HiMCM Summary Page
Team Number: #9535
Problem Chosen: A

Summary

Many public spaces offer ‘free’ charging stations for smartphones, laptops, and electric cars. Before the rise of smartphones, having freely available electrical sockets was not a big deal for malls, airports, or cafes, as many people didn’t have portable electronic devices to charge while on the go. However, with more people owning and using portable electronic devices every year, the strain on the public spaces providing free charging stations will likely increase. The question is also raised of the potential of initiatives to decrease the resulting increase of electricity costs.

In order to determine the total cost for a day of use, three electronic devices were considered for their energy use while charging: smartphones, laptops, and electric vehicles. The method for calculating the total cost for charging a device was based on the average amount of people who go to the specific public place, the amount of time each person charges a device for, the power that each device uses while charging, and the price of electricity. These data points were researched and put together for three different types of public spaces: malls, airports, and cafes.

The model showed that the cost of charging station electricity for malls would increase from $2985.44 in 2019 to $8407.64 in 2023, the cost would increase from $976,676.55 to $1,191,622.50 for airports, and from $2489.89 to $3426.72 for cafes.This resulting increase is not surprising, as smartphone and electric vehicle ownership is projected to increase over the next few years. Alternative energy initiatives were explored, but were determined to be too ineffective to be implemented. An article explaining the findings and recommendations was written for the school newspaper in a concise and easy-to-understand manner.

Article

GOOD MORNING STUDENTS! Welcome back to another edition of Team 9535 News. Often in facilities, there are public charging stations, where customers can charge their electronics for free. In recent years, the number of these charging stations have been increasing. However, does the increase of free public charging stations result in significantly higher costs?

There are various public facilities, but three common public facilities that were focused on were malls, cafes, and airports. In this technology driven world, people often bring their phones and laptops, so many of them need to charge their devices. The average person would have one phone and one laptop to charge.

Assumptions
About 81% of people in the US own a smartphone, and around 60% of people own a laptop. In addition, there is an increasing number of people that drive electric cars, and there are charging stations for those. About 0.4% of people in the US drive an electric car. There are around 1,200 people visiting each mall, around 168,000 people going to each airport, and around 476 people going to each cafe daily. Phones drain around 0.006 kiloWatts per hour and laptops drain 0.065 kiloWatts per hour. The rate that car chargers charge cars is not important for this question because electric cars will charge all the way, meaning it will drain the same amount of electricity regardless of the rate it charges at. The amount of time people spend charging their phone could be 16.25 minutes at the mall, 3 hours and 20 minutes at an airport, and 3 hours at a cafe. Lastly, the price of electricity is on average $0.11 kiloWatt.

Final costs
Putting these numbers into the mall equation gives the total cost of running these stations at a mall is $2985.44. At an airport, plugging the numbers into the airport equation gives a total cost of $976,676.55. At a cafe, plugging the numbers into the cafe equation gives a total cost of $2489.89. These numbers are not that large, and only constitute a small fraction of what the company makes.

Initiatives
However, there can be steps taken to reduce the cost to run these charging stations. One option is to buy electricity from other sources. If the power came from solar panels, then it would cost $8.19 to charge 1 phone per day. This is not efficient, so another alternative to look at are Piezoelectric flooring. These are tiles on a floor that generate electricity when people step on them. But these tile are expensive; it costs over $2 million to install these tiles for a standard size mall, and the cost to maintain the charging stations is only around $8,400. Another potential green solution is to use wind power, which only costs 8.2 cents to generate 1 kiloWatt. This equates to around 0.22 cents to charge 1 phone per day, which is better. However, the best source of energy comes from natural gas, which costs just 0.17 cents to charge 1 phone per day. The downside is that natural gas is non–renewable and contributes to climate change

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Introduction

As the world grows more connected due to the never-ending human march towards technological progress, the need for quick, efficient, and convenient charging increases as well. Many public places, including malls, cafes, and airports, are installing ‘free’ charging stations for phone, electric cars, and other electronic devices.

From 2010 to 2019, the number of smartphone users in the United States rose from 62.6 million to 256.9 million people. This rapid growth of portable electronic devices means leads to a greater need for electricity to charge on the go. Along with the slowly increasing electricity prices, charging requirement for public places will certainly be increasing as time goes on. Electric car ownership has also been increasing with time. The Edison Electric Institute predicts that by 2030, there will be more than 3.5 million electric vehicles sold in the United States. As more new, trendy, and portable technologies are created and become mainstream, such as smart watches, the desire for more ways and places to plug in will only increase.

Impacts and Requirements

Upon installing new charging stations, not only do malls, airports, and cafes need to pay for the redesign of the public space, new charging technologies, and for the electricity itself, but also high volatile fees. In order to compensate for money spent to provide ‘free’ electricity to the public, the charging services must provide some benefit to the establishments that install them. Having freely available Wi-Fi, charging stations, outlets, and electric car chargers increases the number of patrons brought to these places, the amount of time they stay, and how often they frequent the establishments. More expensive phone charging stations have better software that allows the station to steal user information. This information can be used to send directed advertising even after the users unplug, which can lead to more money spent in a mall or other shopping center.The goal of this problem is to model the costs of an increased usage of publicly available free electricity.

Problem Restatement

Model the costs for increased demands and energy usage in public places using the established impacts and requirements. Different types of electronic devices are used in different locations. For example, one is more likely to pull out their laptop and do homework while sitting in a coffee shop compared to a mall. The electricity that is used to charge these devices in public spaces is widely free for the user, however the companies that control the charging stations and outlets still have to pay for the electricity used.

Assumptions

Assumption 1: Each person that owns a smart phone/laptop will charge their smart phone at the public station.
Reasoning: Everyone is usually in the need to charge their phone while on the go.

Assumption 2: Everybody that goes to a Mall charges their devices (one laptop and one phone) at a free outlet.
Reasoning: Some people never charge many devices while other people charge a lot of devices.

Assumption 3: The number of people that will charge a laptop at a mall is 0.
Reasoning: Most people at at Malls do not stay in one place for too long, meaning that they probably would not charge something larger like a laptop.

Assumption 4: The number of people that will charge an electric car at a cafe is 0.
Reasoning: Most cafes do not have chargers for electric vehicles, and they are not a large as malls.

Assumption 5: The power needed to charge a phone,a laptop, or an electric car is constant for all phones, laptops, or electric cars respectively.
Reasoning: Different phones, laptops, and electric cars have different charge times, even amongst the same type of phone. Giving a constant charge time with an average will be accurate and keep the problem simpler.

Assumption 6: At a cafe, users will charge both their laptop and phone for the entire time they're there.

Reasoning: Users that stay at a cafe typically stay there for enough time to charge multiple devices, such as a phone and a laptop.

Assumption 7: At an airport, users will charge both their laptop and phone for the entire time they're waiting at the terminal.
Reasoning: Typically, people at airports have to wait for their flights, giving them enough time to charge multiple devices, such as a phone and a laptop.

Assumption 8: The price of electricity per kWh is the same for all locations and items being charged.
Reasoning: Different states and areas can have different electricity prices, so getting an average price of electricity will keep the data accurate and the problem simpler.

Assumption 9: The commercial price of electricity has plateaued a $0.11 per kWh.
Reasoning: The group could not find any reliable sources for the expected change in price, so the current price of $0.11 per kWh was assumed to remain the same.

Assumption 10: While at a mall, one will be charging their phone for 1/8th the total time they are there.
Reasoning: The group could not find any reliable sources to determine how long people charge their phones at an airport,

Model

Approach

The price of a given public areas electricity consumption is equal to the sum of the total costs to charge each type of device, which in this case are determined to be smart phones, laptops, and electric cars. To find how much money it would cost for one day of average usage, the total amount of time electricity is used for is multiplied by the rate of electricity used by the device charger, and then is multiplied by the price of electricity. The cost of charging for malls, airports, and cafes will be calculated for today an into the future, taking into consideration the projected changes over the coming years.

All data gathered was from United States in order to keep numbers consistent. Information on current electricity prices, usage, and human traffic through public places, along with trends on how these values will be increasing or decreasing over time was gathered from online resources. Some information was readily available, such as the current price of commercial electricity and how that number has been fluctuating and growing over time. Some information, however, was not as readily available, such as the average amount of time someone spends inside of a cafe. Data points such as these had to be assumed from firsthand experience and accounts from opinion sites such as Quora.

General Model

The general formula is: $C = S\,n\,t\,e_i\,p + L\,n\,t\,e_l\,p + n\,V\,t_v\,e_v\,p$

In words, this says that the total cost of free charging for a day is equal to the percent of people who own a smart phone, times the number of people that are at the public place time, times the time each person charges there phone for (in hours), times the power used to charge their phone (in kW), times the price of electricity. Then same calculations are repeated for lap-tops. For electric vehicles, the total number of people was multiplied by the percent of people that own electric cars to find the approximate amount of visitors per day that have electric cars. The cost for charging each of the devices is added together to find the total cost per day. This number can be multiplied by 365 to find the price per year.

This simplified formula can be used for any of the three looked at public places: malls, airports, and cafes, given the assumptions made that will cancel out certain terms for certain locations. The price of installation and materials of electric charging stations was not taken into account for this model. The potential extra profit made from people staying longer due to charging is also not taken into account for this model.

Current Variables

Data gathered from online research and assumptions

Price of Electricity (p)**:** $0.11 per kWh

Percent of people who own electric vehicles (*V*) : 0.4% (0.004)

Percent of people who own a smart phone (*S*): 74% (0.74)

Percent of people who own a laptop (*L*): 60% (0.6)

Number of people that go to a mall daily (n_m)**:** ~1200

Number of people that travel through an airport daily (n_a)**:** 168,163

Number of people who go to a cafe daily (n_c)**:** 476

Energy used by phones while charging (e_i)**:** 0.006 kW/h

Energy used by laptop while charging (e_l)**:** 0.065kW/h

Energy used by cars while charging (e_v)**:** 7kW/h

Time Spent at mall (t_m)**:** 2hr 10 min

Time spent at airport (t_a)**:** 3hr 20 min

Time spent at cafe (t_c)**:** 3hr

Time charging at a mall ($t_m * .125$)**:** 1/8 of the time spent in mall

Time charging at an airport (t_a)**:** 3hr 20 min

Time charging at a cafe (t_c)**:** 3 hr

Current Costs (2019)

Mall

The formula for the cost within a mall is $C_m = S\, n_m\, t_m * .125\, e_i\, p + n_m\, V\, t_m\, e_v\, p$ because of the assumption that there will be no mall-goers charging laptops.

$C_m = S\, n_m\, t_m * .125\, e_i\, p + n_m\, V\, t_m\, e_v\, p$
$C_m = (0.74)(1200)(2.17) * 0.125(0.006)(0.11) + (1200)(0.004)(2.17)(7)(0.11)$
$C_m = 0.159 + 8.02$
Per day: C_m = \$8.18
Per Year: C_m = \$2985.44

Airport

The formula for the cost within an airport is $C_a = S\, n_a\, t_a\, e_i\, p + L\, n_a\, t_a\, e_l\, p$ because of the assumption that there will be no electric cars charged at airports.

$C_a = S\, n_a\, t_a\, e_i\, p + L\, n_a\, t_a\, e_l\, p$
$C_a = (0.74)(168\,163)(3.33)(0.006)(0.11) + (0.6)(168\,163)(3.33)(0.065)(0.11)$
$C_a = 273.50 + 2402.3261$
Per day: C_a = \$2675.83
Per year: C_a = \$976676.55

Cafe

The formula for the cost within an airport is $C_c = S\, n_c\, t_c\, e_i\, p + L\, n_c\, t_c\, e_l\, p$ because of the assumption that there will be no electric cars charged at cafes.

$C_c = S\, n_c\, t_c\, e_i\, p + L\, n_c\, t_c\, e_l\, p$
$C_c = (0.74)(476)(3)(0.006)(0.11) + (0.6)(476)(3)(0.065)(0.11)$
$C_c = 0.6976 + 6.126$
Per day: C_c = \$6.82
Per year: C_c = \$2489.89

Future Costs (2023)

In order to determine how much free electricity will be costing companies for free charging stations, the values of changing variables will be calculated fours years into the future (2023) using current projections and past trends.

Rates of Change

Percent of people who own a smart phone (S): Increasing via the cubic regression line $0.0000252\,x^3 - 0.00459\,x^2 + 0.101\,x + 0.202$ where x is years after 2010

Percent of people who own electric vehicles (V) : Increasing by 30% each year. ($V(1.3)^y$)

Number of people that go to a mall daily (n_m)**:** Decreasing by 7% each year. ($n_m(0.93)^y$)

Number of people that travel through an airport daily (n_a)**:** Increasing by 4.9% each year. ($n_a(1.049)^y$)

Number of people who go to a cafe daily (n_c)**:** Increasing by 8.1% each year. ($n_c(1.081)^y$)

Mall

The 2023 formula for the cost within a mall is $C_m = S\,n_m\,t_m * .125\,e_i\,p + n_m\,V\,t_m\,e_v\,p$ because of the assumption that there will be no mall-goers charging laptops.

$S = 0.0000252\,x^3 - 0.00459\,x^2 + 0.101\,x + 0.202$ where x is 13.
$S = 0.0000252\,(13)^3 - 0.00459\,(13)^2 + 0.101\,(13) + 0.202$
$S = 0.795$

$C_m = S\,n_m(0.93)^y\,t_m * .125\,e_i\,p + n_m\,V(1.3)^y\,t_m\,e_v\,p$
$C_m = (0.795)\,(1200)\,(0.93)^4\,(2.17) * 0.125\,(0.006)\,(0.11) + (1200)\,(0.004)\,(1.3)^4\,(2.17)\,(7)\,(0.11)$
$C_m = 0.1278 + 22.91$
Per day: $C_m = \$23.03$
Per Year: $C_m = \$8407.64$

Airport

The formula for the cost within an airport is $C_a = S\,n_a\,t_a\,e_i\,p + L\,n_a\,t_a\,e_l\,p$ because of the assumption that there will be no electric cars charged at airports.
$S = 0.795$
$C_a = S\,n_a(1.049)^y\,t_a\,e_i\,p + L\,n_a(1.049)^y\,t_a\,e_l\,p$
$C_a = (0.795)\,(168\,163)\,(1.049)^4\,(3.33)\,(0.006)\,(0.11) + (0.6)\,(168\,163)\,(1.049)^4\,(3.33)\,(0.065)\,(0.11)$
$C_a = 355.785 + 2908.93$
Per day: $C_a = \$3264.92$
Per year: $C_a = \$1191622.5$

Cafe

The formula for the cost within an airport is $C_c = S\, n_c\, t_c\, e_i\, p + L\, n_c\, t_c\, e_l\, p$ because of the assumption that there will be no electric cars charged at cafes.

$S = 0.795$
$C_c = S\, n_c (1.081)^y\, t_c\, e_i\, p + L\, n_c (1.081)^y\, t_c\, e_l\, p$
$C_c = (0.795)(476)(1.081)^4 (3)(0.006)(0.11) + (0.6)(476)(1.081)^4 (3)(0.065)(0.11)$
$C_c = 1.023 + 8.365$
Per day: C_c = \$9.39
Per year: C_c = \$3426.72

Potential Initiatives

Alternate Energy Source 1: Piezoelectric

To reduce costs, alternate energy sources were explored. Sustainable Energy Floor (SEF) was a reliable option for piezoelectric flooring. Piezoelectricity involves installing new floor tiles which will harvest power from footsteps. With wide tiles, the heavy foot traffic the mall would receive, and an average generation of 7 watts per step, a mall could draw a lot of energy from the SEF tiles. However, with an upfront cost of \$929.62 per 75cm x 75cm tile, an average-sized mall would have to invest \$2,353,543.68 upfront. Because a mall's cost of charging stations was estimated to be \$3562.56, this cost proved too high to be worth the investment, especially considering the floors would have to be redone every 15 years due to the lifespan of the tiles.

Alternate Energy Source 2: Solar Power

Another alternative source that was considered was solar power. In 2019, it costs \$2.99 per Watt for solar panels. On average, a phone uses one kiloWatt a year. Dividing this by 365 days gives 2.74 Watts per day, and multiplying this by the cost per Watt gives \$8.19 to charge a phone for one day using solar power. Solar panels are not a very cost-efficient way to power phone chargers. In addition, solar power can be inconsistent, since depending on the location of the panels, there may be more clouds and the angle of the sun might be lower, resulting in lower efficiency.

Alternate Energy Source 3: Wind Power

A third method that was considered was wind power. This proved to be much more efficient than piezoelectric flooring and solar power. It costs 8.2 cents to generate 1 kiloWatt from wind power. Dividing the 2.74 Watts per day for each phone by 1000 gives a total consumption of 0.00274 kiloWatts per day. Multiplying this by the cost per kiloWatt gives 0.22 cents per phone per day. This is a much more cost-efficient solution, as it allows for more customers to charge their phones for less money. Another benefit of using wind power is that it is a renewable source, which is better for the environment. However, wind power is not always reliable and is dependent on the location of the wind turbines for high wind speeds.

Alternate Energy Source 4: Natural gas

However, the most cost-efficient way to generate electricity would be from natural gas. It costs 6.3 cents to generate 1 kiloWatt using natural gas. Multiplying the 0.00274 kiloWatts per phone per day by the cost of 1 kiloWatt gives 0.17 cents per phone per day. Natural gas is the cheapest energy source, and it would give the least amount of expenses. One benefit of using natural gas is that it is reliable as long as it is in constant supply. A downside is that it is not renewable or green, so it is bad for the environment and the supply will eventually run out.

Energy Reduction Methods

Other ideas briefly mentioned include charging patrons to use charging stations and have charging stations charge phones slower (reducing electricity spent during the given charging period). While these methods would cut costs, they partially defeat the purpose of the charging station. If patrons cannot use a fast, reliable charging stations for free, they may be discouraged from using the stations altogether, and visit other similar locations that have free charging stations.

Conclusions

According to the developed model, the average amount a money a mall will spend on ‘free’ electricity in 2019 will be $2985.44, while in 2023 a mall will spend $8407.64, largely due to the projected increase of electric car usage. This represents a 280% increase over 4 years. The average amount of money an airport will spend in 2019 on charging stations is $976,676.55, and in 2023 $1,191,622.50, a 120% increase over the 4 years. As for cafes, the cost of free electricity for 2019 was $2489.89 and $3426.72, a 140% increase.

Model Strengths and Weaknesses

The strengths of the model lie in its consideration of people charging at any given time, the total people in a location, the percentage of those people that own each considered electronic device, and the times each person will be at the location. The model uses previous data in each location to estimate how many people will be there at any given time, which eliminates the need to treat it as a variable and gives a more accurate yearly cost projection.

The model’s weaknesses include the assumptions made with both time charging each device and the projected changes of wattage of chargers, people who own a laptop, and the time people will spend in an airport. The model also does not consider inflation from when data was gathered to present day. The model’s assumptions also play into its weaknesses, as every person in a location charging their device and constant electricity prices are both unlikely. The model also assumes charging stations are already installed, which may not be the case for all locations across the country.

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Appendices

Number of people in mall (daily) =
105 000 000 people per year ∗2.1 visits per month∗12 months/6000 malls/365 days per year

Number of people in airport (daily, based on Denver International) =
61, 379, 396 people per year/365 days per year

Change in smartphone ownership (x is years after 2010) =
$0.0000252\,x^3 - 0.00459\,x^2 + 0.101\,x + 0.202$ comes from Line of best fit

(Points : smartphone ownership in US (in millions)/US population (in millions))