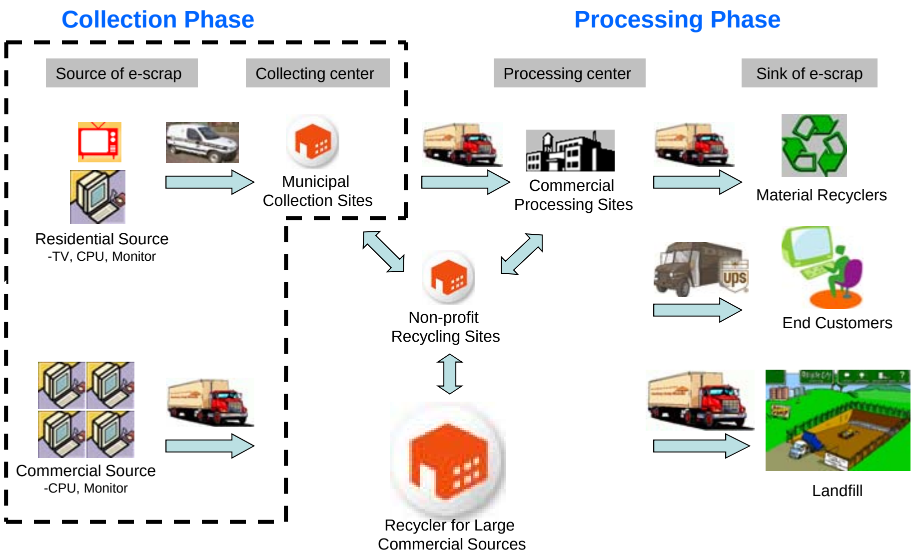
Pre-selection of Site Locations



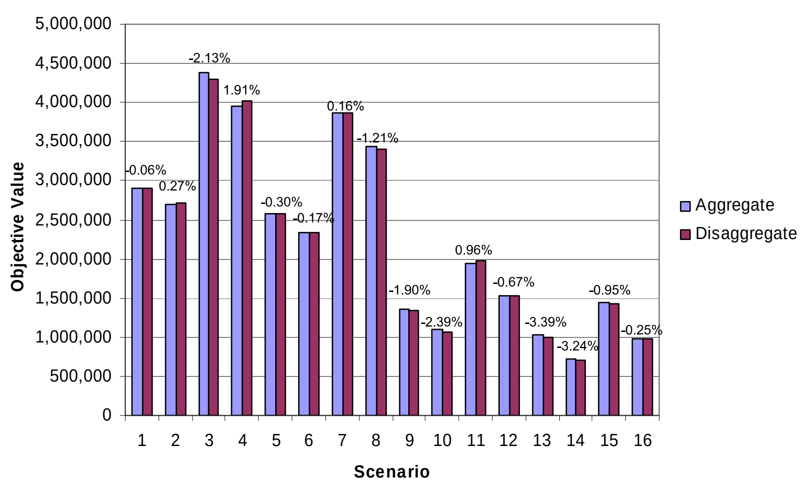
Population

- 0-25,000 (155 counties)
- 25,001-100,000 (64 counties): One-day
- 100,001-500,000 (24 counties): Regular/One-day
- 500,001-3,600,000 (9 counties): Hub/Regular/One-day

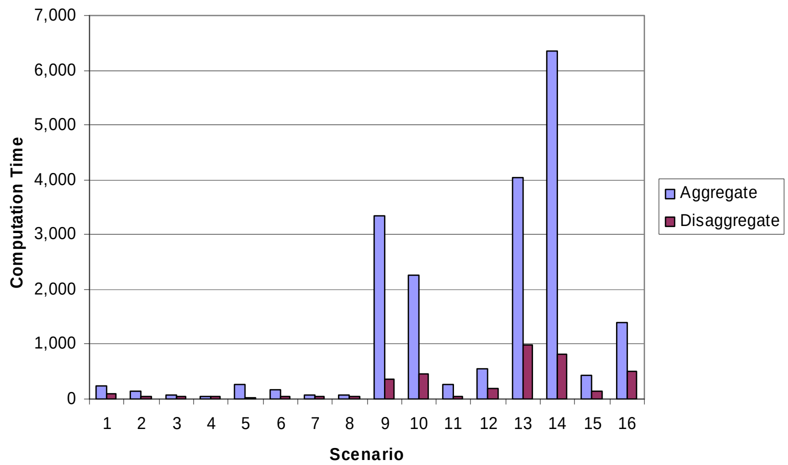
Disaggregation of RPS Infrastructure



Comparison of Objective Function Results

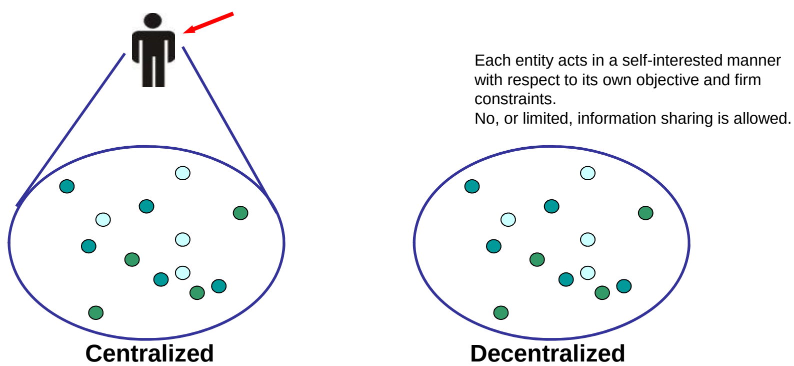


Computation Time Comparison



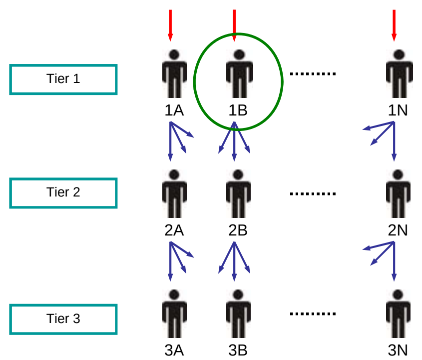
Centralized versus Decentralized Perspectives

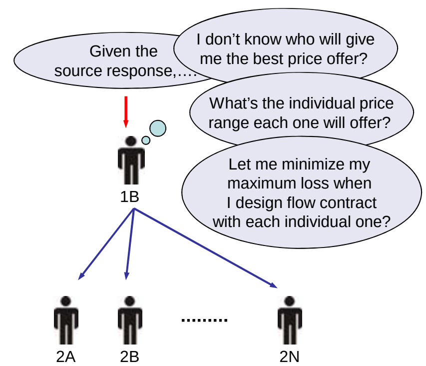
Many studies have been addressed on reverse logistics systems in a *centralized* way (Barros et al. 1998; Fleischmann et al. 2000; Guide and Harrison 2003; Shih 2001).



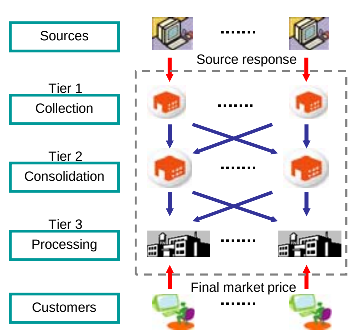
Sometimes we need to understand the differences in the system behaviors and to engineer mechanisms for decentralized systems to exhibit good overall system performance.

The Solution Algorithm





Comparison of Results for Centralized and Decentralized Models



- A three-tier example with five collectors, three consolidation sites, and four processors is examined.
- One may overestimate the system profit by the model if it is assumed that the decisions are made centrally in a system of independent entities.
- The potential factors: price uncertainty and double marginalization

Centralized model (a quadratic programming model)

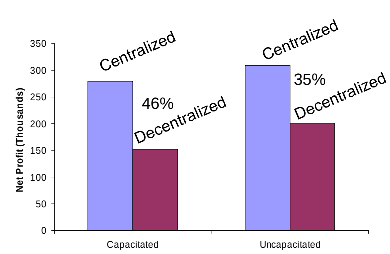
Maximize: Net Profit — Quadratic term w.r.t. price

(Revenues – Acquired and Transportation Costs)

Subject to: **Flow conservation between sites**

Capacity limitations

(Transportation and processing)



Summary

- Efficient reverse production systems
  - Benefit the environment
  - Provide economic development opportunity ($, jobs)
- Effective infrastructure required
  - Collection, transportation, processing
  - Sufficient volumes are critical for economic viability
- Industrial engineers have creativity and good analysis tools to design and operate closed loop supply chains
  - Must address uncertainty
  - Must capture perspective (centralized, decentralized…)