Better Ate than Never: Reducing Wasted Food

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Executive Summary.

Food waste in modern society is a problem which is quickly gaining traction. The Environmental Protection Agency (EPA) estimates that more food reaches landfills than any single material in the trash. This wastes food resources, while 42 million Americans are food-insecure and in need. In order to prevent food waste from reaching landfills and incinerators, we must scrutinize the sources of waste and take novel measures to make use of all edible food. In this paper, we examine three main problems using mathematical modeling.

First, we created a model to see if food waste could be used to feed the food-insecure demographic of a state, using Texas as a test example. To model this we examined data about food waste percentage in North America and data about food production in Texas. We calculated food need based on the diets of children and adults, and computed the percentage of need that could be met using food waste. We found that between pessimistic and optimistic estimates, an average of 30% and 60% of food need can be met by food waste for demographics above and below the 185% poverty level.

After comparing generated food waste to the needs of the food-insecure in Texas, we examined food consumption traits and habits to determine the food waste for specific household types. These included consumer units of both low and high income with varying family dynamics and ages. To address the problem we evaluated the percent of a household's income spent on various types of food prepared at home, such as fruits, meat, and vegetables. Used data about the amount of food wasted at the consumer level by food type, we calculated the percent of a household's income spent on wasted food by income bracket. We then adjusted this model to include out-of-home food waste and household size, creating a cohesive model for all households.

Finally, we provided mathematical models of strategies for the repurposing of wasted food in Illinois. We found the value of specific food items and their rate of purchase from farms in Illinois over a one-year period. Our strategies redirected produce deemed physically unappealing to grocery stores, salvaging $2,396,640 of food that otherwise would have gone to waste. Other waste from the grocery stores is then brought to food shelters, or used in composting to provide both an economic and an environmental boon to the state.

Contents.

Assumptions and Justifications.

General Assumptions:

1. The food loss percentages are an accurate representation for all differing factors of production
    a. **Justification:** Factories for different products use different methods to process their materials, and some create more waste than others. Since we cannot account for such a large amount of variation, we assumed that the data provided to us of the average percentage lost was representative for all factories.
2. No external conditions can cause deviations from standard production values
    a. **Justification:** Food production depends on many factors, such as seasonal characteristics, that can alter the yearly amount of production. We assumed that the data we had was representative of the average production. For example, in Problem 1, we used data on food production in Texas in 2015, assuming that this data would be representative of any year.

For Problem 1:

1. North American food loss data represents food loss that occurs in Texas.
    a. **Justification:** The data we used was provided by the Food and Agriculture Organization of the United Nations on Global Food Losses and Food Waste is a reputable, accurate, internationally-consistent source.
2. The list of food that Texas makes is accurate to what Texas produces.
    b. **Justification:** The list is provided by the cash receipts report of Texas by the USDA's Economic Research Service, a reputable government source.
3. Each consumer unit in Texas contains the average amount of individuals for its income bracket as specified in the Consumer Behavior Based on Income data.
    a. **Justification**: The data represents a survey of consumer units across the United States. Texas is a member of the United States, so we assume the data is representative of Texas.
    b. **Justification:** The average number is not a whole number of individuals, but considering a fractional amount of individuals provides the most accurate estimate of need.
4. The poverty line for a hypothetical household consisting of a non-integer number of members is calculated in dollars as 12060 + (n-1)*4180, in which n is the number of members of the household.
    a. **Justification:** The poverty line for US households is $12060 per year for a financially independent reference person plus $4180 per year per additional family member. An average household used for simplification may have a non-integer number of members, so the $4180 per additional person is calculated as a linear non-discrete function.

5. A typical person in Texas requires $2836.05 to feed themself for a year.
    a. **Justification:** The average cost of a meal in Texas is given as $2.59. Assuming all meals cost this mean amount and person eats three meals a day, the cost of food for a 365-day year is $2.59 * 3 * 365 = $2836.05.
6. Teenagers age 18-19 eat the same amount of food per day as adults age 20 and over.
    a. **Justification:** The NHANES survey of the amount of food people consume per day counts people age 2-19 as children in its survey, but the Consumer Expenditure Survey counts only people age 18-19 as adults. Teenagers age 18-19 are nearly fully developed, so we assume they have the same diet as adults.

For Problem 2:

1. Food sales and costs do not include alcohol.
    a. **Justification:** When billing, most food establishments consider alcohol separate from food.
    b. **Justification:** The United States' Department of Labor's Bureau of Labor Statistics' Consumer Expenditure Survey considers alcohol separate from other food costs when calculating percentage of disposable income.
2. Each person eats the average amount according to our data (insert data here).
    a. **Justification:** In an order for our calculations to be applicable on a large basis, we did not take into account fluctuations in food consumption for the average person as this would be a factor on the personal level that could not be easily quantified for our purposes.
3. Restaurants, schools, and other out-of-home food sources use the same ratio of food types in their meals as in-home intake.
    a. **Justification:** Most restaurants, schools, fast food services, and other out-of-home food sources serve typical meals suitable for human consumption. Therefore, they contain many of the food types as in-home meals.
4. The four examples given in the problem use post-tax income, or disposable income.
    a. **Justification:** Many variables are required when calculating income taxes, and external factors such as tax breaks and bonuses will modify the income tax unpredictably. Additionally, listing the entire process of calculating federal income tax in this paper would detract from our purpose of modeling food waste.

For Problem 3:

1. Any unappealing food is removed during factory processing.
    a. **Justification:** Our plan involved the assumption that the processing plants remove the undesirable food prior to shipping it to the retailers. This also assumed that no additional products were removed due to undesirability during the retail stage to prevent additional variables from entering the plan.

Problem 1.

Restatement of the Problem:

The problem ask us to find the following:

- Create a mathematical model to determine the plausibility of feeding the food-insecure populations in certain states
- Use Texas and National data to demonstrate how the model is applicable to Texas, and how it can be implemented

We plan to achieve this by scrutinizing the data (waste percentages) alongside nation-wide production values to determine the amount of food, if possible, could feed the food-insecure in Texas.

Analysis of the Problem:

To accurately model this problem, we need a model to calculate the amount of food waste produced in a state and a model to calculate need. To calculate food waste, we considered percent waste at various steps between agricultural production and consumption and what food is still likely to be usable. To calculate need, we considered how much food a typical household consumes in a year based on household composition and the degree of food insecurity present in households of various income brackets.

Developing the Model:

Part 1. Food waste of a given state

Using data from the Food and Agriculture Organization of the United Nations about waste percentages for various commodity groups in North America and Oceania, we determined the total waste percentage, the waste percentage of food that enters supermarket retail and consumption, and waste percentage during consumption (Table 1.1). The study listed waste percent of percent of commodity that enters each individual step, so we multiplied the percent retention of each step to calculate the total percentage.

Table 1.1: Waste percentage of various commodity groups generated at various steps of processing (North America and Oceania).

Type	Waste Percentage (Total)	Waste Percentage (Supermarket retail and consumption)	Waste Percentage (Consumption)
Cereals	38.5%	28.5%	27%
Roots and Tubers	60.2%	34.9%	30%

Oilseeds and Pulses	20.5%	5.0%	4%
Fruits and Vegetables	52.3%	36.6%	28%
Meat/Eggs	22.5%	14.6%	11%
Fish and Seafood	49.8%	39.0%	33%
Milk	19.8%	15.4%	15%

To determine how much food waste is generated in a given state, we organized the production (in USD) of cereals, roots and tubers, oilseeds and pulses, fruits and vegetables, meat and eggs, fish and seafood, and milk and dairy products into a 1 x 6 row matrix A. To calculate a low estimate total waste, we multiply matrix A with a 6 x 1 column matrix B containing the chosen waste percentages. We chose to use the percentages in the second column of calculated waste because much of the food waste during agricultural production, post-harvest handling and storage, and processing results in inedible damaged food. As a high estimate, we multiply matrix A with matrix B containing the values in the first column of total waste, assuming that all waste could in fact be salvaged as edible food. The actual value of salvageable food waste should lie between these estimates.

$W_{low} = A \times B_{\text{retail and consumption}}$
$W_{high} = A \times B_{total}$

According to the USDA's Economic Research, Texas, in particular, annually produces $920.058 million in cereals, $131.890 million in roots and tubers, $656.559 million in oilseeds and pulses, $1.59121 billion in fruits and vegetables, $11.2647 billion in meat and eggs, $17.7220 million in fish and seafood, and $1.84814 million in milk and dairy products (all values in USD). Using this data as matrix A, we get
W_{low} = $2,575,299,344
W_{high} = $3,944,166,523

Part 2. Annual consumption of a household
To calculate the food need that exists in a state, we created models of the food requirement of a household and compared it to the amount households in various income brackets could spend on food.

Part 2a. Model 1

R = N * 3 * 365 * 2.59

R = Food requirement (USD), N = Number of people in household, R = 3 * 365 * 2.59 = 2836.05 for one adult

Our first model was a simple calculation based on data about the average cost of a meal in Texas. This model assumes that people of various ages consume the same amount of food (in USD) and that a person eats 3 meals a day in a 365-day year.

Part 2b. Model 2

For our second model, we went more into detail about the daily food requirement of adults versus those of children. We used data about typical diets of different populations from the 2007-10 National Health and Nutrition Survey and the average market price of various food types (Table 1.2) to determine the cost of feeding one adult or one child per day (Table 1.3) by multiplying a 1 x 6 matrix A containing typical daily consumption of each food type by children or adults by a 6 x 1 matrix B containing the unit price for each food type.

Table 1.2: Average price (USD) of various types of foods per serving

Fruits	Vegetables	Dairy	Protein	Grains	Sugars	Fats
$0.3425/cup	$0.5740/cup	$0.1635/cup	$0.1677/oz	$0.0700/oz	$0.0057/tsp	$0.0037/g

Table 1.3: Cost per day (USD) of various food types for children and adults

Type	Children	Adults
Fruits	.3699	.3596
Vegetables	.5281	.9127
Dairy	.3532	.2681
Meat	.7261	1.0280
Grains	.4522	.4529
Sugar, oil, and fat	.3100	.3200
Total	2.7395	3.4313

The most important figures in Table 1.3 are the total cost of food for a child and the total cost of food for an adult, which are used in the calculation below.

$R = 365 * (2.7303 * N_c + 3.4313 * N_a)$

R = Food requirement (USD), N_c = Number of children in household
N_a = Number of adults in household

Part 2c. Determination of need groups and relative aid given
Data from Feeding America about food insecure populations divided the food insecure into three groups: those eligible for SNAP, WIC, free school meals, CFSP, and/or TEFAP (under the 165% poverty line); those eligible for WIC and reduced price school meals (under the 185% poverty line but above the 165% poverty line); and those not eligible for federal nutrition assistance but who may benefit from charitable response (above the 185% poverty line). Because the data from Texas lists only 5.6% of the food insecure population as eligible for WIC and reduced price school meals, we decided to include everyone under the 185% poverty line in one group.

Next, we examined data about income brackets, poverty level, and food expenditure and compared food expenditure to food requirement calculated by our models (Table 1.4) to examine if this division is reasonable and to determine the level of aid for each group. Income brackets up to the $50,000 to $69,999 bracket are spending less than $2836.05 per person per year on food. The 185% poverty line falls approximately in the $30,000 to $39,999 income bracket. Because the $30,000 to $39,999 income bracket spends the least on food per person, our model includes it with the group requiring more assistance. Split along these lines, the group spending the least on food spends about twice as much below the expected cost of food per person as the group spending the most on food while still below the expected cost. Therefore, we define the ratio F_A/F_B in which F_A equals aid given to the lower group and F_B equals aid given to the higher group as 2:1.

Table 1.4: Poverty level and food expenditure as a percent of disposable income by income bracket.

Income (thousands USD, yearly)	**All brackets**	**<15**	**15 to 29**	**30 to 39**	**40 to 49**	**50 to 69**	**70 to 99**	**100 to 149**	**150 to 199**	**>200**
Size of consumer unit (people)	2.5	1.6	1.9	2.3	2.5	2.6	2.9	3.1	3.1	3.2
**165% poverty level ($/year)	30244.5	24037.2	26106.3	28865.1	30244.5	30934.2	33003.3	34382.7	34382.7	35072.4
**185% poverty level ($/year)	33910.5	26950.8	29270.7	32363.9	33910.5	34683.8	37003.7	38550.3	38550.3	39323.6
Annual food expenditure	7,203	3,768	4,437	5,221	6,028	6,739	8,436	10,351	13,550	16,054

($ total)										
Annual food expenditure ($/person)	2881.2	2355	2335.26	2270	2411.2	2591.92	2908.96	3339.03	4370.96	5016.87
Model 1 Ideal food expenditure ($) ***	7090.13	4537.68	5388.50	6522.92	7090.13	7373.73	8224.55	8791.76	8791.76	9075.36
Model 1 Food expenditure below ideal ($/person) ***	-45.15	481.05	500.78	566.05	424.85	244.12	-72.91	-502.98	-1534.92	-2180.83
Model 2 Ideal food expenditure ($) ***	2979.51	1928.11	2278.58	2754.29	2979.51	3104.76	3455.23	3680.45	3680.45	3780.44
Model 2 Food expenditure below ideal ($/person) ***	-1775.27	-1195.09	-1186.35	-1121.62	-1281.37	-1465.97	-1805.34	-2269.86	-3358.43	-4066.01

* All values are averages
** Calculated based on size of consumer unit
*** Calculated as food requirement using Model 1 or Model 2 - food expenditure

Part 3. Overall Model

The cost of feeding the food insecure of a certain region can be calculated as

$C = NC_1(P_A*F_A + P_B*F_B)$

C = Cost, C_1 = Cost of feeding one adult for a year, N = Number of food insecure individuals

P_A, P_B = Percentage of food insecure individuals in group A and group B respectively

F_A, F_B = Assistance given to individuals in group A and group B respectively (in percent of total need)

F_A/F_B = 2:1 (as determined in part 2c)

The percentages P_A and P_B that divide food secure individuals into two groups depend on the ratio of households of certain income levels in a given region. The 185% poverty line is used as a divisor between the two need groups in this model because it is the threshold value for WIC eligibility and data about the population is easily available.

The equations from Part 1 are used to to calculate W_{low} and W_{high}. These two estimates for food waste can be substituted for C to calculate F_A and F_B, or the amount of aid that can be supported by food waste.
To calculate the percentages F_A and F_B, substitute W for C and $2F_B$ for F_A in the equation:
$C = NC_1(P_A*F_A + P_B*F_B)$
To get the equation:
$W = NC_1(2F_BP_A + F_BP_B)$
Using our calculated values for food waste in Texas and the percentages split along the 185% poverty line:
W_{low} = \$2,575,299,344, W_{high} = \$3,944,166,523, P_A = 68.9 %, P_B = 31.0%
To correct for adult and child diets, we calculated that children under make up 22% of the population of households with an annual income less than \$70,000. We used this percentage to weight the estimated number of food insecure individuals in Texas to adult diets:
N = .22*4320050*.7984 + .78*4320050 = 4128251

Using both models and both estimates for food waste in Texas, we determined that a pessimistic estimate would provide for 13.03% of food need for those above the 185% poverty line but who could benefit from charitable response and 26.06% of food need for those below the 185% poverty line. An optimistic estimate would provide for 45.19% of food need for those above the 185% poverty line and 90.38% of food need for those below the 185% poverty line (Table 1.5).

Table 1.5: Value of F_B (percent aid given to higher income group)

Conditions	W_{low}	W_{high}
C_1 = 2836.05 (Model 1)	13.03%	19.96%
C_1 = 1252.461 (Model 2)	29.51%	45.19%

Strengths and Weaknesses:

1. Our Model 1 for food requirement per year is based only on one value for average cost of a meal. It does not account for various food groups and does not differentiate between the dietary needs of children and those of adults.
2. Our Model 2 calculates food expenditure based on market price only, and assumes that all food is bought at a market and cooked at home. In reality, families also eat out at restaurants and/or fast food establishments which sell meals at prices higher than the sum of their ingredients. Home-cooked food requires expenses to operate and clean cooking implements which were not included in the calculation.

3. The data used to calculate waste percentage did not indicate food waste caused by discarding food that is edible but unappealing in appearance, so this waste was grouped with waste of inedible food.
4. Our model provides multiple estimates to compensate for the uncertainty in each individual calculation.

Problem 2.

Restatement of the Problem:

With wide variability in regards to personal food consumption preferences, our job lies in differentiating the factors that influence food waste.

The questions tasks us with discerning:

- The amount of food waste a household generates on a yearly basis per the unit's traits and habits.
- Implement the model in regards to the following households:
  - Single parent with toddler, annual income $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

Analysis of the Problem:

The problem concerns the food consumptions choices made at the household level, requiring us to model the waste habits of individuals in regards to both income and family characteristics. There are a number of unknown variables that we will not be able to account in our problem, including economic fluctuations at both the nation and personal level. We can use mathematical modeling towards describing the relationship between a specific income bracket and familial characteristics, relying primarily on the specificities of the different types of food.

Developing the Model:

To begin work on the model, we first analyzed the disposable income of a household and its distribution among expenses, specifically food at home and the varying food types of which it is composed. Using the United States' Department of Labor's Bureau of Labor Statistics' Consumer Expenditure Survey, updated in August 2017, the mean percentage of disposable income spent on food data varies upon income bracket, as shown in Table 2.1:

Table 2.1: Mean percent of disposable income spent by income bracket

Income (thousands USD, yearly)	All brackets	<15	15 to 29	30 to 39	40 to 49	50 to 69	70 to 99	100 to 149	150 to 199	>200
Food	12.6	15.9	13.9	13	13.7	12.9	13	12.3	12.4	10.1
Food at home	7.1	10.4	9.1	7.6	8.3	7.5	7.3	6.6	6.1	4.5
Cereals/Bakery	0.9	1.3	1.2	1.0	1.2	1.0	0.9	0.8	0.8	0.6
Fats and Oils	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Fruits and Vegetables	1.4	1.8	1.7	1.4	1.6	1.4	1.4	1.3	1.2	0.9
Meat/Eggs	1.4	2.2	1.8	1.5	1.6	1.4	1.4	1.2	1.1	0.8
Fish and Seafood	0.2	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Dairy Products	0.7	1	0.9	0.8	0.9	0.8	0.7	0.7	0.7	0.4

We compiled the intersection of the last 6 rows and the last 10 columns into a 6 x 10 matrix M, where each row represents a type of food and each column represents an income bracket. The distribution of disposable income varies by type of food, which each has different weight percentage of food wasted. We used the consumer level, or the losses and waste of food at the household/consumer unit level because it adequately represents the average consumer unit's wasting habits. So, we created a 1 x 6 matrix N representing the weight percentage of food wasted at the consumer level. This data was retrieved from the Food and Agriculture Organization of the United Nations and can be found below in Table 2.2, and N represents the last row of data.

Table 2.2: Waste percentages of various food types

Cereals/Bakery	Fats and Oils	Fruits and Vegetables	Meat and Eggs	Fish and Seafood	Dairy Products
27.0	4.0	28.0	11.0	33.0	15.0

Now, we can simply model the total percentage of disposable income for a consumer unit as a 1 x 10 matrix NM, as shown in Table 2.3.

Table 2.3: Food waste at home by income bracket per household, in percent of disposable income

All	<15	15 to 29	30 to 39	40 to 49	50 to 69	70 to 99	100 to	150 to	>200

brackets							149	199	
0.97	1.39	1.24	1.02	1.16	1.01	0.97	0.89	0.85	0.63

This model only accounts for food at home, and it is based on the average consumer unit of 1.6-3.2 people (varying by income). Using the model we have currently, a 10-person upper-class family who almost exclusively eats out could produce the same amount of food waste as a single lower-class person who has very little to spend on food altogether. Realistically, this is far from the truth, and a more accurate model taking into account household size and food waste away from home is essential.

Firstly, we will consider out of home costs. For our model, we will assume that a restaurant, school, or other out-of-home food source uses the same makeup of food types as in-home food intake. So, we can use the percent of disposable income spent on food, subtract the percent spent on food at home, and apply the same process to calculate the percent wasted by income bracket. So, we added this to the percent wasted on food at home, as shown in Table 2.4.

Table 2.4: Food waste by income bracket per household, in percent of disposable income

All brackets	<15	15 to 29	30 to 39	40 to 49	50 to 69	70 to 99	100 to 149	150 to 199	>200
1.72	2.13	1.89	1.75	1.91	1.74	1.72	1.66	1.73	1.42

Now, we will take household size into effect. We will calculate the mean percent of income wasted per person, but there exists a disparity between children and adults. Since the average child under 18 years of age consumes a different amount of food than an adult, we will adjust our model accordingly. Using the USDA's Economic Research Service's Economic Information Bulletin 71, updated in February 2011, along with other USDA market reports (see appendix), we can calculate the average price for a serving of fruits, vegetables, dairy, grains, sugars, fats, and protein foods. These resources modeled a sample diet of 3 days, containing various foods of each types. So, in order to include the differences between the various prices of food, we found the average price per day of fruits, vegetables, dairy, grains, sugars, fats, and protein. Using this and the USDA's recommended amount of servings of different types of foods per day, we calculated the average price of a serving of each type of food, shown in Table 2.5.

Table 2.5: Average price (USD) of various types of foods per serving

Fruits	Vegetables	Dairy	Protein	Grains	Sugars	Fats
$0.3425/cup	$0.5740/cup	$0.1635/cup	$0.1677/oz	$0.0700/oz	$0.0057/tsp	$0.0037/g

Using these prices, along with the 2007-10 National Health and Nutrition Surveys, we can determine the average daily cost for food for both children and adults. This is shown in Table 2.6.

Table 2.6: Cost per day (USD) of various food types for children and adults

Type	Children	Adults
Fruits	.3699	.3596
Vegetables	.5281	.9127
Dairy	.3532	.2681
Meat	.7261	1.0280
Grains	.4522	.4529
Sugar, oil, and fat	.3100	.3200
Total	2.7395	3.4313

However, these costs are not absolute. As a family's income increases, so does the amount spent on food. So, instead of using absolute costs, we can represent a child as a portion of an adult in terms of food costs. So, a child spends about (2.7395 / 3.4313) or 79.84% of what an average adult would spend in one day. We can model the number of normalized adults, or proportion of food consumption in a household to that of an average adult, as

Equation 2.1: Number of normalized adults per household, as a function of people and children
$a = \mathrm{f}(p, c) = (p - c) + 0.7984c$,

where a is the number of adults, p is the number of total people, and c is the number of children per household. So, for the average household of 2.5 people and .6 children, we will consider it as having 2.37904 adults. Dividing the amount of food waste per household by the normalized number of adults in the household will yield the food waste per person, as a percent of disposable income of the household. Using average amounts of people and children in a household by income bracket, we achieved results shown in Table 2.7.

Table 2.7: Food waste by income bracket per adult per household, in percent of disposable income

All brackets	<15	15 to 29	30 to 39	40 to 49	50 to 69	70 to 99	100 to 149	150 to 199	>200
0.72	1.38	1.04	0.79	0.80	0.70	0.62	0.57	0.59	0.47

Using this model, it is very simple to calculate amount of food waste per year using a specific household if we have its income and number of people. For example, looking at the average household, with a disposable income of $64,175, 2.5 people, and .6 children, we first calculate the number of normalized adults within the household. Using Equation 2.1, this household in particular contains 2.37904 adults. Then, we multiply this number by the income, yielding $152,674.89. Finally, we multiply this number by the percent in Table 2.7 corresponding to the household's income bracket. In this case, the household falls under the 50 to 69 thousand USD bracket, for a percent of .70 and a ratio of .0070. Multiplying this by the previous $152,674.89 yields $1,068.72 spent on food waste per year for the average household. We can apply this model to any household, including the 4 examples presented in the problem:

Implementation:

1. Single parent with a toddler, annual income of $20,500
    a. The number of normalized adults for this household is 1.7984
    b. This household falls within the 15 to 29 thousand USD income bracket
        i. Its corresponding percent of food waste is 1.04% of income per person
    c. Food waste is (0.0104)*(1.7984)*(20500) = $383.42 USD per year
2. Family of four (two parents, two teenage children), annual income of $135,000
    a. The number of normalized adults for this household is 3.5968
    b. The household falls within the 100 to 149 thousand USD income bracket
        i. Its corresponding percent of food waste is 0.57% of income per person
    c. Food waste is (0.0057)*(3.5968)*(135000) = $2767.74 USD per year
3. Elderly couple, living on retirement, annual income of $55,000
    a. The number of normalized adults for this household is 2
    b. This household falls within the 50 to 69 thousand USD income bracket
        i. Its corresponding percent of food waste is 0.70% of income per person
    c. Food waste is (0.0070)*(2)*(55000) = $770.00 USD per year
4. Single 23-year-old, annual income of $45,000
    a. The number of normalized adults for this household is 1
    b. This household falls within the 40 to 49 thousand USD income bracket
        i. Its corresponding percent of food waste is 0.80% of income per person
    c. Food waste is (0.0080)*(1)*(45000) = $360.00 USD per year

Strengths/Weaknesses:

Strengths:

1. The model represents all income brackets individually, rather than generalizing, which would disregard the income of a household.
2. The model is easy to use and calculate for a specific household.
3. The model is based on accurate, government-provided data.

4. The model can be easily repurposed for any household, regardless of size or income.

Weaknesses:

1. The model falters slightly when considering extremes of the population, such as the extremely rich, elderly, and infants.
    a. The richest income bracket, 200 thousand USD a year and more, has a standard error in income of $20,626.50 and a coefficient of variation of 5.98%, more than 4 times that of any other bracket. Due to the high disparity within this bracket, a more accurate model would require smaller income brackets (such as 200 to 250 thousand, 250 to 300 thousand, etc.) to reduce variation.
    b. The daily food intake of infants and elderly are highly varied as well due to certain medical conditions and abnormal metabolism.

Problem 3.

Restatement of the Problem:

The repurposing of potentially wasted food in the surrounding community is a crucial area for us to target in conserving resources

Our job is to:

- Find a community and use mathematical modeling to provide potential strategies diminishing food waste
- Find which strategies repurpose the maximal amount of food at the lowest cost

Analysis of the Problem:

In an order to influence the Illinois community, the practices at the food production and agricultural level, alongside its intersection with the Supermarket industry in the surrounding community, need to be analyzed. Factors that we can use mathematical modeling to provide insight towards, are the strategies employed between supermarkets and factories in processing, and the end distribution of the food that is often turned to waste. We can then quantify the costs and benefits associated with the novel strategies that limit food waste, and which involve altering practices at the grocery-store level.

Developing the Model:

The first part of our process concerns computing the waste percentages of several commodities in Illinois farms based upon the North American Food Loss Data (Texas Food Data). As the waste percentage measures the food products disregarded for their physical lackluster, these products can still be viable and offered in store. Modern grocery stores often discard items and produce that appear misshapen and unattractive, and offering produce as such would provide an opportunity to purchase lower costing items, compelling the consumer to purchase the food. We compiled the waste percentages alongside annual food type totals, to calculate the value of the waste lost to physical unattractiveness, as follows.

Table 3.1: Values, Percentages, and Commodities purchased from Illinois Farms.

Food Type	Waste Percentage	Total bought from farms in Illinois ($1000s)	Value of Waste ($1000s)
Cereals	13.564%	$144,836	$19,645.5550
Roots and Tubers	38.8%	$24,621	$9,552.948
Oilseeds and Pulses	16.4%	$598,095	$98,087.58
Fruits and Vegetables	24.73%	$7,512,603	$1,857,866.722
Meat	9.3%	$1,854,460	$172,464.78
Milk	5.14%	$313,906	$16,134.7684
Total	N/A	N/A	$2,173,752.348

With the value of waste amounting to $2,173,752,348 lost in the totality of Illinois, there is an ability to redistribute the 'ugly' foods amongst the supermarkets in Illinois. The food will be redistributed to the 907 grocery stores in Illinois with the value calculated below:

Tc = $2,173,752,348/907

Tc = $2,396,640

Tc = Cost allocated to the Supermarkets annually

From the determined costs, the grocery stores will be provided the $2,396,640 value of 'ugly' food on yearly basis, at a reduced value in stores. This measure will encourage the food consumers to purchase foods that would otherwise be thrown out at no cost on the side of the production, handling, and packaging (as this food would be otherwise thrown out), and at no cost for the grocery stores over the course of a year. The grocery stores will able to sell the items for consumers at the reduced rate to minimize food waste. Minimal costs will incur from transportation, as this is a factor that varies with both amount and company utilized, and therefore we will only concern ourselves with the costs from the food itself.

Next, the unsold food can go to nearby homeless shelters or food pantries that have a deficiency in fresh products. There may be some scraps left over which can then be used for compost which can be sold or returned to the farms that produced the products. Composting itself incurs minimal costs that are negligible in our overall model. This plan maximizes reduction of food waste and minimizes the cost. In fact, this plan could even profit all aspects of the businesses involved.

The food groups with the highest waste percentage in the United States for supermarket retail and consumption are: fish and seafood (39%), fruits and vegetables (36.6%), and roots and tubers (34.9%). These food groups are all good for composting which can reduce the amount of food scraps that end up in landfills. Then, farmers in the Kane County area can use the compost produced instead of using fertilizer. Illinois has recently passed two acts (Public Act 98-0239 and Public Act 98-0146). Public Act 98-0239 allowed farmers to bring off site material to compost; this act created more places for people to bring their compost.

Since composting takes up space, this act encouraged more people to compost since it gave people a place to put their compost. Public Act 98-0146 allowed two sites to collect food scraps to demonstrate that the implementation of general composting services is feasible. Since this act was expanded on in 2015, it shows that composting is a feasible service that can be implemented in Illinois. However, composting requires large amounts of space and creates bad odors. The odors can be reduced if local trash collection services collect the compost and store it in their facility. While landfill waste cannot be sold, compost can, provide an incentive to the trash collection services to collect compost from their customers.

Justification and Discussion of the Model:

The model was used as a means to interpret the value of food wasted at the production level, and by what means it could be redistributed into the hands of the consumer. By delineating these costs and outlining a clear strategy our model was able to tackle the problem with a novel perspective.

This model could be improved in regards to the accuracy of the data on the amount of food that is thrown out specifically for its “unappealing” appearance. More specific data will allow us to more accurately estimate the amount of money that could be saved by using our plan to reduce food waste.

The model is additionally sensitive towards the amount of product sold from farms in Illinois, which vary yearly depending on what crops were used in crop rotation, the weather conditions, and length of growing seasons.

The waste percentages can also fluctuate yearly depending on the types of machinery used in different factories. With a more precise percentage of waste based upon food rejected for physical unappeal, we would be better suited to model the redistribution of these foods to the grocery stores.

We did not consider the price of transportation since it can change depending on the company, amount needed to transport, and distance between the stores and the factories, however this could be a significant factor in the exchange of these goods.

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