Assessing Energy Consumption of the Transport Sector in Aleppo, SYRIA

H. Achour[a], A. Marashly[b], A. G. Olabi[a]

a School of Mechanical and Manufacturing Engineering, Dublin City University, Dublin, Ireland

b Faculty of Technical Eng, University of Aleppo, Aleppo, Syria

Corresponding author: achourh2@mail.dcu.ie

Abstract:

Energy consumption from the transport section, in many developing countries, has not been dealt with the same intensity than that of developed countries. Due to the rapidly expanding mobile populations in the developing world, the issue of low carbon development and transport needs to be urgently addressed.

In this paper, two cars using different routes have been employed. Vehicle speed, engine speed along with other data have been extracted from the two cars using an on-board diagnostic reader and a data acquisition software installed in a portable PC. Data has been saved and used to establish driving cycles for Aleppo city in SYRIA and to estimate the energy consumption of the two cars.

A representative driving cycle reflecting the real-world driving conditions is proposed and estimated vehicle emissions is compared with measured results. The method is easy to follow and the results correlate well with the estimated values.

Keywords:

Energy consumption, driving cycles, on board diagnostic, developing country.

1. Introduction

Urban air pollution is one of the major problems confronting the world population. Due to the introduction of recent legislative laws, there has been a more stringent need to find appropriate methods of vehicle emission measurement. These means of emission measurement are to ensure the control of the amount of toxic gases these vehicles produce into the atmosphere. The harmful emissions that are produced from the exhaust pipes of these vehicles are Hydrocarbons (HC), Nitrogen Oxides (NOx), Carbon monoxide (CO), Carbon dioxide (CO2), Particulate Matter (PM) and Sulphur Oxide (SOx). The consequences of these emissions entail air pollution, smog, acid rain, liver damage, cancer, heart disease and the increase in global warming.

Car manufacturers and drivers can help reduce these harmful emissions in three separate ways, (1) Increasing engine efficiency i.e. electronic ignition, fuel injection systems and electronic control units which control the amount of fuel wasted in the engines fuel system. (2) Increasing vehicle efficiency i.e. lightweight vehicle design, reduced air resistance, improved powertrain efficiency and regenerative braking (3), standardized driving technique, unobstructed traffic conditions, cruising at an optimum speed for the vehicle and the reduction of cold starts.

The main aim of this research is to study the effects of a driving cycle on exhaust emissions and how estimated emissions compare to the actual emissions emitted by the same driving cycle. This is done by driving along two separate routes such as a motorway and an urban or secondary road. The emissions will be recorded using appropriate tools and related software. Along with the main objective, there are also a number of areas which this testing will provide information. From testing, an insight should be gained into air pollution and its related effects. It is known that vehicles contribute most to air pollution through car emissions and the methods allows for the effects in high residential areas such as Aleppo to be seen.

An improved understanding of the basic emission mechanisms can help during traffic planning stages which in turn can help the environment. This improved understanding allows for the assessment of environmental impacts and can aid in the design of more efficient methods to help control air quality.

This research covers the following specific objectives:

1. Effects of a driving cycle on gas emissions.

2. Driving behaviour on gas emissions.

3. Urban route emissions measures against Motorway emissions.

The goal of the final results is to help the planning authorities to set a baseline for air pollution which can be directly assigned to vehicles travelling along a specific route, either through motorway or urban route. There is a high level of traffic within Aleppo which travels through residential areas as to avoid the motorway. By highlighting the negative effects this causes in these areas, driving behaviour may in turn be changed to ensure a better and more sustainable environment.

There are many ways of measuring emissions: theoretical, experimental and real life measurement. The use of software such as COPERT 4 [1] (COmputer Programme to estimate

Emissions from Road Transport) has been in effect for many years. It uses equations to interpret the expulsion of emissions from combustion engines. It takes parameters from certain vehicles such as engine size, the technology level and the average speed in kilometres per hour and provides results in g/km. From calculation of these equations, theoretical values for each particular emission can be obtained. These values can be very accurate but are still only theoretical and do not take into account the drivers influence on the car.

With use of the On Board Diagnostics (OBD) signal interpreter, the Elm scan 323 returns emissions values for emissions and the driving cycle. Emissions levels and driving cycles give the general traffic conditions of the car driven and also how the car is being driven by the driver. The aim of this project is to estimate vehicle emissions by defining this driving cycle, the use of the OBD and configured LabVIEW software to help display many helpful characteristics for this research. These characteristics include Acceleration (m/s), Deceleration (m/s), Engine speed (rpm), Vehicle speed (km/h), time parameters (which in turn can be used to define the drive cycle), as well as the engine coolant temperature (C°).

Both of these previous methods for emission analysis give theoretical and experimental values for emission measurement. However these emission measurements cannot currently take effects of weather into account. Humidity, air temperature, altitude, rain, snow and other seasonal effects have a large influence on the emissions measured.

Although average-speed models have a world-wide use in transport sector, there are some difficulties facing this method, such as fleet test data, fleet activity patterns, acceleration issues, identifying of local emissions, etc [2]. However, good correlations between the predicted results of the modelling packages and the actual data obtained by direct measurement are still maintained.

In this paper, the estimation of spark ignition vehicle emissions with the aid of drive cycles was studied. The COPERT 4, OBD and gas analyser methods of emission analysis were examined and compared using the data gathered. Drive cycles of various traffic conditions were obtained. Results will be discussed in details through the paper.

2. Case study: Aleppo city

Syria is classified as a lower middle-income developing country with an average annual growth rate of 2.2% of per capita GDP since 2000; and a population growth rate of 2.45% in 2006 and 2007. The country formally adopted the environmental impact assessment system in 2008 and a comparative research with other systems shows a significant step forward since 2008 [3].

Aleppo is the second capital city located in the northern border with Turkey with an area of 16,000 km^2 and has a population of 4,393,000 making it the largest Governorate in Syria by population. The main source of this city is the agricultural products of the surrounding region, mainly wheat, cotton, pistachios, olives and sheep. Also it has been known as a trade and an industrial city. As an educational part, The University of Aleppo was established in 1958 with twenty five academic faculties, 10 intermediate colleges and 126,861 students in 2008.

Fig. 1. Traffic in city centre.

Fig. 2. City centre measuring station

Traffic is one of the biggest problems in Aleppo, Fig. 1. There is not any major solution found for this big problem yet. The city has only few measuring stations for air quality. However, detailed surveys of the traffic (counts, origin destination) were still carried out in the city centre as well as the Old City where the air pollution is critical and human population density is high. Fig. 2 shows the location of the station for city centre at President Square and Figs 3 and 4 show the daily report of CO and NOx emissions which mainly come out from vehicles. Evaluation of the impact of the planned package for the cleaner transportation system around and inside the Old City would be useful.

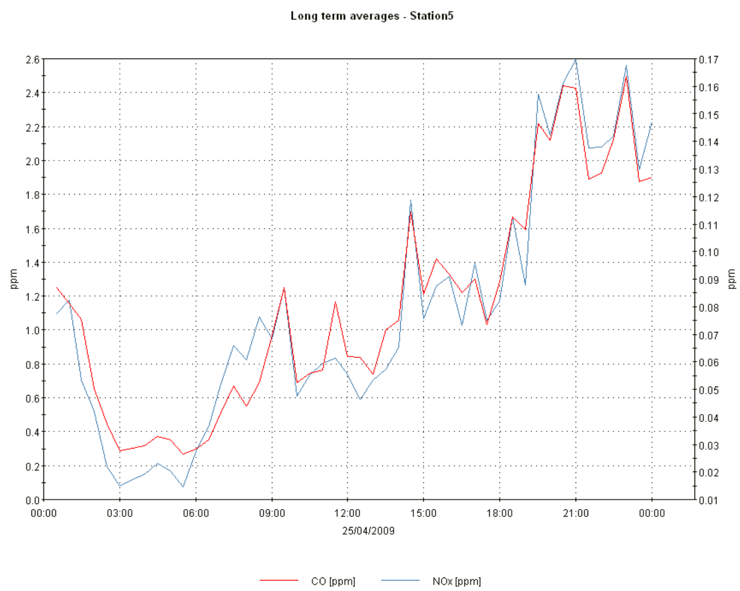

Fig. 3.Daily monitoring of CO, Nox in a weekend day.

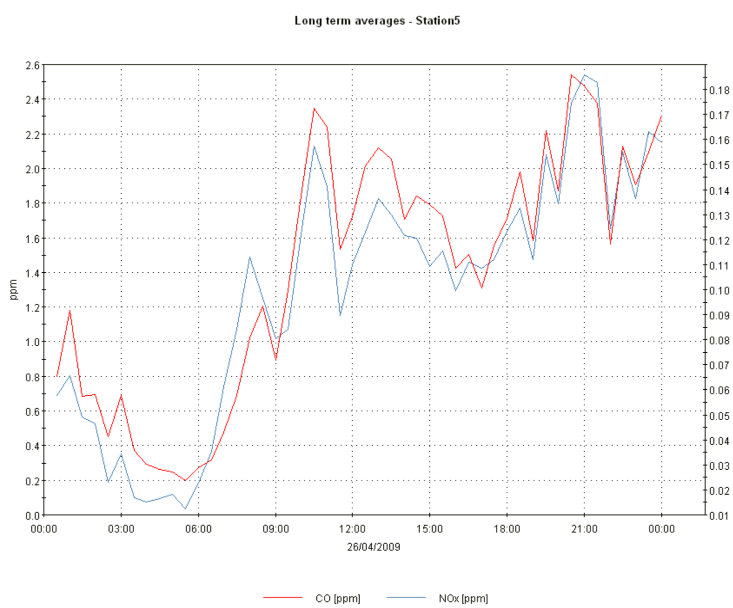

Fig. 4.Daily monitoring of CO, Nox in a workday.

In Aleppo city, there are more than three hundred fifty thousand light duty vehicles running almost daily and there is no sufficient document leading to accurate engine capacity. Table 1 shows the total number of cars in Aleppo and how cars are divided into six sections and not three sections as seen internationally, (i.e. K≤1.4L). Also it was noticed from the table that almost 50% of cars are with unknown engine capacity and there are no alternative fuel system cars taken into account in the data given while some of the countries are carrying out a comparative study of vehicles using bio-fuel and compressed natural gas (CNG) [4].

Table 1. Total number of cars in Aleppo city.

Engine capacity K (litre)	Petrol cars	Diesel cars
1≤ K	38986	1358
1<K≤2	106952	340
2<K≤3	6107	12032
3<K≤4	2323	2880
4<K≤5	376	880
5<K	257	6592
Unknown K	97072	79527
Total	252073	103609
Grand total	355682	

In China, much research has been done on energy consumption analysis and fuel types were compared with each other including alternative fuel systems which are leading to a more developments in fuel technology [5]. This development can in turn reduce the oil consumption for transport [6]. In parallel with these developments; the transport sector has a good effect on a viable eco-driving strategy and reduction of excess fuel consumption [7]. In fact, many of these researches have to be applied in the developing countries as the transport sector is facing problems in oil supply as well as increased use renewable energy in the near future [8]. An example of alternative fuel development includes the use of a proton-exchange membrane fuel-cell for transport in United Arab Emirates, [9].

2. Emission Estimation

Emissions can be determined in many ways, either by direct measurement of emissions or by the application of emissions factors based on empirical expressions derived from real-world tests. In Edinburgh, for instance, the driving cycle was obtained from recorded data in actual traffic conditions using the car chase technique for comparison with the European driving cycle [10]. In Athens, emissions and fuel consumption measurements showed significant variations between Athens driving cycle and the European driving cycles [11]. Outside Europe in Hong Kong, a systematic and practical method for developing representative driving cycle has been developed with a focus on the cost effectiveness for continuous refinement of driving cycle [12].The most useful data sets for this work would come in the form of the COPERT or the TRL (Transport Research Laboratory) emissions factors. Both can describe emissions in terms of grams per kilometre travelled (g/km) and are functions of vehicle speed [13]. For the COPERT factors:

$$EF_{i,\ m,\ n} = \left(\frac{\alpha + \gamma\chi + \varepsilon\chi^{2} + \zeta\chi^{-1}}{1 + \beta\chi + \delta\chi^{2}} \right) \cdot (1 - RF) \quad (1)$$

Where, $Ef_{i,\ m,\ n}$ is the emissions value, in grams per kilometre travelled [g/km] for a given species i, of age m, engine size n, x is the average vehicle speed in kilometres per hour, and α, β, γ, δ, ε, ζ are related to the legislative emission factors for that car i.e. Euro1, 2, 3, etc. RF are coefficients specific to a given engine size m, and technology level n.

CO and Nox has been calculated individually for each time step using equation (1), and then accumulated in order to extract the average EF:

$$\text{Ave EF} = \sum \text{EF}(n) / N \qquad (2)$$

Where EF (n) is the emission factor each time step, N is the number of time steps.

The total EF would become:

$$Ef_{total} = \text{Ave EF} \times \text{Distance travelled} \qquad (3)$$

NOx emission has been calculated by the same steps mentioned above [14].

3. Experimental Work

An On Board Diagnostic (OBD II) reader as seen in Fig.5 has been used and configured to extract the data and save it in a built-in data acquisition package in order to estimate the instantaneous emissions produced from a vehicle. The programme utilized can show and save some of vehicle parameters such as, engine speed, vehicle speed, coolant temperature, and engine load; also it shows accelerations and decelerations of the car during the trip. This type of tool is not compatible with all type of cars, so only limited cars have been tested in this research such as the NISSAN Micra, FORD Focus, FIAT Marea, TOYTA Camry, HYUNDAI Verna, and KIA Rio.

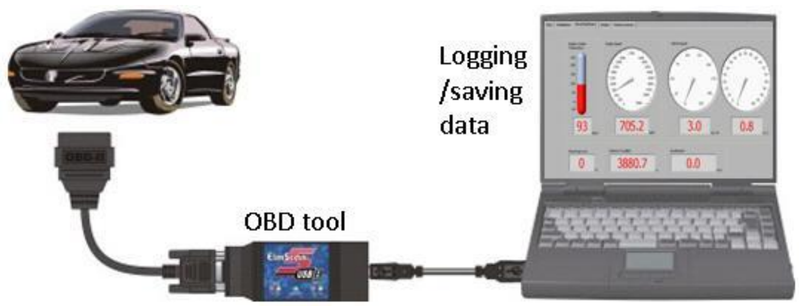

Fig.5. OBD scan tool connected to both car and laptop

Two persons were on-board. The driver has been asked to drive in normal driving condition as if there were no control on his car as this may affect on the factor of driving behaviour and the second person is the technician who monitored the two devices while working to ensure normal results have been taken. After extracting data from the OBD system of the car and logging them into a datasheet, driving cycles have been obtained and emission factors have been estimated. Fig.6 describes the methodology used in the experiments.

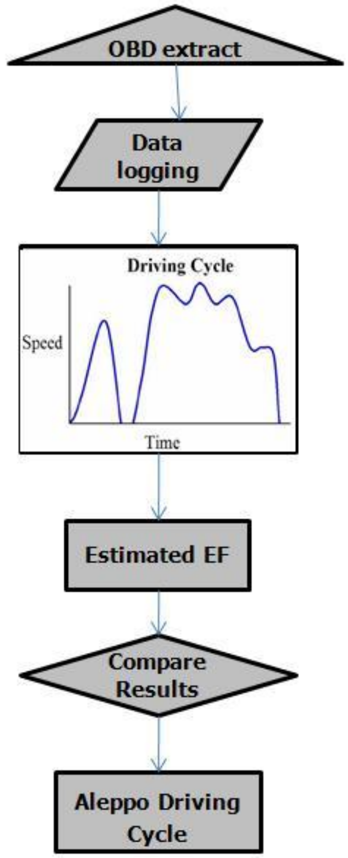

Fig. 6. Flow chart of development of Driving Cycle

3.1. Phase1: Establishing a preliminary driving cycle.

As it is the first time such a driving cycle for the city of Aleppo has been done, many trips have been implemented in order to optimize the results obtained from those trips. The first spark ignition vehicle tested was a passenger car. The model was a KIA Rio (registered in 2007) with legislative standard Euro4 as described in Table 2.

Table 2. Engine specifications of KIA Rio.

Fuel type	**Gasoline**	**Displacement**	1599 cc
Bore x stroke	76.45×87.12 mm	**Max. output**	110Kw@6000 RPM
Compression ratio	10.0:1	**Max torque**	107Nm@4500 RPM

Three trips have been carried out on a daily basis. The first and second trips were during peak hours (going to work and back home) and the third was in the evening time for the same route Fig7. The total trip distance was nearly 6km.

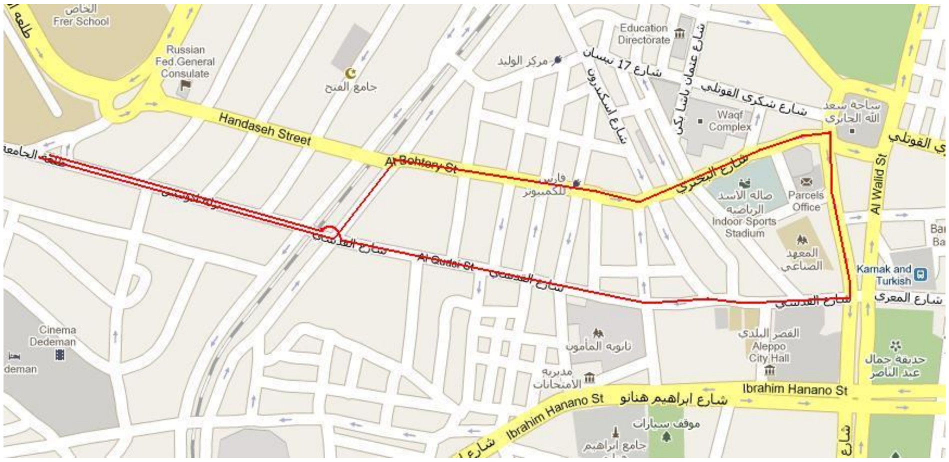

Fig. 7. The route used by the first car. (Home-Work phases)

3.2. Phase2: Assessing Energy Consumption.

The second phase was to assess the emission factors produced from tests carried out on another car in order to implement the methodology used in this research. The second spark ignition vehicle tested was a passenger car. The model was a TOYOTA Camry (registered in 2009) with a legislative standard Euro5. Two trips have been done. The first was during peak hours, and the second was in the evening time for the same route around Aleppo University Campus. The total trip distance was nearly 6km as displayed in Fig 8.

Table 3 Engine specifications of TOYOTA Camry.

Fuel type	**Gasoline**	**Displacement**	2362cc
Bore x stroke	88.5×96.00 mm	**Max. output**	118kW@6000 RPM
Compression ratio	9.8:1	**Max torque**	218Nm@4500 RPM

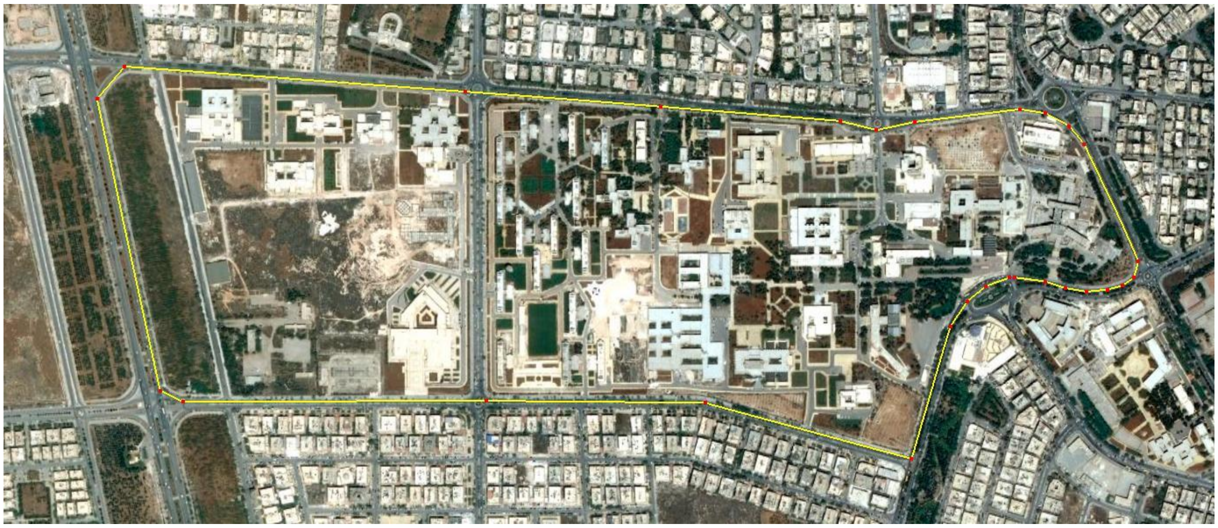

Fig. 8. The route used by the second car.

4. Results and analyses

4.1. Establishing a preliminary driving cycle for Aleppo City

Three optimum trips were chosen for peak hour time (home-work phase) as shown in Fig9.It had been distinguished that the maximum speed reached was 55km/hr and the maximum stops were 15 times in one trip. The trip map was chosen depending on traffic congestion levels and distance from city centre. The streets tested were between city centre and Aleppo University which has around 130,000 students on campus. On testing, some errors had occurred. Therefore, many tests were performed to achieve a representative driving cycle for the city. Fig 10 shows the optimum trips for the evening time mode.

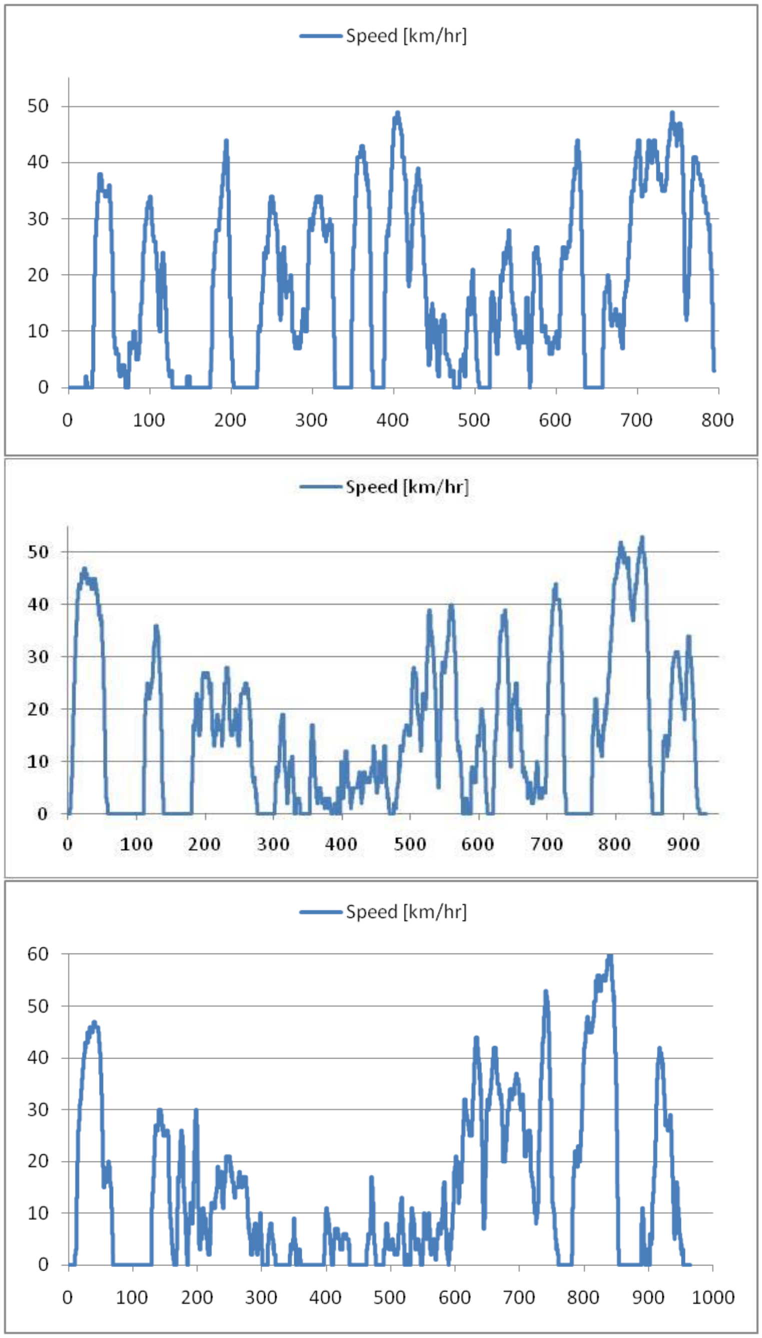

Fig.9. Three Optimum trips for peak hour [time vs speed].

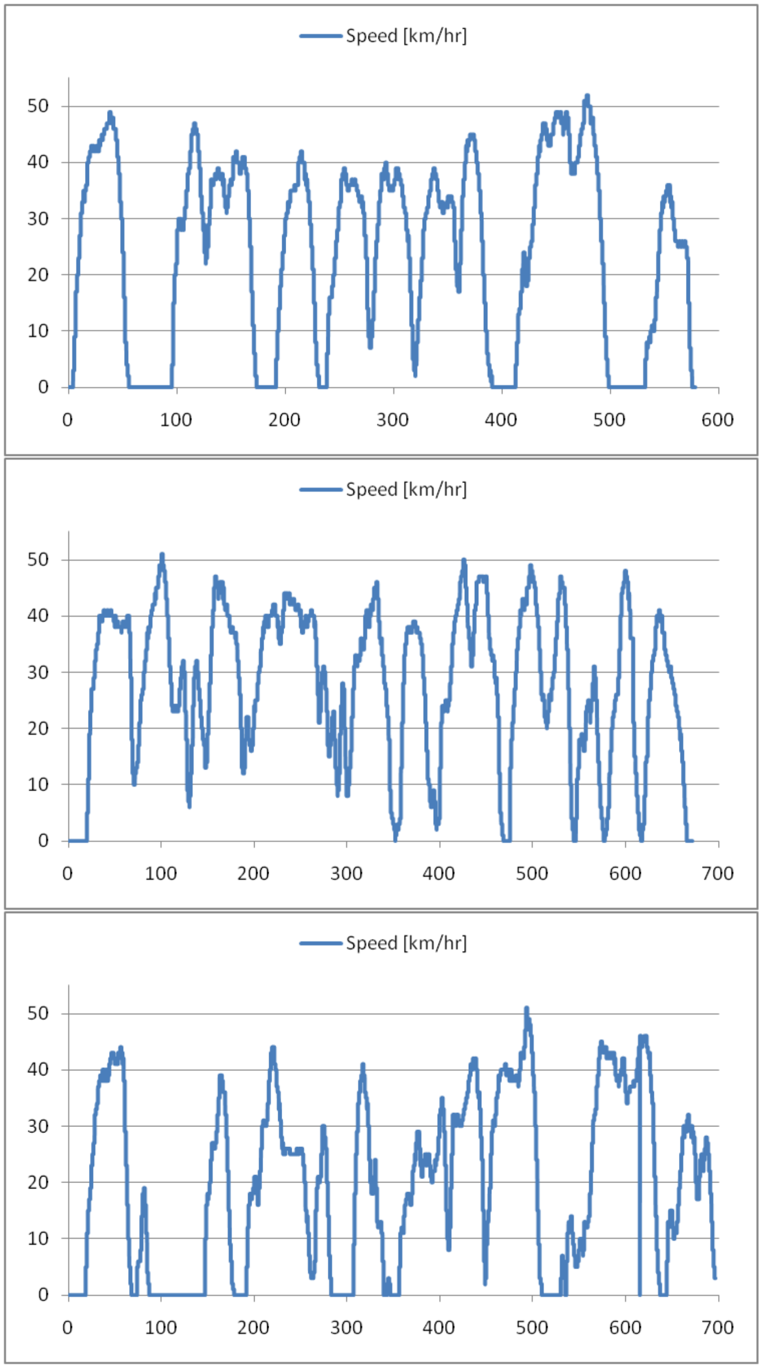

Fig.10.Three optimum trips of evening time [time vs speed].

4.2. Phase2: Assessing Energy Consumption of the Aleppo driving cycle.

Figs 11 and 12 show the driving cycles obtained from both peak hour and off-peak hour trips. The trip in the peak hour consisted of many accelerations and decelerations, and the average speed was 28.72 km/hr. However, the trip in the evening time is less in comparison where the speed reached 32.22 km/hr. There were three traffic lights on the road, but the driving mode was not smooth because of the density of the cars in both trips.

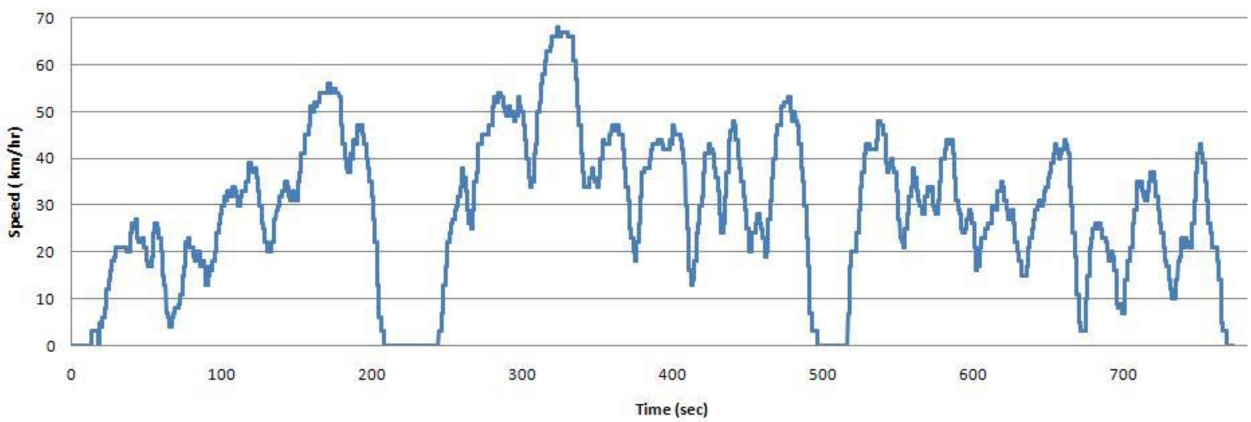

Fig. 11.The Driving Cycle in peak hour (phase 2).

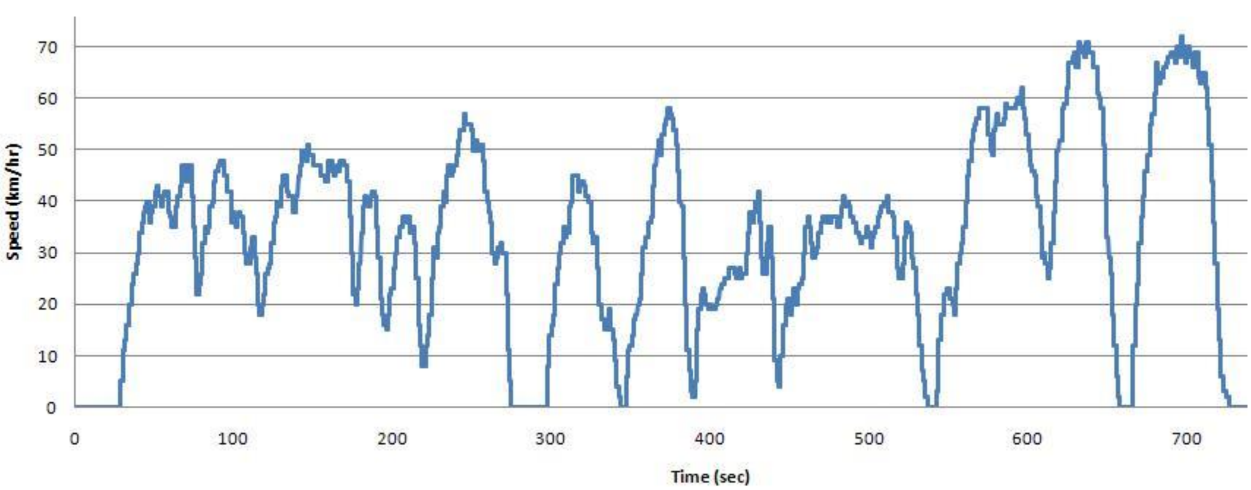

Fig. 12.The Driving Cycle in the evening time (phase 2).

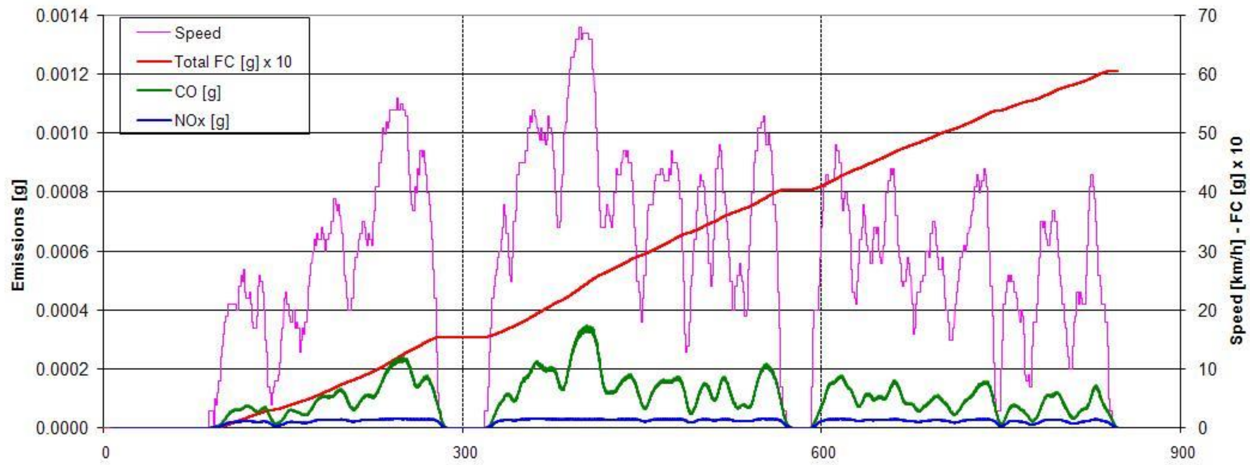

Fig. 13 Energy consumption and emission factors of Aleppo driving cycle

Fig 13 shows for the Aleppo driving cycle in peak hour for CO, NOx emissions are provided in grams per second and the fuel consumption FC is expressed in gram calculated by equation (3) using the related coefficients of the passenger car used. These coefficients were obtained from COPERT hot emission parameters which can be used as European standards for make, year, engine capacity, and legislative standard of the vehicle [15].

Table 4 shows the average emission factors of the trip which were obtained from the COPERT equation after applying the average speed.

Table 4. The average speed, CO, NOx emission, and FC.

	Speed [km/hr]	**CO [g/km]**	**NOx [g/km]**	**FC [g/km]**
Average	28,27	0.1743	0.0499	104.6885

Table 5 shows the total emission factors of the trip when adding the entire emission factor obtained per second.

Table 5. Total emissions obtained from the trip.

	CO [g]	NOx [g]	FC [g]	Time [sec]	Distance [km]
Total	1.201	0.268	606.651	848.28	6.175

5. Conclusions

Pictures taken and data obtained from air quality stations and experiments done in this research provide a clear idea about the transport sector in a busy city like Aleppo in such a developing country. More investigation is needed and work has to be done in order to improve the transport sector in Syria.

As each country has a unique driving cycle which represents the characteristics of the driving and the real amount of emissions from vehicles, individual testing is necessary for each region. A case study on the estimation of the emission values taken from a passenger car has been carried out. A representative driving cycle reflecting the real-world driving conditions has been proposed and estimated vehicle emissions were implemented. This method is user-friendly and the results were shown to be accurate, as real data from Aleppo city was used.

Acknowledgments

Author would like to thank the engineers in the transport sector of Aleppo for their kind help, Dr.Ossama Basmaji for the use of his car in the tests and Mr. Andrew Clarke for the proofreading. I would like to thank Aleppo University for their financial support.

References

[1] Samaras Z, Ntziachristos L. Average hot emission factors for passenger cars and light duty vehicles, Task 1.2/Deliverable 7 of the MEET project. Laboratory of Applied Thermodynamics Report No 9811. Thessaloniki, Greece; 1998.

[2] R.J. North "Assessment of real-world pollutant emissions from a light duty diesel vehicle". PhD Thesis, University of London, 2006.Available online at http://www.cts.cv.ic.ac.uk/documents/theses/NorthPhD.pdf.

[3] Haydar, F. and Pediaditi, K. 2010. Evaluation of the environmental impact assessment system in Syria. Environmental Impact Assessment Review, 30(6), pp.363-370.

[4] López, J.M., Gómez, Á., Aparicio, F. and Javier Sánchez, F. 2009. Comparison of GHG emissions from diesel, biodiesel and natural gas refuse trucks of the City of Madrid. Applied Energy, 86(5), pp.610-615.

[5] Ou, X., Yan, X., Zhang, X. and Liu, Z. 2012. Life-cycle analysis on energy consumption and GHG emission intensities of alternative vehicle fuels in China. Applied Energy, 90(1), pp.218-224.

[6] Hao, H., Wang, H., Song, L., Li, X. and Ouyang, M. 2010. Energy consumption and GHG emissions of GTL fuel by LCA: Results from eight demonstration transit buses in Beijing. Applied Energy, 87(10), pp.3212-3217.

[7] Saboohi, Y. and Farzaneh, H. 2009. Model for developing an eco-driving strategy of a passenger vehicle based on the least fuel consumption. Applied Energy, 86(10), pp.1925-1932.

[8] Lindfeldt, E.G., Saxe, M., Magnusson, M. and Mohseni, F. 2010. Strategies for a road transport system based on renewable resources – The case of an import-independent Sweden in 2025. Applied Energy, 87(6), pp.1836-1845.

[9] Ayoub, K. 2003. Introduction of PEM fuel-cell vehicles in the transportation sector of the United Arab Emirates. Applied Energy, 74(1-2), pp.125-133.

[10] Esteves-Booth, A., Muneer, T., Kirby, H., Kubie, J. and Hunter, J. 2001. The measurement of vehicular driving cycle within the city of Edinburgh. Transportation Research Part D: Transport and Environment, 6(3), pp.209-220.

[11] E. Tzirakis, et al, "Vehicle emissions and driving cycle: comparison of the Athens driving cycle (ADC) with ECE-15 and European driving cycle (EDC)" Global Nest Journal, Vol 8, No 3, pp282-290, 2006.

[12] Hung, W.T., Tong, H.Y., Lee, C.P., Ha, K. and Pao, L.Y. 2007. Development of a practical driving cycle construction methodology: A case study in Hong Kong. Transportation Research Part D: Transport and Environment, 12(2), pp.115-128.

[13] Edward C., Bright T., Air quality and MOLAND: Description of a methodology to determine emissions output and affected populations, Working Paper Series, May 2008, http://www.uep.ie/downloads/index.php.

[14] H. Achour, J.G. Carton, A.G. Olabi, 'Estimating vehicle emissions from road transport, case study: Dublin City', Applied Energy, Volume 88, Issue 5, May 2011, Pages 1957-1964.

[15] http://www.emisia.com/copert/General.html date accessed 15 Dec 2011.