PREVIEW PAPER: AVERAGE

This paper did not receive high marks, and many deficiencies were noted. First, the equations were simply stated without much motivation, and it was not clear what meaning the team gave to their equations.

With respect to the first question, the team provided representations of the data for truck growth. It was not clear how they used this information, though. In terms of their model, the growth rate for electric vehicles resulted in linear growth while the growth rate for internal combustion vehicles resulted in exponential growth. There was no balance of capacity between the two types of vehicles, and while both would grow unbounded the internal combustion vehicles would overtake electric vehicles by a large margin.

With respect to the second problem, the team discussed a number of variables, but their variables seem to be coefficients. The coefficients themselves are not well defined. The team goes on to create a function with the coefficients but the source of the values they used is unclear.

With respect to the third question the team assumes that there is no cost for electricity for the suppliers. The result is that the revenues represent pure profit for the energy suppliers at the charging stations.

With respect to the overall approach, the team did not adequately explore the validity of their results. They explicitly state that their results make sense, but it is not clear how they arrived at their conclusion. Additionally, they provide little discussion about the relative strengths or weaknesses of their model. They do not demonstrate that they examined their models with a critical eye.

The team received a low score due to a number of deficiencies. At the same time, there were some positive aspects of the paper. The team provided enough information to receive some points in most categories, so their overall effort was recognized. In particular, the team provided an answer for each question and was able to achieve some points in almost every category. For example, the summary is weak but includes an overview of the problem as well as results. The team also clearly stated their model and the relevant equations. The team looked at both short and long hauls and compared the growth between the two which is not something many teams did. The team showed some important insights into the underlying context of the questions.

Can You Make Green from Going Green?

Executive Summary

It's no secret that electric vehicles are more environmentally friendly, but the real questions are: It is cheaper than conventional methods? Can you still profit from going green? It is assumed that Electric Semi Trucks will soon be on the market, and many people are curious as to whether these more environmentally friendly vehicles are worth it. So, we sought out to answer these questions.

In problem 1, we had to figure out the ratio of electric semis to diesel semis. This would answer the question to whether there would be enough electric semi-trucks to make a profit or not. Our research showed that if electric semis raised at a constant rate over the next 10 years, the percentages of electric cars would increase.

For the second problem, we had to figure out how many chargers and stations would be needed in the five corridors by using a series of mathematical equations. This would provide a baseline of how many stations and chargers we would need across varying distances.

During the third problem, we focused mainly upon monetary aspects of electric semis. We wanted to see if there was any money to be made from electric semis. To start off, we had to figure out how much it cost to charge a semi battery to fully. To do this, we found that an electric semi battery can hold 500kWh and each Kilowatt costs about seven cents. We then calculated total cost of a full charge, multiplied that by the miles of the trip, which gave us a total number if every trucker were to obtain a full charge. Next, we calculated the total cost of each charger for varying distances and subtracted that from the total sales of full charges. This gave us the amount of profit after construction costs. From all the equations we have created, we have determined that it is possible to make a profit from electric semi-trucks.

Although there are many benefits to electric semi-trucks, none of them would matter if you weren't able to turn a profit by using them. Our models show that companies could in fact make a considerable amount of profit, if every trucker will recharge daily. We must confess, that we believe in going green.

Table of Contents

Global Assumptions

1. Electric semis are more environmentally friendly than ones that are diesel power.

Part I:

1.1 Restatement of Problem

Our goal for Part 1 was to create a mathematical model that would accurately and reasonably show what percentage of semi-trucks will be electric in the next 5, 10, and 20 years. Consideration must be given to the number of diesel and electric semis produced each year.

1.2 Assumptions

1. The Short Haul truck population is included with Long haul's, because they are just Long-Haul trucks used to travel short distances after a certain set of years due to dependability.

2. The question is referring to the amount of electric semi's in the U.S., not the entire world.

3. There is a 12.4% increase of diesel trucks per year.

4. There will be 100,000 new electric semis manufactured per year. [2]

5. There were 109,442 regional trucks and 101,024 long haul diesel semis made in 2019.- Truck Production Data, 2020 MathWorks Math Modeling Challenge, URL [1]

6. The current diesel truck population of 1.7 million will not decrease, and the introduction of electric semis will be added to the total number.

7. Tesla is the front runner of electric semi production and development. [3]

8. There are currently 1.7 million semis [4]

1.3 Variables

Variable	Definition
T_e	Amount of Electric Trucks
T_{ep}	Percentage of Electric Trucks
T_d	Amount of Diesel Trucks
n	Number of years
R_H	Amount of Regional Haul Trucks
L_H	Amount of Long-Haul Trucks
T_g	Diesel Truck Growth

1.4 Solution and Results

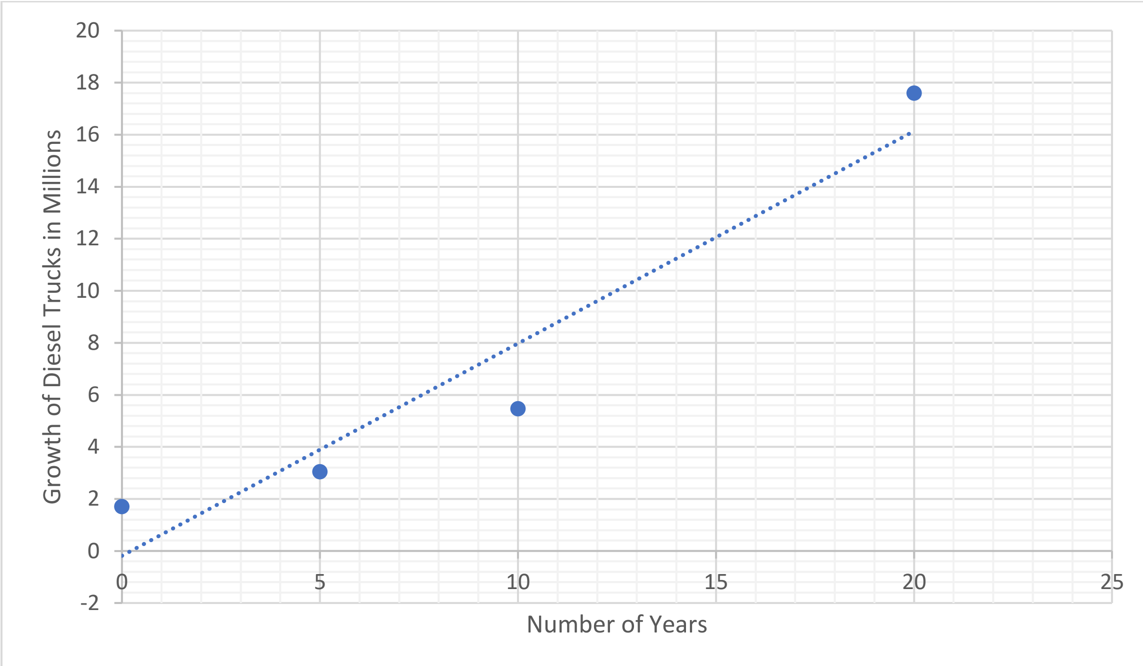
Semi-trucks provide a convenient and effective way to transport goods, enabling our developing society to function. As shown in assumption 1, we assume that the number of Short haul semis are added to the number of Long hauls. By determining this, we could determine the percentage of growth of diesel trucks per year, allowing us to create a model that estimates the total amount of diesel trucks per year. Using the chart below (Figure 1) we took the latest data from 2019 on the number of class 8 semis manufactured [1]. We assume that the question is only referring to the number of electric semis in the United States, by doing so, we ensure that our model is accurate.

Year	Class 8 Tractor Regional Haul	Class 8 Tractor Long Haul	Class 8 total	% Regional Haul	% Long Haul
1999	36,910	180,205	217,115	17%	83%
2000	35,211	105,632	140,843	25%	75%
2001	25,124	48,771	73,895	34%	66%
2002	39,794	62,241	102,035	39%	61%
2003	45,652	60,516	106,168	43%	57%
2004	77,035	77,035	154,070	50%	50%
2005	77,893	112,091	189,984	41%	59%
2006	90,008	114,555	204,563	44%	56%
2007	36,878	48,884	85,762	43%	57%
2008	35,505	57,930	93,435	38%	62%
2009	23,009	46,715	69,724	33%	67%
2010	37,798	44,372	82,170	46%	54%
2011	74,237	71,325	145,562	51%	49%
2012	74,361	80,558	154,919	48%	52%
2013	70,667	67,896	138,563	51%	49%
2014	103,295	74,799	178,094	58%	42%
2015	107,995	95,769	203,764	53%	47%
2016	68,355	55,927	124,282	55%	45%
2017	68,086	70,866	138,952	49%	51%
2018	103,239	91,551	194,790	53%	47%
2019	109,442	101,024	210,466	52%	48%

Figure 1

There are currently 1.7 million diesel powered semi-trucks in the United States [2]. Using this information, we created an equation (shown below) that shows the increase of diesel semis per year. We took the amount of regional haul trucks plus the amount of long haul and divided them by 1.7 million. This gave us the percentage of total growth per year of diesel trucks.

$$\frac{(R_H + L_H)}{T_d} = T_g$$



This equation gave us an annual growth rate of 12.4%

The amount of new electric trucks per year is assumed to be to 100,000 [3]. To get this, we multiplied T_e by n, giving us the number of electric cars per year. Next, we divided the total number of electric trucks per year by the total number of diesel trucks (T_d), then multiplied that with the growth rate of diesel trucks per year. Since we assume that electric trucks won't replace any amount of diesel trucks being currently used, we multiplied 1.7 million by $(1.124)^5$, which shows the growth rate of diesel trucks. Second, we multiplied 100,000 by 5 to show the total amount of electric trucks. We then divided this number by the total amount of diesel trucks, including the growth rate, which gives us the percentage of electric trucks to diesel trucks. The model we used to determine our answer is shown below.

$$T_{ep}(n) = \frac{T_e n}{T_d (1.124)^n}$$

Our model determined that the future percentage of electric semis are as follows:

5 years: 16.4%

10 years: 18.3%

20 years: 11.4%

The percentage of electric trucks in use will steady out and decrease in 20 years. We feel that this is normal when compared to the average manufacturing rates of diesel trucks from 1999-2020.

1.5 Validation

Based upon our assumptions, our model is quite accurate. It accounts for the projected number of electric semis to be made per year, according to Tesla CEO Elon Musk. We assume that Tesla is the frontrunner of electric semi technology. We believe that how soon electric semis will be deployed will depend on this one company. Our model is consistent is consistent with the manufacturing rates of diesel semis, which decreased towards the end of 20 years.

Part II:

2.1 Restatement of Problem

The question asks us to determine the number of stations and chargers needed on five different corridors. We need to evaluate how many trucks, on average, there are per mile. We also must evaluate the different charging needs of trucks based upon the distance they travel.

2.2 Assumption

1. There is one truck for every mile of road [4]

2.3 Variables Used

Variable	**Definition**
S_{avg}	Average Stop
M_{it}	Miles in Trip
L_h	Distance of Long-Haul Truck
R_h	Distance of Regional Haul Truck
N_{ocs}	Number of Chargers/Stations
D_{bs}	Distance Between Stations

2.4 Solution

First, we researched that for every mile there is one semi-truck. The question gave us the number of miles between each destination, so we had to figure out how many stations should be placed between each destination, in addition to how many chargers should be at each station.

Using the model below, we can determine the number of stations and chargers needed. We took the distance of the trip in miles and multiplied it by the amount of stops each truck would have to make. We then divided that by the charge capacity of the truck (500 for a long haul or 300 for a regional).

$$\left(\frac{S_{avg}M_{it}}{L_h}\right) + \left(\frac{S_{avg}M_{it}}{R_h}\right) = N_{ocs}$$

We decided that because there would be one truck per mile [4], there would be more trucks on the routes because they span longer distances. This would mean number of stations would be greater, due to the larger amount of trucks. Therefore, to calculate the distance between stations we took M_{it} and divided it by the number of chargers and stations.

$$\frac{M_{it}}{\left(\frac{S_{avg}M_{it}}{L_h}\right) + \left(\frac{S_{avg}M_{it}}{R_h}\right)} = D_{bs}$$

Corridor	**Number of Stations**	**Number of Chargers**	**Distance Between Stations**
San Antonio, TX, to/from New Orleans, LA	3	3	181.2 miles
Minneapolis, MN, to/from Chicago, IL	11	11	83.3 miles
Boston, MA, to/from Washington, DC	2	2	195.2 miles
Jacksonville, FL, to/from Washington, DC	6	6	120.6 miles
Los Angeles, CA, to/from San Francisco, CA	1	1	300 miles

2.5 Validation

We were asked to create a model that would show the need for stations and chargers on any given route. After researching and evaluating the charge capacity and distance traveled on a single charge of various electric semis, we were able to determine the need for stations and chargers. We confirmed the accuracy of our model on the five corridors provided to us.

Part III:

3.1 Restatement of Problem

We are tasked with developing a mathematical model, which is based upon using the information from part 2, that will accurately show which of the five given corridors will be the most profitable. We must take into consideration the cost to build each charging station, because if the cost outweighs the amount of possible profit, the construction of charging stations would not financially wise.

3.2 Local Assumptions

1. It cost 7 cents per kWh to charge an electric semi battery. [5]

2. Tesla's completed Gigafactory will have a battery capacity of up to 150 gigawatt-hours. [4]

3. Every trucker will charge to full capacity on each given corridor.

3.3 Variables

Variable	**Definition**
C_{pk}	Cent Per Kilowatt
B_k	Battery Kilowatts
C_{pc}	Cost Per Charger
S_{tc}	Total Cost of Station
M_{fc}	Money for a Full Charge
P_t	Profit Total
M_{it}	Miles in trip

3.4 Solution

We assumed it was 7 cents per kilowatt of charging. We also assumed that all the electric semi-trucks had a 500-kilowatt battery, therefore we can figure out that it cost $35 to reach a full charge. We then multiplied the cost of a full charge (M_{fc}) by the miles in trip to get how much money you would make at the station because each mile is equal to one truck. We then determined that the cost per charger (C_{pc}) [5] is equal to $1,150. We multiplied this by the number of chargers, which can be determined by using the equation from problem two. Next, we took the cent per kilowatt (C_{pk}) [4] and multiplied that by battery kilowatts (B_k). Then multiplied that by the miles in trip and subtracted the number of charger's multiplied by the cost of chargers.

$$C_{pk}B_k = M_{fc}$$

$$N_{ocs}C_{ps} = S_{tc}$$

$$M_{fc}M_{it} = P_{pt}$$

$$(C_{pk}B_k)M_{it} - (N_{ocs}C_{pc}) = P_t$$

We used these equations above to rank the five given corridors based upon profit, distance of trip, and the cost per charger.

Our rankings are as follows:

1. Minneapolis, MN, to/from Chicago, IL (making $19,795 per day)
2. Jacksonville, FL, to/from Washington, DC (making $18,440 per day)
3. San Antonio, TX, to/from New Orleans, LA (making $15,590 per day)
4. Los Angeles, CA, to/from San Francisco, CA (making $ 12,220 per day)
5. Boston, MA, to/from Chicago, IL (making $11,350 per day)

3.5 Validation

Based upon all our assumptions, if you use our equations, our information will accurately describe the cost and profit of charging stations being used by electric semi-trucks. We specifically focused upon different monetary aspects, which is more appealing to interested businesses. Our model is realistic and accounts for multiple variables, such as the cost per station compared to the proposed profit made.

References

[1] Truck Production Data, 2020 MathWorks Math Modeling Challenge, URL

[2] https://electrek.co/2018/02/08/tesla-semi-electric-semi-truck-production/

[3] https://www.trucks.com/2019/09/05/everything-we-know-about-the-tesla-semi-truck/

[4] https://www.quora.com/What-is-the-ratio-of-passenger-vehicles-to-semi-trucks-on-roads-in-the-US-at-any-given-time-How-do-those-numbers-change-at-different-times-of-day-or-night

[4] https://seekingalpha.com/article/4163999-tesla-may-hit-wall-on-battery-capacity-2022

[5] https://www.improvenet.com/r/costs-and-prices/electric-car-charger-station-installation-cost#:~:text=