Team Control Number

#9973

Problem Chosen

B

2019
HiMCM
Summary Sheet

Team #9973 is asked to model the impacts of PET bottled water bans in Concord and San Francisco. We clearly show our major assumptions, corresponding justifications, and our major variables before our model section. All variables or data we used are either directly found in credible website and cited in the Work Cited section, or being discussed in details in the Methods of Obtaining Data section. In our model, we evaluate the various impacts of PET ban by using Analytic Hierarchical Analysis (AHP). We show our AHP layer map which not only reveals our five major impacts — environment, health, availability, economy, and ethics, but also the small categories inside each major impact (we have three layers of impacts). We weigh our factors using AHP with Matlab, and all our AHP weighing scales are justified, and the consistency tests passed. For each layer of impacts, we give the formula for scoring index and explain them in detail. In the economy section, we use famous Cobweb model with the assistance of Matlab curve fitting to evaluate economic stability. All our scoring index in each impact are standardized so as to eliminate hidden weighing factor besides AHP weighing factors.

Team #9973 then addresses the similarities and differences on the impacts of PET bottled water ban between an airport and a town or city by discussing the adaptation of models. We keep the majority of our model the same such as still using AHP to weigh different factors, applying Cobweb model, and utilizing similar methods to obtain data as discussed in our Methods of Obtaining Data section. However, some of the differences between an airport and a city or town are still evident and could not be neglected. We take airport's higher mobility, peak and off-peak seasons, more tap water spots into consideration to adjust our model. We also increase our natural disaster AHP weighing scale by using Matlab since natural disasters could cause much more severe casualties in high populated places like airport. Our comprehensive model for town, city, and airport is clearly shown in the Results Display section.

In the last section, we propose a new policy that could minimize PET bottled water ban's harm and maximize its benefits. We impose price floor and governmental production tax on plastic bottled water and beverages, encourage more usage of cheap and clean tap water while protecting the water resources. Our policy also gives the government more money for welfare state to help the poor. Our policy is explained in detail with mathematical formula in the New Policy section. To adapt the new policy, Team #9973 adjusts their model by eliminating the factors of ethics and availability, and adding more weight on economy. Our model could be applied to a town, city, state or a country as all our steps are objective and general enough to apply them for large scales. We understand some of our methods to obtain the data might be time-consuming and not too realistic in a large scale such as a state or a country, but we do offer alternative method to treat bottled water or bottled beverages as single product respectively using average consumption, production, volume, cost, and price for better feasibility.

Contact: Team #9973

New PET Bottled Water Impact Model

Release Date:
Nov. 19^{th}, 2019

November 19^{th}---Today, Team #9973 launches a new model to measure the impacts of the single-serving PET bottled water ban.

According to our impact model, there are five essential factors contributing to the effects of the banning policy, which are environment, health, availability, economy and ethics. Is the policy beneficial overall? Check our final scoring index out!

Why choose our model to analyze the impact of policy in the future?

The most important reason is the objectivity of our new released model. Nowadays, there is a hot debate over the ban of single-serving bottled water in San Francisco airport on August. Many people argue about both positive and negative impacts. However, those are all person opinions, which are very biased. Unlike the personal opinions, our model is objective. Not only we have five general factors, but also there are several sub-factors for each of them. We have a well-developed justified method called "Analytic Hierarchy Process" to weigh the different factors. Therefore, using our model will help a large number of policy makers to make good decisions over plastic bottles consumption.

We also have our new policies proposed!

Our new policy and model adaption:
In order to better solve the issue of consumption of plastic bottled water, we propose several new policies to the government: first, we have to set up price floor and production tax on PET bottled water and impose the tax on beverages as well; second, we should use the collected tax as a revenue for tap water, its filter, and water source protection fee; last, we should use the remaining money for more welfare state to help the poor or build public facilities. Our goal is to limit the number of plastic bottles use without banning all of them for the long-term development. We also could keep quantity of beverage bottles from rising in our new policy.

Support our impact model and new policy for cleaner, healthier, and more economically prosperous communities!

Team #9973, 9:00 PM, 19^{th} November, 2019

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Introduction & Problem Restatement

Plastic bottles are widely used in the modern world. In 2020, the projected number of plastic bottles used will rise to over a half trillion. Many communities around the world have enacted the plastic bottled water bans, which aim to eliminate the negative impacts of plastic bottles.

For instance, Concord, a small town in Massachusetts, United States, proposed the policy of banning the sale of single-serving Polyethylene terephthalate (PET) bottles less than or equal to 34 ounces (1 liter) containing water which is non-sparkling and non-flavored in 2013. San Francisco, a city in California, also adopted this policy to ban the sale of single-serving PET water bottles in 2014. In August 2019, San Francisco Airport complied with the city's law and adopted the PET ban policy. However, those enactments evoke heated debate among the citizens. For those citizens who favor the policy state several reasons such as concerns of plastic garbage and litter, use of fossil fuels in the production of plastic, product transportation emissions, damage to water-providing aquifers and beliefs of unjust profit of businesses on the sale of free resources. For those who oppose the policy such as the International Bottled Water Association (IBWA) argued that the consequences of this ban may lead to "more packaging, more additives, and greater environmental impacts than bottled water."

Therefore, Team #9973 is asked to establish a comprehensive model that objectively measure the impacts of PET bottled water bans within a town and a city such as Concord and San Francisco. In addition, they need to find the similarities and differences between an airport and a town or city so that they could adopt their previous model in airports. In addition, Team #9973 is required to come up with a new PET bottles policy which could enhance beneficial impacts and reduce adverse impacts. They are asked to adjust their models based on their new suggested policy and evaluate their models' generalities. They will eventually compose a one-page article to report their findings and recommendations for a local newspaper.

Assumptions and Justifications

Assumption & Justification #1: Impacts

Team #9973 models the impacts of PET single-serving bottled water ban in five major different aspects: environment, economy, availability, health, and ethics. We assume the other positive or negative impacts caused by the ban and not included in our five aspects are minor impacts that only play very limited role in determining the overall effects of the policy.

Assumption #2: Types of Drinks:

Team #9973 divides up drinks into water and beverages; we further categorize water into single-serving PET bottled water with size of 12 oz, 16.9 oz, 23.7 oz, and 33.8oz. We divide beverages into energy drinks (PET bottles with size of 8.4 oz, 12 oz, 16 oz, and 20 oz), soda(PET bottles with size of 8.55oz, 20 oz, 24 oz, 51 oz, 68 oz, Aluminum cans with size of 7.5 oz, and 12 oz), sports drinks(PET bottles with size of 12 oz, 20 oz, and 32 oz), sparkling water(PET bottles with size of 16.9 oz, and 33.8 oz), tea(PET bottles with size of 16.9 oz), and coffee.

Justification #2: Types of Drinks:

The types of drinks we mentioned above covered the majority drinks on the market that are closely related to the PET bottled water ban. For each drink, we include the most common sizes of the bottle. Alcoholic drinks are not included for two reasons. First, most of them are not contained in a plastic bottle. Second, banning bottled water is far less likely to push someone consuming alcohol than beverages. The change of alcoholic drinks after the ban is minimal.

Assumptions #3: Plastic Bottle Shapes:
To calculate non-recycling plastic amount, we calculate total surface area for consumed plastic bottles first. For the sake of generality and feasibility, we assumed that all categories drinks mentioned in assumption #2 have the same general shape. The illustration below shows the shape of the bottles with a cylinder on the bottom and a cone with flat top above the cylinder.
Justification #3: Plastic Bottle Shapes:
Team #9973 believes a cone with flat top sitting on top of a cylinder can accurately model the shape of a water bottle. Although some plastic bottles have peculiar shapes, the majority of them do have the same shape we modeled. In addition, we are using variables h,H, r, and R(see Variable Designation section) to model the shapes of bottles since we take many different sizes of bottles into consideration. For each different size bottle, h,H,r,and R could be different so that our model is valid and as precise as possible in each condition.

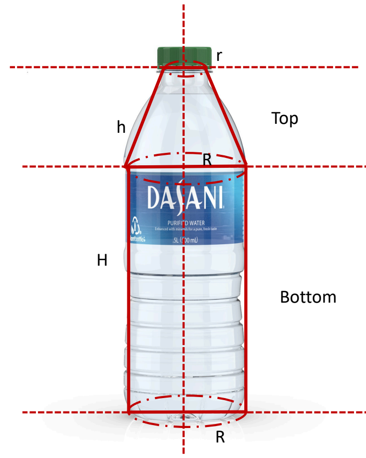
Assumption #4: Uncontrollable Factors – Natural Disasters:
There is a strong connection between natural disasters and water because they cause serious destruction of water source and quality, so PET plastic water bottles seem to be necessities in such critical conditions. Among various types of natural disasters, we assume floods, storms, earthquakes, and droughts are four biggest uncontrollable catastrophes around the world that will be taken into account in our model.
Justification #4: Uncontrollable Factors – Natural Disasters:
The UN Office for Disaster Risk Reduction recorded different disasters between 1995 and 2015, and they highlight some of the most frequently occurring natural disasters such as flood, storm, earthquakes, and drought. Those four types of disasters consist of 82% of total natural disasters.

Assumption #5: Constant Ratio:
If PET bottled water is banned in airport, people will consume more beverage and tap water (airports are well-equipped with tap water). We assume that the ratio of amount of tap water consumed to the amount of beverage consumed will be constant before and after the PET water bottle ban. For example, before the PET ban in airport, people annually consume x L bottled water, y L tap water, and z L beverage in total. After the ban, people will consume annually y + (xy)/(y+z) L tap water, and z + (xz)/(y+z) L beverages in total. Using the same mechanism, the ratio of different types of beverages also remain constant before and after the ban, so we can calculate the amount consumed for each sub-category in the beverage.
Justification #5: Constant Ratio:
It is logical to assume that in a short period of time, the ratio of different beverages and tap water consumed won't change before and after bottled water is banned.

Assumption & Justification #6: Same Likelihood
Team #9973 assumes the likelihood of a person consuming a PET bottled drink is the same. It's not practical to take everyone's preference into consideration. We need generality and by assuming the same likelihood, we will not lose accuracy when the population is large like in a town, city, or country.

Variables Designations

- Plastic bottles shape (as shown on the right):
  r= the radius of lid
  R= the radius of bottom area
  h= the height of top part of the bottle(a cine with flat top)
  H= the height of bottom cylindrical part of the bottle



- s_{flood}= severity of the flood
- s_{storm} = severity of the storm
- s_{earth}= severity of the earthquake
- $s_{drought}$= severity of the drought

S=supply or production, D=demand or consumption, C=cost of production, P=sale price, V = volume of bottle (ml), year = year, pl = place.
Key: $Sa_{water_{year-pl}}$ stands for the number of productions of 12 oz single-serving plastic bottled water in a specific year in a place. For Example, $Sa_{water_{2014-Concord}}$= the number of productions of 12 oz single-serving plastic bottled water in 2014 in Concord.

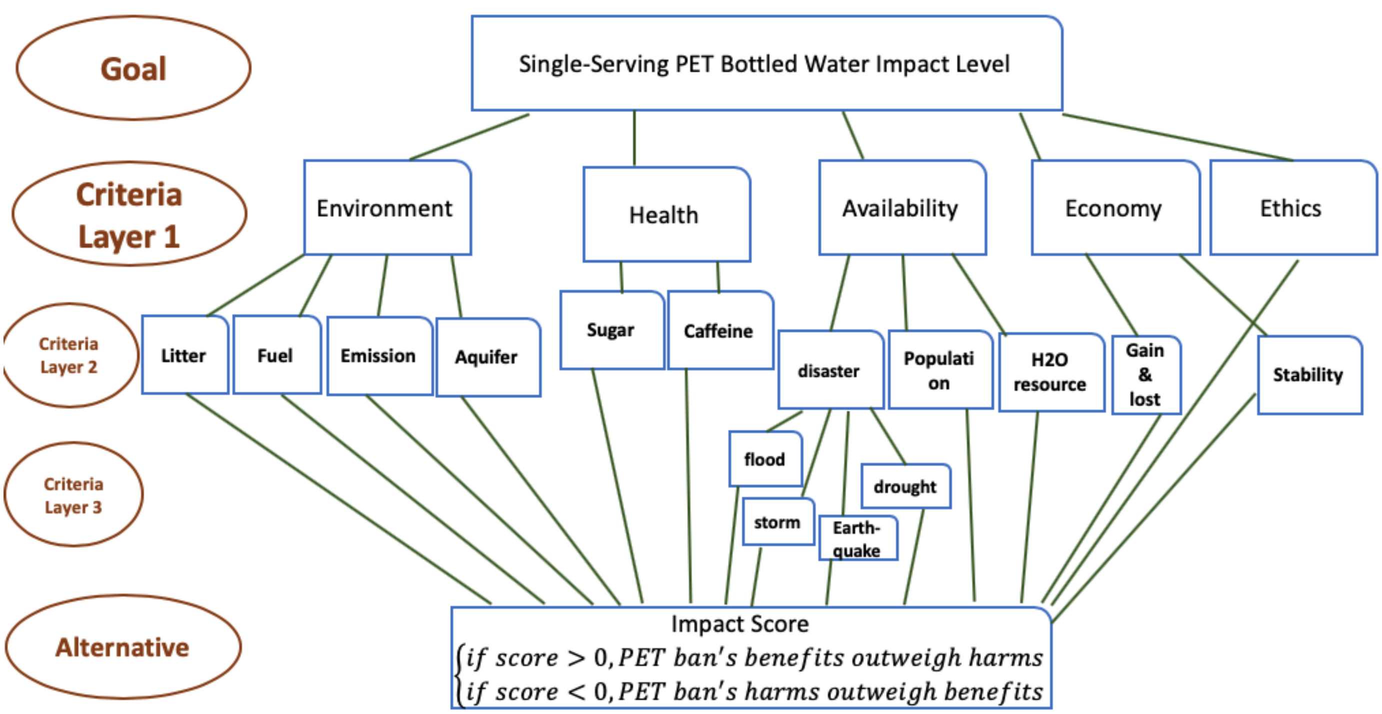
				Quantity Production	Quantity Consumption	Cost	Sale Price
Single-serving plastic bottled water	12 oz $V_{a_{water}}$			$Sa_{water_{year-pl}}$	$Da_{water_{year-pl}}$	$Ca_{water_{year-pl}}$	$Pa_{water_{year-pl}}$
	16.9 oz $V_{b_{water}}$			$Sb_{water_{year-pl}}$	$Db_{water_{year-pl}}$	$Cb_{water_{year-pl}}$	$Pb_{water_{year-pl}}$
	23.7 oz $V_{c_{water}}$			$Sc_{water_{year-pl}}$	$Dc_{water_{year-pl}}$	$Cc_{water_{year-pl}}$	$Pc_{water_{year-pl}}$
	33.8 oz $V_{d_{water}}$			$Sd_{water_{year-pl}}$	$Dd_{water_{year-pl}}$	$Cd_{water_{year-pl}}$	$Pd_{water_{year-pl}}$
Beverage	Soda	aluminum	2.5 oz $V_{m_{soda}}$	$Sm_{soda_{year-pl}}$	$Dm_{soda_{year-pl}}$	$Cm_{soda_{year-pl}}$	$Pm_{soda_{year-pl}}$
			12 oz $V_{n_{soda}}$	$Sn_{soda_{year-pl}}$	$Dn_{soda_{year-pl}}$	$Cn_{soda_{year-pl}}$	$Pn_{soda_{year-pl}}$
		Plastic	8.55oz $V_{a_{soda}}$	$Sa_{soda_{year-pl}}$	$Da_{soda_{year-pl}}$	$Ca_{soda_{year-pl}}$	$Pa_{soda_{year-pl}}$
			20 oz $V_{b_{soda}}$	$Sb_{soda_{year-pl}}$	$Db_{soda_{year-pl}}$	$Cb_{soda_{year-pl}}$	$Pb_{soda_{year-pl}}$
			24 oz $V_{c_{soda}}$	$Sc_{soda_{year-pl}}$	$Dc_{soda_{year-pl}}$	$Cc_{soda_{year-pl}}$	$Pc_{soda_{year-pl}}$
			1.5 L $V_{d_{soda}}$	$Sd_{soda_{year-pl}}$	$Dd_{soda_{year-pl}}$	$Cd_{soda_{year-pl}}$	$Pd_{soda_{year-pl}}$
			2 L $V_{e_{soda}}$	$Se_{soda_{year-pl}}$	$De_{soda_{year-pl}}$	$Ce_{soda_{year-pl}}$	$Pe_{soda_{year-pl}}$
	Sports drink	12 oz $V_{a_{sport}}$		$Sa_{sport_{year-pl}}$	$Da_{sport_{year-pl}}$	$Ca_{sport_{year-pl}}$	$Pa_{sport_{year-pl}}$
		20 oz $V_{b_{sport}}$		$Sb_{sport_{year-pl}}$	$Db_{sport_{year-pl}}$	$Cb_{sport_{year-pl}}$	$Pb_{sport_{year-pl}}$

	(Gaterag)	32 oz $V_{c_{sport}}$	$Sc_{sport_{year-pl}}$	$Dc_{sport_{year-pl}}$	$Cc_{sport_{year-pl}}$	$Pc_{sport_{year-pl}}$
	sparkling water	16.9 oz $V_{a_{spark}}$	$Sa_{spark_{year-pl}}$	$Da_{spark_{year-pl}}$	$Ca_{spark_{year-pl}}$	$Pa_{spark_{year-pl}}$
		33.8 oz $V_{b_{spark}}$	$Sb_{spark_{year-pl}}$	$Db_{spark_{year-pl}}$	$Cb_{spark_{year-pl}}$	$Pb_{spark_{year-pl}}$
	Energy drink (Red Bull)	8.4oz $V_{a_{energy}}$	$Sa_{energy_{year-pl}}$	$Da_{energy_{year-pl}}$	$Ca_{energy_{year-pl}}$	$Pa_{energy_{year-pl}}$
		12oz $V_{b_{energy}}$	$Sb_{energy_{year-pl}}$	$Db_{energy_{year-pl}}$	$Cb_{energy_{year-pl}}$	$Pb_{energy_{year-pl}}$
		16 oz $V_{c_{energy}}$	$Sc_{energy_{year-pl}}$	$Dc_{energy_{year-pl}}$	$Cc_{energy_{year-pl}}$	$Pc_{energy_{year-pl}}$
		20oz $V_{d_{energy}}$	$Sd_{energy_{year-pl}}$	$Dd_{energy_{year-pl}}$	$Cd_{energy_{year-pl}}$	$Pd_{energy_{year-pl}}$
	Lipton tea (16.9 oz)	$V_{a_{tea}}$	$Sa_{tea_{year-pl}}$	$Da_{tea_{year-pl}}$	$Ca_{tea_{year-pl}}$	$Pa_{tea_{year-pl}}$
	Coffee	$V_{a_{coffee}}$	$Sa_{coffee_{year-pl}}$	$Da_{coffee_{year-pl}}$	$Ca_{coffee_{year-pl}}$	$Pa_{coffee_{year-pl}}$

$Q_{tap_{year}}$ stands for the amount of tap water consumed (L) in airport in a specific year. For example, $Q_{tap_{2014}}$ represents the amount of tap water used(L) in airport in 2014.
Using bottle shape variables, we could denote for example $r_{a_{water}}$ as the radius of lid for 12 oz water bottles, $H_{a_{spark}}$ as the height of cylindrical part of 16.9 oz sparkling water.

Analytic Hierarchy Process

1. Analytic Hierarchy Process Layer Map:



2. AHP Scale for different layers and Justifications:

- AHP scale for Layer 1: environment, health, availability, economy, and ethics:

Table 1. Semantics of additive scale for AHP.

Grade	Semantics
0	Equal (equal important)
1	Slightly (slightly more important)
3	Moderate(more important)
5	Strong (strongly more important)
7	Very strong (demonstrably more important)
9	Extremely strong (extremely more important)
10	Absolutely strong (absolutely more important)
2, 4, 6, 8	Compromises/between

	Environment	Health	Availability	Economy	Ethics
Environment	1	3	5	7	9
Health	1/3	1	3	5	7
Availability	1/5	1/3	1	3	5
Economy	1/7	1/5	1/3	1	3
Ethics	1/9	1/7	1/5	1/3	1

<u>Justification</u>: Environment is the most important factor because plastic bottles' environmental impact has a global scale and has extremely huge long-term effects. Health is the next important factor and may affect our daily life. We rank economy as the second least important because PET bottle ban directly affected only a small part of world's economy. Whether company gaining profit on free resource is ethical is controversial, so we rank ethics the last factor.

- AHP scale for Layer 2: Litter, fossil fuel, transportation emission, and aquifer pollution.

We rank the importance of those factors as Litter > fuel > aquifer pollution > transportation emission. Please refer to **the appendix(1)** for this AHP scale table.

<u>Justification</u>: Litter and fossil fuel consumption are the most important factors because they are the two most ways plastic bottles affect our environment. Water pollution is important but third in our table because it is a side effect of litter. Transportation emission when transporting plastic bottles are minimal comparing to daily transportation in the whole world, thus rank the least.

- AHP scale for Layer 2: sugar and caffeine.

Team #9973 believe they are equally important since they are two common additives in beverage that will harm human bodies.

- AHP scale for Layer 2: disasters, population, and water resources:

Team #9973 rank their importance as disasters > population = water resource amount. Please refer to **the appendix(2)** for this AHP scale table.

<u>Justification</u>: PET water bottles are critical resources for natural disasters, without them life could be in jeopardy. Population and water resource amount are of the same importance.

- AHP scale for Layer 2: economy gain and stability:

They are equally important since economic boost needs long term economic stability support, and economic stability requires economic prosperity and constant economic development.

- AHP scale for Layer 3: Flood, storm, earthquake, and drought.

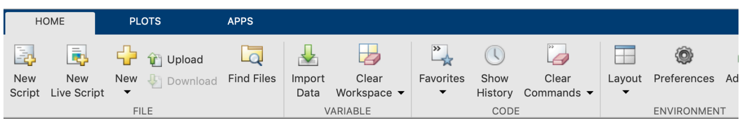
Team #9973 rank importance as flood > storm > earthquake > drought. Please refer to **the appendix(3)** for this AHP scale table.

<u>Justification</u>: we rank them based on their frequency according to the World Economic Forum, flood accounts for 43% of total natural disasters, storm 28%, earthquake 8%, drought 5%.

3. AHP weighing factors and consistency test:

<u>In this section, Team #9973 shows calculating the weighing factors for layer 1(environment, health, availability, economy, and ethics) and its corresponding consistency test as an example. Please refer to **the appendix(4)** for other layers' weighing factors calculation and corresponding consistency tests.</u>

Matlab AHP Weighing Factor Calculations:



```
>> a = [1,3,5,7,9;1/3,1,3,5,7;1/5,1/3,1,3,5;1/7,1/5,1/3,1,3;1/9,1/7,1/5,1/3,1]

a =

    1.0000    3.0000    5.0000    7.0000    9.0000
    0.3333    1.0000    3.0000    5.0000    7.0000
    0.2000    0.3333    1.0000    3.0000    5.0000
    0.1429    0.2000    0.3333    1.0000    3.0000
    0.1111    0.1429    0.2000    0.3333    1.0000

>> [v,d]=eig(a)

v =

   0.8630 + 0.0000i   0.8898 + 0.0000i   0.8898 + 0.0000i   0.8089 + 0.0000i   0.8089 + 0.0000i
   0.4401 + 0.0000i   0.1434 + 0.3661i   0.1434 - 0.3661i  -0.3976 + 0.2926i  -0.3976 - 0.2926i
   0.2170 + 0.0000i  -0.1454 + 0.1379i  -0.1454 - 0.1379i   0.0384 - 0.2695i   0.0384 + 0.2695i
   0.1067 + 0.0000i  -0.0909 - 0.0371i  -0.0909 + 0.0371i   0.0800 + 0.1312i   0.0800 - 0.1312i
   0.0561 + 0.0000i   0.0073 - 0.0610i   0.0073 + 0.0610i  -0.0539 - 0.0353i  -0.0539 + 0.0353i


d =

   5.2375 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0258 + 1.1004i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0258 - 1.1004i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.1446 + 0.1623i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.1446 - 0.1623i
```

```
>> eig(a)

ans =

   5.2375 + 0.0000i
   0.0258 + 1.1004i
   0.0258 - 1.1004i
  -0.1446 + 0.1623i
  -0.1446 - 0.1623i

>> v( :,1)/sum(v(:,1))

ans =

    0.5128
    0.2615
    0.1290
    0.0634
    0.0333

>>
```

Consistency Test: CI = $\frac{\lambda - n}{n-1} = \frac{5.2375-5}{5-1}$=0.059375

Random Consistency Index (RI):

Size of matrix	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Random consistency	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41

CR = CI / RI = 0.059375 /1.12 = 0.053 < 0.1. Our AHP scale passes the consistency test. We get the weighing factors of environment, health, availability, economy, and ethics to be w1, w2, w3, w4, w5 (0.51, 0.26, 0.13, 0.06, and 0.03) respectively. Similarly, we get the weighing factors for layer 2 litter, fuel, water pollution, and transportation emission to be w6, w7, w8, w9(0.51, 0.28, 0.14, 0.07) respectively, weighing factors for layer 2 natural disasters, water resources, and population to be w10, w11, w12(0.6, 0.2, 0.2) respectively, weighing factors for layer 2 sugar and caffeine to be w13, w14(0.5, 0.5) respectively, weighing factors for layer 2 economic gain and stability to be w15, w16(0.5, 0.5) respectively, weighing factors for layer 3 floods, storms, earthquakes, and drought to be w17,w18,w19,w20(0.56, 0.25, 0.09, and 0.09)respectively.

Methods of obtaining data:

1)In a town or city:
We have 22 categories of drinks as listed in our variable designation section. We need to get information for the annual quantity of production, consumption, price and cost for each category. In order to do so, Team # 9973 suggests going to each industry to investigate the quantity of production and their cost of production. For example, if we want to know the amount of 23.7 oz bottled water being produced and its cost, we will go to each water brand industry such as Evian and Dasani for investigation. Similarly, if we want to collect the data on the quantity of consumption and price, we have to go to each major supermarket or grocery stores for investigation to get information of quantity consumption and their selling price.

2) In an airport:
In the airport, we can ask the airport to collect the amount of each categories of bottled water and beverages being imported. Then, for the number and prices of consumption, we suggest going to each store in the airport to collect the data of their selling price and quantity.

3)The shape of plastic bottles:
We assume that one general shape for all plastic bottles (See Variable Designation and Assumption #3 for more details). For that general shape, we have several variables r, R, H, h. The data can be collected by measuring each categories' r, R, H ,and h in the industry.

5)Survey: Simple Random Sampling
In order to find out whether people think company gaining profit on free resource is ethical or not, we will design a survey to choose random group of people to ask the question.

Model in Concord & San Francisco

Team #9973 models the impacts of PET water bottle bans in a town or city. Our model could be applied to all towns or cities, but here we take the Concord and San Francisco as examples. Only plastic bottles are considered in environment section, aluminum is considered only for health, economic, and availability section as they are not plastic litters.

1)**Environment**:

a) Litter:

Team #9973 calculates the total change of the weight of non-recycled plastic bottles before and after the ban. Non-recycled plastic bottles become litter and will harm the environment. We get

the delta weight of litter by calculating the change of PET surface area before and after the ban times PET thickness times PET density.
Concord PET ban happened in 2013, so we calculate the delta using year value of 2014(represent after the ban) and 2012(represent before the ban). San Francisco PET ban happens in 2014, so we use year 2015 and 2013. The final result I1 of this formula eliminates the unit and standardize the number by diving the total plastic waste per year.

$\boldsymbol{I1 = \sum_{\substack{j=water,soda,energy\ drink \\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} \{(D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}}) * [2\pi R_{ij}\ H_{ij} + \int_0^{h_{ij}} 2\pi (r_{ij} + \frac{R_{IJ} - r_{ij}}{h_{ij}}) dh_{ij}]\}}$ *** 0.038cm * 1.38g/cm^3/ 3*10^{14} g, where in Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco. If for a specific j, some i does not exist, then for that i and j, $\{(D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}}) * [2\pi R_{ij} H_{ij} + \int_0^{h_{ij}} 2\pi (r_{ij} + \frac{R_{IJ} - r_{ij}}{h_{ij}}) dh_{ij}]\} = 0$.**

Explanation: $2\pi R_{ij} H_{ij} + \int_0^{h_{ij}} 2\pi (r_{ij} + \frac{R_{IJ} - r_{ij}}{h_{ij}}) dh_{ij}$ stands for the surface area of a specific drink ij. For example, when i=a, j=water, it stands for the surface area of 12 oz water bottle. $(D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}})$ represents the delta number of PET bottles used before and after the ban in a place. 0.038 cm is the average thickness of PET, 1.38 g/cm^3 is the density of PET, 3*10^{14} g is the total plastic waste per year (we divide it to standardize $I1$).

b) Fossil Fuel:
The second aspect of environmental impact is about how much fossil fuel is used in the production of plastic bottles in Concord and San Francisco. The formula below shows the standardized change of the amount of fossil fuel consumption $I2$ before and after the ban:

$$\boldsymbol{I2 = \sum_{\substack{j=water,soda,energy\ drink \\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} (S_{i_{j_{year1-pl}}} - S_{i_{j_{year2-pl}}}) * V_{i_j} * \frac{1}{4} / v_{total}}$$

, where in Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco. If for a specific j, some i does not exist, then for that i and j, $D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}} = 0$

Explanation: $\sum_{\substack{j=water,soda,energy\ drink \\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} (S_{i_{j_{year1-pl}}} - S_{i_{j_{year2-pl}}})$ is the change in quantity of production of plastic bottles for both water and beverages before and after ban in a place(Concord and San Francisco). The amount of oil consumed one bottle is 1/4 of the volume of the bottle as shown in a research, which explains why we multiply 1/4. To standardize the factor, we have to divide it by the total annual amount of oil consumption used for plastic around the world (v_{total}) which we found to be 2.16 * 10^11 L.

c) Water Pollution:
For the last aspect, we determine the amount of plastic bottles which cannot be recycled to cause the water pollution in the ocean. We generate the following formula:

$$\boldsymbol{I_3} = \frac{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} (D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}})}{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} D_{i_{j_{year2-pl}}}} * 8 \text{ million} / 8 \text{ million}$$

, where in **Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco. If for a specific j, some i does not exist, then for that i and j,** $\boldsymbol{D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}} = 0}$

Explanation: Before the ban, x% of $\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} D_{i_{j_{year2-pl}}}$ (the total PET bottles produced) results in the 8 million PET water pollution. If we assume x% does not change, then the change of PET water pollution between before and after the ban is =

$$\frac{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} (D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}})}{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} D_{i_{j_{year2-pl}}}} * 8 \text{ million}.$$

To standardize it, we divide it by 8 million.

d) Transportation Emission:

Transporting plastic bottles for recycling to different areas around the world produces a large amount of carbon dioxide to the environment.

$$\boldsymbol{I4 = 0.12 * [\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} (D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}})]/(1.5 * 10^6) * (5.8 * 10^{14} g) / (1.8 * 10^{15} g)}$$

, where in Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco. If for a specific j, some i does not exist, then for that i and j, $\boldsymbol{D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}} = 0}$

Explanation: 0.12 is the product of 0.3 and 0.4. The total recycled rate is 0.3, and in that 0.3 recycled bottle, 40% is transported to other countries, which will emit lots of carbon dioxide. $\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} (D_{i_{j_{year1-pl}}} - D_{i_{j_{year2-pl}}})$ is the change of the quantity production of plastic bottles before and after the ban. We take the delta quantity and divide it by $1.5 * 10^6$(the capacity of the number of water bottles in. a 40 ft truck) to get the number of trucks needed. One truck annually emits $5.8 * 10^{14} g$ carbon dioxide. By timing $5.8 * 10^{14} g$, we get the change of carbon dioxide emitted due to PET before and after the ban. In order to standardize the factor, we divide it by the annual world CO2 emission, 1.8 *10^{15}g.

2) Health:

After PET bottled water ban, many people choose to drink beverages instead. Sugar and caffeine are two major additives which may cause serious health issues.

a) Sugar:

The average sugar in soda is 2.7 g per 100 mL, in energy drink is 2.8g mL, in sports drink is 1.5g mL, in tea is 1.3 g per 100 mL, and in coffee is 12.6 g per bottle.

Sugar(soda) = 0.027 g/mL, Sugar(energy) = 0.028 g/mL
Sugar(sports) = 0.015 g/mL, Sugar(tea) = 0.013 g/mL

$$\boldsymbol{I5} = \frac{\{\sum_{\substack{j=soda,energy\ drink\\ sports\ drink,tea,spark}} \sum_{i=a,b,c,d,e} \begin{matrix}[\left(\boldsymbol{D}_{\boldsymbol{i}_{j\ year1-pl}} - \boldsymbol{D}_{\boldsymbol{i}_{j\ year2-pl}}\right) * \boldsymbol{V}_{\boldsymbol{i}_j} * \boldsymbol{sugar}(\boldsymbol{j})\ ]\} \\ +\mathbf{12.6}\boldsymbol{g} * (\boldsymbol{Da}_{\boldsymbol{coffee}_{2014}} - \boldsymbol{Da}_{\boldsymbol{coffee}_{2012}})\end{matrix}}{\frac{\mathbf{31}\boldsymbol{g}}{\boldsymbol{day}} * \mathbf{365}\boldsymbol{day}}$$

where in Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco. If for a specific j, some i does not exist, then for that i and j, $\mathbf{D}_{\mathbf{i}_{\mathbf{j}_{year1-pl}}} - \mathbf{D}_{\mathbf{i}_{\mathbf{j}_{year2-pl}}} = 0$

<u>Explanation</u>:

The numerator is the total change of sugar consumed in PET bottles before and after the ban. $\frac{31g}{day}$ is the daily ideal sugar consumption, times 365 day to get annual idea sugar consumption. We divide it by $\frac{31g}{day} * 365day$ to standardize the score.

b)Caffeine

Team #9973 generalizes the following formula:

$\boldsymbol{I6} = \frac{\mathbf{95}\ \boldsymbol{mg} * (\boldsymbol{Da}_{\boldsymbol{coffee}\ \boldsymbol{year1-pl}} - \boldsymbol{Da}_{\boldsymbol{coffee}\ \boldsymbol{year2-pl}})}{\mathbf{400}\boldsymbol{mg/day} * \mathbf{365}\boldsymbol{day}}$**, where in Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco.**

<u>Explanation</u>: The average caffeine in a coffee bottle is 95 mg, and $Da_{coffee\ year1-pl} - Da_{coffee\ year2-pl}$ is the net change of coffee consumed before and after the PET ban. We multiply them to get the delta caffeine consumed before and after the ban. To standardize it, we divide it by the maximum caffeine consumption that will not harm human body which is 400mg/day * 365 day.

3)Availability:

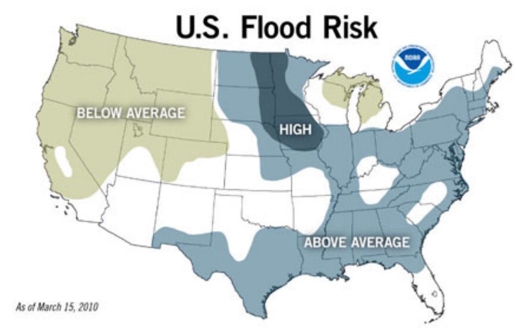
Each region has different levels of water availability, and thus has different basic requirements for PET water bottles. Three factors are discussed: uncontrollable factors, population, and water resource. It's important to note that we will add a negative sign in front of the score indexes $I_7 .. I_{11}$ because the higher levels of disaster risks and the higher population level in city or town, the more water bottles are required (in AHP we denote the final score > 0 to be banning PET's benefits outweighs the harms, that's why we need negative signs).

a) <u>Uncontrollable factors (Natural Disasters)</u>

When facing natural disasters, water bottles are necessities. We analyze the four most common catastrophes around the world: floods, storms, earthquakes and drought. In order to analyze the impact caused by natural disasters, we will calculate the severity of each disaster based on the frequency map online by using the standardized scores of -0.75, -0.5, -0.25 and 0.

i) Floods

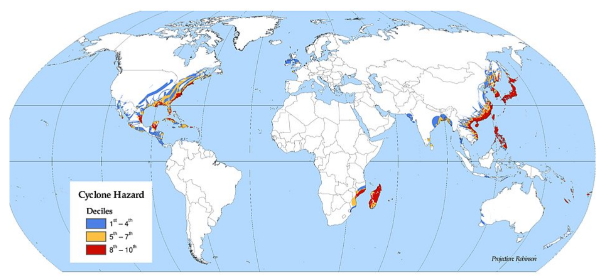
In the U.S. flood risk map on the right (See **appendix(5)** for larger distribution picture), it demonstrates the risk of existing flood. There are four level of flood risk: high, above average, below average and none. Then, we scale them respectively: I_7= -0.75, -0.5, -0.25 and 0. For instance, Concord is in the area of above average, then the scale score for it is -0.5. San Francisco will have the score of -0.25.



ii) Storms

As the graph of global cyclone hazard distribution shows (See **appendix(6)** for larger picture), there are four different levels related to the severity of cyclone hazard around the world: 8^{th}-10^{th}, 5^{th} -7^{th}, 1th - 4^{th}, and 0. Similarly, we scale those factors: I_8= -0.75, -0.5, -0.25 and 0 respectively. Concord has the score of -0.75, while San Francisco has the score of 0.

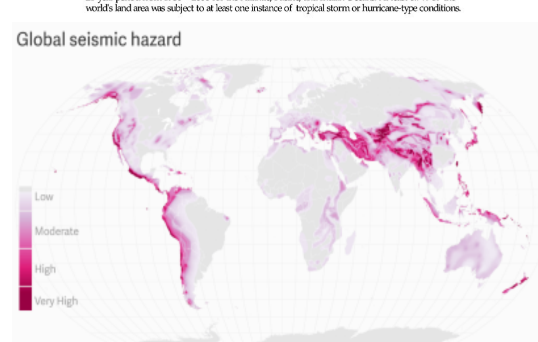
Global Cyclone Hazard Distribution



The cyclone data set is comprised of data collected from more than 1,600 storm tracks during the 21-year period from 1980 – 2000 for the Atlantic, Pacific, and Indian Oceans. At least 6.7% of the world's land area was subject to at least one instance of tropical storm or hurricane-type conditions.

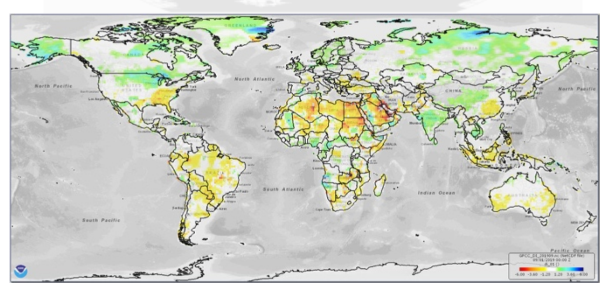
iii) Earthquakes

As the graph of global seismic hazard shows (See **appendix(7)** for larger picture), there are also four different levels of severity: very high, high, moderate and low. We also scale those factors: I_9= -0.75, -0.5, -0.25 and 0 respectively. Concord has the score of 0, while San Francisco has the score of -0.5.



iv) Droughts

The graph on the right shows the humidity around the world (See **appendix(8)** for larger picture). There are four different levels of humidity: -6, -2, 2 and 6, where negative signs refer to the drought and positive signs indicate the humidity. Therefore, in order to scale the severity of droughts, I_{10}=-0.75, -0.5, -0.25 and 0 respectively. Concord has the score of -0.5, while San Francisco has the score of -0.25.



<u>2)Population</u>

Team #9973 takes population into consideration. The higher the population, the more water bottles are necessary. We standardize the score by dividing it by the total population in the state. Since town like Concord only make up a small fraction of total population of a state, we will neglect it. However, for big cities like San Francisco, we could not neglect this factor. San Francisco, for example, has 0.88 million population, and we divide it by California population, which is 39.56 million (we add a negative sign for I_{11} as higher population density, more water bottles are needed). $I_{11} = -\frac{\boldsymbol{Population\ in\ city}}{\boldsymbol{population\ in\ state}}$

3)Water Resource
If there is not enough water resource in the city or town or at least in its state, then more bottled water is needed. Please see **the appendix(9)** for the research of the surface drinking water provided by intermittent, ephemeral, and headwater streams in the U.S. The fourth column about the total stream miles in source protection areas indicate the abundance and distribution of water. We generalize the following formula:
I_{12}**=stream miles in source protection area of the state that a city or town is in / total stream miles in source protection areas**
For Concord, the total stream mile in MA is 2636 miles, and the total US mile is 357403.5, so I_{12} is 32688.3/357403.5. For San Francisco, the total stream mile in CA is 32688.3 miles, so I_{12} is 32688.3/357403.

4)Economy:
In this section, we will measure the effects of PET bottled water ban on economy mainly in the aspects of economic gain or loss, and economic stability.
1)Economic Gain or loss:
The total economic gain on selling PET bottle drink is the quantity of bottles sold times average (price - cost). Team #9973 generalizes the following formula to be I_{13}:

$$\frac{\sum_{\substack{j=\text{water,soda,energy drink}\\ \text{sports drink,tea,spark,coffee}}} \sum_{i=a,b,c,d,e,m,n} \left[\left(\mathbf{P}_{i_{j_{year2-pl}}} * \mathbf{D}_{i_{j_{year2-pl}}} - \mathbf{C}_{i_{j_{year2-pl}}} * \mathbf{S}_{i_{j_{year2-pl}}}\right) - \left(\mathbf{P}_{i_{j_{year1-pl}}} * \mathbf{D}_{i_{j_{year1-pl}}} - \mathbf{C}_{i_{j_{year1-pl}}} * \mathbf{S}_{i_{j_{year1-pl}}}\right)\right]}{\mathbf{abs}\left[\sum_{\substack{j=\text{water,soda,energy drink}\\ \text{sports drink,tea,spark,coffee}}} \sum_{i=a,b,c,d,e,m,n} \left(\mathbf{P}_{i_{j_{year1-pl}}} * \mathbf{D}_{i_{j_{year1-pl}}} - \mathbf{C}_{i_{j_{year1-pl}}} * \mathbf{S}_{i_{j_{year1-pl}}}\right)\right]}$$

, where in Concord, year1 is 2014, year2 is 2012, and pl is Concord; in San Francisco, year1 is 2015, year2 is 2013, and pl is San-Francisco. If for a specific j, some i does not exist, then for that i and j,

$$\left[\left(\mathbf{P}_{i_{j_{year2-pl}}} * \mathbf{D}_{i_{j_{year2-pl}}} - \mathbf{C}_{i_{j_{year2-pl}}} * \mathbf{S}_{i_{j_{year2-pl}}}\right) - \left(\mathbf{P}_{i_{j_{year1-pl}}} * \mathbf{D}_{i_{j_{year1-pl}}} - \mathbf{C}_{i_{j_{year1-pl}}} * \mathbf{S}_{i_{j_{year1-pl}}}\right)\right] = \mathbf{0}$$

Explanation:
The numerator is the net change of the economic gain or loss for selling PET bottle drink. In order to standardize it, we standardize it by dividing it by the denominator which is the absolute value of the annual year economic gain or less for selling PET bottles before the ban.

2)Economic Stability:
Team #9973 measures the impact of PET bottled water ban on economic stability by using the Cobweb Model.
Justifications: The reasons we use Cobweb Model are the following:
1.There is an economic major change/fluctuation due to PET water bottle ban, and Cobweb model measures the economic stability in critical fluctuation period.
2.Cobweb Model applies best when quantity produced is predetermined before the price is observed. Since water(drink) is a free resource, there should be some basic amount guaranteed produced before the price settled. Thus, Cobweb model could be applied well.

Team #9973 will treat all the drinks in the variable designation section as a single drink by getting average consumption, production, cost, and price in order to get a generalized result of Cobweb Model. We denote the following new variables:

$$\boldsymbol{Snew_{year-pl}} = \frac{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark,coffee}} \sum_{i=a,b,c,d,e,m,n} (S_{i_j\ year-pl})}{22}$$

such that if for a specific j, some i does not exist, then for that i, j, a=0 where a=$S_{i_j\ year-pl}$

$$\boldsymbol{Dnew_{year-pl}} = \frac{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark,coffee}} \sum_{i=a,b,c,d,e,m,n} (D_{i_j\ year-pl})}{22}$$

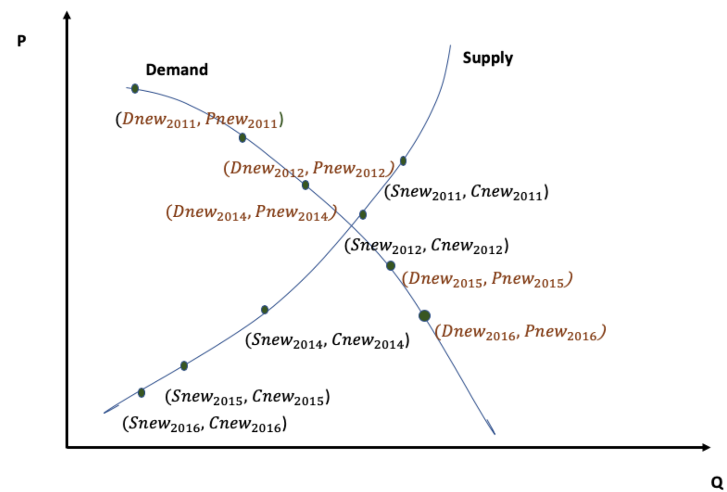
such that if for a specific j, some i does not exist, then for that i, j, a=0 where a=$D_{i_j\ year-pl}$

$$\boldsymbol{Pnew_{year-pl}} = \frac{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark,coffee}} \sum_{i=a,b,c,d,e,m,n} (P_{i_j\ year-pl})}{22}$$

such that if for a specific j, some i does not exist, then for that i, j, a=0 where a=$P_{i_j\ year-pl}$

$$\boldsymbol{Cnew_{year-pl}} = \frac{\sum_{\substack{j=water,soda,energy\ drink\\ sports\ drink,tea,spark,coffee}} \sum_{i=a,b,c,d,e,m,n} (C_{i_j\ year-pl})}{22}$$

such that if for a specific j, some i does not exist, then for that i, j, $C_{i_j\ year-pl}$=0



We could get $Snew_{year-pl}$, $Dnew_{year-pl}$, $Cnew_{year-pl}$, $Pnew_{year-pl}$ for year near the PET bottle ban year, such as in Concord PET ban happens in 2013, we will measure $Snew_{year-Concord}$, $Dnew_{year-Concord}$, $Cnew_{year-Concord}$, $Pnew_{year-Concord}$ for year = 2011,2012, 2014, 2015, and 2016. Similarly, for San Francisco, since PET bottle ban happened in 2014, we will use year = 2012,2013,2015,2016,2017. We will use curve fitting in Matlab to get the functions for the supply curve S_{newpl} and demand curve D_{newpl}. To get the best polynomial curve fitting's degree n entered in Matlab, we use Matlab codes to get n. Please see **the appendix(10).**

when the curve S_{newpl} and D_{newpl} intersects, we denote the corresponding quantitiy to be $\boldsymbol{Q_{equi}}$, when $\frac{dS_{newpl}}{dx}\Big|_{x=Q_{equi}} > \frac{dD_{newpl}}{dx}\Big|_{x=Q_{equi}}$, the economy is stable. We also denote scoring index $\boldsymbol{I_{14}} = \frac{\frac{dS_{newpl}}{dx}\big|_{x=Q_{equi}} - \frac{dD_{newpl}}{dx}\big|_{x=Q_{equi}}}{\frac{dD_{newpl}}{dx}\big|_{x=Q_{equi}}}$**, where pl stands for Concord or San Francisco.**

5)Ethics:

Some people claim selling water on a market is not ethical since water is a free resource like air that should not be used for merchants to make profits. Team #9973 takes it into consideration. We do not use Immanuel Kant's deontology since it is hard to measure objectively whether or not gaining profits on water is ethical; instead, we will follow utilitarianism, trying to create the largest amount of good for the greatest amount of people. We will use simple random sampling to achieve it. In a town or city, we will number people by their social identity number. Then we will draw some number of people in the population randomly to vote on whether or not they think it's ethical to gain profit on selling PET bottled water, a free resource. The number of people we draw will be 0.1 * total population in the city or town. If the majority of people who are drawn and show up in voting votes it's ethical to gain profit on water, then I_{15}= -$\frac{\sum_{i=1}^{14} I_i}{14}$, if vote not ethical to gain profit on water, then $I_{15} = \frac{\sum_{i=1}^{14} I_i}{14}$. We denote I_{15} as the average of the previous 14 scoring index so that all scores are standardized, and there are no other hiding weighing factors besides AHP weighing factors.

Airport

Our model can be generalized to model the impact of PET water bottle ban in airport. In this section, we will discuss our model's similarities and differences between city/town and airport.

a) Similarities
1)In airport, the major five different impacts of PET ban are still environment, health, availability, economy and ethics. We still use Analytic Hierarchy Process to weigh each factor contributed to the impact model, and the AHP weighing factor are still the same as nothing significantly changes from city/town to airport in these 5 factors.
2)The method of obtaining data are essentially the same that we will ask the airport to collect the amount of each categories of bottled water and beverages being imported.
3)For the environmental factor, we still measure the surface area of consumption of non-recyclable plastic bottles, the amount of fossil fuels producing the plastic bottles, water pollution and transportation emission of those recyclable bottles.
4)For the availability, we will use same factors (disasters, population, and water resources); we could still get the airport risk level for uncontrollable factor by locating it on various risk maps.
5)For the economy, the Cobweb model could be applied still. For the health and ethics, we do not have to change the model since the only differences are the quantity consumed, quantity produced, and price; we will have the same type of survey to randomly ask people in the airport.

b) Differences
i) Mobility: In cities or towns, many people habitat for a very long time. However, most people go to the airport for traveling, and they only stay there for short time. The population mobility in the airport is much higher than in the city or town, and thus it's not adequate enough to measure the population in a specific time. For the population section in our previous model, we need to plug in the total guest an airport receives per day rather than the population in airport at a specific time.

ii) Peak vs. Off peak
There is peak and off-peak season in airport. During peak season such as national holidays, winter and summer break, many people choose to travel out of town. As a matter of fact, the population during peak time is higher than the population during off-peak time. Therefore, we have to collect the data about when the peak time in the airport is and calculate the total number of people an airport receives per day separately during peak and off-peak seasons.

iii) Tap Water
Tap water fountains are far more common in the airport than in the city. Therefore, we have to take the quantity of tap water into consideration. If the single-serving bottled water are banned in the airport, many people prefer to drink directly from the fountains for their convenience. Since tap water fountain is free, we only have to think about the quantity of tap water being consumed before and after ban.
<u>Calculation:</u>
Before the ban, people have three options to drink water in an airport: single-serving bottled water, tap water fountain, and beverages; after the ban of single-serving bottled water, people have two options either tap water or beverages. After the ban, the consumption of single-serving bottled water will be zero. Using our **assumption & Justification #5 constant ratio**, we can get the quantity of each sub-categories of drinks being consumed and produced after the ban.
We define set U = { m_{soda}, n_{soda}, a_{soda}, b_{soda}, c_{soda}, d_{soda}, e_{soda}, a_{sport}, b_{sport}, c_{sport}, a_{spark}, b_{spark}, c_{spark}, a_{energy}, b_{energy}, c_{energy}, d_{energy}, a_{tea}, a_{coffee}}
We denote U_k as the kth element in the set. $C_U U_k$ is the complimentary set where it contains all elements in the U except for U_k.

$$\boldsymbol{S}_{U_{k_{afterban-airport}}} = \boldsymbol{S}_{U_{k_{beforeban-airport}}} + \sum_{i=a,b,c,d} (\boldsymbol{S}_{i_{water_{beforeban-airport}}}) * \frac{S_{U_{k_{beforeban-airport}}}}{\sum_{j=C_U U_k} S_{j_{beforeban-airport}} + Q_{tap_{beforeban}}}$$

$$\boldsymbol{Q}_{tap_{afterban}} = \boldsymbol{Q}_{tap_{beforeban}} + \sum_{i=a,b,c,d} (\boldsymbol{D}_{i_{water_{beforeban-airport}}}) * \frac{Q_{tap_{beforeban}}}{\sum_{j=C_U U_k} D_{j_{beforeban-airport}} + Q_{tap_{beforeban}}}$$

$$\boldsymbol{D}_{U_{k_{afterban-airport}}} = \boldsymbol{D}_{U_{k_{beforeban-airport}}} + \sum_{i=a,b,c,d} (\boldsymbol{D}_{i_{water_{beforeban-airport}}}) * \frac{D_{U_{k_{beforeban-airport}}}}{\sum_{j=C_U U_k} D_{j_{beforeban-airport}} + Q_{tap_{beforeban}}}$$

iv) Uncontrollable factors
The population is higher in the airport, and thus when there are natural disasters, more people will be in jeopardy in airport. Therefore, we will increase the weighing factor of uncontrollable factor comparing to other availability factors (water resources, and population) for airport by redoing AHP. The new weighing factors for uncontrollable factor, water resource, and population in airport are respectively 0.71, 0.14, and 0.14.

v) Economy

Most of the factors are the same for both airport and city model, but the only difference is about the quantity and price of production and consumption of bottled water. Since more people need to drink water in airports, they are willing to pay a higher price to buy the bottled water. Therefore, the change in price does not significantly affect the change in quantity, meaning that the curve will be more inelastic, but it will not significantly change our model.

Results Display

We denote the final score to be $\mathbf{I_{final}}$. Using the weighing factor we get in AHP section, we have the following formula:

For city and town(San Francisco and Concord):

$\underline{\mathbf{I_{final}} = (w1 * w6)I_1 + (w1*w7)\ I_2 + (w1*w8)\ I_3 + (w1 * w9)\ I_4 + (w2 * w13)I_5 + (w2 * w14)\ I_6 + (w3 * w10 * w17)\ I_7 + (w3 * w10 * w18)\ I_8 + (w3 * w10 * w19)\ I_9 + (w3 * w10 * w20)\ I_{10} + (w3 * w12)\ I_{11} + (w3 * w11)\ I_{12} + (w4 * w15)\ I_{13} + (w4 * w16)\ I_{14} + w5 I_{15},}$

where w1=0.51, w2=0.26, w3=0.13, w4=0.06, w5=0.03, w6=0.51, w7=0.28, w8=0.1, w10=0.07, w10=0.6, w11=0.2, w12=0.2, w13=w14=w15=w16 =0.5, w17=0.56, w18=0.25, w19=w20=0.09.

$\mathrm{I1} = \sum_{\substack{\mathrm{j=water,soda,energy\ drink}\\ \mathrm{sports\ drink,tea,spark}}} \sum_{\mathrm{i=a,b,c,d,e}} \{(\mathrm{D}_{\mathrm{i_j}_{\mathrm{year1-pl}}} - \mathrm{D}_{\mathrm{i_j}_{\mathrm{year2-pl}}}) * [2\pi \mathrm{R_{ij}}\ \mathrm{H_{ij}} + \int_0^{\mathrm{h_{ij}}} 2\pi(\mathrm{r_{ij}} + \frac{\mathrm{R_{IJ}} - \mathrm{r_{ij}}}{\mathrm{h_{ij}}})\mathrm{dh_{ij}}]\} * 0.038\mathrm{cm} * 1.38\mathrm{g/cm^3} / 3*10^{14}\ \mathrm{g}$, $\mathrm{I2} = \sum_{\substack{\mathrm{j=water,soda,energy\ drink}\\ \mathrm{sports\ drink,tea,spark}}} \sum_{\mathrm{i=a,b,c,d,e}} (\mathrm{S}_{\mathrm{i_j}_{\mathrm{year1-pl}}} - \mathrm{S}_{\mathrm{i_j}_{\mathrm{year2-pl}}}) * \mathrm{V_{i_j}} * \frac{1}{4} / \mathrm{v_{total}}$; $\mathrm{I3} = \frac{\sum_{\substack{\mathrm{j=water,soda,energy\ drink}\\ \mathrm{sports\ drink,tea,spark}}} \sum_{\mathrm{i=a,b,c,d,e}} (\mathrm{D}_{\mathrm{i_j}_{\mathrm{year1-pl}}} - \mathrm{D}_{\mathrm{i_j}_{\mathrm{year2-pl}}})}{\sum_{\substack{\mathrm{j=water,soda,energy\ drink}\\ \mathrm{sports\ drink,tea,spark}}} \sum_{\mathrm{i=a,b,c,d,e}} \mathrm{D}_{\mathrm{i_j}_{\mathrm{year2-pl}}}}$; $\mathrm{I4} = 0.12 * [\sum_{\substack{\mathrm{j=water,soda,energy\ drink}\\ \mathrm{sports\ drink,tea,spark}}} \sum_{\mathrm{i=a,b,c,d,e}} (\mathrm{D}_{\mathrm{i_j}_{\mathrm{year1-pl}}} - \mathrm{D}_{\mathrm{i_j}_{\mathrm{year2-pl}}})]/(1.5 * 10^6) * (5.8 * 10^{14}\mathrm{g}) / (1.8 * 10^{15}\mathrm{g})$; $\mathrm{I5} = \frac{\{\sum_{\substack{\mathrm{j=soda,energy\ drink}\\ \mathrm{sports\ drink,tea,spark}}} \sum_{\mathrm{i=a,b,c,d,e}} [(\mathrm{D}_{\mathrm{i_j}\,\mathrm{year1-pl}} - \mathrm{D}_{\mathrm{i_j}\,\mathrm{year2-pl}}) * \mathrm{V_{i_j}} * \mathrm{sugar(j)}\ ]\} + 12.6\mathrm{g} * (\mathrm{Da}_{\mathrm{coffee}_{2014}} - \mathrm{Da}_{\mathrm{coffee}_{2012}})}{\frac{31\mathrm{g}}{\mathrm{day}} * 365\mathrm{day}}$, $\mathrm{I6} = \frac{95\ \mathrm{mg} * (\mathrm{Da}_{\mathrm{coffee}\ \mathrm{year1-pl}} - \mathrm{Da}_{\mathrm{coffee}\ \mathrm{year2-pl}})}{400\mathrm{mg/day} * 365\mathrm{day}}$, $I_7 = S_{flood}$, $I_8 = S_{storm}$, $I_9 = S_{earth}$, $I_{10} = S_{drought}$, $I_{11} = -\frac{Population\ in\ city}{population\ in\ state}$, I_{12}=stream miles in spa in state a city or town is in / total stream miles, $I_{13}\ \frac{\sum_{\substack{\mathbf{j=water,soda,energy\ drink}\\ \mathbf{sports\ drink,tea,spark,coffee}}} \sum_{\mathbf{i=a,b,c,d,e,m,n}} [(\mathbf{P}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year2-pl}} * \mathbf{D}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year2-pl}} - \mathbf{C}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year2-pl}} * \mathbf{S}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year2-pl}}) - (\mathbf{P}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}} * \mathbf{D}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}} - \mathbf{C}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}} * \mathbf{S}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}})]}{\mathbf{abs}[\sum_{\substack{\mathbf{j=water,soda,energy\ drink}\\ \mathbf{sports\ drink,tea,spark,coffee}}} \sum_{\mathbf{i=a,b,c,d,e,m,n}} (\mathbf{P}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}} * \mathbf{D}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}} - \mathbf{C}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}} * \mathbf{S}_{\mathbf{i}\,\mathbf{j}\,\mathbf{year1-pl}})]}$, $\boldsymbol{I_{14}} = \frac{\frac{\mathbf{d}S_{newpl}}{\mathbf{dx}}\Big|_{x=Q_{equi}} - \frac{\mathbf{d}D_{newpl}}{\mathbf{dx}}\Big|_{x=Q_{equi}}}{\frac{dD_{newpl}}{dx}\ |_{x=Q_{equi}}}$, $I_{15} = \frac{\sum_{i=1}^{14} I_i}{14}$.

For airport: All are the same, except I_{11} will be measured in peak and off-peak seasons separately, w10 changes to 0.71, w11=0.14, w12=0.14, calculation for production and consumption changes to $S_{U_{k_{afterban-airport}}} =$

$$S_{U_{k_{beforeban-airport}}} + \sum_{i=a,b,c,d} (S_{i_{water_{beforeban-airport}}})* \frac{S_{U_{k_{beforeban-airport}}}}{\sum_{j=C_U U_k} S_{j_{beforeban-airport}} + Q_{tap_{beforeban}}},$$

$$D_{U_{k_{afterban-airport}}} = D_{U_{k_{beforeban-airport}}} + \sum_{i=a,b,c,d} (D_{i_{water_{beforeban-airport}}})* \frac{D_{U_{k_{beforeban-airport}}}}{\sum_{j=C_U U_k} D_{j_{beforeban-airport}} + Q_{tap_{beforeban}}}$$

Model Evaluations

Strengths:
1.Generalized: Our model is generalized that we could apply it to all areas around the world by just changing the values we need to plug in to the model.
2.Objective: Our model is not subjective, and we did not use any information such as expressing personal opinions. Even though we do the survey to ask people's opinions to analyze whether our model is ethical or not, we choose the random sampling method to avoid the subjectivity in selecting group. We also have Analytic Hierarchy Process to find the weighing factors more objectively and effectively.
3.Justified: For every assumption, we have justifications to them by using the credible sources online. Also, all scoring index is standardized to avoid hidden weighing factors other than the AHP weighing factors.
4.Practical: Our model is practical in our daily life. All of our methods of obtaining data are achievable because we only have to investigate in the current industry and market. Since some data are too complicated such as the peculiar shapes of some plastic bottles, we simplified the model by treating them one common shape.

Weaknesses:
1.Big bottled water: We neglect the plastic big bottled water which is above 1 liter. Although we believe this does not significantly affect our calculation because this only consists of very small portion in the market, and not many people are willing to buy the big plastic bottled water since they are not very portable compared to the small bottled water. Big bottled water does exist, and some people choose to buy big water rather than the small one.
2.Additives: When analyzing the health effect brought by the ban of single-serving plastic bottled water, we only consider sugar and caffeine and neglect the other additives to the sugary drinking. Even though we justify that other additives other than sugar and caffeine will affect the health only a little, they do play a role and some of them are really harmful to human body such as edible pigment.
3. Tap Water: We believe tap water is healthy as supported by a credible source in the work sited section. However, there are also some news saying tap water has toxic chemicals that could make people sick. Our model fails to consider harms brought by tap water.

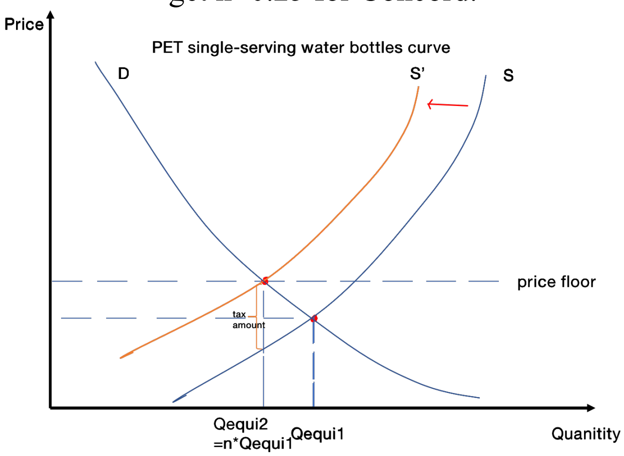
New Policy & Model Adaptation

1)New Policy Explanation:

As our model shows, although the Concord PET bottled water ban tries to reduce plastic bottles, it has the following problems: people might consume more plastic bottled beverage, which actually ended up with more PET bottles used; when people consume more plastic beverage, they intake much more sugar and additives such as caffeine, which are bad for the body. Some regions have high frequency of natural disasters, and thus water bottles seem to be necessities in critical situations. Team #9973 suggests the following PET bottles policy that could minimize the harm and maximize the benefits:

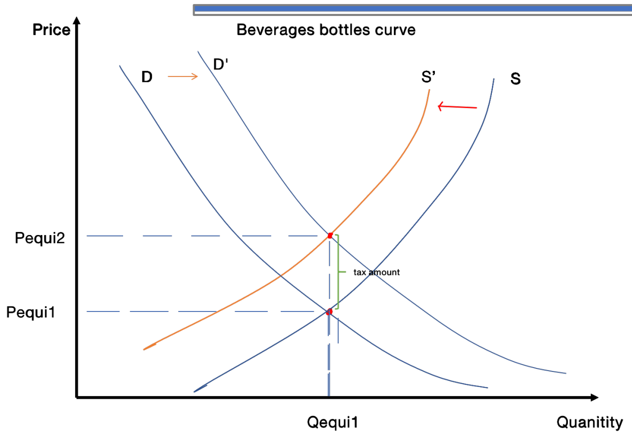
Instead of banning all PET single-serving bottled water, we will restrict quantity of PET bottled water. We denote the amount PET bottled water consumed after the policy is n times the original quantity consumption. We believe PET bottled water are necessary sometimes, and their level of necessity in a region varies based on the risk level of the natural disasters.

We denote $I_{disas} = \left| \frac{I_7 + I_8 + I_9 + I_{10}}{4} \right|$, $\begin{cases} if\ I_{disas} > 0.75, n = 0.5 \\ if\ I_{disas} \in (0.5, 0.75], n = 0.375 \\ if\ I_{disas} \in (0.25, 0.5], n = 0.25 \\ if\ I_{disas} \in (0, 0.25], n = 0.125 \end{cases}$, we could easily get n=0.25 for Concord.



Using the same methods shown in the Economic section, we treat all water bottles as the same goods. We find the S curve for water bottles using curve fitting in Matlab when we plug in year = 2008, 2009, 2010, 2011, 2012 for Concord in five different $Snew_{year-pl}$ points, where $Snew_{year-pl} = \frac{\sum_{i=a,b,c,d}(S_{i_{water\ year-pl}})}{4}$. We could use the same method to get D curve. It's logical to assume that the market is around the equilibrium before the policy as there are no major shocks in plastic bottled water. We denote the equilibrium PET bottled water quantity and price before the policy to be Q_{equi1}, P_{equi1} respectively, so the desired quantity after the policy is (n*Q_{equi1}). In order to achieve it, we set up price floor p_{floor} such that ((n*Q_{equi1}), p_{floor})is on D curve. The policy will also raise the governmental tax on producing PET water bottles so that the S curve could shift to the left and goes through the point ((n*Q_{equi1}), p_{floor}). The total tax collected could be calculated to be (p_{floor}-P_{equi1})*(n*Q_{equi1}).

Our policy will also assure that people will not consume more beverages after the water bottle ban by adding governmental tax on beverages. Using the same method (Matlab Curve fitting), we could get the S and D curve for beverages. The demand curve initially will shift to



the right, as people will substitute the loss of (1-n) * Q_{equi1} quantity of water by drinking beverages. We could calculate D' as it is a horizontal shift from D. In order to keep beverages quantity the same after our PET bottled water policy, we suggest imposing governmental tax on producers and thus shift the S curve to the left to S', which crosses D' exactly when quantity is Q_{equi1}. The total tax collected could be calculated to be (P_{equi2} - P_{equi1})* Q_{equi1}

Besides imposing price floor and production tax on PET bottled water and adding production tax on plastic beverage

bottles, we encourage the use of tap water. Research shows that tap water is healthier than plastic bottled water, and much cheaper. The price for the water filter, periodic maintenance, and 3785 Litter tap water only cost 235 dollars. In order to make sure the tap water source is protected, our policy learns from Raleigh, NC's Watershed Protection Fee to spend 90 dollars for each household so as to protect the water source. All tap water fee and Watershed Protection fee is paid as a form of governmental subsidy, which is collected by the taxation of water and beverage plastic bottles' production. The remaining governmental money (G) could be spent as a welfare state to help the poor or improve the infrastructures. We calculate the remaining governmental money to be:

$$G = (p_{floor} - P_{equi1}) * (n * Q_{equi1}) + (P_{equi2} - P_{equi1}) * Q_{equi1} - \left(\frac{((1-n) * Q_{equi1}) * \frac{\sum_{i=a,b,c,d} (v_{i_{water}})}{4}}{3.785 * 10^6 mL} * (235 + 90) \right)$$

2)New Policy Summary (for more detail, please see 1) New Policy Explanation)

a) Impose price floor and production tax on PET water bottles. Impose production tax on beverages.

b) Use the collected tax as a revenue for tap water, its filter, and water source protection fee.

c) Use the remaining money G for more welfare state to help the poor or build public facilities.

3) New Policy Strengths:

We reduce plastic water bottles amount, which are good for the environment. At the meantime, we keep the beverage amount the same, so our health will not be harmed. We also take different regions' natural disasters risk level into consideration as in some regions, plastic water bottles are more important than other regions. In addition, we generate more governmental revenue and use it for healthier tap water and welfare state.

4)Model Adaptation:

We keep our model the same except the following:

a) For the availability factor, we don't need uncontrollable factor (natural disasters) as a sub-factor because in the new policy, we already use it to decide the value of n. Therefore, we will change our AHP weighing scale. The weighing scale for population and water resources is now 0.5 and 0.5.

b) For the economy factor, Cobweb could still be applied, but for the economic gain, we now focus on macroeconomics – how the government is doing as a whole rather than microeconomics shown in our previous model to measure individual companies' profits. We keep the AHP scale for economic gain and stability the same, but for the economic gain, we now will use the remaining governmental money G. In order to standardize it, we divide it by the total production tax collected on bottled beverages and water.
c) We will remove the factor ethics, one of our Layer 1 impact. In our new policy, we partially restrict bottled water. For those people who think gaining profit on free resource like water is unjust, our policy is in-between since we do cut down unjust profit, but not entirely. It's hard to judge it ethically.
d) We will increase our economy AHP weighing scales since we now deal with macroeconomics, an entire town, city, or country's prosperity. Consequently, we modify our Layer 1 AHP scale using Matlab: economy, environment, health, availability respectively weigh 0.39, 0.39, 0.15, and 0.07.

5) Model Generality:
Our model could be generalized to larger communities such as cities, states, or countries without loss of too much accuracy. We have four AHP layer1 impacts – economy, environment, health, and availability. All impacts are weighed with justifications using AHP, and all scoring index in each factor is standardized to eliminate hidden weighing factors. The skeleton frame for our model is the same no matter what size of community we are applying to as all factors are weighed and score standardized. In order to apply it to larger communities, we just need to find the value of all our variables such as how many 16.9 oz bottled water are produced in that specific community per year as shown in the variable designation section. The methods of obtaining the data work great in a town or city, but it might be difficult when the community gets bigger such as a large state or a country. However, as we have shown in the Economy section, we could solve this problem by simplifying the model without loss of too much accuracy by treating all bottled water as one bottled water with the average volume, all beverages bottles as one beverage bottle with average volume so that we could much easily get the quantity produced and consumed for water and beverage bottles and plug them in to the standardized and weighed scoring formulas.

Conclusion

After weighing different factors contributing to the ban policy of single-serving plastic bottled water, we derive the formula to analyze the impact brought by the ban policy. If the score is above 0, then the ban's benefits outweigh the harms; if the score is less than 0, then the ban's harm outweigh the benefits. Our model is also beneficial to the future development. Since there are still many cities and towns not banning the plastic bottled water, we recommend our model to them to analyze the influence if they want to ban the plastic bottles. If the result is good for them to ban the plastic bottles, they can propose the ban policy just as San Francisco and Concord. If not, we also recommend our new policy, which aims to reduce the number of plastic bottles consuming by not banning the plastic bottles completely. Our model not only can be used to analyze the impact of plastic bottled water ban in different regions, it could also serve as an inspiration to analyze other policies objectively and comprehensively in the globe.

Appendix

1. Litter, fossil fuel, water pollution, and transportation emission AHP scale table:

	Litter	Fossil	water pollution	transportation emission
Litter	1	2	4	6
Fossil	1/2	1	2	4
Water Pollution	1/4	1/2	1	2
Transportation emission	1/6	1/4	1/2	1

2. Disasters, population, and water resources AHP scale table:

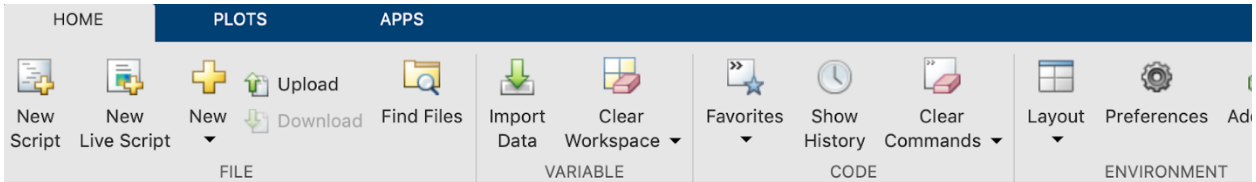
	Natural Disasters	Water Resources	Population
Natural Disasters	1	3	3
Water Resources	1/3	1	1
Population	1/3	1	1

3. Flood, storm, earthquake, and drought AHP scale table:

	Flood	Storm	Earthquake	Drought
Flood	1	3	5	5
Storm	1/3	1	3	3
Earthquake	1/5	1/3	1	1
Drought	1/5	1/3	1	1

4. Matlab AHP Calculations:

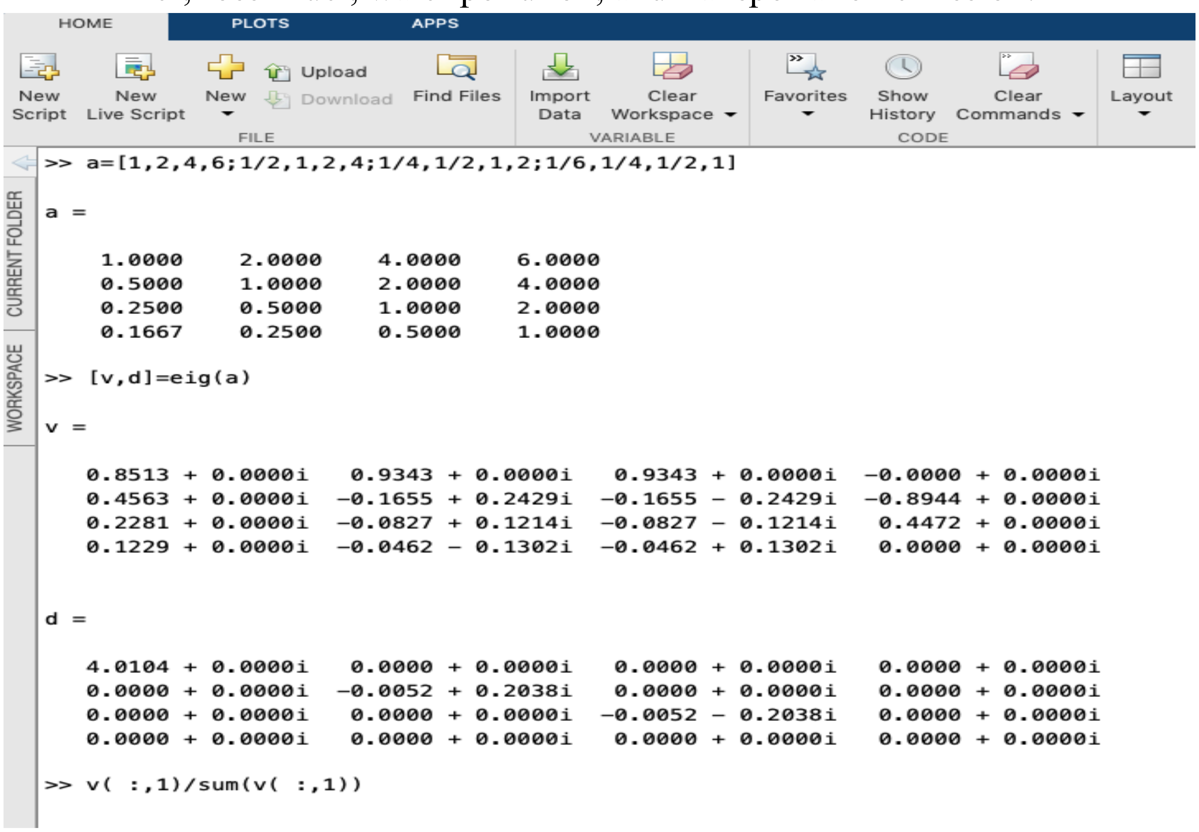
- Environment, health, availability, economy, and ethics:




```
>> a = [1,3,5,7,9;1/3,1,3,5,7;1/5,1/3,1,3,5;1/7,1/5,1/3,1,3;1/9,1/7,1/5,1/3,1]

a =

    1.0000    3.0000    5.0000    7.0000    9.0000
    0.3333    1.0000    3.0000    5.0000    7.0000
    0.2000    0.3333    1.0000    3.0000    5.0000
    0.1429    0.2000    0.3333    1.0000    3.0000
    0.1111    0.1429    0.2000    0.3333    1.0000

>> [v,d]=eig(a)

v =

   0.8630 + 0.0000i   0.8898 + 0.0000i   0.8898 + 0.0000i   0.8089 + 0.0000i   0.8089 + 0.0000i
   0.4401 + 0.0000i   0.1434 + 0.3661i   0.1434 - 0.3661i  -0.3976 + 0.2926i  -0.3976 - 0.2926i
   0.2170 + 0.0000i  -0.1454 + 0.1379i  -0.1454 - 0.1379i   0.0384 - 0.2695i   0.0384 + 0.2695i
   0.1067 + 0.0000i  -0.0909 - 0.0371i  -0.0909 + 0.0371i   0.0800 + 0.1312i   0.0800 - 0.1312i
   0.0561 + 0.0000i   0.0073 - 0.0610i   0.0073 + 0.0610i  -0.0539 - 0.0353i  -0.0539 + 0.0353i


d =

   5.2375 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0258 + 1.1004i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0258 - 1.1004i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.1446 + 0.1623i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.1446 - 0.1623i
```

```
>> eig(a)

ans =

   5.2375 + 0.0000i
   0.0258 + 1.1004i
   0.0258 - 1.1004i
  -0.1446 + 0.1623i
  -0.1446 - 0.1623i

>> v( :,1)/sum(v(:,1))

ans =

    0.5128
    0.2615
    0.1290
    0.0634
    0.0333

>>
```

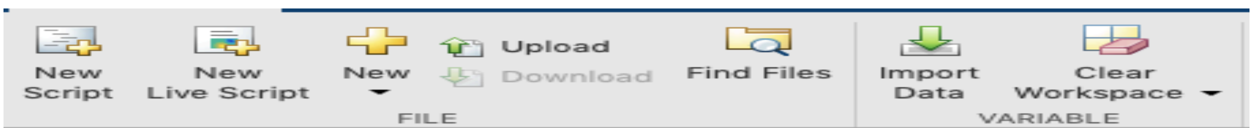
- Litter, fossil fuel, water pollution, and transportation emission:




```
>> a=[1,2,4,6;1/2,1,2,4;1/4,1/2,1,2;1/6,1/4,1/2,1]

a =

    1.0000    2.0000    4.0000    6.0000
    0.5000    1.0000    2.0000    4.0000
    0.2500    0.5000    1.0000    2.0000
    0.1667    0.2500    0.5000    1.0000

>> [v,d]=eig(a)

v =

   0.8513 + 0.0000i   0.9343 + 0.0000i   0.9343 + 0.0000i  -0.0000 + 0.0000i
   0.4563 + 0.0000i  -0.1655 + 0.2429i  -0.1655 - 0.2429i  -0.8944 + 0.0000i
   0.2281 + 0.0000i  -0.0827 + 0.1214i  -0.0827 - 0.1214i   0.4472 + 0.0000i
   0.1229 + 0.0000i  -0.0462 - 0.1302i  -0.0462 + 0.1302i   0.0000 + 0.0000i


d =

   4.0104 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i  -0.0052 + 0.2038i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.0052 - 0.2038i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i

>> v( :,1)/sum(v( :,1))
```

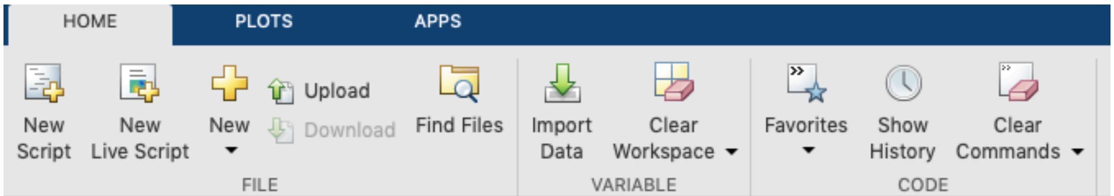
```
ans =

    0.5132
    0.2751
    0.1376
    0.0741
```

- **Natural Disasters, Population, and water resources:**



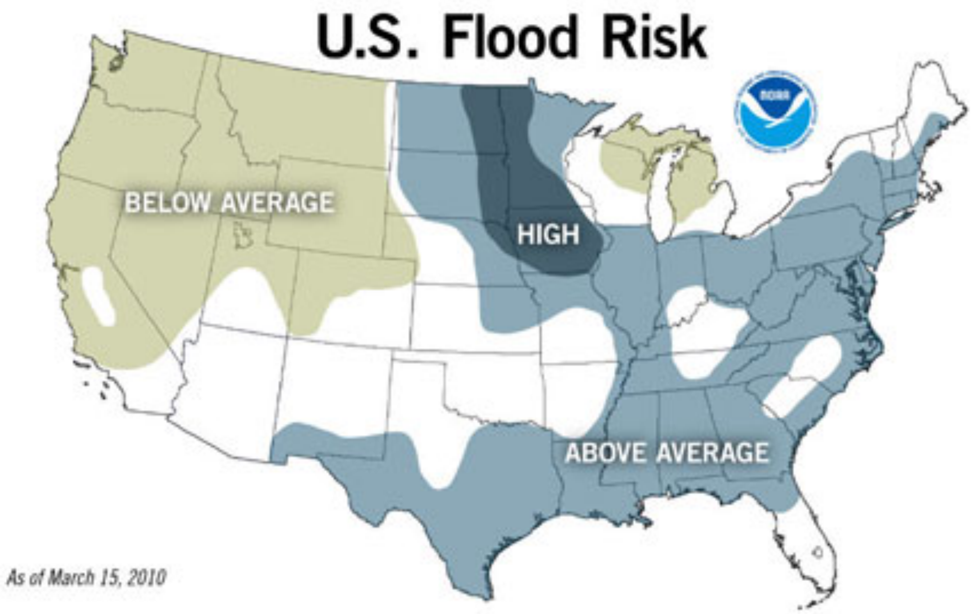

```
>> a= [1,3,3;1/3,1,1;1/3,1,1]

a =

    1.0000    3.0000    3.0000
    0.3333    1.0000    1.0000
    0.3333    1.0000    1.0000

>> [v,d]=eig(a)

v =

   -0.9045    0.0000   -0.8748
   -0.3015   -0.7071   -0.1642
   -0.3015    0.7071    0.4558


d =

    3.0000         0         0
         0   -0.0000         0
         0         0    0.0000

>> v( :,1)/sum(v( :,1))

ans =

    0.6000
    0.2000
    0.2000
```

- **Flood, storm, earthquake, drought**

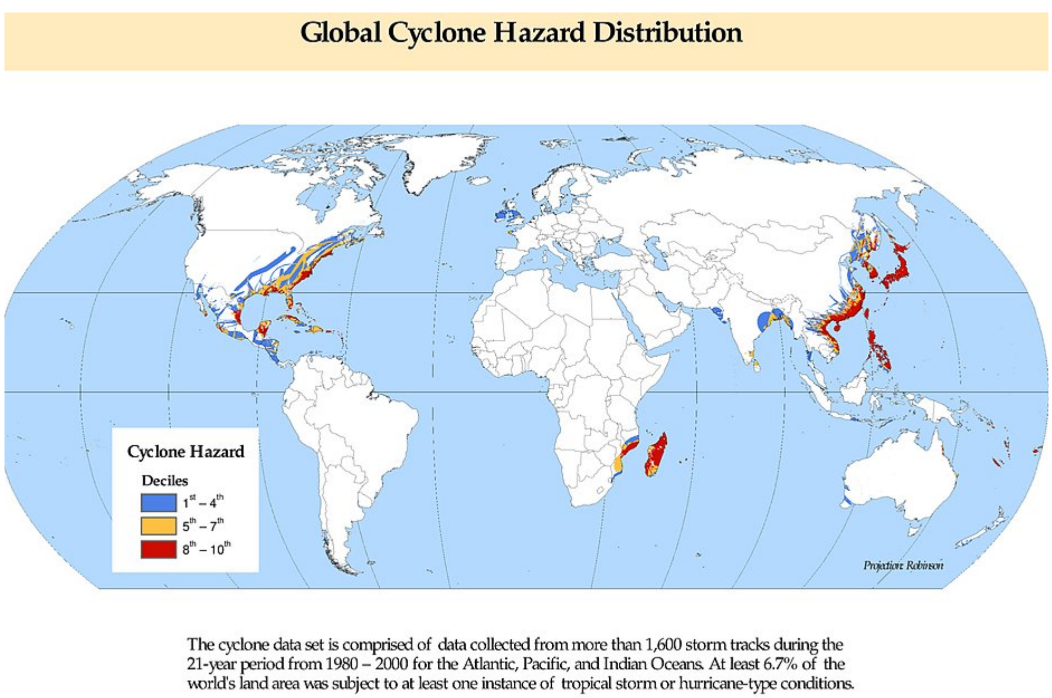



```
>> a= [1,3,5,5;1/3,1,3,3;1/5,1/3,1,1;1/5,1/3,1,1]

a =

    1.0000    3.0000    5.0000    5.0000
    0.3333    1.0000    3.0000    3.0000
    0.2000    0.3333    1.0000    1.0000
    0.2000    0.3333    1.0000    1.0000

>> [v,d]=eig(a)

v =

   0.8919 + 0.0000i   0.9128 + 0.0000i   0.9128 + 0.0000i  -0.0000 + 0.0000i
   0.3977 + 0.0000i  -0.1314 + 0.3654i  -0.1314 - 0.3654i   0.0000 + 0.0000i
   0.1522 + 0.0000i  -0.0538 - 0.0714i  -0.0538 + 0.0714i  -0.7071 + 0.0000i
   0.1522 + 0.0000i  -0.0538 - 0.0714i  -0.0538 + 0.0714i   0.7071 + 0.0000i


d =

   4.0435 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i  -0.0217 + 0.4188i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.0217 - 0.4188i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i

>> v( :,1)/sum(v( :,1))

ans =

    0.5596
    0.2495
    0.0955
    0.0955
```

5. Flood Map:



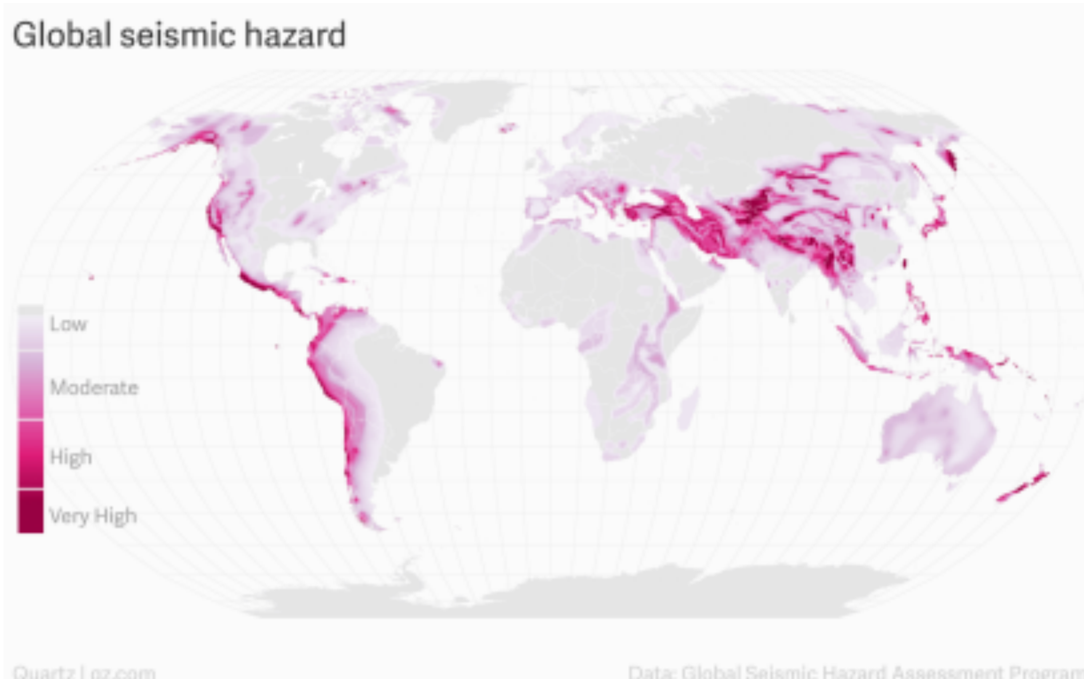
6. Storm Map:



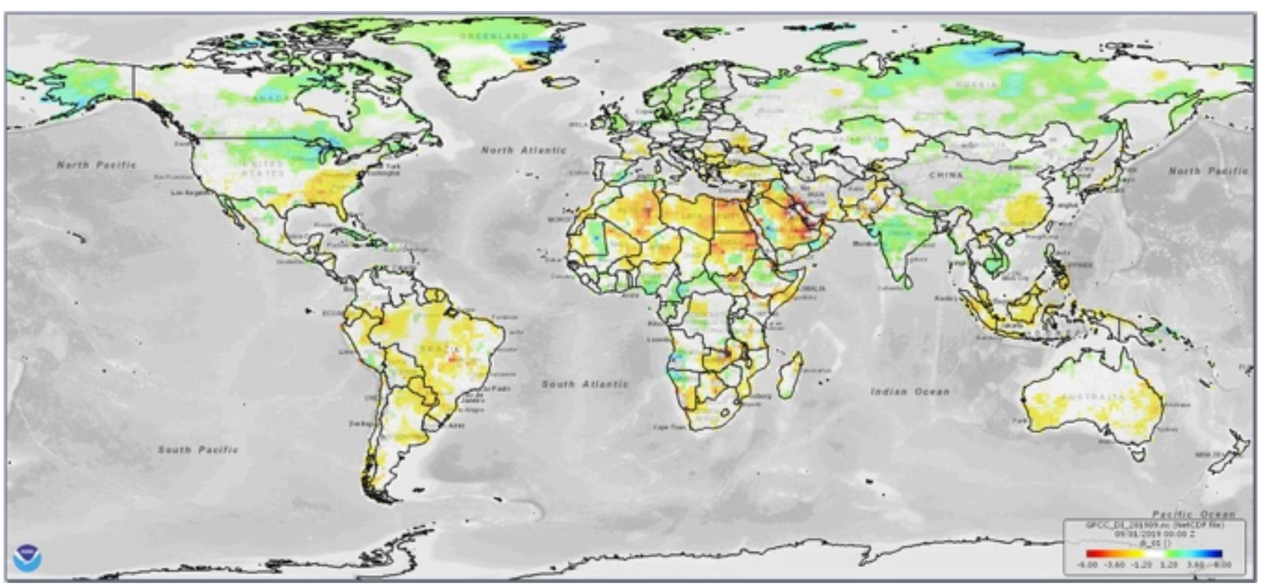
Global Cyclone Hazard Distribution

Global seismic hazard distribution

7. Earthquake:



8. Droughts:



9.Water Resources

Analysis of the Surface Drinking Water Provided By Intermittent, Ephemeral, and Hea
Completed by U.S. EPA in July 2009

The objective of this study is to illuminate regional patterns of dependence on intermittent, ephemeral and headwater strean surface drinking water systems in the continental United States. This was accomplished by analyzing the stream types foun SPA is the area upstream from a drinking water intake that provides water to a public drinking water system during a 24 ho population, based on county. The percent of streams in SPAs that are I/E/H was calculated by determining the proportion c contained in the mapped SPAs for each geographic unit. "Total Population Served" is the sum of all populations served by unit whereas the "Population Dependent" includes only populations for those systems fed by SPAs containing I/E/H waters Data Sources: National Hydrography Dataset at medium resolution and the Federal Safe Drinking Water Information Syste

State	Total Population Served by Public Drinking Water Systems using surface water	Population Dependent on Public Drinking Water Systems relying on I/E/H	% Population Dependent on Public Drinking Water Systems relying on I/E/H	Total stream Miles in Source Protection Areas	Miles of Intermittent /Ephemeral /Headwater in SPAs	% of streams in SPAs that are Intermittent /Ephemeral /Headwaters
TOTAL	**124,364,960**	**117,447,743**	**94%**	**357,403.5**	**207,476.4**	**58%**
AL	2,705,859	2,681,327	99%	10238.8	5,552.2	54%
AR	948,185	941,225	99%	7854.0	5,088.7	65%
AZ	3,254,601	3,254,601	100%	8101.3	6,381.3	79%
CA	7,320,360	7,314,715	99.92%	32688.3	18,592.2	57%
CO	3,866,332	3,772,743	98%	16894.9	10,509.9	62%
CT	2,241,030	2,241,030	100%	1431.9	844.8	59%
DE	281,400	281,400	100%	344.4	183.6	53%
FL	1,808,955	1,808,955	100%	2597.7	580.2	22%
GA	4,918,344	4,912,944	99.89%	9897.6	5,557.1	56%

10.Get Polynomial Degree n using Matlab:

```
for i=1:5
y2=polyfit(x,y,i);
Y=polyval(y2,x);
if sum((Y-y)^2)<0.1
c=i
break;
end
end
```

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