THE EFFECTS OF RANDOMIZED DISTRIBUTION OF VEHICLES STOPS ON FUEL CONSUMPTION AND ENVIRONMENTAL POLLUTION: UNIVERSITY CAMPUS CASE STUDY

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Abstract

Traffic congestions around the world are becoming major nuisances due to the huge number of cars travelling through the streets. The effects of traffic congestion are concentrated on fuel consumption and environmental pollution. This work is concentrated on the study of the effects of randomized distribution of vehicles stops on fuel consumption and environmental pollution. This case study was conducted at a university campus were12 stops situated randomly around the university campus. It is clear that the optimal fuel consumption occurs at speeds 50-80 km/h, and from the study (according to stops situations) it is difficult to reach these speeds. The results of this study showed the location and number of vehicle stops had major effects on amount of fuel consumption and environmental pollutions.

Keywords: Air Pollution, Fuel Consumption, Vehicle Emissions, Exhaust Emission, Traffic Congestion

1. Introduction

The subject of environmental pollution is gaining in importance due to its impact on people's daily life, including health related problems. The current major development in the industry and technology and economic recovery are all factors that increase the effects of environmental pollution. Streets and roads are carrying larger numbers of vehicles which are turning into the main source of environmental pollution. Today's on-road vehicles produce over a third of the carbon monoxide and nitrogen oxides in our atmosphere and over twenty percent of the global warming pollution.

The estimated number of motor vehicles in use in the world as of 2013 were 1,129,000 billion cars, including light, medium, heavy duty trucks, and buses as shown in Table 1. In last two years there is growth ratio of 1.0363 each year. In 2013, a total of 84.1 million cars and commercial vehicles were built worldwide, led by China, with about 19.3 million motor vehicles manufactured, followed by the United States with 10.3 million, and Japan with 9.9 million.

Table 1 : Historical trend of worldwide vehicle registrations

Historical trend of worldwide vehicle registrations 1960-2010 (thousands)									
Type of vehicle	**1960**	**1970**	**1980**	**1990**	**2000**	**2005**	**2009**	**2010**	**2013**
Car registrations	98,305	193,479	320,390	444,900	548,558	617,914	684,570	707,764	811,237
Truck and bus registrations	28,583	52,899	90,592	138,082	203,272	245,798	295,115	307,497	318,663
World total	126,888	246,378	410,982	582,982	751,830	863,712	979,685	1,015,261	1,129,900

In early 2013, administators of Anbar University, Iraq decided to introduce new 12 vehicle stop inside university campus. This case is considered to be air pollution problem and it is important to measure the effects of these vehicles stops on the environment campus (Warner, 2008).

The work aims to estimate the total emissions of the vehicles, estimate the total fuel consumption of the vehicles, and establish a statistical base for projecting future emission levels of vehicles.

2. Vehicular Air Pollution

Air pollution became a major problem in the world because of the uncontrolled uses of natural resources. Transportation produces 30% of the total global warming emissions that are more than 1/3 of all carbon dioxide emissions. Small passenger cars and light trucks represent the lion’s share of U.S. transportation emissions and collectively generate more than 1/5 of the nation’s total global warming pollution. The remaining transportation emissions is due to medium size vehicles and heavy-duty vehicles (primarily freight trucks and buses), adding aircraft, shipping, rail, military, and other uses. Every gallon of gas burned emits nearly twenty five pounds of carbon dioxide and other global-warming gases into the atmosphere. About 5 pounds of that is due to the extraction of petroleum and the production and delivery of the fuel. Nevertheless, the great bulk of heat-trapping emissions (about nineteen pounds per gallon) come right out of a car's tailpipe. It adds up fast. Each year, the average car sends seven tons of carbon dioxide into the atmosphere about 3.5 times the vehicle's weight (Smit et.al. 2008; Zhu et.al. 2012).

3. Literature Review

Many works are published in this field and some of these works are listed below:

Höglund and Niittymäki (1999) used the methodology of traffic simulation and calculations of emissions related to singular vehicles driving patterns, by a specially developed computer program. The aggregated results of total emissions, for various substances depending on real traffic situations in different times of the day, give the possibility for a comparison of different alternatives. The results show that the complexity of finding such a best alternative to be feasibly designed and implemented. The emitted amounts are highly dependent on vehicle speed changes through the interaction between the various vehicles in the traffic flow (Höglund and Niittymäki 1999).

Dominici et al. (2003) explained a critically review and compare epidemiological designs and statistical approaches to estimate relations between air pollution and health. They implemented the following questions: design statistical methods to estimate associations between air pollution and health, estimated health effects of air pollution in time series studies, and then evaluated the challenges and future research opportunities relevant to regulatory policy (Dominici et al. 2003).

Janes et al. (2008) used the panel study design to evaluate the short-term health effects of air pollution. Standard statistical methods are available for analyzing longitudinal data, but the literature reveals that these methods are poorly understood by practitioners. They reviewed standard statistical methods for modeling longitudinal data, Marginal, conditional, and transitional approaches for correlation and dealing with missing data. They also explained techniques for controlling for time-dependent and time-independent confounding and for exploring and summarizing that Janes et al. (2008).

Akpinar et al. (2009) presented the relation between mentioned air pollution concentrations such as the total suspended particles (TSP) data and Carbon dioxide (SO2) and meteorological factors such as temperature, wind speed, relative humidity and atmospheric pressure was studied for Elazıg Turkey city. According to the regression analysis results of non-linear and linear, it is found that there is a moderate and small level of relation between the concentrations of air pollutant and the meteorological factors in that city (Akpinar et al. 2009).

Lelieveld et al. (2013) calculated air pollution by fine particulate matter (PM2.5) and ozone (O3) that increased strongly with industrialization and urbanization. They estimated the premature mortality rates and the years of human life lost (YLL) caused by anthropogenic PM2.5 and O3 in 2005 for epidemiological regions defined by the World Health Organization (WHO). This work based on high resolution global model calculations that resolve urban and industrial regions in greater detail compared to related work (Lelieveld et al. 2013).

Dobrot and NatasaPetrovica (2013) examined Europe Union member countries air pollution per inhabitant, using statistical approach.Then measured the air pollution per inhabitant and evaluating this measurement by ranking those countries. Then explained the results of ranking, which came as a result of this research and abilities of specific countries to cope with the environmental problems such as air pollution. Then defined the measurement of the air pollution per inhabitant, which includes the whole set of input parameters, and discovering which of these parameters were crucial for ranking of countries.

4. Efficiency of Fuel Consumption:

The maximum permitted levels of pollutants atmospheric that are harmful to human health are indicated by the European Union Ambient Air Quality Directive and in that case the government is try to do that work towards the full compliance with these standards. The air quality standards for nitrogen dioxide and small particles present the greatest problem, especially for those people living in urban areas that are situated close to busy roads that cause big air pollution. Emissions of these air quality pollutants from vehicles at the road are reduced by applying certain factors such as; improving the performance of fuels and setting accurate limitation increasingly stringent emission for new cars. Over the last twenty years increasingly stringent emission limits have been set at a European level, starting with the limits in 1993. Currently all new cars must have certain specifications to reach the Euro 5 standard and all models sold have had to reach that standard from the beginning of 2011(West et.al. 1998).

For new cars models at their type approval test, the level of air quality pollutant emissions and their information must be mentioned. Unlike the CO2 and fuel consumption for air quality pollutant emissions that should not be used to directly compare different models of vehicle. These emissions are indicative rather than absolute, and those emissions will vary within an acceptable range between individual production vehicles for each model. It is necessary to know the average speed of the vehicle that reduces the fuel consumption as shown in figure 1that gives the relationship between vehicle speed and fuel consumption. It is possible to split this figure into four sections, as denoted below (note that this curve is concern with low duty vehicle) (Wenzel, 2010 and Rakha et.al. 2000) :

- Speed from zero to 30 km / h: In which, the fuel consumption is high.
- Speed of 30 to 55 km / h: In which, increasing the speed of the vehicle with less fuel consumption.
- Speed of 55 to 80 km / h: In which, the best fuel consumption possible.
- Speed of 80 to 120 km / h: In which, fuel consumption increases with increasing speed of the vehicle.

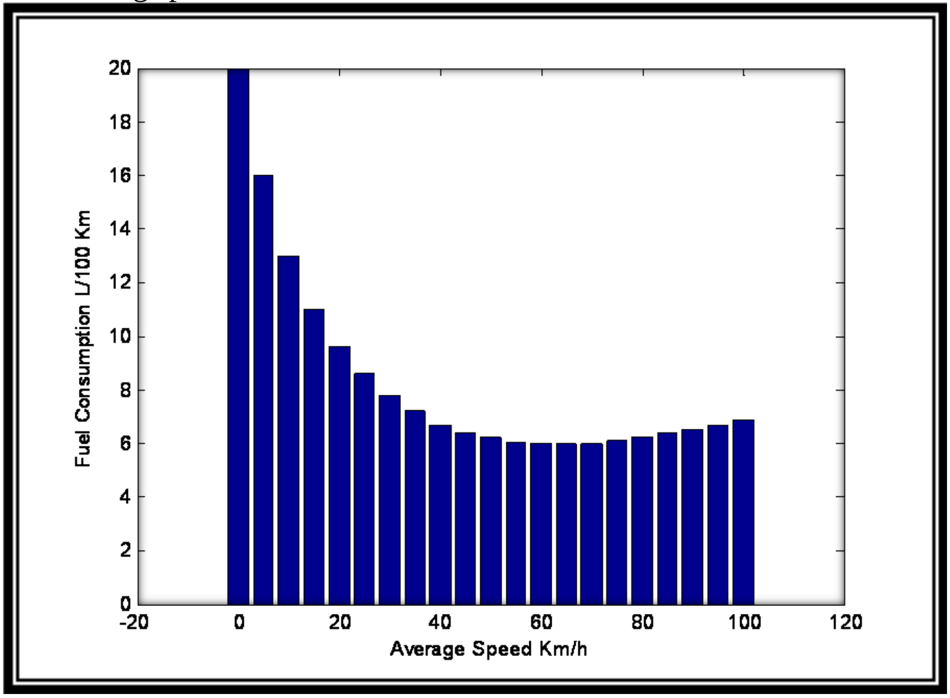

Figure 1: The relation between speed and fuel consumption in small vehicles

5. Vehicles Exhaust Emission

Oxides of nitrogen, Carbon monoxide, un-burnt hydrocarbons and particulate matter are the main air quality pollutant emissions from diesel petrol and other fuel engines as illustrated in figure 2. Oxides of nitrogen, un-burnt hydrocarbons, and carbon monoxide, are invisible gases. Particulate matter is normally invisible although diesel engines will generate visible particles under certain operating conditions that seem as smoke. The cars emissions and regulations are mentioned by the Euro emissions standards. Modern cars produce very small quantities of air quality pollutants when they're kept in good operating conditions. On the other hand the emissions from huge number of cars lead to significant air pollution problems. Petrol engines will also produce visible particles if they are burning engine oil or running rich. Small particles can also be produced by car tire and brake wear. Unlike emissions of Carbon Dioxide (CO2), emissions of the air quality pollutants are not directly linked to fuel consumption. Pollutant emission levels depend mainly on vehicle technology production and the state of maintenance and performance of the vehicle. Other factors, such as driving conditions, speeds limitations, driving style, ambient temperature and environment stats also affect these conditions. However, as a starting point, all new passenger cars must meet and reach minimum EU emissions standards to reach a minimum emission.

The effects of these exhaust gases are shown in figures 2 and 3asdescribed below in more detail:

- **Carbon monoxide (CO)** reduces the blood's oxygen carrying capacity which can reduce the availability of oxygen to key organs. High levels of exposure can be fatal, such as might occur due to blocked flues in domestic boilers. At lower concentrations CO may pose a health risk, particularly to those people that are suffering from heart disease.
- **Oxides of Nitrogen (NOx)** react in the atmosphere to form nitrogen dioxide (NO2) which can have adverse effects on health, particularly among people with respiratory illness. High levels of exposure have been linked with increased hospital admissions due to respiratory problems, while long term exposure may affect lung function and increase the response to allergens in sensitive people. NOx also contributes to smog formation, acid rain, can damage vegetation, contributes to ground level ozone formation and can react in the atmosphere to form small particles.
- **Particulate Matter (PM)** small particles have an adverse effect on human health, particularly among those with existing respiratory disorders. Particulate matter is associated with increased hospital admissions due to respiratory and cardiovascular problems, bringing forward the deaths of those suffering from respiratory illnesses and a reduction in life expectancy.
- **Hydrocarbons (HC)** contribute to ground level ozone formation leading to risk of damage to the human respiratory system. In addition, some kinds of hydrocarbons are carcinogenic and they are also indirect greenhouse gases.
- European Union emission regulations for new light duty vehicles (passenger cars and light commercial vehicles) are summarized (CO=1.0 g/Km, HC=0.1 g/Km, NOx=0.06 g/Km and PM=0.005 g/Km) as the shown in figure 3 (Frey et.al. ,2008; Bandeira et.al. 2012; Zervas and Lazarou 2007).

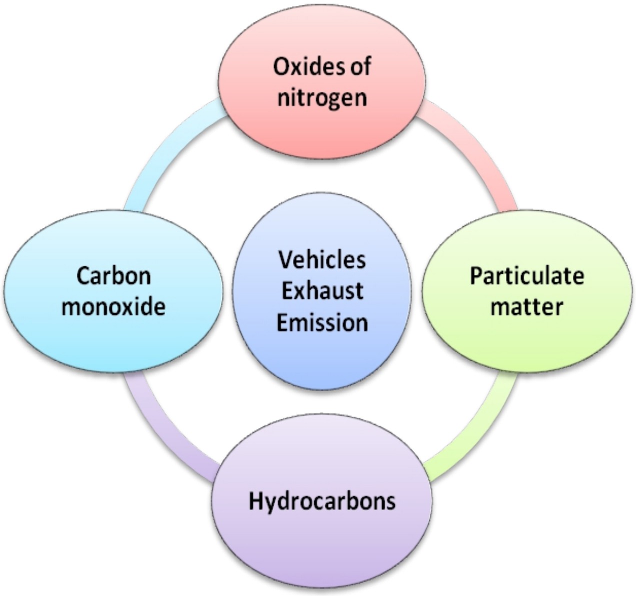

Figure 2: Vehicles exhaust emission

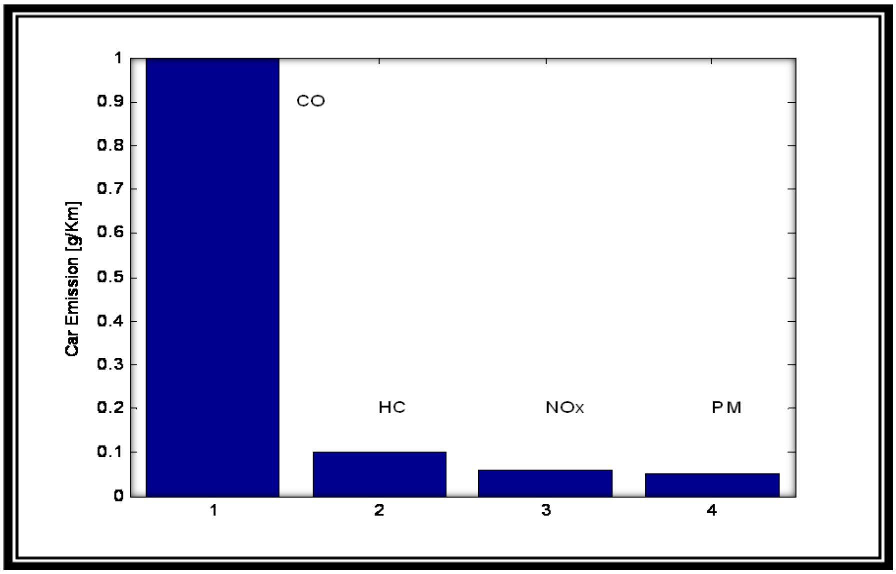

Figure 3: Car emission standard

6. The Proposed Solution of the Selected Case Study:

Anbar University campus was the selected location for this case study. It's located 5 Km from the center of the City of Anbar. This university is surrounded by a well done road of about 5 Km as shown in figure 3. At the beginning of 2013 the managers are situated 12 vehicle stops on the circular road. According its figures contains more than a thousand of teachers, more than a thousand of employees, and more than 10 thousands of students.

Approximately 3,000 vehicles are estimated to use this circular road every day to gain access to places of work within the university campus (except for vehicles with special functions).The main point that this circular road that is dose not made for high speed vehicles because it is not a street road and it have many curves that limited the vehicles speed. The introduction of those stops caused additional problems such as, increased time delays and fuel consumption as well as increased pollution of the environment.

Figure 3: the university campus environment

7. Results and Analysis:

According to this study we can mention the following points:

There are about 3000 cars pass through the circular road daily.

The fuel consumption and environmental pollution are calculated daily and for a period of one academic year (considering 200 day for the academic year).

According to the selected park that has about 50% new cars that travelled less than 100000 Km (less than 5 years of production year) and 50% used cars that travelled more than 100000 Km (more than 5 years of production year).

Considering the standard fuel consumption as denoted in figure 2, then the analysis of obtained results can be divided into two parts:

First part dedicated to fuel consumption in which we can see that the fuel consumption after putting the 12 car stops is approximately duplicated because the cars cannot reach their steady. The total fuel consumption before putting cars stops 864 litters and this is becomes 1752 litters after putting cars stops as shown in figure 4. The fuel consumption is calculated for one academic year approximately 200 days, this leads to fuel consumption of 172800 litters before putting cars stops and 350400 litters after putting cars stops as shown in figure 5; this means there are additional 177600 liters of fuel consumption or 264000 $ each year at this small campus.

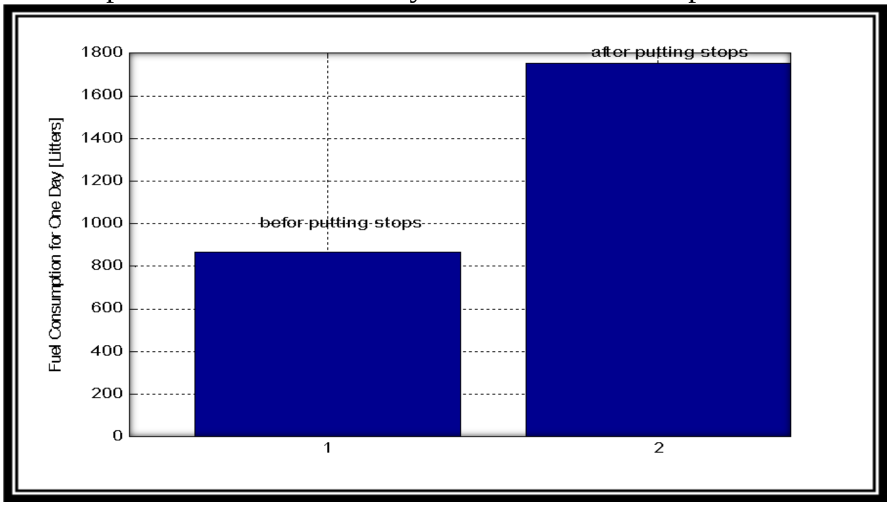

Figure 4: Fuel consumption for one day of 3000 cars passing

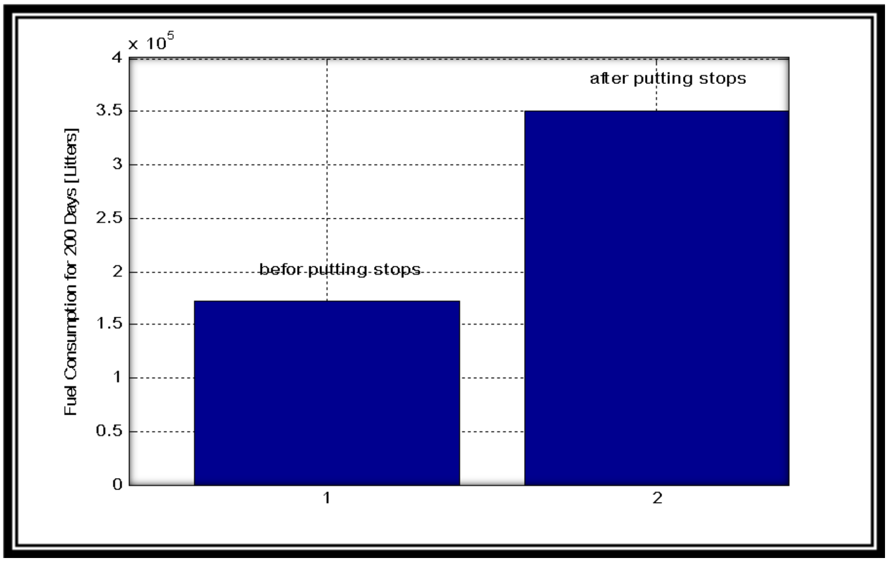

Figure 5: Fuel consumption for 200 days of 3000 cars passing

Second part dedicated to cars exhaust emission that deals with the European Union emission standards. The measurement is concern with the distance of 5 Km around the university campus but with the adding of 12 cars stops, the required time to pass this distance is approximately duplicated. The total emission before putting cars stops (CO=15000 g, HC=1500 g, NOx=900 g and PM=75 g) and this is becomes (CO=30000 g/Km, HC=3000 g/Km, NOx=1800 g/Km and PM=150 g/Km) after putting cars stops as shown in figure 6. The total emission is calculated for one academic year approximately 200 days, this leads to exhaust emission of (CO=3000000 g, HC=20000 g, NOx=12000 g and PM=1000 g) before putting cars stops and (CO=6000000 g, HC=40000 g, NOx=24000 g/Km and PM=2000 g/Km) after putting cars stops as shown in figure 7; this means cars exhaust emission is duplicated each year at this small campus, that adding a big air pollution to the environment.

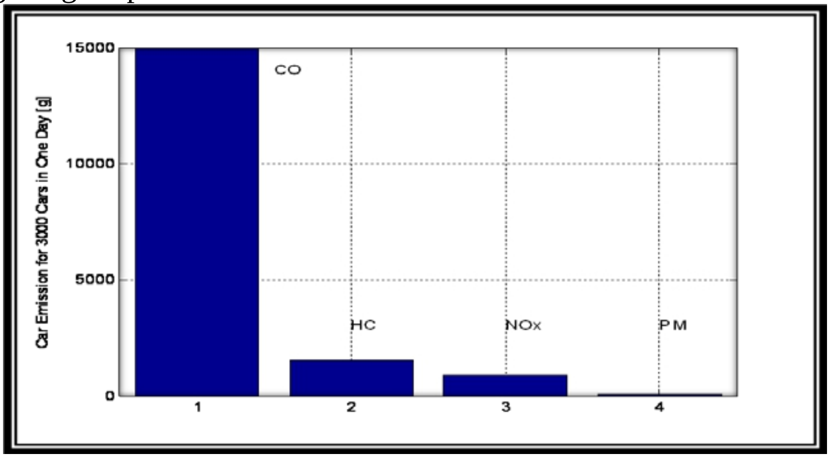

Figure 6: Car Emission for 3000 Cars in One Day

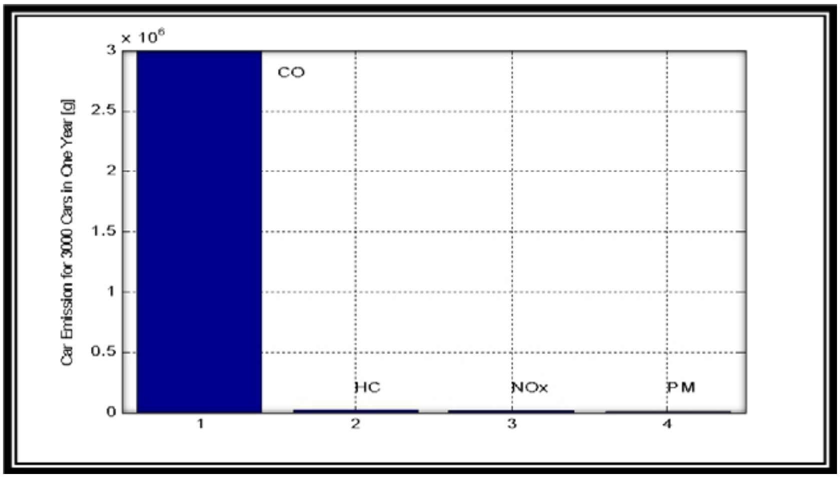

Figure 7: Car Emission for 3000 Cars in One Year

8. Conclusion

Fuel-efficient vehicles use less gas to travel the same distance compared to their less efficient counterparts. When less fuel is burned, fewer emissions are generated. When emissions go down, the pace of global warming slows. According to this study we can conclude the following:

- Sudden stops leads the car speed to approach to zero, which increase fuel consumption to maximum that you cannot avoid at the new situation.
- The 12 cars stops that were situated at the university campus are located without feasible study and these stops are fixed randomly.
- The introduction of these 12 car stops cause the cars speed to reach to zero and it is impossible to reach the steady speed and according to the calculation the fuel consumption is duplicated.
- According to the obtained result, there are about 177600 liters of fuel consumption or 264000 $ adding each year at this small campus.
- There is about exhaust emission of (CO=3000000 g, HC=20000 g, NOx=12000 g and PM=1000 g) before putting cars stops and these values are duplicated after putting cars stops.

The findings of this study give credence to the concept of governments introducing new legislations as well as providing the necessary resources to encourage the introduction of automobiles hat run on alternative fuels like clean diesel, biodiesel, ethanol, hydrogen, and compressed natural gas or that run on hybrid technology.

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