PREVIEW PAPER: AVERAGE

The team's summary is good, and they provide a clear, simple model for question one. The model lacked details and there is little discussion about the motivation for the different terms within the model. The description of the model for question three was particularly lacking. On the plus side it has a nice discussion of the sensitivity of the model in question one. Also, the team's examination of using wasted food as compost was interesting, but they could have looked at more ways of keeping food within the system.

Better ATE Than Never: Reducing Wasted Food

Executive Summary

In a world with a growing market for food, food waste has also grown. This is due to the fact that food is thrown out for many reasons that could be prevented. For example, food that is deemed “unattractive” never makes it to store shelves, despite the fact that they are perfectly normal outside of their appearance. This is most common in the United States, where food makes up the largest percentage of material that goes into the garbage. Another reason for the rise in food waste would be in overconsumption, as many people buy more than they can eat, and as a result, the food goes into the garbage. While working on ways to solve this expanding problem, we used mathematical models to find solutions that would fix this.

When presented the problem our team knew that it would have to take into consideration the amount of food that people consume as well as the population of any particular area that has a problem with food insecurity. In order to be able to understand the topic it was in our best interest to get familiar with the reasons on how so much food could thrown away and we came to realize that it is mostly based on the consumer and producer. Based on these findings it was then up to our team to solve our initial task of creating a model that would be able to establish the capacity that a state within the United States of America could have in providing for its food insecure people. With the model created based on the research it was found that a state like Texas with the second highest population of 27,469,114 people, has the sufficient amount of wasted food that could be repurposed for people that desperately need it.

We were then asked to find the amount of food that would be wasted based on a few different types of circumstances. In our case we looked at the income as well as the number of people within a household that will have distinct traits and behaviors, which will result in a different amount of wasted food that each provide. In our method to creating this model we first had to examine the percentage of 13.1% from household’s income that would be spent on food and then calculating the portion of that food that would not be eaten.This was then formulated to use the cost wasted on food and by figuring out the average cost of food per day for an individual was $6.75 and it would give us the total amount of pounds wasted when divided.

This then leads into our third task of knowing how to be able to find affordable ways to efficiently repurpose the wasted food. This would be accomplished by making sure everyone gets the sufficient amount of food they need, however we would then make sure that the food is getting to those who are food-insecure. This would be done by delivering waste by truck or through existing sink disposal pipes to a municipal water resource recovery facility (WRRF), so that the material can be treated and then reused. Another method that we used was to have a series of biological processes to break down biodegradable material to produce biogas and digestate.

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Introduction

Much of the food produced in the United States is wasted. This is largely caused by the buying market looking for produce that is aesthetically pleasing rather than how edible and fresh it is. Because of this, a large factor of food that is malformed, but still comestible, is disposed of before it even reaches the market. The Environmental Protection Agency has estimated that more food ends up at landfills and incinerators than any other waste product. Additionally, food that is not sold when it does reach stores ultimately ends up being thrown away. When the food does eventually reach households, it is not always completely consumed. Some rots before people get the chance to eat it. Some is throw away by picky eaters. Some is overeaten, which is also wasteful. Furthermore, the resources used in producing these plants: such as water, fertilizer, pesticides, land, labor, etc., also go down the drain.

Simultaneously, about 42 million Americans are food-insecure. Using the food that is thrown away can help to solve this issue. Food that is currently “rejected” can be sold at a lower cost, or donated to people in need. In addition, after food is at a point when it cannot be consumed, it can be utilized in other ways, which also saves money. Some ideas by which it can be used include composting, using the food for animal feed, or turned into renewable energy with centralized anaerobic digestion. In this way, food wastage can be largely reduced, whilst solving other problems at the same time.

Part 1: Just Eat It!

1.1 Restatement of the problem

This part of the problem asks to make a model showing whether or not food wasted in a state can be used to feed its food-insecure population, and demonstrating how the model works with Texas.

1.2 Assumptions and Justifications

- Assumption: The number of food-insecure individuals will remain far less than the total population
    - Justification: the population of food-insecure individuals in the United States is 13.4% of the total population
- Assumption: The amount of food needed per person will remain constant.
    - Justification: It is based on the average amount of food (in pounds) an average American consumes
- Assumption: The amount of food wasted every year will remain constant.
    - Justification: This model is made to demonstrate if the food-insecure individuals can be fed by the the amount of food *currently* wasted.

1.3 The Model

Wasted food in each state can be used to feed the food-insecure population of that state. This can be demonstrated with the statistics of Texas for the variables in the following model:

$$F_n \times I \leq F_w \times P$$

Variables:

- P: population of the state
- I: population of food-insecure individuals

Constants:

- F_w (food wasted per year per person)= 639.341 lbs
- F_n (food needed per year per person in a year)= 1715.5 lbs

1.4 Reasoning

The amount of food wasted in US per capita is 639.341 pounds, factoring in food lost during the production to retailing processes. When this is multiplied by the population of a state, the product comes out to be the total amount of food wasted in that state altogether. The amount of food consumed by a person each day is 4.7 pounds **(1)**. After this is multiplied by 365 days, it

is found that each person consumes 1715.5 pounds a year. Furthermore, when 1715.5 is multiplied by the population of food-insecure individuals, the total amount of food needed to feed these people is found.

This model can be demonstrated with the population of Texas and its food-insecure population to fill in the variables. Texas has a total population of 27,469,114 people, and 4,320,050 food-insecure individuals. When the total population of Texas is multiplied with the amount of food wasted per person, the approximate amount of food wasted in Texas is found:

$$27,469,114\ people * 639.341\ lbs\ of\ food = 17,562,100,000\ lbs\ of\ food\ wasted\ total$$

When the population of food-insecure individuals is multiplied with the amount of food needed per person, the total amount of food needed to feel this population is found:

$$1715.5\ lbs\ needed\ per\ year\ per\ person * 4,320,050\ people = 7,411,045,775\ lbs\ needed\ per\ year$$

This data shows that the food-insecure population can be fed with the the food that is wasted, with enough food left over to feed them a second time still having more to spare.

$$17,562,100,000\ lbs - 7,411,045,775 lbs = 10,151,054,225\ lbs\ of\ food\ left\ over$$

The model works, showing that it is, in fact, possible to feed the food-insecure population with the food wasted in that state.

1.5 Sensitivity Analysis

In order to test how sensitive the model is to other variables, one can interchange the variables with the populations of other states. One state the model was tested against was New York. The total population of New York is about 19.75 million people **(14)**. The population of food-insecure people is 2,502,250 people. When plugged into the model, it still works:

$$19,750,000\ people * 639.341\ lbs\ of\ food\ wasted = 12,627,000,000\ lbs\ of\ food\ wasted\ total$$

This shows the total amount of food, in pounds, that is wasted by the total population of the state of New York.

$$1715.5\ lbs\ needed\ per\ year\ per\ person * 2,502,250\ people = 4,292,610,000\ lbs\ needed\ per\ year$$

This shows the amount, in pounds, of food needed to feed the food-insecure population.

$$12,627,000,000\ lbs - 4,292,610,000\ lbs = 8{,}334{,}390{,}000 \text{ lbs left over}$$

After these calculations, it is clear that the amount of food wasted is still more than the amount of food needed to feed the food-insecure population of that state.

Part 2: Food Foolish?

2.1 Restatement of the problem

When it comes to choosing the food to eat, many people will base their choices on personal preference. Determine how the income, number of family members within a household, and personal choice can impact the amount of food waste a household generates in a year.

2.2 Assumptions and Justifications

- Assumption: The amount of food eaten per person will stay the same.
    - Justification: The factors that are considered for each person will remain constant because each person has different dietary needs and this model will be used to view average households.
- Assumption: An infant is not taken into account as an adult.
    - Justification: An infant will not be able to consume a sufficient amount of food to make a substantial change in food wasted as they are given a strict diet.

2.3 The Model

There was an evaluation for the four particular cases of:

- Single parent with a toddler, annual income of $20,500
- Family of four (two parents, two teenage children), annual income of $135,000
- Elderly couple, living on retirement, annual income of $55,000
- Single 23-year-old, annual income of $45,000

Based on the needs of each case the model created is able to provide a cost for the amount of food that would be wasted in the household:

$$C = \frac{(.064 \times N)}{2641}(399.2 \times H)$$

Variables:

- N: Income
- H: Number of people in a household
- C: Cost for the amount of food waste a household generates

Constants:

- .131: percentage of income spent on food
- 2641: average food cost for a U.S. household per person
- 339.2: the average number of pounds that Americans waste over the course of one year

As shown above the cost will first be determined by multiplying the average cost that a family will make based on their income. Based on findings, Americans spend 13.1% of their income on food **(2)**. Afterwards, by taking the projected amount of money a household can use for food then it can be divided by $2,641 spent annually per person **(3)**. Calculating these values will provide the necessary costs that can then be used to multiply the average amount of food eaten by each person.

Moving onto the second half of the equation, the 399.2 lbs used was calculated by first finding that an estimate of 1,996 lbs are consumed by an average American over the course of one year **(4)**. Then using this number, 20% of the average amount was found to obtain the average number of pounds wasted by an American over a year
(5). By using these constants the 399.2lbs of potentially wasted food will be multiplied by the number of members in a household (H).

Next, by finding the cost of wasted food that a household creates, we can then find the amount it generates. It is known that average food cost is $6.65 per day per person **(6)**. The original cost found can be applied to this equation:

$$A = \frac{C}{6.65}$$

Using this equation we can generate the amount of waste a household generates and actually find the estimated number in weight that the household will not use (A).

2.4 Reasoning

Figure 2.1 Amount of Food Waste a Household Generates Annually

Amount of Food Waste a Household Generates

NUMBER IN HOUSEHOLD	ANNUAL INCOME (USD)	FOOD WASTED (LBS)	COST (USD)
1	$20,500.00	61.04	405.93
1	$45,000.00	133.99	891.06
2	$55,000.00	327.54	2,178.14
4	$135,000.00	1,607.92	10,692.69

As it can be seen, the model can demonstrate that the there is a clear correlation between a the increased amount of income and when the number of people within a household increases then the food wasted will increase. The traits and habits of a household will be based on the number of people and income made since with less income there will be less food to waste and with more people there is potential to waste more food.

Part 3: Hunger Game Plan?

3.1 Restate the Problem

Opportunities in repurposing potentially wasted food have begun to be recognized by communities. Find ways to repurpose food being wasted in ways that are cost efficient; repurposing the maximum amount of food at the minimum cost, and compute the costs and benefits that come from the strategies.

3.2 Assumptions and Justifications

- Assumption: The amount of food eaten per person will stay the same.
    - Justification: The factors that are considered for each person will remain constant because each person has different dietary needs and this model will be used to view average households.
- Assumption: An infant is not taken into account as an adult.
    - Justification: An infant will not be able to consume a sufficient amount of food to make a substantial change in food wasted as they are given a strict diet.

- Assumption: Data for income of households is normally distributed
    - Justification - Assuming normality of makes the median and mean the same, hence makes it possible to solve the problem.
- Assumption: A gram of food comprises of ⅓ of fat, ⅓ of protein, and ⅓ of carbohydrates.
    - Justification: In order to have calories, the gram of food has to be made up of these three nutrients because minerals, water and vitamins do not really have enough calories to be accounted for.

3.3 The Model

Mean house income - $57,617 (ASSUMING NORMALITY)
(16)

Average household size - 2.5
(15)

Money spent on food = 13.1%
Total money spent = 0.131 x 57,617 = $7547.827
Average caloric consumption = 2000 calories
Average caloric consumption per household = 2000 x 2.5 = 5000 calories
Dollars per 2000 calories - $6.65/ day
Cost of a calorie = $0.003325
Dollars per 5000 calories - (5000/2000) x 6.65 = $16.625/ day = 16.625 x 365 = $ 6068.125/ year
Extra money spent = $7547.827 - 6068.125 = $1479.702
Extra calories bought = (1479.702/6.65) x 2000 = 445023.157895 cal

Calories in a gram of fat = 9
Calories in a gram of protein = 4
Calories in a gram of carbs = 4
(https://fiberfacts.org/fibers-count-calories-carbohydrates/)

Calories in 1 gram of food = calories in 1 gram of fat/3 + 2(calories in 1 gram of carb/protein)/3 = 9/3 + 2(4/3) = 17/3= 5.67
445023.157895 cal to grams of food = 445023.157895/5.67= 78487.33 grams

M_{HI} = Mean Household Income = $57,617
H_p = Average household population = 2.5 people

M_S = Average Portion of money spent = 0.131
C_C = Cost of 1 Calorie = $0.003325
C_F = Calories in a gram of food = 5.67 cal
C_p = Average calories per person = 2000 cal
T_H = Total Households in an area

2 Methods -
1. WATER RESOURCES RECOVERY FACILITY (WRRF) WITH AD = Financial benefit of $23/TON

2. CENTRALIZED ANAEROBIC DIGESTION (CAD) = financial benefit of profit of $21/TON

WRRF = $23/ TON
CAD = $21/ TON

Model for total financial benefit - Using one of the two methods (WRRF or CAD)

$$(\text{WRRF or CAD})(T_H(\frac{\left[\frac{[M_{HI} \text{ x } M_S]}{C_C}\right] - 365\,[C_p \text{ x } H_p]}{C_F \text{ x } 10^6}))$$

3.4 Reasoning

Method 1:

WATER RESOURCES RECOVERY FACILITY (WRRF) WITH AD
Delivering waste by truck or through existing sink disposal pipes to a municipal water resource recovery facility (WRRF), where it is treated with anaerobic digestion; the remaining biosolids can be applied to land for beneficial reuse**(7)**.

Method 2:
CENTRALIZED ANAEROBIC DIGESTION (AD)
A series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen resulting in two end products: biogas and digestate. There are many

different AD technologies, including wet and dry versions, the latter being generally better suited for food waste mixed with yard waste **(7)**.

Conclusion

Our team has been able to create models that will assist in figuring out the requirements that a state would need in order to be able to find out how many food insecure individuals they can feed. Through research and calculations it was found that there is about 639.341 lbs of food wasted per year per person and 1715.5 lbs of food needed per year per person in a year. Based on these results a state like Texas would be able to determine that it would be capable of using wasted food to give to food insecure citizens. Also, in the second model we created, it was able to determine the amount of food wasted by household based on income and number of people within the household. The model used could be able to use found data to calculate the cost that they waste and then convert that into the amount of pounds they would be wasting. In the third model the economic benefits of two methods are explained.

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