A Model on the Opportunity-Cost of Reducing Food Waste to MathWorks Math Modelling Challenge 2018

Team 11122

Mathworks Modeling Challenge

1. Executive Summary

A critical concern for our global community is the exponential growth of the population, which threatens to stretch current foods supplies thinner and thinner. According to the United Nations there needs to be a 59% to 98% increase in food production by 2050[1] to keep pace with the growing population. However, another model presented by the Food and Agriculture Organization of the United Nations (FAO) showed that about ⅓ of the food is wasted, from production processes to consumption. Furthermore, according to the Environmental Protection Agency (EPA), in the United States alone there are 42 million Americans, including 13 million children, that are considered food insecure[2], where food insecurity is defined as the lack of consistent access to enough food for a healthy and active lifestyle. As a result of this growing issue, we have been assigned the task of create a model by which citizens can better understand the effects of their food wastage and to suggest methods by which governments can begin to circumvent this wastage.

In the first section, we created a method by which states could compare their food requirements, with their most recent annual food production. Measured in Calories, these values are calculated by with data given as well as data provided by the state of Texas. We can then consider whether the food wasted could feed the citizens of Texas who are food insecure and then determine whether it is feasible to transport food from counties with an excess to counties with a shortage of food.

Next, we created a program capable of estimating annual household waste using demographics collected from family members. Utilizing data provided by the National Institutes of Health, we calculate a coefficient for how much food a given individual likely wastes. Then we multiple that against an estimate for their required caloric intake given by the Harris-Benedict approximation. Taking the summation of these values across all family members gave an estimate well within reason for total household waste.

Finally, we implemented the model derived from Part 1 to show how Southern California can optimize its food to cost ratio, as well as how the food waste can be reduced. The main strategies that we compared in the consideration of reducing food waste were 1) The allocation of food wasted in household consumption towards feeding livestock 2) The distribution of waste food in production 3) The redistribution of unsold waste in retail. The maximal amount of food reduced was found to be through the redistribution of waste in the production of food.

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[1] Elferink, Maarten, and Florian Schierhorn.

[2] "What Is Food Insecurity in America?"

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2. Part 1: Just Eat It

2.1 Problem Statement

- Create a mathematical model that a state could use to determine whether the state could feed its food insecure population through the distribution of waste food. The model will use wasted food data generated in that state.
- To show the accuracy of the model, demonstrate how the model would work for the state of Texas.

2.2 *Interpretation of Problem*

We took the problem as a simple comparison between two values: the amount of wasted food and the amount of food required by food insecure individuals. Based on the difference between these two values we can determine whether a given region has the resources to reallocate it's food and feed everyone.

2.3 Assumptions

1) Due to the generalized definitions of "food insecurity" and the state of being "food secure", we will only be considering Calories as feeding the food insecure population, not necessarily ensuring that each individual will consume adequate amounts of each food type.
2) We will also be considering all Calories as equal without regard to the nutritional content of each type of food. This assumption is reasonable because of the massive amount of food wasted resulting in greater dietary variety the dietary, and necessary because of the vast variety of foods produced and consumed in a state like Texas.
3) All food is being transported by trucks, with no usage of aquatic, rail, or air delivery. All food is approximated to have the same cost per mile per Calorie for transport despite different caloric and actual densities. Thus, the same funds are expended to transport a Calorie of milk as to transport a Calorie of corn.
4) We are assuming that when food is being transported by trucks for the distribution of food from counties with excess to counties with a shortage of waste food, the effort is being made to acquire food for all of its insecure citizens. Furthermore, we will assume that no food spoils during transportation due to sufficient refrigeration.
5) In the computation of the average caloric requirements of the food-insecure, it was assumed that their demographics for age, gender, and activity match the demographics for the country as a whole. Similarly, it was assumed that the food-insecure are sedentary like most Americans.
6) For the sake of simplicity, we assume that all resources in a county - including retail stores, farms, and household - lie at its geometric center. While not perfectly representative, this allows us to treat each county as an individual node in a web and to estimate distances between resources, vastly reducing the number of nodes required to model any state.
7) All transport travel distances are approximated to be the distance from the center of the origin county to the center of the destination.
8) We considered Texas as an isolated system independent of the imports and exports of waste food.
9) We assume that all retail and production waste can be recovered without consequence, and that the recovered food

can be distributed within the county, both at no cost.

2.4 Design of the Model

We begin by separating each state into counties as the smallest division land. All food production and population food insecurity will be considered in a county basis. In determining the whether the wasted food could have been used to feed the food insecure population, Calories will be used as the main unit in consideration. First, we will be calculating the Calories needed per country from those within the county population that are considered food insecure, where the subscript *i* denotes a county:

$$N_i = c_n p_i$$

where c_n is the Calories needed per person, p_i is the number of people in the county that are food insecure and N_i is the total number of Calories needed in county *i*. The variable p_i will be determined based on county statistics, while c_n is a constant of 1857 Calories, which is determined by multiplying the average caloric needs of a sedentary individual of a particular age and gender and multiplying it by the decimal representation of the percentage of individuals of the US population that fit the given criteria. This is done for all ages and genders and the sum is computed.

Next, the Calories wasted per county is calculated, given county *i* and food type *f*:

$$W_i = \sum[c_f(w_f T_f + R_f r_f)],\ \ \forall f$$

where c_f is the Calorie density, w_f is the percentage of food lost for food type *f*, and T_f is the total production of the food type. This number is then subtracted by the retail loss, which is represented by R_f and r_f as the total retail amount of the food type and the percentage wasted, respectfully. By taking the sum of all of the food types, the amount of Calories wasted can be determined, signified by W_i.

It can be determined whether a county is able to feed its food insecure citizens by simply subtracting W_i from N_i:

$$C_i = W_i - N_i$$

If C_i is greater than or equal to 0, then it is possible to feed the food insecure population within the county. To determine whether the entire state can feed its food insecure population, the following test is used, where each county's C_i value is aggregated:

$$\sum C_i \geq 0,\ \ \forall i$$

When this condition is true, it is possible to feed all the food insecure people in a given state.

Now that it can be determined whether it is possible for a state to feed its food insecure population, we must consider if each county is able to feed its food insecure citizens. Even if the aggregate of C_i is a positive number, it does not correlate to each county's C_i is positive. Thus, to feed a whole state's food insecure citizens, the counties with positive C_i will need to transport food to counties with negative C_i. This will be optimized with the equation:

$$z = a \sum D_j F_{jf} \frac{M_f}{M_{truck}},\ \ \forall f$$

where *a* is the cost of shipping per mass, D_j is the optimum distance to travel to county *j*, F_{jf} is the food shipped to county *j* of food type *f*, and M_f/M_{truck} is the mass ratio of food type *f* and the truck. Our goal is to optimize *z*. This will be done with Python coding.

Furthermore, we will get the distances between every two counties of the given state with Java coding, and with the results of C_i for each county, we can determine how the counties in deficit of food can best get food from counties with a surplus of food. This is done by first finding a county with a shortage of food, and then finding all possible permutations of ways a county with a surplus will deliver the food. By analyzing the given permutations, the optimized solution to feed all of a state's food insecure population. This solution is also obtained with Python coding.

2.5 Application

When applying this model to the state of Texas, we must account for 254 counties. Each county will have its own value of N_i, W_i, and C_i based on the production and waste in the specified county. The production is separated into different food types, which was determined from the United States Department of Agriculture's National Agricultural Statistics Service[3]. The food types, mentioned above as subscript *f*, are as listed: cattle, wheat, milk cows, corn, sorghum, oats, rice, soybean, sunflower oil, sugar cane, peanuts, sunflower non-oil. For example, when looking at the county of Anderson, TX, the number of Calories needed in Anderson is shown below:

$$N_{Anderson} = (1857)(11710) = 21,745,470\ Calories$$

To calculate $W_{Anderson}$, the data for each food is needed. According to the US Department of Agriculture, Anderson mainly produces cattle, with 37,500 heads of cattle. Thus, $W_{Anderson}$ will only consider waste of cattle. The caloric value for all food products can be found in the table that follows.

Name	Unit (u)	Conversion Factor (Cal/(u*day))	Category	Weight/u (lb/u*day)
Cattle	Head	974[4]	meat	1,390[5]
Wheat	Bushels	179[6]	cereals	60
Milk Cows	head	13824	dairy	6
Corn	Bushels	268[7]	cereals	48
Sorghum	Bushels	236[8]	cereals	50
Oats	Bushels	155[9]	cereals	32
Rice	Cwt	138[10]	cereals	100
Soybeans	Bushels	333[11]	cereals	60
Sunflower Oil	pounds	10.9[12]	Oilseed and Pulse	1
Sugarcane	tons	648	Fruit and vegetable	2000
peanuts	pounds	7.05	Oilseed and pulse	1

A python program was written and used to determine the food lost during production and during retail. For Anderson, the production and retail losses are as shown:

$$Production\ Loss_{\ Cattle} = 36525590.3226\ \ Cal$$

$$Retail\ Loss_{\ Cattle} = 590.3226\ Cal$$

From this information, the amount of food wasted in Anderson can be determined:

$$W_{Anderson} = 3,470,465\ Calories$$

Thus, the value of $C_{Anderson}$ is determined as:

$$C_{Anderson} = W_{Anderson} - N_{Anderson} = -18,275,005\ \ Cal$$

From this analysis of Anderson, we can see that this country is at a deficit, and cannot produce enough Calories to ensure that its population can be food secure.

When looking at the entire state of Texas, that is, the aggregate of all of the C_i of the counties, $\sum C_i$ turns out to be a positive number, or more specifically:

$$\sum C_i = 7057879240\ Calories$$

[3] "USDA's National Agricultural Statistics Service Texas Field Office."
[4] Oklahoma Department of Agriculture
[5] "The Relationship Between Cow Size & Production"
[6] Traditional Oven

[7, 8, 9, 10, 11] Fat Secret - Food Database
[12] Nutrionix - Foot Database

This shows that the state of Texas is able to support its entire population as a whole, even though some counties, as shown with Anderson, cannot support its population to be food secure.

As a solution to the problem of the deficits in some counties and surpluses in others, we have developed a system of trucks to bring food from counties with surplus to counties with deficit. To do so, we first calculated the distances from each county to every other county in Texas. For example, to travel from Anderson to several selected counties in Texas, we used the results from a Java program we created. This program takes a list of each county and its center of area of its longitude and latitude. An example of outputs from Anderson to other counties is shown below, with units in meters:

Anderson County --> Andrews County : 659473
Anderson County --> Angelina County : 119191
Anderson County --> Aransas County : 434438
Anderson County --> Archer County : 345013
Anderson County --> Armstrong County : 632315
Anderson County --> Atascosa County : 428441
Anderson County --> Austin County : 224402

This algorithm first divides counties into 2 mutually exclusive categories: excess counties and deficit countries. Deficit counties, even after saving all the food wasted at the production and retail stages, need extra food to feed their insecure population. Excess counties have extra food even after feeding their population. Then the algorithm ships food from the excess counties to the deficit counties, starting at the county with the largest deficit. We would then calculate the cost of shipping all of the food to that county which depends distance the food needs to travel and amount of food. In other words we are using a greedy algorithm. While this greedy algorithm will not give the optimum solution, it will give a near optimum solution and therefore is a viable method of testing the feasibility of our solution.

2.6 Analysis

3. Part 2: Food Foolish?

3.1 Problem Statement

Our task for this problem is as stated:

- Create a mathematical model that can be used to demonstrate annual food waste for a household, taking into consideration habits and traits.
- Show the results of the model for:
    - Single parent with a toddler, with an annual income of $20,500
    - Family of four (two parents, two teenage children), with an annual income of $135,000
    - Elderly couple, living on retirement, with an annual income of $55,000
    - Single 23-year-old, with an annual income of $45,000

3.2 Interpretation of Problem

We considered the food waste based on the consideration of different social and physical distinctions, such as height and income. From there, we generalized an average Calorie intake as well as the estimated percent chance an individual would waste food based on the individual's demographics.

3.3 Assumptions

1) First, when calculating the number of Calories wasted per year, we are using the National Institutes of Health's self reported data. Although this data is self reported, we are assuming that it is an accurate representation of the American population.
2) We will also be assuming that each food demographic, which is used to calculate

the total daily Calorie intake, will be weighted equally. That is, grains will not be weighted more or less than proteins.

3) When required, we assumed demographic data about each of the test cases based on averages for the information given. For example, in case 3 we used the average age of retirees when calculating the caloric requirement for the couple.
4) We are also assuming that individuals consume only the amount of calories they need as predicted by the Harris-Benedict's formula , with no excess.

3.4 Design of Model

As we are creating a mathematical model for the annual household waste of food, we will also calculate the percentage lost, to emphasize the amount a household wastes, annually. First, we will be calculating the annual Calorie consumption for a household. The annual Calorie intake per household is modeled below:

$$C_t = \sum 365 c_p, \ \ \forall p$$

where, p represents each member of a household, c_p is the daily Calorie intake, which is determined Harris-Benedict's formula[8]:

$$c_{p\,(♀)} = [655 + 4.35w + 4.7h - 4.7a]c$$
$$c_{p\,(♂)} = [65 + 6.23w + 12.7h - 6.8a]c$$

where w is the individual's weight in pounds, h is the individual's height in inches, a is the individual's age in years, and c is the activity factor, which is defined in the table below:

Amount of Physical Activity		**Factor (c)**
Sedentary (little or no exercise)		1.2
Lightly active (light exercise/sports 1-3 days/week)		1.375
Moderately active (moderate exercise/sports 3-5 days/week)		1.55
Very active (hard exercise/sports 6-7 days a week)		1.725
Extra active (very hard exercise/sports & physical job or 2x training)		1.9

[8] "Harris Benedict Equation For Men."

Finally, it is important to note that c_p varies from males to females, which is denoted by the male and female symbols, ♀ and ♂, respectively.

Now that the total consumed Calories each year are known, the total wasted Calories per year will now be determined. We will be considering three different factors: household income quintile, age, and gender. The data for factoring in the above three components was determined empirically by the National Institutes of Health, and are shown in the table below[9]:

Component		**Factor**
Household Income Quintile (q)		
Q1: <$29,000		.129
Q2: $30,000 to $59,999		0.126
Q3: $60,000 to $84,999		0.125
Q4: $85,000 to $124,999		0.077
Q5: $125,000<		0.0506

[9] Neff, Roni A., Marie L. Spiker, and Patricia L. Truant.

Age (a)		
0-18		0.144
18-64		0.132
65<		0.108
Gender (g)		
Female		0.134
Male		0.121

By taking the average of these four components, the percent of food wasted, w_p, can be found, that is:

$$w_p = \frac{q+a+g}{3}$$

The amount of Calories wasted per year, W_t can then be calculated as follows:

$$W_t = \sum 365 c_p w_p, \ \forall p$$

where w_p is calculated for each person in the household and c_p is calculated as shown above.

Finally, the percentage of Calories lost to waste per year is found by dividing W_t by C_t:

$$\%\ lost = \frac{W_t}{C_t}$$

3.5 Application

To demonstrate this model, we will be showing the annual food waste for four different household scenarios. To reduce redundancy, the calculations will only be demonstrated for the first household scenario, while the other three will only have the data recorded on tables.

Household 1 is defined as a single parent with a toddler, with an annual income of $20,500. In this case, the parent's daily Calorie intake can be calculated as shown below, under the assumption that the parent is a male, age 23, 177.8 lbs, 69.4 in, and lightly active:

$c_{p\ (parent)} = [65 + 6.23(177.8) + 12.7(69.4) - 6.8(23)]1.375$

$c_{p\ (parent)} = 2609\ Calories$

$w_{p\ (parent)} = \frac{0.129+0.132+0.121}{3} = 0.1273$

The toddler will be assumed to be a 2 year old male, 30.8 lbs, 36.4 in, and also lightly active:

$c_{p\ (toddler)} = [65 + 6.23(30.8) + 12.7(36.4) - 6.8(3)]1.375$

$c_{p\ (toddler)} = 960\ Calories$

$w_{p\ (toddler)} = \frac{0.129+0.144+0.121}{3} = 0.1313$

Since there are only two members of this household, the total number of Calories needed for this household per year is:

$C_t = 365(c_{p\ (parent)} + c_{p(toddler)}) = 1.303 \times 10^6 Calories$

and the amount wasted per year is:

$W_t = 365(c_p\, w_{p\ (parent)} + c_p w_{p\ (toddler)}) = 1.672 \times 10^5\ Calories$

Thus, this household wastes around 12.8% of the food.

The rest of the examples are shown in the table below. All individuals will be assumed to be lightly active, and their age and gender will also be assumed. From the age and gender, the data for height and weight will be obtained from the United States Department of Health and Human Services[10].

Household 2	**Variable**	**Value**
Adult 1 (M, age 47)	c_p	2608 Cal
	w_p	0.101
Adult 2 (F, age 47)	c_p	1888 Cal
	w_p	0.106
Teenager 1(M, age 16)	c_p	2128 Cal
	w_p	0.105
Teenager 2 (F, age 16)	c_p	1798 Cal
	w_p	0.110
$C_t = 3.07 \times 10^6\ Cal$		

[10] "Anthropometric Reference Data for Children and Adults: United States, 2011–2014."

$W_t = 3.23 \times 10^5\ Cal$

Household 3	Variabl e	Value
Adult 1 (F, age 65)	c_p	1807 Cal
	w_p	0.118
Adult 2 (M, age 65)	c_p	2234 Cal
	w_p	0.123
$C_t = 1.47 \times 10^6 Cal$		
$W_t = 1.78 \times 10^5\ Cal$		

Household 4	Variabl e	Value
Adult 1 (F, age 23)	c_p	1986 Cal
	w_p	0.131
$C_t = 7.25 \times 10^5 Cal$		
$W_t = 9.50 \times 10^4 Cal$		

3.6 Analysis

Our model uses the Harris-Benedict formula to determine the daily Calorie intake per person. This model predicts dietary requirement using their height, weight, age, gender, and exercise levels. It's important to note that not each of these factors are given equal weight. For example, exercise level is rated between 1.2 and 1.95. If we vary this for the adult of household the ideal needs of a person and expects that these people will only eat what they need. Given that 36.5% of American adults are obese[11], it is obvious that or model will underestimate the calories consumed by each household, risking underestimation of household waste as well. This was a necessary assumption in the absence of clear information on the overeating habits of Americans.

However, our model would still preserve the percent of food wasted despite underestimations of the food entering the home. For the four example households, our model predicted that 12.8%, 10.5%, 12.1%, and 13.1% of calories would be wasted respectively. Unfortunately, external sources differ greatly on predicted waste in the average home. Some estimate that waste by cost is as low as 9.2%[12] while others estimate that nearly 25% of food is wasted by American consumers[13]. While it is difficult to access which of these is truly representative, it is promising that our model produces results in between both estimates. Similarly promising results are produced by the USDA estimate of total food waste being between 30% and 40%[14], with our prediction representing a healthy portion of that.

4. Part 3: Hunger Game Plan?

4.1 Problem Statement

Our task for this problem is as stated:

- Create a mathematical model that can be used to provide insight and determine strategies that repurposes waste food at the minimum cost in the chosen community, which is determined to be Southern California.

[11] "Adult Obesity Facts." *Centers for Disease Control and Prevention,* 29 Aug. 2017, www.cdc.gov/obesity/data/adult.html.

[12] Buzby JC, Wells HF, Hyman J. The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the united states. Economic Information Bulletin, United States Department of Agriculture, ii-33. 2014.

[13] Jp. "How Much Food Does the Average American Waste?" *U.S. News & World Report,* U.S. News & World Report, 2 Apr. 2013, money.usnews.com/money/blogs/my-money/2013/04/02/how-much-food-does-the-average-american-waste.

[14] "U.S. Food Waste Challenge." *USDA Office of the Chief Executive,* www.usda.gov/oce/foodwaste/faqs .htm.

- This mathematical model will quantify the costs and benefits associated with our strategies.

4.2 Interpretation of Problem

We took this problem as an extension of part 1, applied to our local region. Just as in part 1, we determine whether an area can feed everyone by subtracting surplus from demand.

In addition, we also intend to provide a possible path by which counties can exchange food to achieve full consumption. This model will come with the associated cost.

4.3 Assumptions

1) Assumptions (1) - (7) and (9) from Section 2.2 remain valid and unchanged.
2) Assumption (8) from Section 2.2 is modified to reflect that we are only Southern California is being accounted for in terms of the waste food exchange.

4.4 Design of Model

The main strategies that we decided to compare in potential strategies that would reduce food waste were:

1) Using food waste in consumption to feed animals, which would indirectly give us a surplus to feed the food insecure population
2) Through the use of discarded food and waste from production, along with rejected shipments
3) The amount of food wasted in unsold and excess food through retail departments

Transportation constraints were often the most cited barrier to donating with 41% of respondents identifying it as a barrier to donation. Because of this, by redistributing food to ones in need, we are able to manipulate the aggregate in order to decrease food waste. For example, California could use food waste from consumption as animal feed, which isn't necessarily fit for redistribution towards human consumption. By doing so, the extra feed in the form of grain and other surpluses could be distributed to the food insecure population.

Furthermore, retailers typically have many locations with multiple food related departments, each of which can have different processes or requirements for how food waste is handled or diverted. Finally, due to customer demands around variety, consistency, and freshness, retail can generate high volumes of food waste that is safe and edible but was simply overstocked, no longer meets appearance standards, or has damaged packaging.

We use a virtually unchanged version of the model provided in Section 2.4, changing values such as the amount of Calories produced per day of each category of food, and the amount of each food type that enters retail centers.

4.5 Analysis

From this model, it is determined that Southern California is not able to ensure its entire population is food secure, thus, it is impossible to find a method of distributing food from counties with excess food to those with a shortage. This is primary due to the high population of Southern California and the low amount of productions in each county. The maximal amount of food reduced was therefore found to be through the redistribution of waste in the production of food.

County	Total Wasted Food (Cal/day)	Retail Wasted (Cal/day)
Imperial	549176711.787	2192.6268

Los Angeles	1609667.3272	169000.9272
Orange	1267107.2596	52454.3796
Riverside	64513688.6044	38623.9644
San Bernardino	65478072.6524	35250.6924
San Diego	4930836.7874	54225.3474
Santa Barbara	16822909.9866	7336.8666
Ventura	8555492.7706	14083.4106

5. Conclusion

Based on the models and data from each part, we have completed an analysis on food waste for a large population, as shown with the state of Texas, food waste in a household, as shown in Section 3, and in a medium sized land area, as shown in the analysis of the waste in Southern California. While smaller groups of population may have surpluses and shortages, as shown in the individual counties of Texas, but with the whole consideration of Texas, there is no shortage. By considering the individual household waste, we can see that it is possible to find a distribution based on income for different locations. Finally, by taking Southern California, half of a state, rather than the entire state of Texas, we can see that Southern California is not self sufficient to make all of its population food secure.

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7. Appendix

Distances Between SoCal Counties
Texas Waste
Food Production by County Texas
Population Insecurity by County Texas
Waste Values by County Texas
TX_insert_food_production.py
TX_insert_distances.py
TX_csv-to_pop_insecure.py
TX_calculate_share_totaly.py
DistanceCalculator.java
City.java
CA_insert_food_production.py

Distances between SoCal Counties

```
Imperial County --> Los Angeles County
: 298212.51828646497
Imperial County --> Orange County :
235737.1446309844
Imperial County --> Riverside County :
97347.51640010858
Imperial County --> San Bernardino
County : 215858.48066788595
Imperial County --> San Diego County :
132454.68659941922
Imperial County --> Santa Barbara
County : 463723.8929849304
Imperial County --> Ventura County :
378924.1867082707
Los Angeles County --> Orange County :
73154.17909776392
Los Angeles County --> Riverside
County : 214748.637228223
Los Angeles County --> San Bernardino
County : 204275.4746515746
Los Angeles County --> San Diego
County : 189565.90533144624
Los Angeles County --> Santa Barbara
County : 167539.40445144553
Los Angeles County --> Ventura County
: 82065.15257899195
Orange County --> Riverside County :
164303.67525694246
Orange County --> San Bernardino
County : 196898.7157415039
Orange County --> San Diego County :
117913.29000512954
Orange County --> Santa Barbara County
: 229285.6124761052
Orange County --> Ventura County :
146239.1572726563
Riverside County --> San Bernardino
County : 126433.57734081362
Riverside County --> San Diego County
: 106443.74190442488
Riverside County --> Santa Barbara
County : 382287.34098168253
Riverside County --> Ventura County :
296812.3818635664
San Bernardino County --> San Diego
County : 211144.3853315201
San Bernardino County --> Santa
Barbara County : 354543.8935230684
San Bernardino County --> Ventura
County : 275777.44972686615
San Diego County --> Santa Barbara
County : 345392.3786939942
San Diego County --> Ventura County :
263794.204541154
Santa Barbara County --> Ventura
County : 85483.5349736263
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Texas Waste

County	Production Waste	Retail Waste
Anderson	36525590.3226	590.3226
Andrews	6331168.6636	168.6636
Angelina	10422727.6498	927.6498
Aransas	1656052.9954	252.9954
Archer	212605884.332	84.3318
Armstrong	436596900.0	0.0
Atascosa	2578105.9908	505.9908
Austin	60779452.9954	252.9954
Bailey	581012800.0	0.0
Bandera	5551968.6636	168.6636
Bastrop	34090843.318	843.318
Baylor	172867000.0	0.0
Bee	717631137.327	337.3272
Bell	2275941626.27	3626.2674
Bexar	299163008.296	20408.2956
Blanco	9447884.3318	84.3318
Borden	4480400.0	0.0
Bosque	39456168.6636	168.6636
Bowie	1011.9816	1011.9816
Brazoria	293079710.599	3710.5992
Brazos	27274276.9586	2276.9586
Brewster	10908884.3318	84.3318
Briscoe	172147400.0	0.0
Brooks	11395800.0	0.0
Brown	81632921.659	421.659
Burleson	494116168.664	168.6636
Burnet	15584421.659	421.659
Caldwell	281796421.659	421.659
Calhoun	992977568.664	168.6636
Callahan	36710084.3318	84.3318
Cameron	316876638.249	4638.249
Camp	9545284.3318	84.3318
Carson	1735426000.0	0.0
Cass	12272737.3272	337.3272
Castro	5494541684.33	84.3318
Chambers	123702937.327	337.3272
Cherokee	46296305.9908	505.9908
Childress	7402400.0	0.0
Clay	129571484.332	84.3318
Cochran	1181836300.0	0.0
Coke	16305000.0	0.0
Coleman	304228884.332	84.3318
Collin	802699313.825	9613.8252
Collingsworth	11980200.0	0.0
Colorado	307664168.664	168.6636
Comal	703980264.977	1264.977
Comanche	362457084.332	84.3318
Concho	220638800.0	0.0
Cooke	192829421.659	421.659
Coryell	106431043.318	843.318
Cottle	10324400.0	0.0
Crane	2045400.0	0.0
Crockett	9545200.0	0.0
Crosby	16455000.0	0.0
Culberson	9155600.0	0.0
Dallam	6061293400.0	0.0
Dallas	5287345.1622	27745.1622
Dawson	59636084.3318	84.3318
Deaf Smith	3723141768.66	168.6636
Delta	9253000.0	0.0
Denton	260773980.185	8180.1846
DeWitt	53570168.6636	168.6636
Dickens	22751800.0	0.0
Dimmit	84.3318	84.3318
Donley	28682500.0	0.0
Duval	22889084.3318	84.3318
Eastland	27759168.6636	168.6636
Ector	2241802.3042	1602.3042
Edwards	7499800.0	0.0
Ellis	1837622686.64	1686.636
El Paso	9276.498	9276.498
Erath	628522421.659	421.659
Falls	2134240168.66	168.6636
Fannin	1149131337.33	337.3272
Fayette	263100252.995	252.9954
Fisher	9934800.0	0.0
Floyd	915233000.0	0.0
Foard	8181600.0	0.0
Fort Bend	1024481336.87	7336.8666
Franklin	65796484.3318	84.3318
Freestone	40908168.6636	168.6636
Frio	425145568.664	168.6636

Gaines	1102999968.66	168.6636
Galveston	6821373.272	3373.272
Garza	4675200.0	0.0
Gillespie	6366952.9954	252.9954
Glasscock	28819000.0	0.0
Goliad	0.0	0.0
Gonzales	205788168.664	168.6636
Gray	565232252.995	252.9954
Grayson	906497349.309	1349.3088
Gregg	1349.3088	1349.3088
Grimes	40421252.9954	252.9954
Guadalupe	739613602.304	1602.3042
Hale	2076793937.33	337.3272
Hall	23330800.0	0.0
Hamilton	174994284.332	84.3318
Hansford	3212623600.0	0.0
Hardeman	117961000.0	0.0
Hardin	5357590.3226	590.3226
Harris	24398659.4486	48659.4486
Harrison	16753474.6544	674.6544
Hartley	485600000.0	0.0
Haskell	260642600.0	0.0
Hays	173782739.631	1939.6314
Hemphill	19869000.0	0.0
Henderson	52721643.318	843.318
Hidalgo	2356176907.83	9107.8344
Hill	2762413537.33	337.3272
Hockley	932818452.995	252.9954
Hood	13052190.3226	590.3226
Hopkins	386995337.327	337.3272
Houston	45778252.9954	252.9954
Howard	6720937.3272	337.3272
Hudspeth	0.0	0.0
Hunt	493700927.65	927.6498
Hutchinson	808177368.664	168.6636
Irion	5649200.0	0.0
Jack	22505184.3318	84.3318
Jackson	2484396084.33	84.3318
Jasper	8084537.3272	337.3272
Jeff Davis	9545200.0	0.0
Jefferson	173919782.949	2782.9494
Jim Hogg	16655400.0	0.0
Jim Wells	421.659	421.659
Johnson	168818686.636	1686.636
Jones	245250468.664	168.6636
Karnes	240842084.332	84.3318
Kaufman	83251180.6452	1180.6452
Kendall	337.3272	337.3272
Kenedy	20941000.0	0.0
Kent	17069500.0	0.0
Kerr	6331505.9908	505.9908
Kimble	6720600.0	0.0
King	3993400.0	0.0
Kinney	0.0	0.0
Kleberg	142576337.327	337.3272
Knox	355668000.0	0.0
Lamar	937677305.991	505.9908
Lamb	2938252084.33	84.3318
Lampasas	6265168.6636	168.6636
La Salle	12467200.0	0.0
Lavaca	126192168.664	168.6636
Lee	36038168.6636	168.6636
Leon	50648168.6636	168.6636
Liberty	92852843.318	843.318
Limestone	374006252.995	252.9954
Lipscomb	121087200.0	0.0
Live Oak	23376084.3318	84.3318
Llano	19967168.6636	168.6636
Loving	1363600.0	0.0
Lubbock	303880204.608	3204.6084
Lynn	194633000.0	0.0
McCulloch	172643084.332	84.3318
McLennan	1927789698.62	2698.6176
McMullen	9740000.0	0.0
Madison	27759084.3318	84.3318
Marion	1655884.3318	84.3318
Martin	2727200.0	0.0
Mason	15876200.0	0.0
Matagorda	1536463137.33	337.3272
Maverick	5649790.3226	590.3226
Medina	1185958905.99	505.9908
Menard	8766000.0	0.0
Midland	1686.636	1686.636
Milam	1146803753.0	252.9954
Mills	10772500.0	0.0
Mitchell	8960884.3318	84.3318

Montague 50779168.6636 168.6636
Montgomery 5565.8988 5565.8988
Moore 4279741168.66 168.6636
Morris 84.3318 84.3318
Motley 0.0 0.0
Nacogdoches 25811674.6544 674.6544
Navarro 612667505.991 505.9908
Newton 84.3318 84.3318
Nolan 51194084.3318 84.3318
Nueces 3070911879.26 3879.2628
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Oldham 57612100.0 0.0
Orange 5260527.6498 927.6498
Palo Pinto 25811252.9954 252.9954
Panola 19967252.9954 252.9954
Parker 30682349.3088 1349.3088
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Polk 10714505.9908 505.9908
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Rains 29074884.3318 84.3318
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Refugio 811175000.0 0.0
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Rockwall 3896927.6498 927.6498
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Rusk 22889590.3226 590.3226
Sabine 3019484.3318 84.3318
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Upshur 67613221.659 421.659
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Van Zandt 132806505.991 505.9908
Victoria 1246110927.65 927.6498
Walker 23863758.9862 758.9862
Waller 35064505.9908 505.9908
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Washington 39447337.3272 337.3272
Webb 29709867.2812 2867.2812
Wharton 3537894621.66 421.659
Wheeler 24236600.0 0.0
Wichita 169643833.641 1433.6406
Wilbarger 218754284.332 84.3318
Willacy 1510656168.66 168.6636
Williamson 2584226228.57 5228.5716
Wilson 278763305.991 505.9908
Winkler 84.3318 84.3318
Wise 39768674.6544 674.6544
Wood 123647421.659 421.659
Yoakum 29414084.3318 84.3318
Young 107134768.664 168.6636
Zapata 16460684.3318 84.3318
Zavala 58153684.3318 84.3318

Deficit 55net sum 100956033462

Some Data for Texas County Location

Anderson County --> Andrews County : 659473.8503192937
Anderson County --> Angelina County : 119191.42477567533
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