Introduction

Generally speak, to calculate the energy demand and the charging devices demand, we mainly consider two parts: the Electronic car charger(e-car) and the plug-in. In the later model, we will build a model to help the shop manager to estimate the energy consumption and the demand for charging devices.

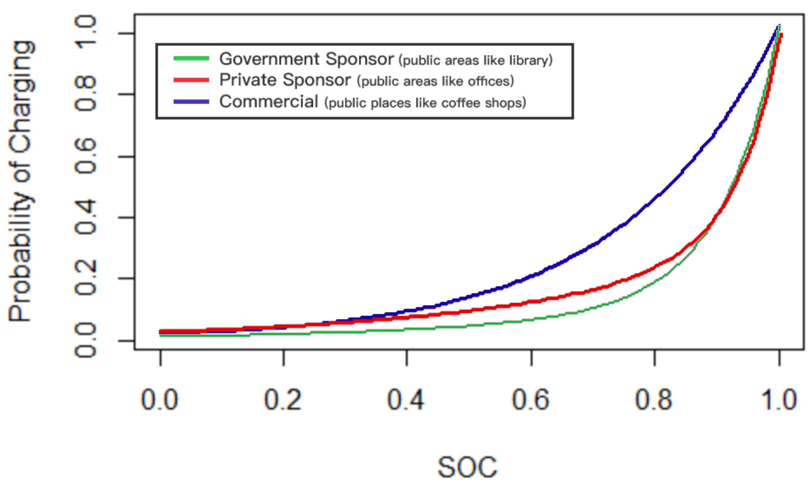
Assumption

1. People only use the plug in to charge their phone
2. The total electric quantity for phone and the e-car are the same for everybody.
3. No maintaining fee for the car charger and plug in
4. Everyone has one phone which have power of 3000mAh and 3.6v

Part 1: the energy consumption for e-car and the device demand model

Model 1: The relationship between SOC and the probability for people to charge their car

SOC mean the energy consumption percentage for a single car. Like if SOC=10%, it means that the user had already used 10% of the total electric quantity in car. By fitting the data collected by the `NHTS2009` (National Household Travel Survey 2009). It is easy for us to draw the graph which shows the relationship between *SOC* and *the probability that people charge their car* in various places, we define this function as $P(x)$, where x represent *SOC*



data analyzed by Mr. Tao in Configuration Ratio for Distributed Electrical Vehicle Charging Infrastructures

according to the fitting result from Mr. Tao, the joint probability density function are:

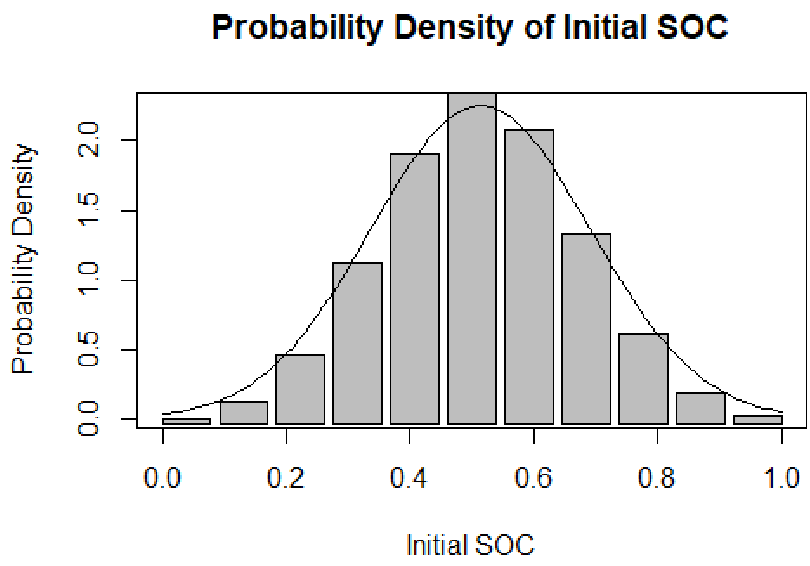
$$p_{\text{c-work}}(x) = 0.007483\mathrm{e}^{-1.289x} + 0.0196\mathrm{le}^{3.95x}$$

$$p_{\text{c-shop}}(x) = 0.01272\mathrm{e}^{2.474x} + 1.528 \times 10^{-5}\mathrm{e}^{10.95x}$$

$$p_{\text{c-recreation}}(x) = 0.02576\mathrm{e}^{2.566x} + 2.244 \times 10^{-7}\mathrm{e}^{14.86x}$$

Model 2: The relationship between initial SOC and the probability

The US department of energy initiated the EV Project which make a statistics on the driving and charging pattern of electric vehicles. And the result of initial SOC is shown below, which is likely to be a normal distribution. We define it as $f(x)$



Also, according to the fitting result from Mr. Tao, the joint probability density function are: $f(x) = \frac{1}{\sqrt{2\pi} \times 0.1772}\mathrm{e}^{-\frac{(x-0.5137)^2}{2\times 0.1772^2}}$

Model 3: The Energy consumption model for E-car

Variable

TERM	DESCRIPTION
$C_{\text{e-car}}$	consumer who own e-car
T	electronic capacitor for an e-car
x	SOC: the electricity that already used
$E_{\text{e-car}}$	energy consumption
t	time

TERM	DESCRIPTION
$B_{charger}$	the building cost for single car charger
$P_{\text{e-car}}$	probability that consumer own E-car

Firstly, we assume that the function of distribution graph for coffee bar is: $C(t)$ For different shops, we have different distribution function. After the model part, we will show a demo.

$C(t)$: The distribution for consumer number in different time

For the people who own the E-car, the probability they use the E-car can be simply describe as:

People use e-car charger = $P_{\text{(the SOC for car owner is x)}} \times P_{\text{(the E-car owner want to charge)}} \times C_{e-car}$ = $f(x) \times p(x) \times C_{e-car}$

For the energy demand for a single car to charge from $(1 - Soc)$ to the full-charged status, it can be describe as:

$E_{\text{for single car}} = T \times x$

If we considered the demand for all the people, the function will be like:

$E_{e-car}(x) = \sum_{x=0}^{10} f(\frac{x}{10}) \times p(\frac{x}{10}) \times C_{e-car} \times T \times \frac{x}{10}$

For the $f(x)$. because it only depended on the individual willing for each car-owners, no matter where the statistic is taking place. However, for the function $p(x)$, it correlate with the place. Therefore, we can rewrite the $E_{\text{e-car}}$function as:

$E_{e-car}(x) = \sum_{0}^{10} \frac{1}{\sqrt{2\pi} \times 0.1772} \mathrm{e}^{-\frac{(\frac{x}{10} - 0.5137)^2}{2 \times 0.1772^2}} \times p(\frac{x}{10}) \times C_{e-car} \times T \times \frac{x}{10}$

Model 3.1: The costing model for E-car

The cost is made by two parts: the *Fixed costs* and *Variable cost*, which is:

$CE_{total} = CE_{fixed} + CE_{variable}$

For the $CE_{variable}$, it can be easily calculated by: $CE_{variable} = E_{e-car} \times F$, whereas F there represent the cost for unit energy (W*h)

To find the CE_{fixed}, we need to know the total number of car charger: Q_{e-car} that should be build, to get it, we build a model to represent the highest demand of car charge in a day, which can be described as:

$Q_{e-car} = p(x) \times f(x) \times C(t) \times P_{e-car} | (f(x) \times p(x))' = 0, C(t)' = 0$

Therefore, the CE_{total} will be:

$CE_{total} = Q_{e-car} \times B_{charger} + F \times E_{e-car}(x) \times d$, whereas d represent the day.

Part 2: the energy consumption for plug-in and the devices demand model

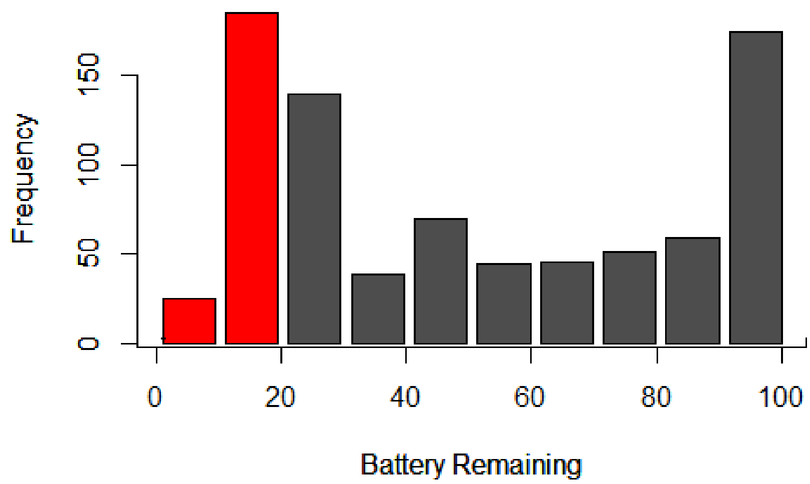
Model 4: The Energy consumption model for plug-in

According to the research by LG, when the phone' s power is less than 20%, people will began to show the wonder of charging. Therefore, the probability that a consumer in a shop need to charge his/her phone is:

$P_{\text{charge phone}} = P_{\text{power less than 20\%}} \times P_{\text{charge in public place}}$

For the $P_{\text{charge in public place}}$. we can consider it as 100% since the coffee bar provide enough plug-in

To get the data from $P_{\text{power less than 20\%}}$, we use the data collect from the charging behavior from a person in a whole day



For the red part, it represent the situation that $charge < 20$, which take 25.21008% of the whole data. Therefore, $P_{\text{power less than 20\%}} = 25.21008\%$

Assume that the total traffic per day is C. Them the total Energy consumption can be describe as:

$E_{plug-in} = P_{\text{power less than 20\%}} \times P_{\text{charge in public place}} \times C \times T_{phone} \times(1\text{-}20\%)$

For the $T_{phone} \times(1\text{-}20\%)$, it can be calculate by:

$T_{phone} \times (1+\sigma)\times(1\text{-}20\%) = \frac{3000mAh\times1.8\times3.6v\times0.8}{1000} = 0.015552$ kWh, where as σ there represent the energy loss when charging.

Then, the function of $E_{plug-in}$ can be write as:

$E_{plug-in} = 0.2521008 \times C \times 0.015552kWh = 0.004 \times C$

Model 4.1: The costing model for Plug-in

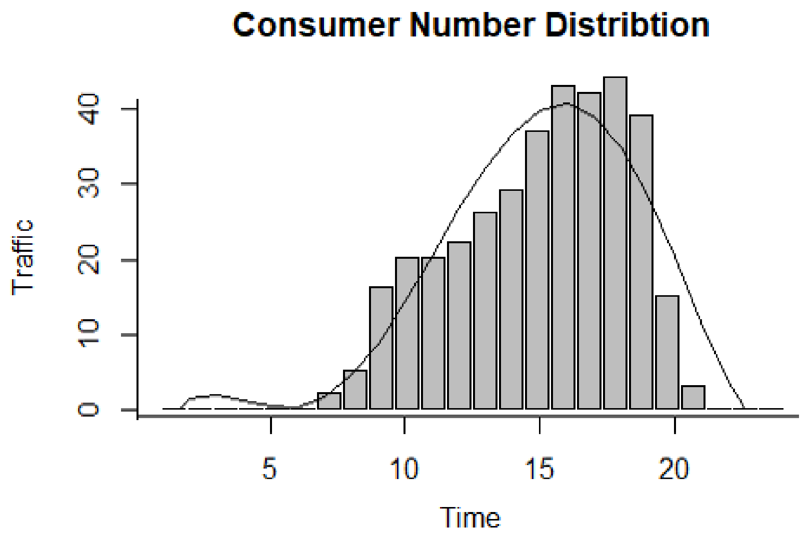
Similar to the model 3.1, we need to know the number of plug-in. To calculate that, considering the possible max plug-in usage which can be measured by:

$Q_{plug-in} = C(t)|PR(t) = 0.2$, whereas $PR(t)$ represent the function which describe the relationship between charge and time. Finally, we can modeling the total cost for plug-in: CP_{total} as:

$CP_{total} = E_{plug-in} \times F \times d + Q_{plug-in} \times B_{plug-in}$

Apply

There is a coffee bar in the center of the city, which has the consumer traffic distribution shown below:



Data from a Starbuck in Switzerland.

Energy consumption for E-car charging

According to the model 1, the coffee shop has the attribute of shop. Therefore, its p(x) should be

$p(x) = 0.01272\mathrm{e}^{2.474x} + 1.528 \times 10^{-5}\mathrm{e}^{10.95x}$

For the P_{e-car}, according to `Nanalyze`, there are approximately 21.6% of people who own electronic car.

For the constant variable: C_{e-car}, according to the graph, it should be:

C_{e-car} = $\sum_0^{24} C(t) \times P_{e-car} = 363\times$ 21.6% ≈ 78

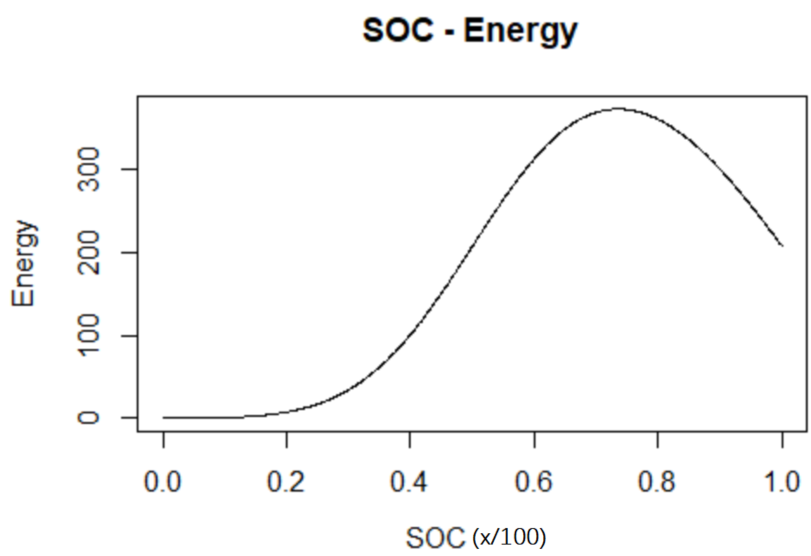
For the T, we use Tesla Model 3 as an example, its T = 50 kWh

Then, we can apply the p(x) function to model 3, which is:

$E_{e-car}(x) = \sum_{x=0}^{10} \frac{1}{\sqrt{2\pi}\times 0.1772} \mathrm{e}^{-\frac{(\frac{x}{10}-0.5137)^2}{2\times 0.1772^2}} \times (0.01272\mathrm{e}^{\frac{2.474x}{10}} + 1.528 \times 10^{-5}\mathrm{e}^{\frac{10.95x}{10}}) \times 78 \times 50 \times \frac{x}{10}$

=> E= 1903.946 kw*h

Which shown below.

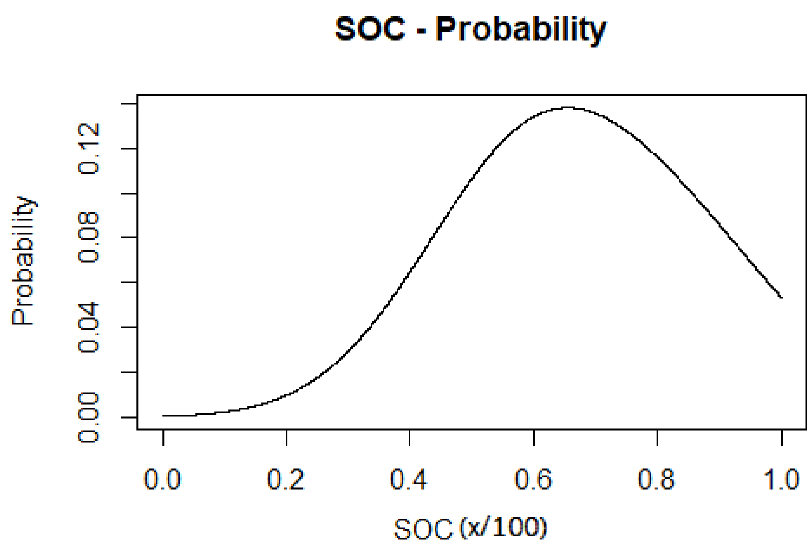


`[breifly explain this graph]`

After we get the energy consumption model, we can calculate the model 4.1

According to our calculating, when t=18, C(t) raise to the max value, which is 44.

And when x=65.45(SOC = 0.6545), $f(x) \times g(x)' = 0$, and $f(x) \times g(x) = 0.1379595$



Therefore, for the model 3.1, we can calculate its $Q_{charger}$

$Q_{e-car} = (p(x) \times f(x) \times C(t) \times P_{e-car}|(f(x) \times p(x))' = 0, C(t)' = 0) = 0.1379595 \times 44 \times 0.216 \approx 1.3$

which means to satisfied all the consumer' s demand for charging their car, the number of e-car charger they have to build is 2

And for the F, we use the American electric charge: F=0.12 dollar/kWh, and for the $B_{charger}$, the most common charging devices cost: $1,000. Then, we can use model 3.1 to solve the cost out:

$$CE_{total} = Q_{e-car} \times B_{charger} + F \times E_{e-car} \times d = 1.3 \times 1000 + 0.12 \times 1903.946 \times d = 1300 + 228.47352 \times$$

Conclusion:

For the conclusion, to satisfied consumer' s demand in charging e-car, the coffee bar should build 1.3 e-car charging station, approximately use 1903.946 kWh power. For the relationship between price and day, it can be describe as: $CE_{total} = 1300 + 228.47352 \times d$.

Energy Consumption for plug-in

According to the $E_{plug-in} = 0.00048 \times C$, we can easily calculate the Energy cost plug-in is: $0.004 \times 343 = 1.372kWh$

Then, to get the $Q_{plug-in}$, we use model 14.1, when PR(t)=0.2, t = 18 or t = 12. In these two situation, the C(t) = 22 and 44. To satisfied all the consumer' s demand, we use 44 for our t. Therefore, $Q_{plug-in} = 44$

For F, we use 0.12

For the most common plug-in, it cost $10 t build one. Therefore, B=10

$$CP_{total} = E_{plug-in} \times F \times d + Q_{plug-in} \times B_{plug-in} = 1.372 \times 0.12 \times d + 44 \times 10 = 0.16464 \times d + 440$$

Conclusion:

For the conclusion, to satisfied all consumer' s demand to charge their phone, the coffee bar should install 44 plug-in, and everyday, those plug-in will cost them 1.372 kWh, and the cost function though time is:
$CP_{total} = 0.16464 \times d + 440$