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Mechanism for Coordination between the Collector and the Dismantler in a Reverse Supply Chain

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ABSTRACT

The growing desire of consumers to acquire the latest technology (both at home and in the workplace), along with the rapid technological development of new products, has led to a new environmental problem: waste. The only way to tackle this problem is design and implementation of reverse supply chains. Implementation of an efficient reverse supply chain requires coordination among a number of parties, such as the collector, the dismantler, the shredder, and the recycler. In this paper, we identify four different scenarios of homogeneous and heterogeneous products, and formulate some potential interactions between the collector and the dismantler, for each of those scenarios.

Keywords: Reverse Supply Chain, Coordination, Strategic Planning, Remanufacturing, Dismantler.

1. MOTIVATION

Rapid industrial revolution and population growth have put severe pressure on the environment. Discarded electronic equipment (also called e-waste) is one of the fastest growing waste streams, due to the growing sales and rapid obsolescence of these products. According to a 2002 report [1], fourteen states in the USA have no landfill capacity left, and eight states have less than 10 years of landfill capacity left. The Environmental Protection Agency (EPA) advocates reverse supply chains for reducing the pressure on the environment. A reverse supply chain is a series of activities required to collect a product discarded by a consumer and recover its (product's) left-over market value. Remanufacturing and recycling are the major recovery options applied in this process.

An important driver for companies engaged in a reverse supply chain is that many discarded products represent a resource for recoverable value [2]. Furthermore, increasing environmental consciousness of consumers and regulations of governments offer the possibility of satisfying customer demand from remanufactured products instead of exclusively producing new products and disposing of all discarded products. This mode of demand satisfaction may offer a cost advantage over production of new products if the sum of unit production cost and unit disposal cost exceeds unit remanufacturing cost. Another advantage is that remanufacturing lead times may be much shorter than production lead times. For example, spare components demand may be met by remanufacturing from discarded products instead of initiating a re-supply with a substantial lead time.

Implementation of an efficient reverse supply chain requires a number of parties (see Figure 1), including: (i) the collector who collects discarded products and pays acquisition fees (or gives incentives) to the customers (who discarded the products), (ii) the dismantler who buys the discarded products from the collector, determines which components (of the products) to sell on the secondary market and at what prices, and sells the "hulk" to the shredder (see (iv)), (iii) the secondary market where remanufactured products and components are sold, (iv) the shredder who recovers recoverable materials (metals, etc) from the hulk and sends them to the recycler (see (v)), and sends unrecoverable materials to the landfill, and (v) the recycler who recycles recoverable materials and sells the output to the suppliers of raw material.

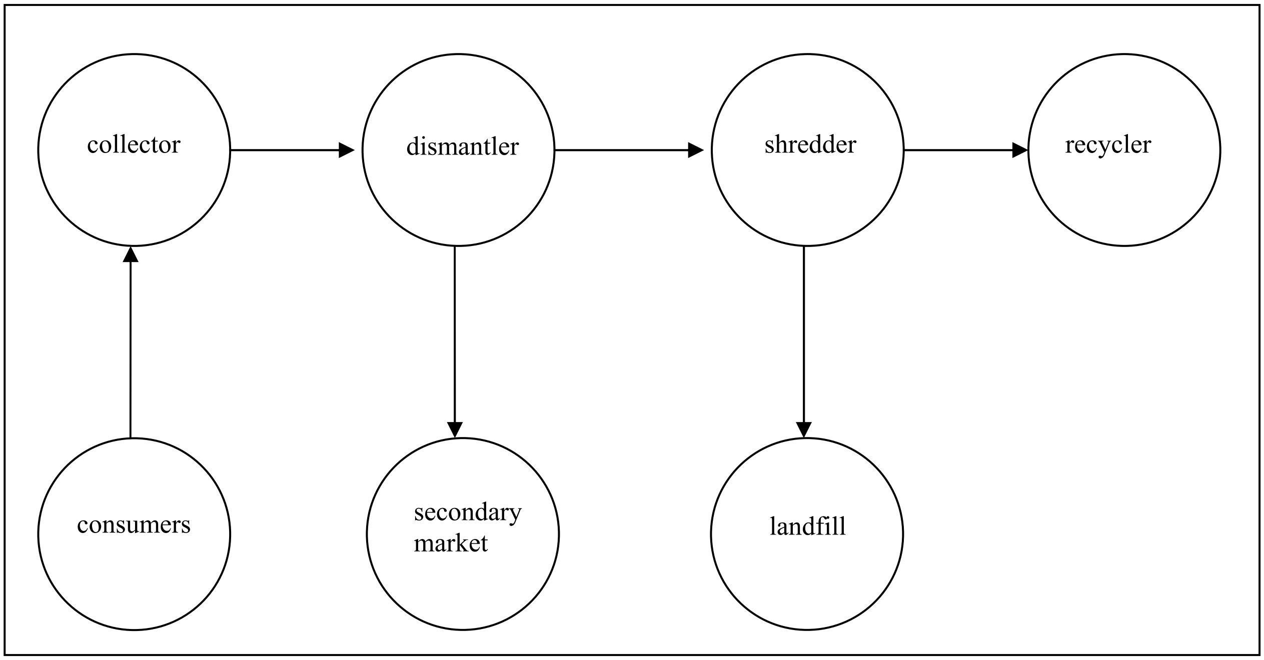

Figure 1. Reverse Supply Chain (partial)

A supply chain is fully coordinated when all decisions are aligned to accomplish system-wide objectives [3]. Lack of coordination occurs when decision makers have incomplete information or incentives that are not compatible with system-wide objectives. Two methods for accomplishing coordination are centralized decision making (single entity optimizes the chain) and decentralized decision making (multiple entities optimize the chain). Study of interactions among different parties in the supply chain is the first step to achieve coordination in the supply chain. In this paper, we identify four different scenarios, and formulate some potential interactions between the collector and the dismantler, for each of those scenarios.

2. DIFFERENT SCENARIOS

We define a homogeneous discarded product as that which is discarded as a whole (for example, glass bottle, and television set), and a heterogeneous discarded product as that which is discarded in components (for example, computer and car).

We consider four different scenarios in this paper:

S1. <u>Homogeneous discarded product and single remanufactured product</u> (see Figure 2)

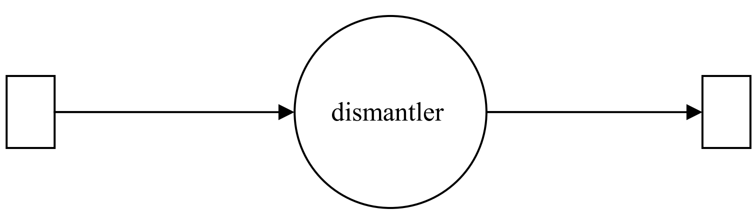

Figure 2. Scenario S1

An example is a glass bottle.

S2. Homogeneous discarded product and multiple remanufactured components (see Figure 3)

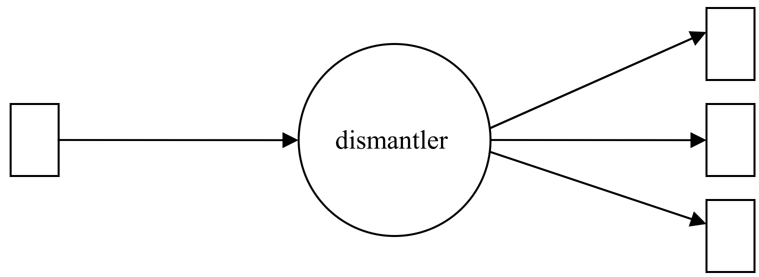

Figure 3. Scenario S2

An example is a printer.

S3. Heterogeneous discarded product and single remanufactured product (see Figure 4)

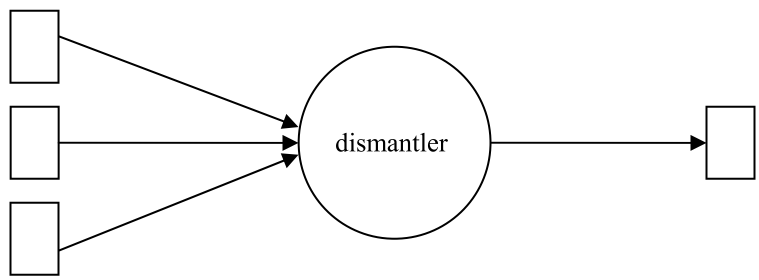

Figure 4. Scenario S3

An example is a mobile phone.

S4. Heterogeneous discarded product and multiple remanufactured components (see Figure 5)

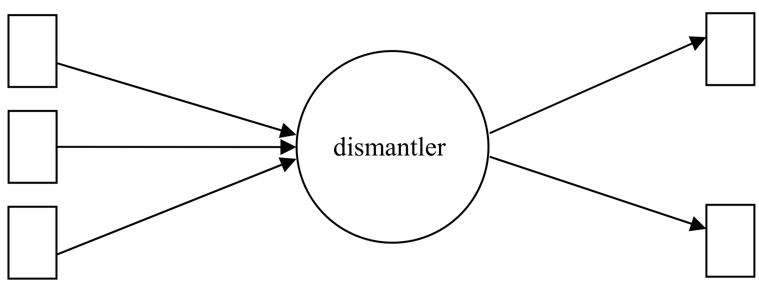

Figure 5. Scenario S4

An example is a car.

3. INTERACTIONS BETWEEN THE COLLECTOR AND THE DISMANTLER

For simplicity and since our focus is on formulating the interactions between the collector and the dismantler, we assume that the shredder is absent and his activities too are performed by the dismantler instead. We also assume that the acquisition fee for a particular type of discarded product is fixed (in other words, discarded products of a particular type are more or less in the same condition). Furthermore, we do not consider disposal cost and recycler's profit.

The objective is to maximize the reverse supply chain profit in a centralized decision-making setting. The decision variables are the acquisition fee (affects the supply) of each discarded product or component and the selling price (affects the demand) of each remanufactured product or component.

Nomenclature

a	positive constant (depends on the type of product and the type of component);
b	positive constant (depends on the type of product and the type of component);
c	collection cost (depends on the type of product and the type of component) incurred by the collector;
f	acquisition fee (depends on the type of product and the type of component) incurred by the collector;
i	type of component;
k	type of product;
m	dismantling cost (depends on the type of product and the type of component) incurred by the dismantler;
p	selling price (depends on the type of product and the type of component) of remanufactured component;
q	multiplicity (depends on the type of product and the type of component) of component;
r	cost (depends on the type of product and the type of component) incurred by the dismantler to remanufacture;
s_h	salvage value (depends on the type of product) of the hulk;
s	salvage value (depends on the type of product and the type of component) of component;
u	positive constant (depends on the type of product and the type of component);
v	positive constant (depends on the type of product and the type of component);
w	price (depends on the type of product and the type of component) at which the product or component is sold by the collector to the dismantler.

Scenario S1

Profit of the collector

$$\sum_k (w_k - c_k - f_k)(u_k + v_k f_k)$$

Profit of the dismantler

$$\sum_k (s_{hk} - m_k)(u_k + v_k f_k) + (p_k - r_k)(a_k - b_k p_k)$$

Model formulation

Maximize $\sum_k (w_k + s_{hk} - m_k - c_k - f_k)(u_k + v_k f_k) + (p_k - r_k)(a_k - b_k p_k)$

subject to $(a_k - b_k p_k) \leq (u_k + v_k f_k) \forall k$

Scenario S2

Profit of the collector

$$\sum_k (w_k - c_k - f_k)(u_k + v_k f_k)$$

Profit of the dismantler

$$\sum_k s_{hk} + \sum_k \sum_i (s_{ki} - m_{ki}) q_{ki} (u_k + v_k f_k) + \sum_k \sum_i (p_{ki} - r_{ki})(a_{ki} - b_{ki} p_{ki})$$

Model formulation
Maximize

$$\sum_k (w_k + s_{hk} - c_k - f_k)(u_k + v_k f_k) + \sum_k \sum_i (s_{ki} - m_{ki}) q_{ki} (u_k + v_k f_k) + \sum_k \sum_i (p_{ki} - r_{ki})(a_{ki} - b_{ki} p_{ki})$$

subject to $(a_{ki} - b_{ki} p_{ki}) \leq (u_k + v_k f_k) q_{ki} \forall k, i$

Scenario S3

Profit of the collector

$$\sum_k \sum_i (w_{ki} - c_{ki} - f_{ki})(u_{ki} + v_{ki} f_{ki})$$

Profit of the dismantler

$$\sum_k \sum_i (s_{ki} - m_{ki})(u_{ki} + v_{ki} f_{ki}) + \sum_k (p_k - r_k)(a_k - b_k p_k)$$

Model formulation

Maximize $\sum_k \sum_i (w_{ki} + s_{ki} - m_{ki} - c_{ki} - f_{ki})(u_{ki} + v_{ki} f_{ki}) + \sum_k (p_k - r_k)(a_k - b_k p_k)$
subject to $(a_k - b_k p_k) q_{ki} \leq (u_{ki} + v_{ki} f_{ki}) \forall k, i$

Scenario S4

Profit of the collector

$$\sum_k \sum_i (w_{ki} - c_{ki} - f_{ki})(u_{ki} + v_{ki} f_{ki})$$

Profit of the dismantler

$$\sum_k \sum_i (s_{ki} - m_{ki})(u_{ki} + v_{ki} f_{ki}) + \sum_k \sum_i (p_{ki} - r_{ki})(a_{ki} - b_{ki} p_{ki})$$

Model formulation

Maximize $\sum_k \sum_i (w_{ki} + s_{ki} - m_{ki} - c_{ki} - f_{ki})(u_{ki} + v_{ki} f_{ki}) + \sum_k \sum_i (p_{ki} - r_{ki})(a_{ki} - b_{ki} p_{ki})$
subject to $(a_{ki} - b_{ki} p_{ki}) \leq (u_{ki} + v_{ki} f_{ki}) \forall k, i$

4. CONCLUSIONS & FUTURE RESEARCH

Implementation of an efficient reverse supply chain requires coordination among a number of parties, such as the collector, the dismantler, the shredder, and the recycler. In this paper, we identified four different scenarios of homogeneous and heterogeneous products, and then formulated some potential interactions between the collector and the dismantler in each of those scenarios.

In our future research, we plan to work on the following:

- Possible solutions to the model formulations in the four scenarios.
- Insights and possible propositions in centralized coordination.
- Decentralized coordination.

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