Linear Programming Uses for Recycling and Product Reuse

Tara Demeyer
Management Science I

Outline

- Introduction
- Construction Waste Recycling
- Paper Waste Recycling
- Printer Component Reuse

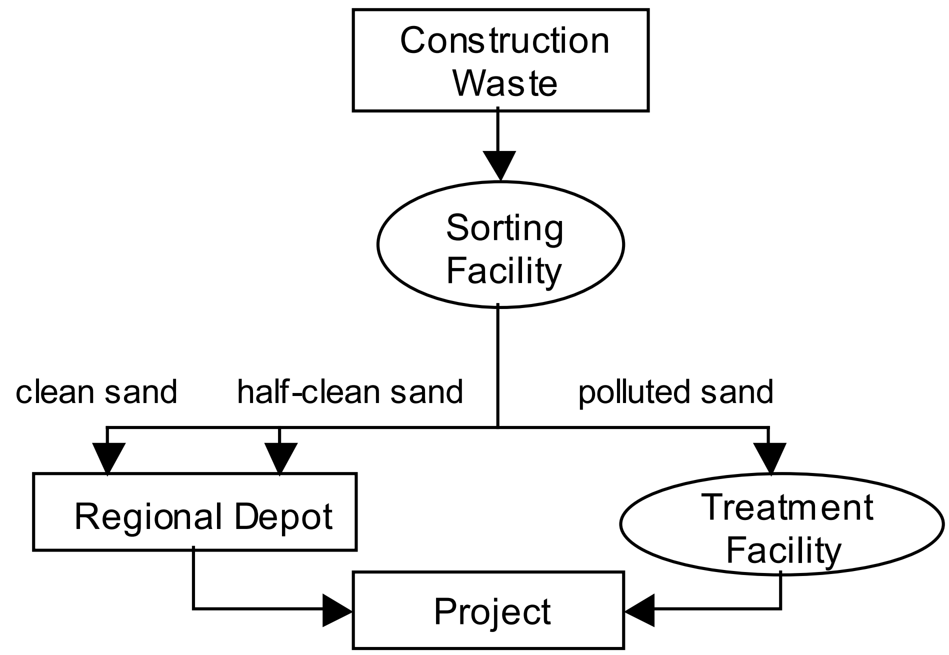
Reverse Logistics

- Returns/ Damaged Product
- Recycling of waste materials
- Reuse of product components

Construction Waste Recycling

(A.I. Barros, R. Dekker, and V. Scholten, 1999)

- Three types of sand
- Facility location model from 33 possible sites
- Based in the Netherlands



$$
\begin{aligned}
\min \quad & \sum_{j=1}^{n} f_j y_j + \sum_{k=1}^{p} g_k z_k \\
& + \sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij} u_{ij} + \sum_{j=1}^{n}\sum_{k=1}^{p} b_{jk} v_{jk} \\
& + \sum_{k=1}^{p}\sum_{\ell=1}^{q} c_{k\ell} w_{k\ell} + \sum_{j=1}^{n}\sum_{\ell=1}^{q}\sum_{s=1}^{2} e_{j\ell s} x_{j\ell s} \qquad \text{(SP)}
\end{aligned}
$$

$$
\text{s.t.} \quad \sum_{j=1}^{n} u_{ij} = o_i, \quad i = 1, \ldots, m, \tag{1}
$$

$$
\sum_{j=1}^{n} x_{j\ell 1} + \sum_{k=1}^{p} w_{k\ell} = d_{\ell 1}, \quad \ell = 1, \ldots, q, \tag{2}
$$

$$
\sum_{j=1}^{n} x_{j\ell 2} = d_{\ell 2}, \quad \ell = 1, \ldots, q, \tag{3}
$$

$$
\sum_{k=1}^{p} v_{jk} = t_3 \sum_{i=1}^{m} u_{ij}, \quad j = 1, \ldots, n, \tag{4}
$$

$$
\sum_{\ell=1}^{q} x_{j\ell s} \leqslant t_s \sum_{i=1}^{m} u_{ij}, \quad j = 1, \ldots, n, \; s = 1, 2, \tag{5}
$$

$$
\sum_{\ell=1}^{q} w_{k\ell} \leqslant \sum_{j=1}^{n} v_{jk}, \quad k = 1, \ldots, p, \tag{6}
$$

$$
(1 - t_3) \sum_{i=1}^{m} u_{ij} \leqslant H_j y_j, \quad j = 1, \ldots, n, \tag{7}
$$

$$
\sum_{j=1}^{n} v_{jk} \leqslant R_k z_k, \quad k = 1, \ldots, p, \tag{8}
$$

$$
y_j, z_k \in \{0, 1\}, \; j = 1, \ldots, n, \; k = 1, \ldots, p, \tag{9}
$$

$$
\begin{aligned}
& u_{ij}, v_{jk}, w_{k\ell}, x_{j\ell s} \geqslant 0, \quad i = 1, \ldots, m, \\
& j = 1, \ldots, n, \qquad k = 1, \ldots, p, \\
& \ell = 1, \ldots, q, \qquad s = 1, 2. \qquad\qquad (10)
\end{aligned}
$$

Construction Waste Recycling

(A.I. Barros, R. Dekker, and V. Scholten, 1999)

- Costs
  - Transportation
  - Fixed
  - Processing
- Constraints
  - Flow constraints
  - Demand constraints
  - Capacity constraints

Construction Waste Recycling

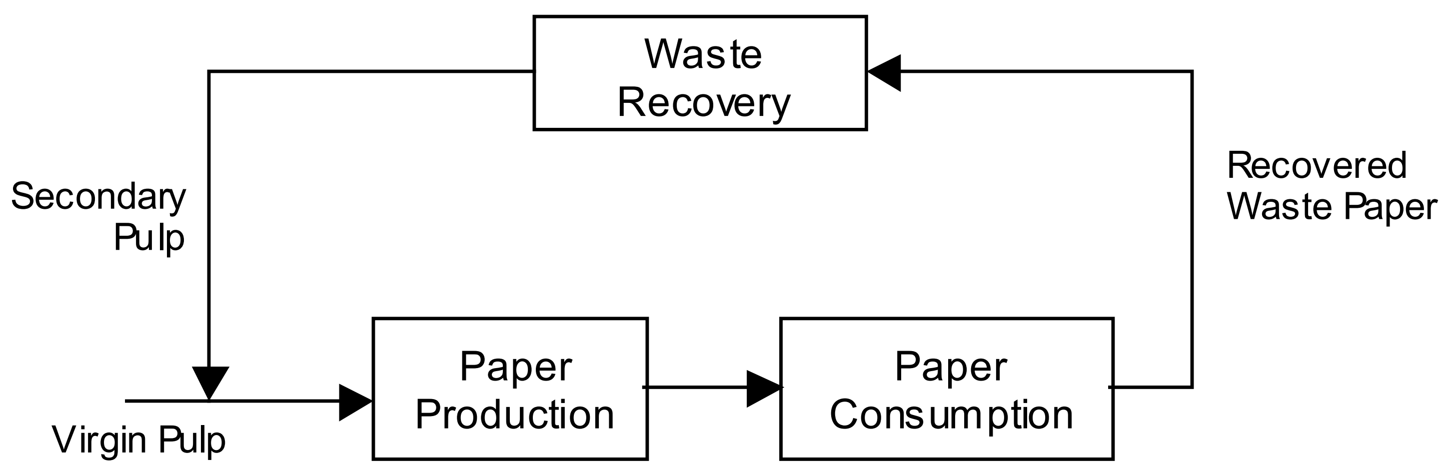
(A.I. Barros, R. Dekker, and V. Scholten, 1999)

- Results
  - On average 22 facilities were used in order to maximize the amount of sand recycled while minimizing the number of facilities.

Paper Waste Recycling

(Glassey and Gupta, 1974)

- Paper Production Cycle
  - Production > Consumption > Recycling > Reuse in Production



Paper Waste Recycling

(Glassey and Gupta, 1974)

1. Newsprint
2. Uncoated Groundwood Paper
3. Coated Paper
4. Uncoated Book Paper
5. Writing and Related Paper
6. Bleached Bristols
7. Unbleached Kraft Packaging and Industrial Covering Paper
8. Other Packaging and Industrial Covering Paper
9. Tissue Paper
10. Unbleached Kraft Linerboard
11. Bleached Packaging
12. Box Board
13. Building Paper, Board, etc.

	Description	*Nos. Corresponding to [8]*
1.	News	6, 7, 8, 24, 25
2.	Groundwood Shavings	22, 23, 26
3.	Flyleaf Shavings	27
4.	Magazine and Books	28, 29, 42, 43
5.	Waste Ledger	30, 38 to 41
6.	Envelopes and Tab Cards	31 to 37, 44, 45, 46
7.	Kraft Bags and Cuttings	14 to 17, 19 to 21
8.	Corrugated Cuttings	9 to 13
9.	New Colored Krafts	18
10.	Box Board Cuttings	4
11.	Mixed Waste Paper	1 to 46

Paper Waste Recycling

(Glassey and Gupta, 1974)

- Estimated savings of $238 million annually if the minimum virgin pulp was used and the maximum amount of secondary pulp was extracted from paper waste
- What would the model look like with population increases and increased computer usage?

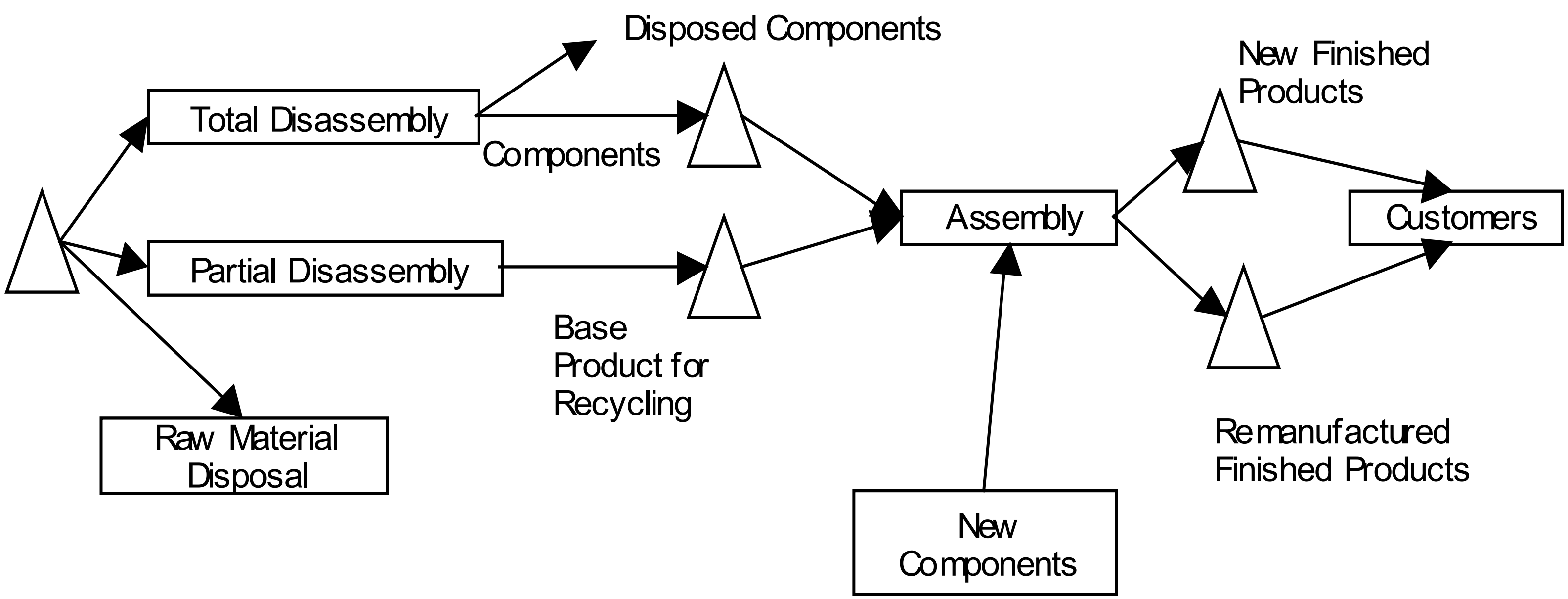
Printer Component Reuse

(Clegg, Williams, and Uzsoy, 1995)

- Study of Xerox printers and printer cartridges
- Model includes
  - Partial and full disassembly
  - Component analysis
  - New and used component use
  - Sales of new and remanufactured products

Printer Component Reuse

(Clegg, Williams, and Uzsoy, 1995)



Printer Component Reuse

(Clegg, Williams, and Uzsoy, 1995)

- While the model is large it is fairly easy to solve with present software
- No solutions were calculated for the article in 1995

Thank You

Questions?