Problem B: Bottle Battles

2019 Team #9538

Summary

Towns and regions across the country have enacted bans on water bottles. Concord, Massachusetts was the first to take action against the rise in plastic waste and pollution. The town banned the sale of single-serving Polyethylene terephthalate (PET) water bottles less than one liter (34 oz) in size in order to address such issues. However, people who oppose the ban believe that the unintended consequences far outweigh the benefits that Concord is striving for. Our job was to determine the advantages and disadvantages of each side and create a model to measure the impact of the ban, which includes both positive and negative components, and to use that model to make recommendations on how to obtain an optimal situation.

Our method was to first consider what variables affected the situation, and then to analyze the importance of each variable. The ones that we deemed to be the most important through researching the process the recycled PET goes through and the process by which wasted PET goes through. Basing our model off of this research, we were able to develop equations to measure the environmental impact, the amount of money paid for the processes, as well as the cash flow of stores and airports in bigger cities. The outcomes of these equations , such as the percentage of plastic produced that is going to be wasted, the amount of money, and whether the amount of money stores and airports receive after the ban is greater than or less than the amount of money the received before the ban, all of which leads to the conclusion on whether or not a ban on PET plastic water bottles is indeed beneficial to the town/city/region or not. We had to consider ways that not only local stores were affected but also consider consumers who would be affected by inflated prices of big water bottles as well as an increase in additives in drinks. Consumers also consisted of people in high needs areas and people in emergency situations where their well being and need for water bottles had to be considered.

Once we were able to develop the model we then applied our model to the towns of Concord and San Francisco as Concord had plenty of stores as well as some high needs areas in which we could determine the frequency of water bottles that would be allowed. For San Francisco, we could use the airport as a way to monitor the cash flow as well as to see if our model could apply to bigger cities around the world.

Article

As concerns for pollution and its effects on the environment grow, communities across the globe are beginning to take action against issues such as plastic waste. Single-serving plastic water bottles are among the primary targets of such action. To address issues concerning plastic waste in the form of single-serving PET water bottles, some areas in the United States, notable Concord, MA (the first US town or city to enact a ban on PET water bottles) and San Francisco, CA (the largest US city to comply with a PET water bottle ban).

Water bottle bans like the one Concord has issued have potentially positive and negative impacts. Impacts can be considered from both monetary and environmental perspectives.

For bottle production companies, the financial impacts are extremely important to consider as they have the most immediate impacts on the company. Companies could lose money because they are unable to sell PET water bottles that they have already poured money into manufacturing. As the number of communities with bans on single-serving PET water bottles grows, the demand for PET water bottles lessens. Water bottle production companies will lose money from this lessened demand and should be careful to avoid further losses by not overproducing water bottles.

This caution should also be practiced by businesses selling water as well. If communities ban PET water bottles, stores in those communities will have to get rid of existing stock. In transition periods of adopting such bans, it is recommended that stores do not continue to stock up on PET single-serving water bottles. It would be in their best interest to sell as much of their existing stock as possible and replenish their supply immediately with bottled water that complies with the communities regulations for the ban. Finding water alternatives for PET bottled water will be more difficult for consumers when bans go into place. Local businesses stocking ban-complying bottled water will be helpful for consumers.

As with any issue that has potential environmental impacts, the effects of single-serving PET water bottle bans on the environment need to be carefully considered. Plastic waste is a key issue today. The aim of water bottle bans and other types of bans that hope to be plastic-reducing is, of course, to lower the negative consequences everyday products like water bottles have on the environment. If a ban does not decrease plastic water bottle waste, the ban may not be effective. In this case, it might make sense to just not have a ban at all. To measure this, communities should take close looks at the amount of waste they are sending to landfills and recycling both before and after enacting a ban. A trial period where factors like these can be considered is recommended.

In trial periods for bottle bans, communities should be monitoring and keeping track of positive and negative impacts. If the positive impacts are deemed to outweigh the negatives, the community should keep the ban in place. If the negatives are more plentiful, the ban should be undone. Some important factors to consider are the aforementioned environmental and monetary impacts.

For any communities considering enacting a ban on single-serving PET plastic water bottles, weighing the impacts the ban will have on your community and the world around is the most important thing to do.

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Introduction

Around the world, many communities have begun to focus on reducing plastic waste through the enactment of water bottle bans. The bans target the sales of single-serving PET water bottles specifically. PET, also known as Polyethylene terephthalate or PETE, is a synthetic, lightweight plastic that is mostly used in packaging and fabric making (cite). Bans on plastic water bottles, like Concord, Massachusetts' 2013 bylaw, tend to prohibit the sale of PET water bottles containing a liter or less of plain water. Drinks such as sparkling water, juices, and sodas are not prohibited.

Such bans have stirred discussion among the opposition. Some argue that plastic water bottle bans have the potential to be harmful in the event of a natural disaster or in areas with little access to fresh water. In addition, organizations such as the International Bottled Water Association (IBWA) have concerns that bans may increase the use of additives to plastic-bottled beverages. The bans may also cause an increase in the amount of packaging used by water bottle companies, thereby causing detrimental environmental effects.

Despite these concerns, communities across the United States continue to join Concord, MA in the prohibition of single-serving water bottles. Notably, the city of San Francisco as well as the San Francisco airport, SFO, have both banned the sale of single-serving plastic water bottles on city property and within the airport, respectively.

Problem Restatement

The goal is to model the positive and negative impacts of the water bottle ban and apply the model to locations such as Concord and San Francisco. Then, develop a model displaying the impacts on airports and identify similarities and differences between the model for town/cities and the model for airports. Use these models to adjust the ban in maximize positive impacts and reduce overall negative impacts and write an article discussing these findings.

Givens

- 1 liter = 34 ounces
- The ban was of the selling of single serving, Polyethylene terephthalate bottles, that were less than 1 liter in size, containing water
- San Francisco also enacted a ban, and San Francisco Airport complied
- The International Bottled Water Association is against these bans

Assumptions

- No one is providing free small PET plastic water bottles
- All plastic considered is PET

- All plastic waste considered is generated by water bottles (assumed this when finding model data)
- PET plastic water bottle is the same in towns, cities, and airports

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Models

Goals and Concept

Our main goal was to develop a widely applicable model that addressed at least one positive and one negative impact of PET water bottle bans. To do this, we tried to account for two types of impact: environmental impact and monetary impact. These two divisions were further split into impact on water bottle production and recycling companies and consumers.

Positive Impacts

Some potential positive impacts of PET water bottle bans include the reduction of plastic waste and pollution, including the emission of fossil fuels and emissions for product transportation. Bans also encourage consumers to seek alternatives to PET water bottles that may be more environmentally friendly, and businesses no longer profit as much from the sale of water, a free resource.

Negative Impacts

While PET water bottle bans bring many positive impacts, they come at the cost of some negative impacts on the environment and communities with little to no access to water. The material PET water bottles are made from allows for companies to reduce both the amount and cost of packaging water bottle products. Bans on single-serving PET water bottles may force companies to resort to using even more packaging, which becomes increasingly difficult to recycle the more there is. Because the ban targets plain water, some companies may also want to include more additives in their products to circumvent this rule. In addition, bottled water is a necessary and critical resource in areas of the world that do not have accessible freshwater sources. Bottled water may also become essential in the case of an emergency situation that compromises the quality and/or availability of freshwater.

Information Needed

- Environmental Impact
- Amount of waste/pollution produced before and after a ban
- Find data on the amount of waste before the ban
- Find data on the amount of waste after the ban
- Effects on local stores

- How will their cash flow be affected before and after a ban
- How much the stores paid production companies before and after the ban
- What the monthly income was of the average store before and after the ban
- Number of customers
- What will their prices become after the ban
- Understand the average pricing for different sized water bottles
- Understand how impacted the stores would be by taking away any bottles less than 34 oz
- How the prices were affected after the ban
- Effects on airports
- How will their cash flow be affected before and after a ban
- Regular pricing of water bottles in airports
- How much airports paid production companies
- How the prices were impacted after the ban
- Production and Recycling Impacts
- How much will both of these processes cost before and after the ban
- Pricing of new materials
- Price of increased recycling process

Model I

Variables

I_E - Environmental Impact
I_{MT} - Monetary Impact of Town
S_P - Solid Waste Produced
S_R - Solid Waste Recycled
L_P - Liquid Waste Produced
L_R - Liquid Waste Recycled
G_P - Gas Waste Produced
G_R -   Gas Waste Recycled
M_P - Money Spent in Production
M_R - Money Spent in Recycling
P_B - Money Stores Gave to Production Companies Before the Ban
P_A - Money Stores Gave to Production Companies After the Ban
B_B - Number of Bottles sold before the Ban
B_A - Number of Bottles sold after the Ban
B_S - Number of Small Bottles sold before the Ban
D_B - Pricing of Bottles before Ban

D_A- Pricing of Bottles after Ban
D_S- Pricing of Small Bottles after Ban

Formulas

These are the models taking into consideration the positive impacts
Net Cost of Economy of a Town
MIT = MP + MR = Amount of Money Spent
Cash flow of Stores and Airports
BA*DA - Total Prices of all Bottles and Sizes sold after the ban
BB*DB - Total Prices of all Bottles and Sizes sold before the ban
BS*DS - Total Prices of all Bottles for Small Sizes sold before the ban
The cost for consumers after the ban should be less than or equal to the cost before the ban.

$$\sum B_A \times \sum D_A - P_A \geq \sum B_B \times D_B - \sum B_S \times D_S - P_B$$

Environmental Impact

$\Delta S = S_P - S_R$ = amount of solid waste going into the environment
$\Delta L = L_P - L_R$ = amount of liquid waste going into the environment
$\Delta G = G_P - G_R$ = amount of gaseous waste going into the environment
$I_E = \frac{\Delta S + \Delta L + \Delta G}{S_P + L_P + G_P}$ = percentage of waste produced added into the environment

Net Cost of Economy of a Town

This is the amount of money spent by towns.

$$I_{MT} = M_P + M_R$$

Cash Flow of Stores and Airports

Total cost of all-sized bottles sold before the ban: $B_A \times D_A$
Total cost of all-sized bottles sold after the ban: $B_B \times D_B$
Total cost of small-sized bottles sold after the ban: $B_S \times D_S$

$$B_A \times D_A - P_A \geqslant B_B \times D_B - B_S \times D_S - P_B$$

Model II

Variables

Before the ban:
G_I - Waste Generated
R_I - Waste recycled

C_I - Waste Combusted with Energy Recovery

L_I- Average Amount of Waste Sent to a Landfill

After the ban:

G_F - Waste Generated

R_F - Waste Recycled

C_F- Waste Combusted with Energy Recovered

L_F- Average amount sent to landfill

Formulas

If $L_I \div G_I \geqslant L_F \div G_F$, the ban has a positive impact

If $L_I \geqslant L_F$, then there is also a positive impact

Model Results

Towns and Cities

Concord, MA

To apply our model to the town of Concord, Massachusetts, we planned on using data to plug in to our formulas. We planned on doing this for both the environmental impact and the monetary impact. We ultimately decided not to plug in data on the town level, but a national scale instead. However, for Concord we reasoned that the environmental impact would not be very high due to the town's small size and population. The monetary impact on an individual would be comparable to the impact on an individual anywhere in the nation with the same ban.

San Francisco, CA

Like with Concord, we did not plug in any data from San Francisco into our model. We also reserved this for comparison across the nation. The monetary impact on an individual would likewise be comparable to the impact on an individual from Concord or other places in the United States, but the overall environmental impact of such a ban would be much greater due to the size of the city and population alone.

Nationwide

United States

Using the data researched, we determined that 24% of plastic nationwide goes to landfills and is not recycled. Annually, the cost of recycling and the cost of producing new PET materials is $6 billion (see Appendix B). Banning single-serving PET plastic water bottles can be considered beneficial if the

amount of plastic going to landfills (the environmental impact) and price of bottled water (the monetary impact) are minimized according to out model. Looking at both the environmental and monetary impacts is how we decided to determine whether or not a ban would be beneficial.

Airports

SFO

The analysis of data using our method for the San Francisco International Airport was similar to those of Concord and San Francisco. In 2017, SFO served 55.8 million passengers [5]. Assuming passenger traffic through SFO was even throughout the year, an estimated 152,877 travelers passed through SFO on any given day. This figure is between the populations of Concord and San Francisco, so it makes sense to apply the same model.

The San Francisco International Airport has not only banned PET bottled water less than one liter in size, but also discontinued its sales of water bottles larger than one liter. The combination of the ban and decision not to sell large bottles of water has significantly reduced consumer options for bottled water in the airport. This has led to a loss of approximately $40.6 million [#].

Model Pros and Cons

Strengths

Our model addresses both the monetary and environmental impacts of the PETE single-serving water bottle ban. We deemed it important to focus on both of these types of impacts because simply making decisions with the consumer in mind has potentially detrimental consequences for the environment. In addition, it allowed us to account for different types of waste. We dealt with waste and pollution entering the environment in different states of matter, accounting for different types of impacts on the environment. We also approached extra money consumers would need to spend on non-PET water bottles as a type of waste.

The model itself is straightforward, making it easily scalable. The model can be applied to a small community, like a school system or town, or a larger community like a major city or state.

Weaknesses

Our current model does not account for waste in terms of pollution and money, but not time. Wasted time, whether it be during the production process or the extra drive consumers must make for single-serving water bottles outside of their town/city, is an important factor in decision making for bans. We also did not account for the cost of offering free PET water bottles. A business may give away free PET water bottles, given that they do not ask for voluntary donations, which would cause them to lose money. Because there is no cost attached to such water bottles, our model cannot track them. Finally, our model only focuses on the amount of waste going out into the environment. It does not

address the effects that this waste will have once out in the environment.

Discussion

Changes to Concord Bylaw

We decided that no major changes needed to be made to Concord's water bottle bylaw. However, we do have a list of recommendations for the town in regards to the sale of single-serving PET water bottles.

To start, the town should encourage businesses to purchase and sell water bottles that are made from environmentally friendly materials. Doing so will provide production companies with the incentive to produce more environmentally friendly products. In addition, local stores will be able to make more revenue if they sell alternatives to PET water bottles rather than not having other options. The importance of selling water bottles with amounts of additives comparable to amounts before the ban should also be emphasized to business owners.

The ability to sell PET water bottles up to one week after an emergency or natural disaster has ended is an important part of the bylaw that should remain unchanged. Extensions of this grace period should be made on a case by case basis decided jointly by the town government and its citizens. If there are areas in Concord deemed high needs, the town should reevaluate the ban. In the case of areas being deemed high needs, it would make sense for the town to set maximum prices on water bottles or to provide exceptions to high needs individuals. This is a process that would need to be handled by the town.

(see Appendix B)

New Model

For large cities, states, and regions, our model is applicable. The populations of such communities are small enough that a committee could reasonably manage the ban and violations relating to the ban. As the scope gets larger, however, the model becomes less and less applicable. Countries, continents, or the world as a whole would be difficult to manage because of the amount of resources management would require. A management team or council might not be able to provide the attention to detail necessary to hold bottle productions to the proper standard. It would also be extremely difficult to efficiently act in emergency situations if the committee was spread too thin. High Needs areas would also likely not receive the attention they need for access to freshwater.

References

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[6] Slotnick, David. "Plastic Water Bottles Are Banned at San Francisco Airport Starting This Week - Here's What You Need to Know." Business Insider, Business Insider, 20 Aug. 2019, https://www.busi-nessinsider.com/plastic-water-bottle-airport-ban-san-francisco-sfo-2019-8.

Appendices

Appendix A

1960-2017 Data on Plastics in MSW by Weight (in thousands of U.S. tons)

Management Pathway	1960	1970	1980	1990	2000	2005	2010	2015	2016	2017
Generation	390	2,900	6,830	17,130	25,550	29,380	31,400	34,480	34,870	35,370
Recycled	-	-	20	370	1,480	1,780	2,500	3,120	3,240	2,960
Composted	-	-	-	-	-	-	-	-	-	-
Combustion with Energy Recovery	-	-	140	2,980	4,120	4,330	4,530	5,330	5,340	5,590
Landfilled	390	2,900	6,670	13,780	19,950	23,270	24,370	26,030	26,290	26,820

Plastic Waste Management: 1960-2017
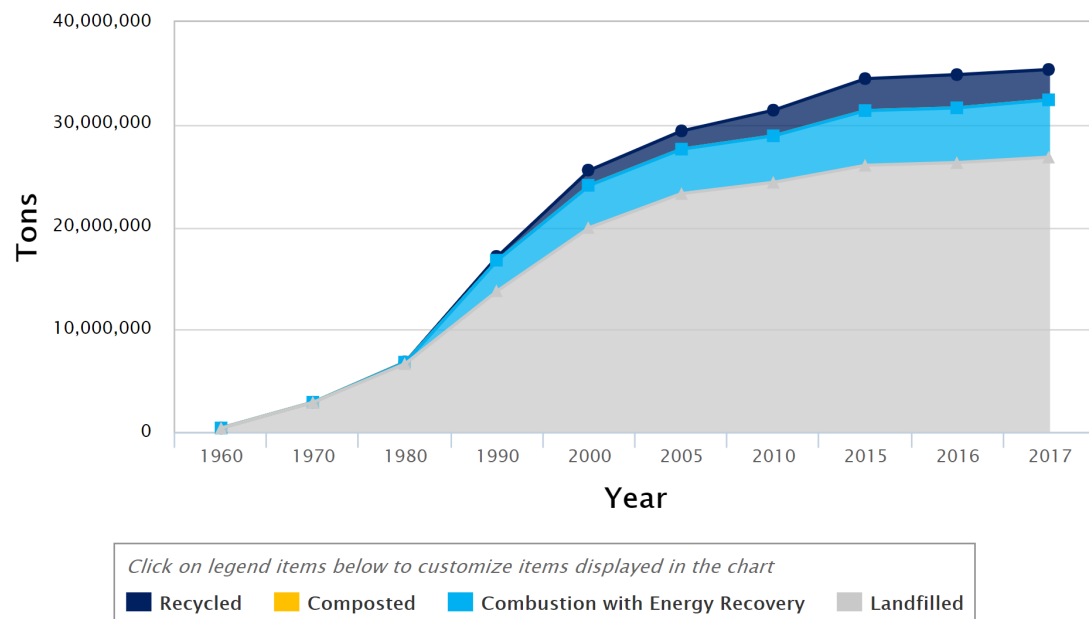
Appendix B

Math for Concord Bylaw Changes

$I_E = \frac{\Delta S + \Delta L + \Delta G}{S_P + L_P + G_P} = \frac{\Delta \text{Work}}{\text{Total Work}}$

$= \frac{50 \text{ billion} - 38 \text{ billion}}{50 \text{ billion}} = 24\%$

This is the amount of plastic waste diverted from landfills.

$I_{MT} = M_P + M_R$

= 4.5 billion + 1.5 billion = 6 billion

$6 billion is the amount of money spent nationwide in this process.

Math for Airport Model

$B_B \times D_B$ is the money lost.

= 28 million tons × $1.45 = $40.6 million dollars.