FACTORS AFFECTING THE RATE OF CO_2 EMISSIONS FROM VEHICLES OF DIFFERENT ENGINE TYPES

New Mexico

Supercomputing Challenge

Final Report

March 18, 2015

Team 90

Miyamura High School

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ABSTRACT

Many scientists believe that the drastic change in the climate is due to the increasing amount of carbon dioxide in the atmosphere that warms the entire Earth. Combustion of fossil fuels to produce electricity has been studied to be the primary source of carbon dioxide emissions. Gasoline and diesel combustion in transportation accounts for 32% of the total emissions; these are the secondary sources of carbon dioxide. Our team's project goal is to determine the factors that affect the rate of carbon dioxide emissions from vehicles of various engine sizes (4-cylinder, V-6, V-8, and diesel engine). These said factors are speed limit, traffic lights, and traffic congestion. We are using Netlogo program to simulate a small-scale traffic grid focusing on four vehicles set at specified locations on the grid to measure the amount of carbon dioxide emitted from each car. Data are collected, analyzed, and discussed. The results of this project are summarized and further study has been recommended.

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QUESTION, VARIABLE, AND HYPOTHESIS

QUESTION

Which factor or factors show significant effect on the rate of carbon dioxide emissions from vehicles with various engine sizes?

VARIABLES

Three factors had been identified in our model to have affected the rate of carbon dioxide emissions from vehicles with various engine sizes. These are speed limit, traffic lights, and traffic congestion. Throughout the trials, we kept the number of crossings or intersections constant at 2 while we changed the values of speed limit and number of cars using sliders, to observe the effect of each identified factor on the rate of carbon dioxide emissions of the four vehicles. We also changed the traffic lights (from red to green and vice versa) with a switch and a slider to control the switching of lights according to the number of ticks per cycle.

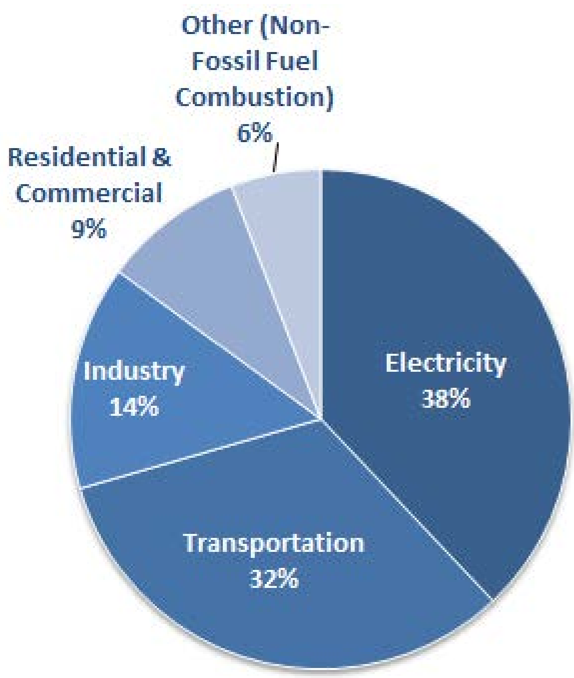
HYPOTHESIS

We believed that traffic lights and traffic congestion would show the most significant effect on the rate of carbon dioxide emissions; every time the cars would stop when traffic light is red, increased carbon dioxide would be emitted for every second that the cars are waiting for their turn to move forward. In addition, more cars mean more carbon dioxide emissions that would increase the presence of this greenhouse gas in the atmosphere.

BACKGROUND RESEARCH

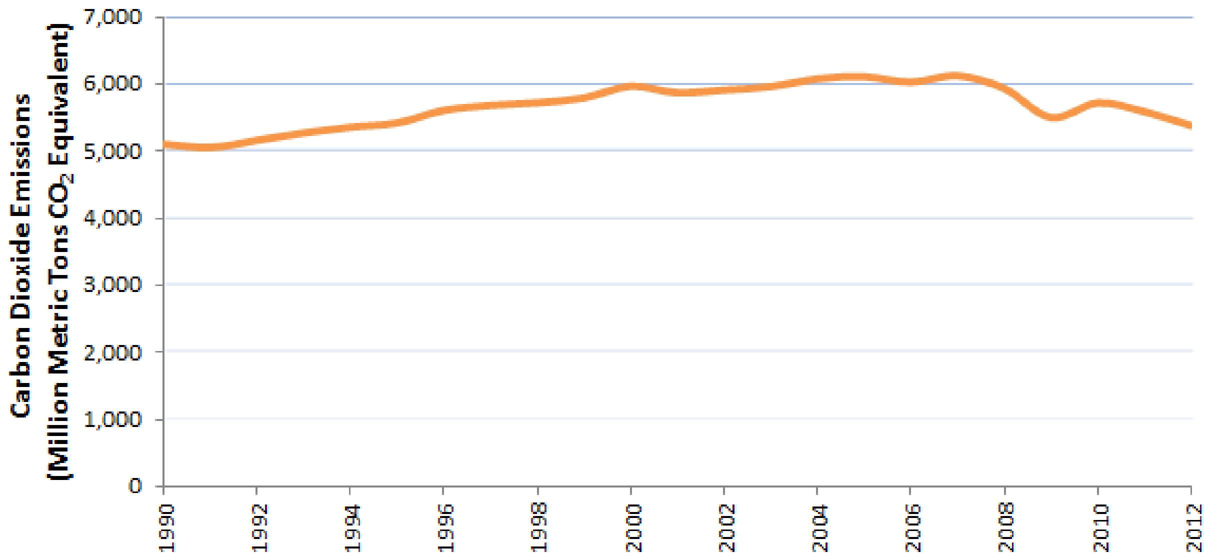
Studies show that the major sources of carbon dioxide emissions in the United States are electricity and transportation (see Figure 1). In 2012, about 38% of the total U.S. carbon dioxide emissions came from the combustion of fossil fuels, specifically coal, to generate electricity; this is the largest source of carbon dioxide emissions in the nation. The second largest source of carbon dioxide gas comes from transportation through the combustion of fossil fuels like gasoline and diesel. This accounts for about 32% of the total emissions.

FIGURE 1. *Carbon Emissions from Different Sources*



Between the years 1990 to 2012 (see Figure 2 on the next page), carbon dioxide emissions in the United States increased by about 5%. Several factors have been studied to be the sources of this increase. Some of these sources are increased population and economic growth, fluctuating energy prices, development of new technologies, and changing seasonal temperatures. Emissions from transportation contributed to about a 5% increase as well. It has been noted that as the level of carbon dioxide in the atmosphere increases, the greenhouse effect has also increased. This means that the dominant factor of the warming of the Earth is the increased emission of carbon dioxide in the atmosphere.

FIGURE 2. *Carbon Dioxide Emissions in the United States*



SAMPLING METHOD

A. Mathematical Computation

The U.S. Environmental Protection Agency (EPA) provides carbon emission rates and calculations consistent with the agency's regulatory work. The amount of carbon dioxide emitted from burning the fossil fuel depends on the amount of carbon in the fuel. Ninety nine percent (99%) of the carbon is emitted as carbon dioxide and the rest are hydrocarbons and carbon monoxide which are quickly converted into carbon dioxide once these gases reach the atmosphere.

According to the EPA calculations, an average carbon dioxide emission from a gallon of gasoline of an average passenger vehicle is 8,887 grams of CO_2/gallon. Therefore, a 1 mile driving of each type of vehicle shown in table 1 is calculated below.

4-cylinder vehicle:

$$CO_2 \text{ emissions/mile} = \frac{CO_2 \text{ per gallon}}{MPG} = \frac{8{,}887 \text{ grams}}{33.4} = \frac{266.08 \text{ grams/gallon}}{1 \text{ mile}}$$

V-6 vehicle:

$$CO_2 \text{ emissions/mile} = \frac{CO_2 \text{ per gallon}}{MPG} = \frac{8{,}887 \text{ grams}}{21.0} = \frac{423.19 \text{ grams/gallon}}{1 \text{ mile}}$$

V-8 vehicle:

$$CO_2 \text{ emissions/mile} = \frac{CO_2 \text{ per gallon}}{MPG} = \frac{8{,}887 \text{ grams}}{20.0} = \frac{444.35 \text{ grams/gallon}}{1 \text{ mile}}$$

In addition, according to the EPA calculations, diesel creates 15% more CO_2 per gallon. This means that if the emitted CO_2 per gallon is 8,887 grams from an average passenger vehicle, then diesel will create about 10,220.05 grams of carbon dioxide (see calculations below).

$$8{,}887 \text{ grams} \times .15 = 1{,}333.05 + 8{,}887 = 10{,}220.05 \text{ grams of } CO_2$$

Diesel Engine:

$$CO_2 \text{ emissions/mile} = \frac{CO_2 \text{ per gallon}}{MPG} = \frac{10{,}220.05 \text{ grams}}{14.0} = \frac{730.00 \text{ grams}}{1 \text{ mile}}$$

B. Netlogo Modeling

In Netlogo, we displayed a traffic grid with multiple lanes. The lanes had several cars with four distinct vehicles with different engine types (4-cylinder is represented by a blue car; v-6 is represented by a black van; v-8 is represented by a red truck; and diesel is represented by an orange school bus) wherein each was placed at a specified location. The total number of ticks represented the elapsed time when all vehicles reached a certain distance (in this model, we decided to have a constant distance of 10 miles or 16 kilometers). Once the distance is reached, all vehicles would disappear and the tick counter would stop from running. The amount of carbon dioxide emitted from each vehicle of specific engine type would be displayed through the monitor that was created for each specific car. For a distance of 10 miles, each vehicle, depending on its engine type, would emit a certain amount of carbon dioxide that is calculated based on the changing speed limit. The calculations are shown below:

<u>For a 35 mi/hr speed limit:</u>

4-Cylinder: 10 ~~mi~~ / 35 ~~mi~~/hr = 0.29 hr * 2660.8 g CO_2 = 760 g CO_2

V-6: 10 ~~mi~~ / 35 ~~mi~~/hr = 0.29 hr * 4231.9 g CO_2 = 1,227 g CO_2

V-8: 10 ~~mi~~ / 35 ~~mi~~/hr = 0.29 hr * 4443.5 g CO_2 = 1,289 g CO_2

Diesel: 10 ~~mi~~ / 35 ~~mi~~/hr = 0.29 hr * 7300 g CO_2 = 2, 117 g CO_2

<u>For a 45 mi/hr speed limit:</u>

4-Cylinder: 10 ~~mi~~ / 45 ~~mi~~/h = 0.22 hr * 2660.8 g CO_2 = 591 g CO_2

V-6: 10 ~~mi~~ / 45 ~~mi~~/h = 0.22 hr * 4231.9 g CO_2 = 931 g CO_2

V-8: 10 ~~mi~~ / 45 ~~mi~~/h = 0.22 hr * 4443.5 g CO_2 = 978 g CO_2

Diesel: 10 ~~mi~~ / 45 ~~mi~~/h = 0.22 hr * 7300 g CO_2 = 1,606 g CO_2

<u>For a 65 mi/hr speed limit:</u>

4-Cylinder: 10 ~~mi~~ / 65 ~~mi~~/h = 0.15 hr * 2660.8 g CO_2 = 399 g CO_2

V-6: 10 ~~mi~~ / 65 ~~mi~~/h = 0.15 hr * 4231.9 g CO_2 = 635 g CO_2

V-8: 10 ~~mi~~ / 65 ~~mi~~/h = 0.15 hr * 4443.5 g CO_2 = 667 g CO_2

Diesel: 10 ~~mi~~ / 65 ~~mi~~/h = 0.15 hr * 7300 g CO_2 = 1,095 g CO_2

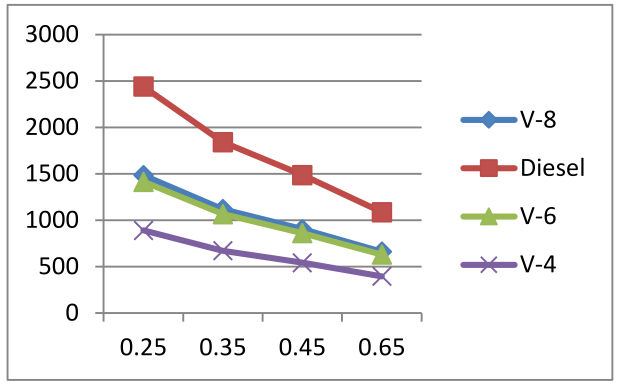
RESULTS

Data Table 1. *Number of Cars vs.* CO_2 *Emissions at 25 Ticks per Cycle*

WITHOUT TRAFFIC LIGHTS

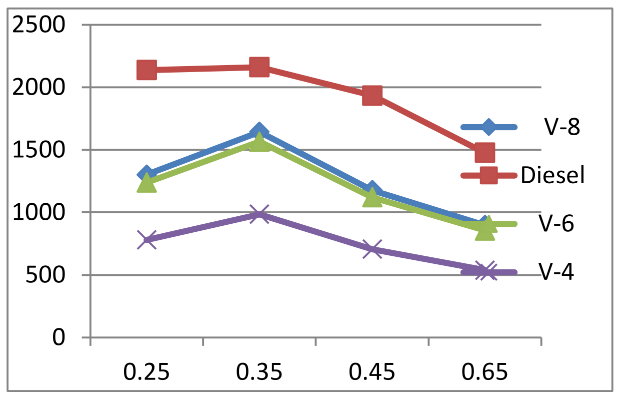
Number of cars: 4

Speed Limit	V-8	Diesel	V-6	V-4
0.25	1485	2440	1414	890
0.35	1120	1841	1067	671
0.45	904	1486	861	542
0.65	661	1087	630	396



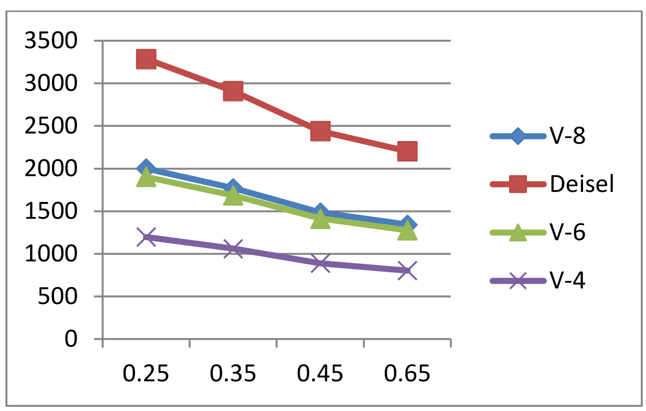
Number of cars: 50

Speed limit	V-8	Diesel	V-6	V-4
0.25	1301.2	2137.8	1238.8	779.8
0.35	1644	2160.2	1565.2	985.4
0.45	1176.8	1934	1120.6	705.6
0.65	898.8	1477.2	855.8	538.6



Number of cars: 75

speed limit	V-8	Diesel	V-6	V-4
0.25	2000.6	3286.8	1904.2	1198.8
0.35	1771	2909.8	1686	1061.4
0.45	1484.8	2439.4	1413.6	890
0.65	1341.6	2204.4	1276.2	804.2

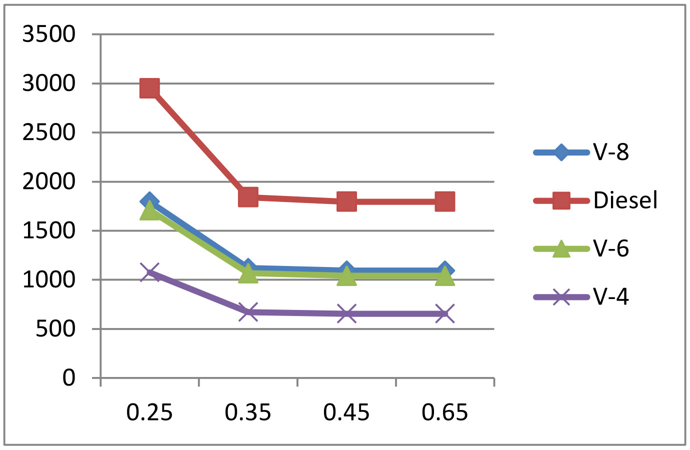


WITH TRAFFIC LIGHTS

Ticks per cycle: 25

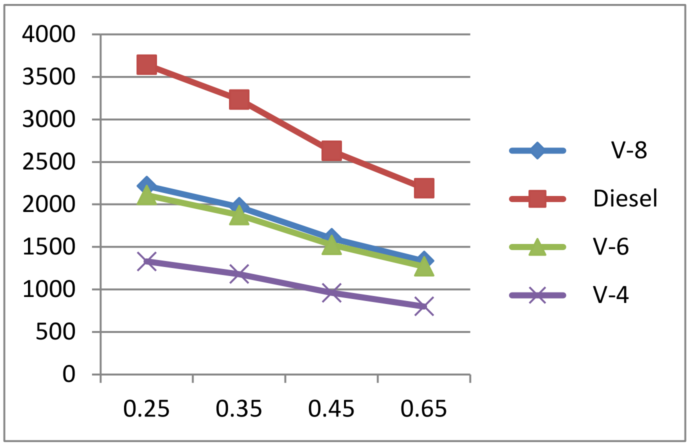
Number of cars: 4

Speed Limit	V-8	Diesel	V-6	V-4
0.25	1795	2950	1709	1076
0.35	1120	1841	1067	671
0.45	1093	1796	1041	655
0.65	1093	1796	1041	655



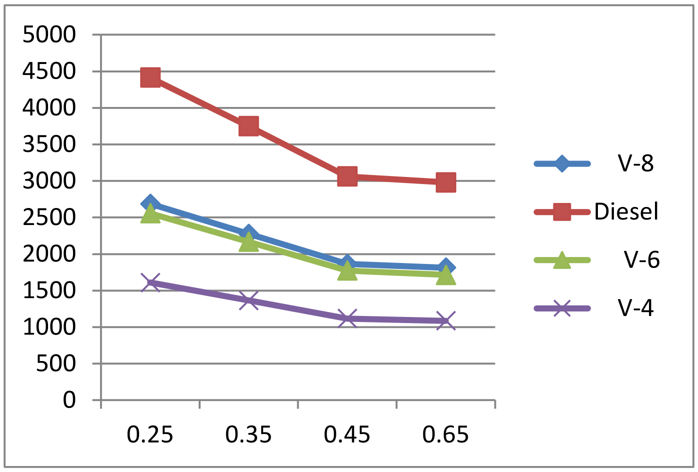
Number of cars: 50

Speed Limit	V-8	Diesel	V-6	V-4
0.25	2216.2	3641.6	2110.6	1328.6
0.35	1968	3233.6	1873.8	1179.2
0.45	1600.8	2630.2	1524	959.6
0.65	1333.4	2191.2	1269.6	799.4



Number of cars: 75

Speed Limit	V-8	Diesel	V-6	V-4
0.25	2686.4	4413.4	2557.2	1610
0.35	2276	3749.2	2166.8	1363.8
0.45	1862.6	3060.4	1773.2	1116.4
0.65	1814.2	2980.8	1714.8	1087.2

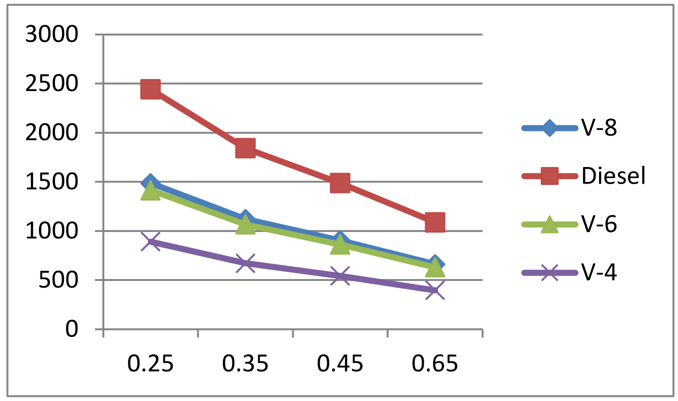


Data Table 2. *Number of Cars vs. CO_2 Emissions at 50 Ticks per Cycle*

WITHOUT TRAFFIC LIGHTS

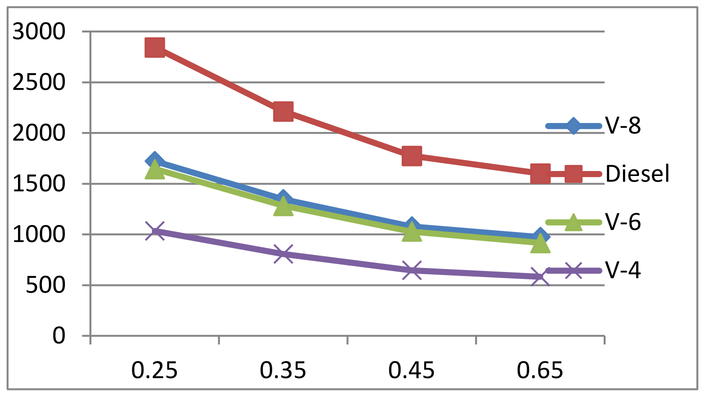
Number of cars: 4

Speed Limit	V-8	Diesel	V-6	V-4
0.25	1485	2440	1414	890
0.35	1120	1841	1067	671
0.45	904	1486	861	542
0.65	661	1087	630	396



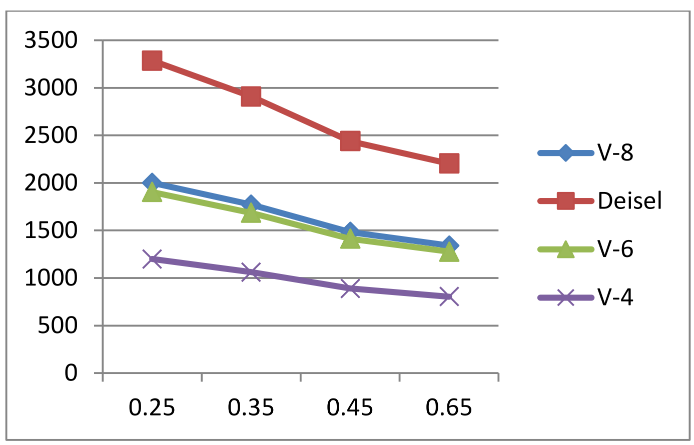
Number of Cars: 50

Speed Limit	V-8	Diesel	V-6	V-4
0.25	1722.4	2844.8	1645	1035.6
0.35	1347	2213.4	1282.6	807.4
0.45	1079.8	1774.4	1028	647.2
0.65	974.2	1601.2	916	584.2



Number of cars: 75

speed limit	V-8	Diesel	V-6	V-4
0.25	2000.6	3286.8	1904.2	1198.8
0.35	1771	2909.8	1686	1061.4
0.45	1484.8	2439.4	1413.6	890
0.65	1341.6	2204.4	1276.2	804.2

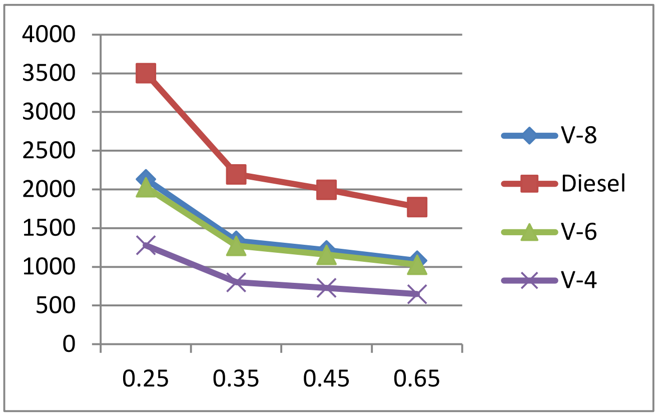


WITH TRAFFIC LIGHTS

Ticks per cycle: 50

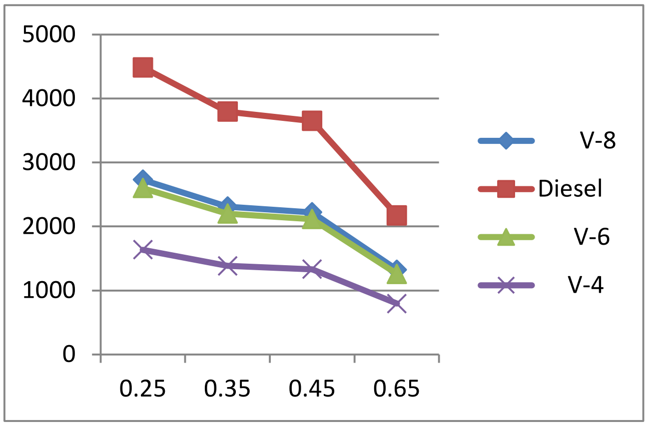
Number of cars: 4

Speed Limit	V-8	Diesel	V-6	V-4
0.25	2133	3504	2030	1278
0.35	1336	2196	1272	801
0.45	1215	1996	1157	728
0.65	1080	1774	1028	647



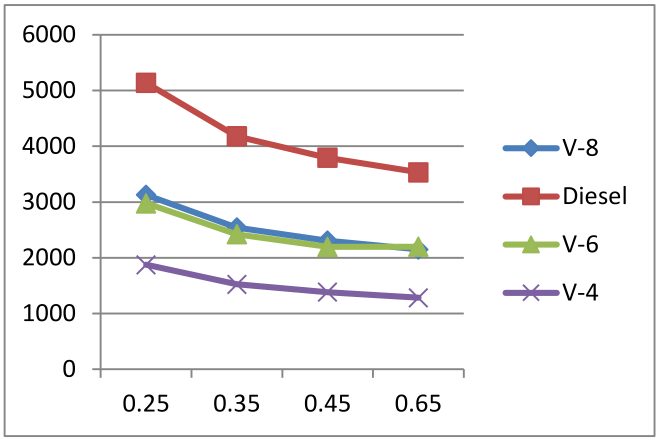
Speed Limit	V-8	Diesel	V-6	V-4
0.25	2732	4488.8	2600.8	1637
0.35	2311	3796.8	2200	1385.2
0.45	2222	3650.4	2115	1331.8
0.65	1322.8	2172.8	1259.4	793.2

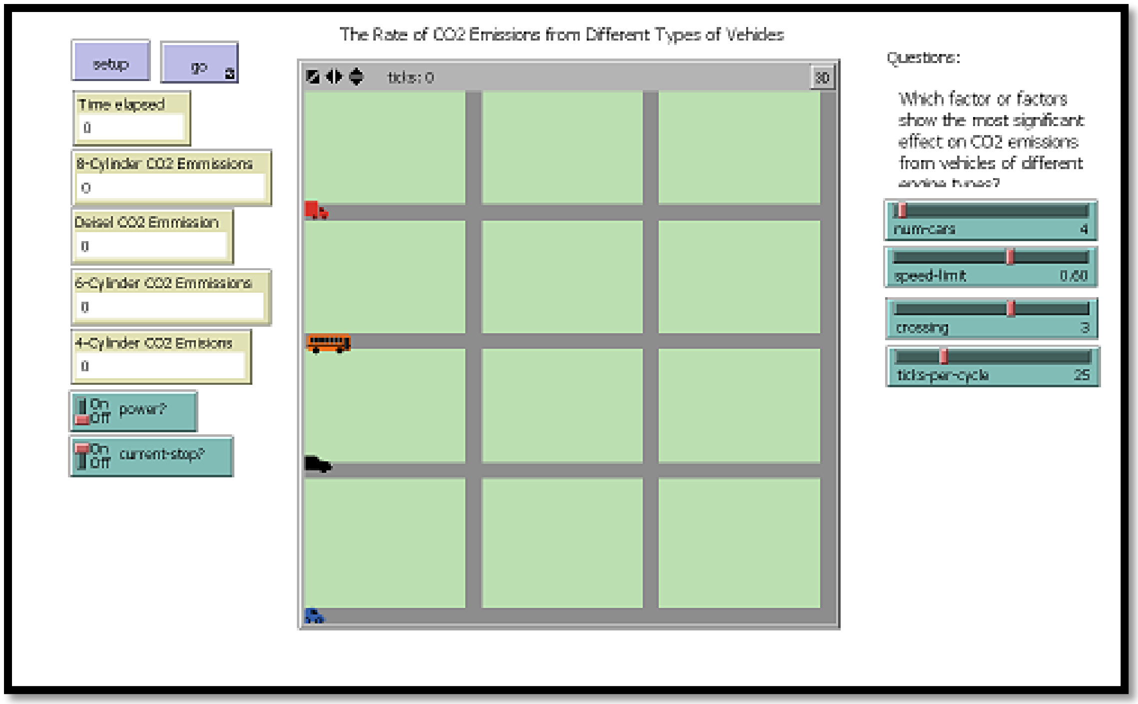
Number of cars: 50



Number of cars: 75

Speed Limit	V-8	Diesel	V-6	V-4
0.25	3126.4	5136.6	2976.2	1873.8
0.35	2543.2	4178.2	2421	1524
0.45	2308.2	3792.4	2196.4	1383.4
0.65	2149	3530.8	2198.2	1283





Three different factors were studied and tested in our model. These were the ticks per cycle to switch the traffic lights from green to red and vice versa, number of cars to produce greater or less traffic congestion, and speed limit set to .25mph, .35mph, .45mph, and .65mph under two conditions, no traffic lights and with traffic lights.

During the first trial, we measured the carbon dioxide emissions of each of the four vehicles with different engine sizes (4-cylinder, v-6, v-8, and diesel engine) as they ran a constant distance of 10 miles or 16 kilometers with varying speed limit without traffic lights. We set the values of the ticks per cycle to 25 and 50, and set the number of crossings or intersections to 2. We did the same tests and same conditions with 50 and 75 cars to see how traffic congestion could affect the rate of carbon dioxide emissions of each vehicle being tested.

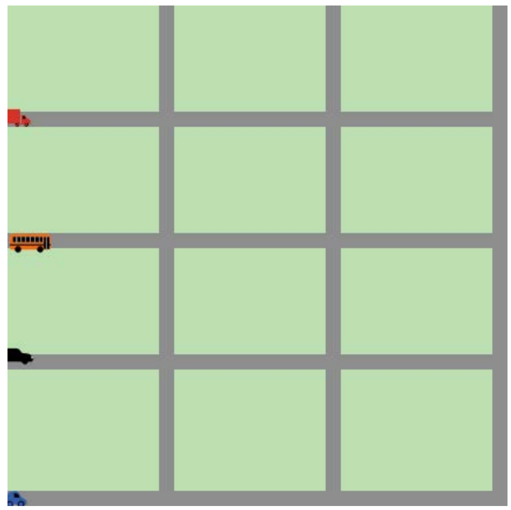
Without traffic, we compared the rates of carbon dioxide emission rate with less traffic (only four vehicles) and with more traffic (by the addition of more cars on the grid), and having the ticks per cycle set at twenty-five at first them at fifty. We observed a dramatic increase of carbon dioxide emissions from all four vehicles. Nearly every vehicle increased its CO_2 emissions by six hundred to a thousand grams. With traffic lights and the speed limit set at .25, the amount of carbon dioxide gas was increased by about nine hundred for the eight-cylinder, about one thousand five hundred for the diesel, about nine hundred for the six-cylinder, and about six-hundred for the four-cylinder. The final run of the model showed a decrease of emissions as the speed limit was increased by 0.10. Each vehicle showed a significant decrease of its CO_2 emissions when speed limit value was increased - nine hundred for the eight-cylinder, one thousand five hundred for the diesel, nine hundred for the six-cylinder, and six hundred for the four-cylinder. This tells us that CO_2 emissions and speed limit show an inverse relationship – the faster the vehicles run, the less CO_2 gas would be emitted.

With traffic lights, the carbon dioxide emissions from the four vehicles increased dramatically, about 400 to 500 grams, compared to running with no traffic lights. The increase of the speed limit value still exhibited a decrease in the amount of CO_2 emissions but in comparison to having no traffic lights when the vehicles ran, the amount of the emissions was still higher.

DISCUSSION OF RESULTS

We did several tests on four specific vehicles with different engine sizes (4-cylinder is represented by a blue car, V-6 is represented by a black van, V-8 is represented by a red truck, and diesel engine is represented by an orange school bus). The setting of the Netlogo world in our model was at 16 maximum patch x-coordinate and maximum 16 patch y-coordinate to represent a distance of 16 kilometers or 10 miles for the entirety of the trials or tests. Another factor that was held constant during the trials we performed in our model was the number of intersections or crossings – it was held constant at 2. The tests were done under two conditions, with or without traffic lights.

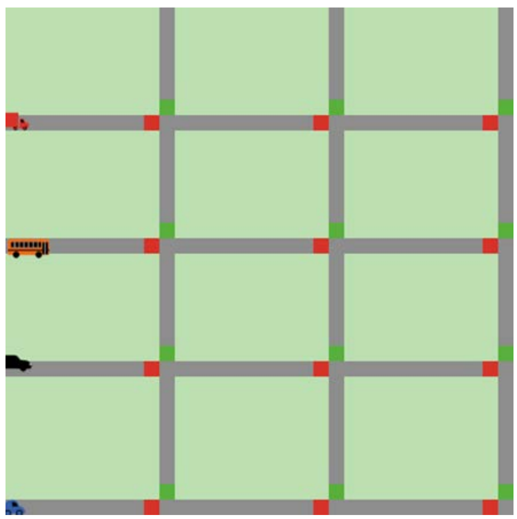
A. Without Traffic Lights



During several trials, we observed an increased rate of CO_2 emissions with increasing number of cars and decreasing speed limit. This trend was observed to be the same throughout all the tests we did even though we changed the number of ticks per cycle from 25 to 50 as well as the number of cars from 4 to 50 to 75 using different sliders. Based on the results and data we have gathered, we believed that congested traffic forces vehicles to slow down even more while CO_2 is continually emitted for every second that the vehicles slowly move its way through traffic. Out of the four tested vehicles, diesel engine had emitted the most amount of CO_2 and the 4-cylinder engine emitted the least amount which was not really surprising to us since we learned from our research that the bigger the engine, the greater amount of fuel it could hold, therefore the greater the emissions of the greenhouse CO_2 gas and vice versa. What truly surprised us was the noted slight difference of the CO_2 emissions between V-8 and V-6 engines considering the fact that V-8 engine vehicle had greater fuel capacity than V-6; we expected V-8 vehicle to emit more CO_2 than V-6 vehicle. In addition, we were surprised to observe in our data a greater CO_2

emission at .35 speed limit than .25. We always thought that the slower the vehicles run based on the speed limit, the more CO_2 would be emitted, but in this case, it proved us wrong. We believed that the placement of the cars on the road during traffic had to do with the unusual results we observed. Since our model would automatically place other cars on the grid every time the setup button is executed (except for the specific four vehicles we focused on in our study) when the simulation was run, it showed us results that we did not expect at all.

B. With Traffic Lights



At 25 ticks per cycle, switching of traffic lights would automatically occur (from green to red and vice versa). We observed a significant decrease of the rate of CO_2 emissions from the four specific vehicles when the value of the speed limit was increased from 0.25 to 0.35, and remained constant when the speed limit was changed from 0.45 to 0.65. Again, we did not expect for this result to occur but we believed that at 25 ticks per cycle, the traffic lights switched quickly from green to red and the reduced speed limit of 0.25 made all four vehicles to run slower and were stopped at the first intersection when the switching of the traffic lights took place, thus emitting more CO_2 gas in the process. At speed limits of 0.35, 0.45, and 0.65, all four vehicles ran with more speed and were able to pass through the intersections quickly without stopping before traffic lights could switch to red; CO_2 emissions were observed to be significantly reduced.

With increased number of cars (50) at 25 ticks per cycle and at speed limit of .25, CO_2 emissions were higher compared to only having four cars on the road which we expected. With more traffic, the speed of the vehicles would decrease emitting more CO_2 gas. As the speed limit increased (from 0.25 to 0.65), we noted a constant decrease of CO_2 emissions from all four vehicles. This time, our prediction was right that increased speed limit would reduce CO_2 emissions from each type of vehicle, and vice versa. Diesel engine vehicle still produced the greatest amount of CO_2 gas and the 4-cylinder engine vehicle produced the least. Both V-8 and V-6 engine vehicles still produced almost the same amount of CO_2 gas within a 10 mile distance.

At 50 ticks per cycle, the switching of traffic lights took a little longer than 25 ticks per cycle. We still observed a significant decrease of the rate of CO_2 emissions from all four vehicles when the speed limit was increased from 0.25 to 0.35 and a slight decrease when the speed limit was increased from 0.35 to 0.65. About more than 500 grams of CO_2 were emitted by each vehicle of four at speed limit of 0.25 for the reason that vehicles at this speed limit ran slower and were stopped at the second intersection. As the speed limit was increased, there was a slight decrease of CO_2 emissions as vehicles ran faster toward their destination. With more traffic, there was a significant increase of CO_2 emissions from all four vehicles at speed limit of 0.25 (about 1,000 grams). This does not surprise us knowing that more cars mean reduced speed and increased CO_2 emissions.

Finally, changing the ticks per cycle from 25 to 50 does not show any effect on the rate of CO_2 emissions from the four vehicles, maybe because the distance was not long enough for all vehicles to make several stops at different intersections.

CONCLUSION

According to research, transportation accounts for about 32% of the total carbon dioxide emissions in the United States. The combustion of gasoline in many vehicles increases the amount of carbon dioxide gas in the atmosphere. We have identified three factors that significantly increase the rate of CO_2 emissions from vehicles of differing engine sizes (4-cylinder, V-6, V-8, and diesel). These identified factors are speed limit, traffic lights, and traffic congestion. The results showed us that there is an inverse relationship between speed limit and carbon dioxide emissions. As the speed limit increases the rate of CO_2 emissions decreases within two conditions (with and without traffic lights). On the other hand, there is a direct relationship between traffic congestion and carbon dioxide emissions. Having more cars on the grid creates increased traffic congestion which also increases the rate of CO_2 emissions from all four vehicles. Also, the addition of traffic lights significantly increases the rate of CO_2 emissions which tells us that these two variables are directly related.

After several tests and observations, we have finally made a conclusion that all three factors (speed limit, traffic lights, and traffic congestion) significantly affect the rate of CO_2 emissions from all four vehicles. Since the situations shown in our simulation cannot be avoided within the city limit, our team suggests for vehicle drivers to avoid (if possible) driving on roads with more traffic or with traffic lights to reduce the emissions of CO_2 gas. The best solution for everyone to try doing is to purchase hybrid cars if one can afford to do so or buy a car with smaller engine size.

IDEAS FOR FUTURE RESEARCH

Out team plans to continue with the study of CO_2 emissions from different vehicles but this time instead of focusing on different engine sizes, we would switch our focus to the different types of vehicles such as regular cars (typical passenger vehicles), hybrids, solar cars, and the standard cars (use of manuals). We would like to determine which of this car is more reliable in producing the least amount of CO_2 gas under several conditions. The same three conditions (changing speed limit, number of cars, and increasing traffic congestion) would still be tested in this future model but we would like to add other conditions such as weather factors like rain, snow, and wind. Additionally, we would like to study the rate of CO_2 emissions of the vehicles running at varying distances (short and long distances) to find out which type of car is the best to use when traveling long distances in terms of reduced CO_2 emissions.

ACKNOWLEDGMENTS

Supercomputing Challenge Program for supporting us financially beyond and above and for the opportunity to program and compete

NMCS4All for providing us with a computer science class at Miyamura High School to learn the concepts and coding

Mr. Dustin Byford, for paying for our team's registration

Mrs. Dolino for coaching and helping us complete our project

Mr. Jeremy Jensen and **Ms. Julie Scott** for their unwavering support

Mr. Nick Bennett, for helping us complete our model

Mr. Drew Einhorn, for the great suggestions on how to gather data

Miyamura High School administration for their continued support

Gallup-McKinley County School District

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