OPTIMAL RECYCLING POLICY

Operations Research II

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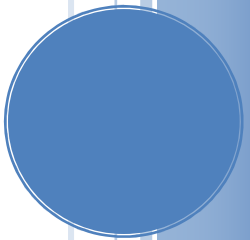

Motivation

In today's world, environmental protection is a key component of our lives. Recycling is viewed as a way to help protect our natural resources. However, a deeper look into recycling shows that it is not always a cost effective and environmentally friendly process. Many people have argued that collection costs can out weigh the benefits of recycling.

In cities such as New York, San Jose, and New Jersey the recycling programs came to be inefficient. New York City had to shut down its recycling program in 2002 because its costs the city $239 per ton to recycle as opposed to $132 per ton to just dump it (Sanders). In San Jose, the recycling cost was $28 per ton compared to $147 per ton. Atlantic County, NJ also found that recycling brought in 2.45 million, but costs the county 3 million in collection, sorting, and facility fees. On the other hand you have a small town such as Madison, Wisconsin which was able to recycle 50% of its household products, thus saving half a million in landfill fees and gaining a revenue of half a million from the recycled items (Black).

A current evaluation of these places like New York City, Atlantic County, and San Jose show the use of some sort of recycling program. In New York, Mayor Bloomberg said there were two types of recycling groups: paper and then metal, glass, and plastics. The recycling group that is efficient and pays for itself is paper. The city has a lot of trouble recycling plastics. Not all plastics are reusable, like yogurt containers and certain types of PET and HPDE plastics. However, people mix them up anyways so most content in those blue recyclable bags are in fact not reusable at all.

With the confusion on what is recyclable, most people will just throw everything in the trash. Advocates say the city can implement new policies or programs to improve on the quantity brought to recycling. One suggestion that was posed is getting building superintendents

to retrieve the recyclable from the black trash bags (Sanders). However, this is more of a regulation imposed on individuals. It would be hard to find an incentive for these individuals to routinely rummage through black trash bags; there must be a more uniform city policy to get the most efficiency, for example the single stream policy can be of use. This policy will be elaborated further into the paper.

Currently, Atlantic County will start using the single stream policy starting January 1st of 2009 (Atlantic County Utilities Authority). And in San Jose, a Zero Waste Policy was recently implemented. The city of San Jose has a vision to utilize all waste into some form of resource by 2022 (City of San Jose). From observing historical trends and policies, we can conclude that recycling is beneficial as long as the current policy is efficient and fitting with the particular place in question.

With all the focus on monetary concerns, it is easy to forget that the purpose of recycling was not cost reduction but conservation. Recycling reduces air pollution from incineration, stops the degradation of land and ground water from landfills, cuts down the number of trees used for paper, and creates less of a reliance on petroleum for plastics.

For our final project in this Operations Research class, we will explore the cost and benefits of recycling. Our purpose is to optimize the costs of recycling by utilizing the objective function and constraints. More specifically, we intend to minimize the cost of this process, which is a perfect example of what operations research entails.

In all mathematical models, we consider the equations we use to be relevant to the situation at hand. As you can see, Recycling is prevalent everywhere on the Carnegie Mellon campus. Next to every trashcan, there is a recycling can for bottles/cans. In numerous areas there are bins for paper; places such as the University Center will even have electronics, and

food disposal bins. Our model will be based on the recycling needs of Carnegie Mellon's Environmental Protection sector. We will primarily focus on Carnegie Mellon University by taking into account the resources available to the school and the needs of the Carnegie Mellon University community.

Types of Policies

In our analysis we will be focusing on two different recycling policies. There is the traditional policy where each material is recycled separately, and there is the "single-stream" policy. Single-stream involves gathering together all recyclable materials and having them be separated afterwards at a recycling facility. The institution or city does not have to worry about separating out the materials. There exists only one type of recycling bin. After the institution collects the recycled material, the recycling company then comes to pick up the bins and they sort different recycled materials at a different site.

As of right now, most cities and institutions have a traditional recycling policy in place. So the institutions collect different recyclable materials separately, and the garbage company comes to pick up each bin along with the non-recyclable garbage. So these are the two policies that we have right now, and the purpose of this project is to choose the optimal policy for Carnegie Mellon University.

Recycling at Carnegie Mellon University

Carnegie Mellon University currently has a traditional recycling policy in place. There are four recycling bins for every one garbage bin in place. This means that all the students, faculties, and everyone on the campus can participate in the recycling process. Recycling is done

on the campus, and then the garbage company comes to pick up the recycled garbage. However a question arises if the current recycling policy, non single-stream is the optimal policy for Carnegie Mellon University. To get the answer to this question, two mathematical models are set up for each of recycling policies based on the data from Carnegie Mellon.

To better understand how we model this problem, an explanation of the current program at Carnegie Mellon University is needed. Another important thing to be aware of is that the city has nothing to do with Carnegie Mellon's recycling program. The people involved are all from private organizations. There are only two companies in Pittsburgh that deal with recycling and waste disposal. The two companies are called Waste Management and Allied Wastes. Currently, the waste and recyclable material on campus are collected weekly. Depending on the type of material, the procedure for recycling is different. For example, paper is collected and grouped by Carnegie Mellon University hired custodial workers and driven to the compactor. Meanwhile items such as aluminum and plastic are too heavy to remove personally through Carnegie Mellon University, so outside companies are called to haul it away.

Carnegie Mellon University entered in a new 5-year contract with Waste Management last year. This new contract costs 30% more than the previous contract. The terms of the contract are as follows: Carnegie Mellon receives rebates for every ton of material they recycle. For example, office paper is fixed at $25 per ton, and cardboard depends on the market price, but it is roughly $(Market Price -30) per ton. There are six pickups per week and each pick up costs $30. The gross profit is based on a sliding scale. The Environmental Protection Agency asks for a 35% recycling rate. Carnegie Mellon University is currently at 19% and is aiming for 25%. Last year, in 2007, Carnegie Mellon University spent approximately $300,000 on recycling, but does

not have a strict budget for wastes contract. Due to the declining economy, Carnegie Mellon University is in need of a new program.

The basic assumption behind this mathematical modeling is that the model includes only the four recyclable materials to along with non-recyclable waste. The four elements are paper, cardboard, co-mingled, and scrap metal. These are chosen because they represent more than 90% of total recycled materials. Newspapers, office paper, and any other recyclable paper is included in the paper category. Co-mingled includes cans and bottles since they are recycled together, and scrap metal represents iron, copper and all kinds of recyclable metal.

	Total Net Cost ($)	Total Quantity (ton)	Net Cost/Ton
Paper	-3621.00	201	-18.00
Cardboard	-8000.00	242	-33.00
Scrap Metal	-170.00	37	-4.60
Co-Mingled	-139.00	96	-1.50
Miscellaneous	696.00	124	5.60
Waste	220,769.00	3066	72.00

The first model to attack is the one that Carnegie Mellon University is currently using, which is the traditional, non-single-stream policy:

$$\text{Cost} = \sum_{i=1}^{5} (c_i - r_i)x_i + L \quad \text{(where i= 1….5)}$$

- x_i - quantity in tons of element i
- c_i - cost of recycling 1 ton of element i
- r_i - rebate for 1 ton of element i
- L - labor costs

Each i represents 5 materials that we are going to use for this model as we assumed before modeling. x_i is the quantity of the each element in tons. c_i includes all the cost of recycling 1 ton of each element, such as gas for transportation and any other expected or unexpected cost. r_i is the rebate we get from the company for 1 ton of each element. The biggest portion occupied in the total cost is a labor cost. It costs approximately 50,000 dollars for the worker's wage. If we subtract how much we get, r_i, from the money we spend, c_i, the result is going to be how much we spend in the summation, either it gives a positive or negative value. Since this cost is calculated in 1 ton, the total cost is easily calculated by multiplying the total quantity x_i, which gives $(c_i - r_i) x_i$. Five elements are selected as we assumed for this model, the total cost to recycle is summation of $(c_i - r_i) x_i$ for each element. If we add the labor cost, which is represented by L, $\sum (c_i - r_i) x_i + L$ (where i= 1….5), this gives the total cost for non single-stream policy.

The second model is a single-stream policy:

$$\text{Cost} = (K - R)\sum_{i=1}^{4} x_i + c_5 x_5 + L \text{ (where i= 1….4)}$$

- K - cost of single-stream 1 ton
- R - rebate from single-stream 1 ton
- L - labor costs

The main difference between single-stream policy and non single policy in our mathematical modeling is the existence of rebate from each element. For the non single-stream policy, there is a rebate for each element. However for the single-stream, there is no specific rebate for each element, but one whole rebate for all the elements. K represents the cost of recycling 1 ton of every element. R is the rebate for 1 ton of everything as stated above. If we subtract how much we can get from recycling, R, from how much we spend, K, we get the number that costs to

recycle 1 ton of elements. The value that mulitiplied this total cost with the total quantity of all the elements, $\sum x_i$, gives the cost to recycle in total. The summation of this total cost and the labor cost L, results the total cost for single stream policy.

Optimal Policy for Carnegie Mellon University

Based on the current recycling data from Carnegie Mellon University, the optimal policy for Carnegie Mellon University is the current policy. The marginal costs associated with recycling the most common types of recyclable materials are all negative. We compare the two policies:

Current: Single-Stream:

$$\text{Cost} = \sum_{i=1}^{5} (c_i - r_i)x_i + L \qquad \text{Cost} = (K - R)\sum_{i=1}^{4} x_i + c_5 x_5 + L$$

The specific single-stream contract being proposed to Carnegie Mellon University will provide the university with a trash compactor and collect all the recyclable waste for no cost and no rebate. Therefore, the costs associated for each policy for Carnegie Mellon University specifically are:

Current: Single-Stream:

$$\text{Cost} = \sum_{i=1}^{5} (c_i - r_i)x_i + L \qquad \text{Cost} = (K - R)\sum_{i=1}^{4} x_i + c_5 x_5 + L$$

where $(c_i - r_i) < 0$ for $i = 1...5$ $\qquad = c_5 x_5 + L$

Since the labor and maintenance costs (L) are the same regardless of which policy is used, it is obvious that Carnegie Mellon University benefits more from the current recycling policy. If Carnegie Mellon University switched to Single-Stream, they would effectively be losing the “profits” they receive from recycling each material separately.

Optimal Policy in General

This is not to say that Single-Stream is never a viable option. It is important to remember that due to the high volatility in the market prices of recyclable materials, rebates associated with recycling different materials individually can fluctuate greatly. In addition, the marginal costs of recycling the different materials can vary greatly depending on the type of location the recycling policy is in place for. Areas with large marginal costs associated rely on rebates more heavily to help reduce the overall cost of their recycling programs.

The marginal rebates one receives from single-stream policies are typically very small but stable, which could potentially make it a good policy choice for areas whose overall costs are more sensitive to market price fluctuations. This is the fundamental difference between Single-Stream and traditional recycling policies. While single-stream eliminates the potential high rebate opportunities that come with high market prices for certain materials, it also eliminates potential high cost situations that come with low market prices.

Smaller institutional programs such as Carnegie Mellon University will typically benefit from the traditional policy since their marginal costs will be very small compared that of larger municipalities.

Successful Single-Stream Policies

One example of a city that benefited greatly from converting to a single-stream recycling is Hartford, Connecticut (Heather Brandon). The initial cost for switching policies was approximately $3 million. However, now that the policy is in place, it has paid almost immediate dividends. After converting to single-stream in May of 2008, the city doubled the amount of

tonnage it recycled per week after only 25 weeks of switching its recycling policy. The city receives a rebate of $10 per recycled ton from this policy.

While $10 per recycled ton does not seem like very much, considering how rebates for some individual materials such as paper are typically $25 per ton, it is important to recall once again that the greatest benefit to the single-stream policy is the potential high costs of recycling less valuable materials that are avoided. It is estimated that in the first 25 weeks of switching to single-stream, Hartford has saved approximately $30,000 in landfill disposal fees. This was not the case in other large, urban areas such as New York City.

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