PREVIEW PAPER: ABOVE AVERAGE

The paper received mixed reviews, and it was given a wide range of scores by the pre-triage judges. For the first question, the team took a common approach by using a high order polynomial to approximate the number of vehicles in the future. They made use of a fourth order polynomial in time for the number of electric as well as diesel vehicles. The resulting approximation had a higher coefficient of variation, but they provided no further rationale as to why this is a reasonable model. Additionally, the results of their model were problematic in that they projected that no electric trucks would be built for the first 15 years. It was not clear how they used their model in making their projections.

With respect to question two, the team made use of a rudimentary model for the number of stops, and it was based on the range of the vehicles and distances of the corridor. The team did not make use of any other factors including geographic or human considerations.

With respect to question 3, the team investigated a metric that incorporates the per capita GDP, daily truck traffic, and station costs, but they assigned arbitrary weights to the various factors. This is a common issue with many papers, and it is understandable given the short time that teams have to put together a model. In this case, though, the team did not adequately discuss this as a potential problem with their model, and it was not clear that they recognize this as an important part of their model that can be improved.

On the positive side, the team accounted for the relationship between diesel and electric vehicles. In particular they noted that the numbers of diesel vehicles should decline as more electric trucks are introduced. During the pre-triage phase it was not common for a team to recognize the important balance between the different types of vehicles.

Another positive aspect was that the team provided a very nice discussion of the revenue associated with both diesel and electric vehicles over their lifespans. They included the resulting profit in their calculations and factored this into their method of deciding how a company would decide whether or not to buy a diesel or electric vehicle. Also, for problem 2 the team recognized that vehicles are not always charged to full capacity and may only be charged to 20-80% of their range. This demonstrated that the team had a good grasp of a key insight into the way electric vehicles would be used in practice. Another key insight is that the team looked forward in time to incorporate the advancement of battery technology, and they factored that into the way electric vehicles would be adopted in the future.

Finally, the team provided a good set of assumptions and provided reasonable rationale for their assumptions.

Elon's Electrucks Need Time

1 Executive Summary

North America's trucking industry is one of the largest industries on the continent, providing critical services in transportation that form the foundation of the United States' economy and citizen expectations in quality of life. However, trucking has remained a relatively stagnant market in terms of technological innovation, costs, and growth, as overall production levels of Class 8 Semi trucks have changed little since 1999[5]. As such a large and important industry, trucking is ripe for innovation, which is why many are drawing their attention towards electric vehicles to improve on cost, distance, efficiency, and sustainability. Our team set out to model the impact EV (electric vehicle) innovations will have on long and regional haul transportation using class 8 vehicles.

The first part of this involved looking at when electric vehicle innovation leads to electric-powered semi trucks being a more profitable alternative to diesel-based trucks, and how adoption of EVs in transportation will grow. To do this, we calculated costs and revenue over the lifetime of both the average diesel and electric truck. To model adoption, we used three main factors— production of electric vehicles, demand for EVs based on profitability, and rotation of fleets as trucks age. Within this change, we used profitability to model demand as well as based Tesla Semi production levels on Tesla Model S levels in order to analyze at what point profitability demanded that Businesses move to EVs.The data led us to the conclusion that battery technology improvements would only lead to adoption beginning in 13 years, though it would quickly pick up pace afterwards reaching 20% adoption in just 20 years.

Arguably the biggest hurdle in the face of Electric Vehicles reaching mass adoption is related to the availability of charging infrastructure, which became the second part of our problem. To determine the number of charging stations needed across key routes, we found the distance for each route, the battery range of a semi, and ideal battery usage for a semi truck to calculate the number of charging stations. Due to the high range of a tesla semi battery (500 miles), we found a relatively low amount of stations per route. (2) from San Antonio, to New Orleans, (2) from Minneapolis to Chicago, (2) from Boston to Harrisburg, (3) from Jacksonville to Washington DC, and (2) from Los Angeles to San Francisco. Chargers necessary per station were calculated using peak traffic data, and charging time, and ranged from 207 to 426 chargers per station.

Finally, using an equation that compared the weighted values of each route - standardized with a reference value of the Minneapolis, MN to Chicago, IL route - it was determined that the Los Angeles, CA to San Francisco, CA route would prove to be the most valuable, primarily due to the high number of trucks that would pass along it, meaning that local business would see a great benefit from it being built.

Contents

2 Introduction

Our team's restatement of the given problems, as well as our assumptions for all of them and the definitions of our terms used, are given below.

2.1 Restatement

Our tasks were as follows:

1. Create a mathematical model to represent what percent of semi trucks will be electric in 2025, 2030, and 2040, using all the factors we chose to consider and ignoring the implications of infrastructure on the switch between diesel and electric.
2. If all trucks were electric, create a model to find how many charging stations, and individual chargers at each station, are needed to support traffic along several major corridors:
    - ❑ San Antonio, TX and New Orleans, LA
    - ❑ Minneapolis, MN and Chicago, IL
    - ❑ Boston, MA and Harrisburg, PA
    - ❑ Jacksonville, FL and Washington, DC
    - ❑ Los Angeles, CA and San Francisco, CA
3. Create a model to find the value of investing in a corridor, counting any and all factors we chose, including costs and benefits, and apply it to the previous five corridors to rank them.

2.2 Global Assumptions

- ❑ *Short haul (SH) semis are irrelevant*. We did not include short haul semi truck roles in our models due to their small number, making up less than 5% of all semis on the road.
- ❑ *Truck classes 1 through 7 are irrelevant*. Although some semis may occupy the role of a class 6 or class 7 truck, there are other vehicles that can serve the same purpose, and so their dominant role as a class 8 truck is assumed to be their only role.
- ❑ *Self-driving capabilities will not matter before 2040*. Although there has been significant progress in the field of self-driving vehicles, here, we assume that those technologies will either not be reliable enough (as laws are quite strict in regulating driverless vehicles, and the technology must rise to meet them unless changed) or will fail to be implemented due to political or social opposition, meaning that companies will have the same personnel costs.
- ❑ *All newly purchased vehicles will serve a long haul (LH) role*. Companies often assign new semis to long haul roles due to their prime condition, while those about five years or older in age are relegated to regional (R) roles due to their decreased performance, so we assumed that all semis would follow such a usage pattern.

- *Monetary values considered are real, unaffected by inflation*. We will not be predicting inflation, as it is mostly irrelevant to our model, and so all values handled will be considered real and in terms of United States dollars in 2020.
- *The amount of semis in use stays constant.* Although we completed calculations that considered the number of semis being produced, we decided that since, at the same time, semis are being dropped from use due to their age and obsalence, we would assume the volume of semis to remain constant at about 1.7 million.

2.3 Global Definitions

- "Tare weight" refers to the unladen weight of a semi truck and its container, while no cargo is being transported.
- "Electruck" is occasionally used hereafter to refer to electric semis.

3 Problem 1: Shape Up or Ship out

3.1 Local Assumptions

- *Operating factors, excluding electricity and fuel, are equivalent between electric and diesel trucks.* Factors such as driver salaries, insurance policies, permits, licenses, tolls, and tire retreading are assumed equal between electric and diesel trucks, as those are all too numerous and too insignificant to merit their own variables; e.g., there will be virtually no difference between an electric and a diesel driver, or tires will wear at the same rate whether driven by a diesel or electric engine.
- *Operating costs, including electricity and fuel costs will remain constant.* As fluctuations in oil prices, taxes, energy costs, etc, are difficult to predict, we kept them outside the scope of our model and assumed both electricity and diesel costs to remain constant.
- *Tare weight is irrelevant and cargo weights are constant*. Although tare weight is reported to be inferior among electric semis at this point in time, typical loads are, in fact, equivalent to diesel semis, but due to lack of data, we will assume that typical loads will remain constant in the next couple decades[3].
- *The cost of a diesel truck will remain constant over the next twenty years*. Since we are excluding inflation from our models, and will not model changes in demand and supply for diesel markets, we will not factor in changes in the price of diesel trucks.
- *The cost of electric trucks, excluding the production of batteries, will remain constant over the next twenty years.* Similar to diesel trucks, except we do expect that batteries will decrease in price in the near future as they have been for years past.
- *No tax incentives.* Since tax incentives have begun to expire nationally for manufacturers such as Tesla for consumers, we assume that as production increases for electric vehicles, more tax incentives will expire, and as electric vehicles proliferate, they will become obsolete, meaning that they will not factor into our model.

3.2 Variables

3.2.1 Constants

Variable	Definition	Units	Value
i_D	Initial cost of semi, diesel	$USD	120 000
i_E	Initial cost of semi, electric	$USD	180 000
l_D	Lifetime distance of semi, diesel	Miles	1 110 000
l_E	Lifetime distance of semi, electric	Miles	1 000 000
m_D	Cost of operating factors inc. fuel, diesel	$USD per mile	0.433
m_E	Cost of operating factors, inc. fuel, electric	$USD per mile	0.20

3.2.2 Independent and Dependent Variables

Variable	Definition	Units
P_D	Profit over lifetime per truck, diesel	$USD
P_E	Profit over lifetime per truck, electric	$USD
R_D	Revenue over lifetime per truck, electric	$USD
R_E	Revenue over lifetime per truck, diesel	$USD
T_y	Years since 2020	Years
A	Percent Profitability difference	%

3.3 Developing the Solution

3.3.1 Lifetime of a Diesel Truck

According to the data provided by Moody's,

- Diesel truck life is about 12 years, and
- LH trucks average approximately 110 thousand miles/year in the first 5 years, and then their mileage typically declines to 80 thousand miles/year in remaining years[1].

Thus, the total calculated lifetime distance (l_D) of a diesel semi truck is calculated to be 110 000 miles.

3.3.2 Calculating Cost of Maintenance for Diesel

According to the American Transportation Research Institution's November 2019 Report, the operating costs of a diesel per mile include

- $.433 per mile for fuel of diesel trucks[2],
- $.776 per mile for Driver wages/benefits[4],
- $.176 per mile for other operational costs[4], and
- $.171 per mile for the repair and maintenance of diesel trucks in 2018[2].

Thus, the total operating costs per mile of a diesel truck was determined to be $1.556 per mile.

3.3.3 Revenue of a Class 8 Semi Truck Over Lifetime

Assuming that the average revenue earned per mile, and per weight carried, is about the same between electric and diesel trucks, and that tare weight is equivalent, there is a *linear relationship* between distance travelled over a lifetime and expected revenue of a truck. We looked at Knight-Swift, the largest trucking company in the US, and their fleet to find what this revenue may be. In 2018, Knight-Swift trucks earned $5 344 066 000 in revenue and drove a total of $1.9 billion miles. This means the average rate for a fully loaded truck shipment is $2.813 per mile.[12]

3.3.4 Profit of a Diesel Truck Over Lifetime

The profit for a diesel truck over its lifetime would be

$$P_D = (R_D - m_D)l_D - i_D$$

Which, using our constants, gives us

$$P_D = (\$2.813 \text{ per mile - } 1.556 \text{ per mile})(1\ 110\ 000 \text{ miles})$$

a total profit of $1 395 270 over the lifespan of a diesel truck**.**

3.3.5 Initial Purchase Price of an Electric Truck

Tesla sells an electric class 8 semi-truck with a 500 mile range for a base price of $180 000. Over time however, battery costs will decrease as technology improves. For this analysis, we will assume that as this happens, the price of a 500 mile truck will decrease, rather than an electric semi gaining increased range as Tesla would likely push for increased adoption with lower entry points.

We found that, conservatively, battery cost per kWh will decrease by 9% per year according to the ICCT. As the cost of the battery is \$108 260[6], and the total cost is \$180 000, we can model that all the non-battery related aspects of the price cost \$71 740. As battery price decreases by 9% each year, we can use an exponential function with an initial value of the 2020 battery cost of \$108 260 to model the purchase price of a semi truck, given a 10% tax incentive for electric vehicles, to be

$$P_E = (.9)[71\ 740 + (108\ 260)(0.91)^t\ ]$$

Where t is the number of years since 2020.

3.3.6 Cost of Operation for Electric Semi Trucks

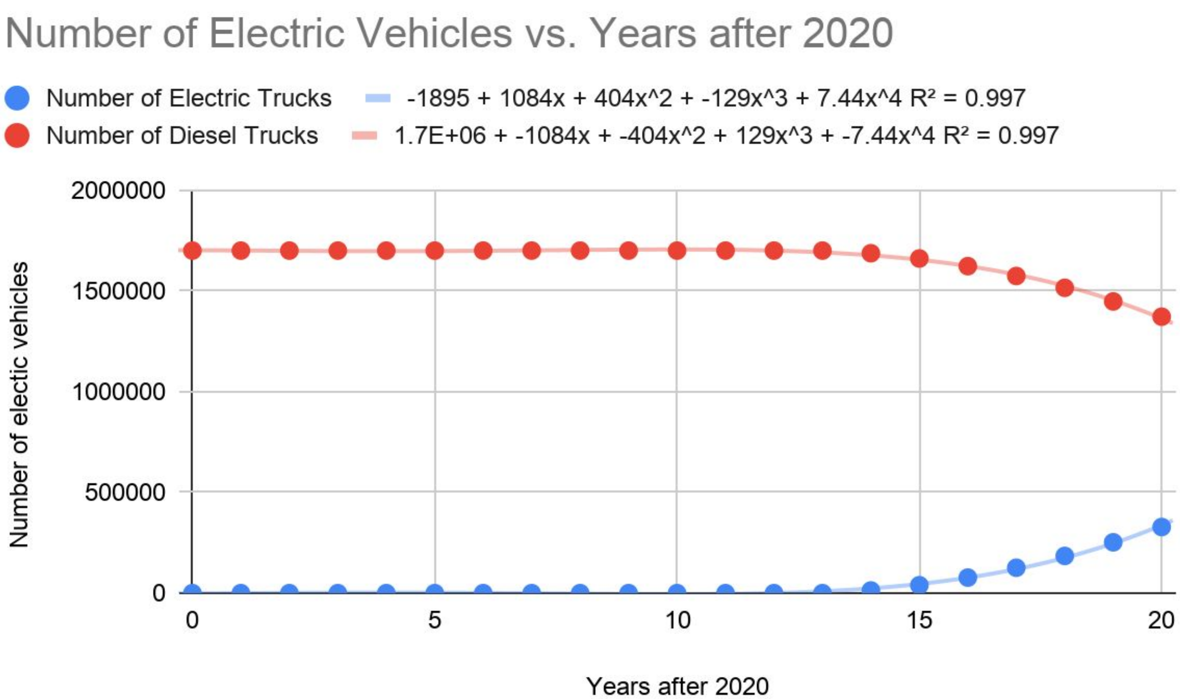
Given constant operational costs across, the only difference in operating costs come between fuel and electricity for diesel. The average commercial cost of electricity is \$0.10 per kWh[7]. The Tesla Semi uses up to 2kWh[8] of energy per mile, meaning the charging cost is \$0.20 per mile, \$.233 per mile cheaper than diesel fuel. Thus, the total operating cost per mile is \$1.323 per mile.

3.3.7 Profit for Electric Semis

We assume the revenue of an electric truck is equal to the revenue of a diesel truck, per mile. The profit for an electric truck over its lifetime is estimated to be lower than that of the diesel truck, as the 500 mile Semi's battery and drive motors are rated for 1 000 000 miles of charge cycles and driving, lower than that of the diesel truck. However, given lower operating costs and differing initial cost, we model the profit of an electric semi with

$$P_E = (R_E - m_E)l_E - i_E$$
$$P_E = (\$2.813 \text{ per mile - } \$1.322 \text{ per mile})(1\ 000\ 000 \text{ miles}) - (.9)\ [\$71\ 740 + (\$108\ 260)(0.91)^t\ ]$$
$$P_E = \$1\ 426\ 434 - \$97434(.91)^t$$

3.4 Results



Years after 2020	Number of Electric Trucks	Number of Diesel Trucks	Percent Electric
0	0	1700000	0
1	0	1700000	0
2	0	1700000	0
3	0	1700000	0
4	0	1700000	0
5	0	1700000	0
6	0	1700000	0
7	0	1700000	0
8	0	1700000	0
9	0	1700000	0
10	0	1700000	0
11	0	1700000	0
12	0	1700000	0
13	0	1700000	0

14	13055	1686945	0.7679411765
15	39174	1660826	2.304352941
16	77181	1622819	4.540058824
17	126007	1573993	7.412176471
18	184677	1515323	10.86335294
19	252306	1447694	14.84152941
20	328087	1371913	19.29923529

We can take profitability of the an Electric Truck and compare it to that of a Diesel Truck by using this equation:

$$A = \frac{P_E - P_D}{P_D}$$

From this we are able to display the increased profitability of the electric vehicles over Diesel vehicles, and assuming that after a profitability difference of +2% all buyers are willing to switch electric, thereby limiting the change in electric cars to that of the production rate, while if the profitability difference is less than +2% we see about a conversion factor of about 50% of the new Truck buyers willing to buy electric as replacement for the trucks being decommissioned, but still ofcourse limited by the max production rate of the manufacturers.

$$Number\ of\ people\ willing\ to\ convert = 50 * (\frac{P_E - P_D}{P_D})$$

We are able to simulate this by using arrays of arrays and dividing up the constant truck population into 12 rows each representing a year while 141667 columns represent each individual vehicle. We are then able to represent electric vehicles as 1 and diesel vehicles as 0. We first initialize the entire 2d- array as completely having 0 thereby representing a market with zero penetration from electric vehicles. We then move the values from the row below them to the one directly above for every row except the last. We then take the last row and depending on the profitability difference and the production rate we are able to calculate the number of cars that will most likely be replaced by electric vehicles. We continue to do this for 20 cycles or 20 years and take the electric truck population data and plot it over time. Simply enough we are able to get the population of diesel trucks by subtracting the total constant number of semis that will be in use and subtracting it by the number of electric vehicles to get the number of diesel vehicles. As for the ratio it can be gotten by dividing the population of electric vehicles by the total constant number of semi's.

3.5 Strengths and Weaknesses

The greatest strength of our model is how we considered several variables in the profit margins of electric and diesel semis while also ensuring that we combined those that we could to keep calculations relatively simple. In addition, much of our data came from reputable sources within the industry, which should ensure our calculations are as accurate as they may be when it comes to what data we have chosen to use.

However, its greatest weakness is the unknown, and the variables that we failed to consider. Laws may change, regulations may loosen or grow stricter, and incentives may be cut or grow more generous. While we did attempt to make a detailed profit function, that may have come at the expense of focusing as much on an accurate production function, as well as the exact details of fleets' conversions from diesel to electric. As such, factors may change in the future that will invalidate our predictions unless modified to account for them even if they did not seem to matter at the time this was created.

4 Problem 2: In It for the Long Haul

4.1 Local Assumptions

- *Charging stations will be used exclusively by class 4 vehicles and above.* The problem specifically refers to semi-trucks when considering the traffic among these corridors, so whether due to these stations being designed as truck stops or because consumers are still using gasoline cars, all stations in this problem will be considered for semi use only.
- *All class 4 vehicles and above are electric trucks.* Given that the problem specified such vehicles, we considered that any vehicle in this category would fall under our scope.
- *Percent of the battery used is the percent of the range used*. Since we cannot find any data on how the change in range may be larger or smaller when battery level is near its maximum or minimum, we are assuming that percent of the range traveled and percent of the battery used are equivalent.
- *Peak traffic for a given peak traffic hour in the day, is equivalent to 10% of average daily traffic .*
- *The number of stations accounted for is considered for a single truck leaving its city at full charge.*

4.2 Variables

4.2.1 Constants and Coefficients

Variable	Definition	Units

$\bar{r}$	Average range of vehicles on the route	Miles
σ	Ideal percent of battery used	%
k	Portion of traffic composed of class 4 and above vehicles on route	%
$\overline{T}_d$	Average Annual daily traffic on route	Vehicles per day

4.2.2 Independent and Derived Variables

Variable	Definition	Units
d	Distance traveled along the route	Miles
s	Number of stations required along a route	Stations

4.3 Developing the Solution

4.3.1 Calculating the Constants

We calculated the average daily traffic by taking the average value of all the given data points for a given route in excel. We calculated *k*, the portion of traffic composed of class 4 and above vehicles, by the same method. The distance was taken using google maps. To get $\bar{r}$ we took it from Tesla, a max of 500 miles[8]. To get σ , because ideal battery health is maintained between 20% and 80%, we took sigma to be 60% of total charge, or .6.

Charging stations needed would be equal to distance of the route divided by the max range of an electric semi times the acceptable battery use. The amount of times a single vehicle, starting at max charge, would need to recharge is given by the equation

$$S = \frac{d}{r\sigma}$$

Which, disregarding other limitations and factors, would be the number of charging stations needed for a given route. All results are rounded up to the nearest integer.

Route	Distance of route	Average Daily Traffic (T, vehicles per day)	Portion of traffic composed of class-4 vehicles (K)	Charging Stations Needed	Chargers Per Station

San Antonio to New Orleans	544 miles	77,580	23.4%	1.81 (2)	341
Minnesota to Chicago	566 miles	103,082	10.74%	1.89 (2)	208
Boston to Harrisburg	390 miles	75,435	16.5%	1.3 (2)	234
Jacksonville to Washington DC	706 miles	84 803	13.0%	2.35 (3)	207
Los Angeles to San Francisco	382 miles	134 347	16.91%	1.27 (2)	426

The Tesla Semi has a 500 mile cycle, given the rate of battery usage of 2 kW hours per mile, we can calculate that the semi has a 1000 kW hour battery. Assuming the best charger (1600 kW in 30 minutes) in every station[5], and a 1000 kW hour battery, it takes 0.1875 hours, or about 11.25 minutes to charge a semi truck from 20% to 80%.

Assuming peak traffic flow for any given hour is about 10% more than the average daily value, we can calculate the number of chargers per station necessary, at a given peak traffic hour, by the equation

$$\overline{T_d} * k * .1 * .1875$$

$k * \overline{T_d}$ gives us the average daily trucking traffic, multiplied by .1 to find the amount of traffic for a peak hour. That is then multiplied by the amount of time necessary to charge a truck, in hours, to give the number of charging stations necessary.

4.5 Strengths and Weaknesses

Several key weaknesses in the equation fail to account for many factors. Essentially solving for a single car, traveling only on ideal battery life, starting at 80% battery capacity. Additionally, charging locations are only placed as trucks run out of battery. In reality, truck stops, and subsequently charging stations, will be more frequent than only the max, and drivers will stop to accommodate their personal needs. Additionally, as thousands of trucks will be travelling at any given time, they will be staggered in both timing and battery capacities. Thus, although our model predicts a few massive charging centers per route, it's likely there would be several more charging centers along any given route.

5 Problem 3: I Like to Move It, Move It

5.1 Local Assumptions

- *The price of charging stations is constant*. Realistically, it's probable that charging stations would have different prices for construction depending on local geography and supply. However, here, since there are so many stations we are looking at, and such great differences already between each route, we are assuming that each station has roughly the same cost.
- *The investment in charging stations all goes to local businesses*. Since investment is considered a bonus of this program, we are assuming that officials would choose to source as much of the supply from local businesses as possible in order to ensure that the communities in which the project takes place will benefit from it.
- *Any benefit to rural economies vastly outweighs the benefit to urban economies*. Since urban economies will already have such high GDP values with or without this investment in their corridors, we believed it was safe to assume that we could look only at the benefit to rural economies to determine the benefit of this investment.

5.2 Variables

5.2.1 Constants

Variable	Definition	Units	Value
M	Macroeconomic multiplier for investment	N/A	1.3
Φ	Price of a charging station	$USD per station	$2 750
I_{T0}	Reference value for total investment after multiplier	$USD	$743 600
$\overline{Y}_0$	Reference value for rural GDP per capita	$USD	$34 722
$\overline{T}_{t0}$	Reference value for daily truck traffic	Trucks per day	11 071
α	Weight of the investment factor	N/A	2
β	Weight of the GDP per capita factor	N/A	5
γ	Weight of the daily truck traffic factor	N/A	2

5.2.2 Independent and Dependent Variables

Variable	Definition	Units
S	Charging stations along the route	Stations
n	Number of regions (of GDP per capita) on route	Regions
Y	GDP per capita in regions	$USD
$\overline{T}_t$	Average daily truck traffic	Trucks per day
I_s	Total local investment due to the station cost	$USD
I_T	Total local investment after calculation	$USD
V	Value of the project on a route	N/A

5.3 Developing the Solutions

5.3.1 Investment Results on Route

Given our assumptions, the cost of charging stations along a route can be easily by considering the previously found number of chargers multiplied by an average cost of a charger[13], or

$$I_s = s\Phi$$

Furthermore, it is generally accepted in macroeconomics that any investment in an economy will be multiplied by a factor decided by consumers' marginal propensity to consume. Here, we have simplified the calculation by looking directly at the spending multiplier, M, which was found to be roughly 1.3[9]. Thus, one can calculate the total investment in the local economies with

$$I_T = MI_s$$

5.3.2 Calculating the Rural GDP per Capita on the Route

As we have abstracted the data down to the lowest feasible level for our calculations, states, we can use the formula

$$\overline{Y} = \frac{\sum_{i=1}^{n} Y_i}{n}$$

To calculate the average rural GDP per capita along the route, which we will consider in our ranking of each corridor. Rural GDP per capita per state was abstracted here by finding the national proportion of rural GDP per capita to urban GDP[10] per capita and multiplying it by the state GDP per capita[11].

5.3.3 Final Ranking Function

When considering the value of each investment, there is a degree of bias as we must choose what components of the investment and benefits to prioritize, which is shown in the equation below, which will give us the final answer for the value of each region. As well as the previous two values calculated, we include the average daily truck traffic as another factor in our ranking, as the higher volume of traffic will further increase local spending. In addition, the reference values chosen are based off of the Minneapolis to Chicago route, as it is a medium length route.

$$V = \alpha \frac{I_T}{I_{T0}} - \beta \frac{\overline{Y}}{\overline{Y}_0} + \gamma \frac{\overline{T}_t}{\overline{T}_{t0}}$$

5.4 Results

Rank	Route	I_T	$\overline{Y}$	$\overline{T}_t$	V
1	Los Angeles, CA to San Francisco, CA	$1 522 950	$39 649	22 718	2.491
2	San Antonio, TX to New Orleans, LA	$1 219 075	$42 223	18 154	0.478
3	Jacksonville, FL to Washington, DC	$740 025	$28 934	11 024	-0.186
4	Minneapolis, MN to Chicago, IL	$743 600	$34 722	11 071	-1.000
5	Boston, MA to Harrisburg, PA	$836 550	$40 431	12 447	-1.324

As the coefficients of the function are designed to give regions with more value a higher score, our calculations determined that the Los Angeles, CA to San Francisco, CA route is the most valuable to invest in, mostly due to its high volume of traffic.

5.5 Strengths and Weaknesses

One strength of our model is in its flexibility. The format is simple enough to follow to expand upon and add more variables in order to further refine calculations for each route's value, and the weight coefficients are straightforward and simple, allowing for anyone to adjust them if they believe the priorities for values are off.

Of course, it does have its weaknesses. For one, it is rather simple and abstract, and could be further refined to consider local circumstances than it already is. Since it is a normative value as well, that of course makes it inherently biased, and no matter who calibrates the equation, it will be biased by their beliefs in which values have greater or less relative importance.

6 Conclusion

The future is now! Already, the profit of an electric semi is nearly as much as that of a diesel semi, and soon enough, we project that they will exceed diesel in most standards. There are already many reasons for companies to begin shifting over to an electric fleet of semis, but the case will only grow stronger as time goes along for them both because of legislation and their bottom line.

However, the amount of infrastructure this shift will require is going to be a large investment for the government and any private interests that take part. It will be a project almost as big as the Interstate Highway System itself - and that is only considering electric semis, and no other classes of vehicles, including non-commercial drivers.

But while it may come with great cost, it will be smart for business, and investment always brings at least some benefit to the local communities receiving the projects. Truck traffic will further pay off the cost for these regions, and rural areas in desperate need of investment will get their much needed attention.

Even if Rome can't be built in a day, the foundations are already present, and soon enough, both businesses and the government will be able to agree that electric vehicles are superior to diesel semis.

APPENDIX A: Citations

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www.evconnect.com/blog/how-to-figure-out-the-installation-cost-of-electric-vehicle-charging-stations/.

APPENDIX B: Code Excerpts

```
package solution;

public class Electruck {

    int one[][]= new int[12][141667];
    int t=0;

    public Electruck(){
        for (int i=0; i< one.length;i++) {
            for (int j=0; j<one[i].length;j++) {
                one[i][j]=0;
            }
        }
    }

    public void next(){

        int chant= (int) change();
        for (int i=0; i< one.length-1;i++) {
            for (int j=0; j<one[i].length-1;j++) {
                one[i][j]=one[i+1][j];
            }
        }
        for (int j=0; j<141667;j++) {
            one[11][j]=0;
        }
        for (int j=0; j<chant;j++) {
            one[11][j]=1;
        }
        t++;
    }
    public int sum() {
        int counter=0;
        for (int i=0; i< one.length;i++) {
            for (int j=0; j<one[i].length;j++) {
                if(one[i][j]==1) counter++;
            }
        }
        return counter;
    }
    public double profita() {
        double q=(((1426434-(97434*Math.pow(0.91, t)))-1395270)/1395270);
        if ((q*100)>2) {
        //System.out.println(1);
        return(1);
        }
        else {
    //  System.out.println(q);
        return 50*q;
        }
    }
    public double change() {
        int p=(82180-(11413*t)+(35487*t*t));
        double buy= (profita()*141667);
        if (p<141667) {
            if(buy<p)
                return  (buy);
            else
                return p;
        }
        else {
            if(buy<141667)
                return  (buy);
            else
                return 141667;
        }
    }
}
```

Java Program for Part 1

```python
# Create an array of 1.7 million trucks with 0
# 0 = diesel, 1 = electric
trucks = [0] * 1700000
totalTrucks = 1700000
electricProduced = 0

# main loop
for i in range(20):
  # Truck lifespan is 12 years, 1/12th of fleet is replaced each year
  numToChange = totalTrucks / 12

  # Calculating electric vehicles produced
  electricProduced = 82180 - 11413*i + 35487*(i**2)     # Production growth for Model S
  if electricProduced > numToChange:
    electricProduced = numToChange

  # replace one twelfth of trucks array
  replaceArray = [0] * int(numToChange-1)

  # Calculate percent profitability of electric over diesel
  pElectric = 1426434 - 97434*(0.91**i)
  pDiesel = 1395270
  percentMore = ((pElectric - pDiesel) / pDiesel)
  if percentMore < 0:
    percentMore = 0

  # Assume 3% profitability leads to a 100% adoption rate
  percentImpact = percentMore * 33.3
  if percentImpact > 1:
    percentImpact = 1

  # How many trucks to buy? The amount changing * the demand (percentImpact)
  electricToBuy = percentImpact * numToChange

  # What if we haven't produced enough? Set it to max produced
  if electricToBuy > electricProduced:
    electricProduced = electricToBuy

  for j in range(0,int(electricToBuy)-1):
    replaceArray[j] = 1

  # Get the section of the array to replace (next spot with 0)
  startIndex = int(trucks.index(0))
  endIndex = int(startIndex + numToChange - 1)
  if endIndex < totalTrucks:
    trucks[startIndex:endIndex] = replaceArray

  # Find the number of electric trucks
  numElectric = 0
  for truck in trucks:
    if truck == 1:
      numElectric = numElectric + 1
  print(numElectric)
```

Python Used in Part 1 of Problem: numElectric used to generate graph data