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Research paper

Developing a General Methodology and Construct a Driving Cycle with an Economic Performance Evaluation for Basrah City

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Abstract

In this paper, a statistical method is employed to develop a driving cycle for Basrah city and to find out the factor score and the Euclidean distance analysis by the Statistical Package for the Social Sciences (SPSS). A simple electronic system is built to construct the driving cycle, the system considered a microcontroller and a GPS sensor connected to a PC through a simple C++ code. The development of the proposed driving cycle represents the first model driving cycle in the city of Basra. The advisor software package is used to investigate the economic performance of the internal combustion engine based on HC, CO, and NOx exhaust emissions. It was found that the obtained driving cycle is significantly different than the other driving cycles in terms of exhaust emissions and fuel consumption and within the expected range of emissions. The developed driving cycle model obtained is a representative delicate estimation of the exhaust emissions and fuel consumption, and will be utilized for future work to obtain a good performance of the hybrid electric vehicles.

Keywords: *Driving Cycle, Fuel economy, Exhaust emission, Statistical method, Advisor software package*.

1. Introduction

The main function of the constructing driving cycle is for evaluating the fuel consumption and exhaust emission. The method employed to develop driving cycles depends on a prior collection of data, it is identified time and location of a certain region or routes [1].

Driving cycles are used as traffic engineering purpose estimation. Also, a driving cycle can be defined as a series of data collected represent several parameters such as speed, gear ratio and distance versus time, in a part of a road segment or a certain region [2].

In some regions of the world in the early 1970s, the development of driving cycles began broadly. The driving cycles separated into two parts: the "Modal" and "polygonal", that is developed by the data acquired and which is developed using on-road data, such as "Transient Driving Cycles", which symbolizes the actual driving pattern on-road, where are being made many improvements to be driving cycles [3].

The patterns of driving cycle differ from region to region and from one city to another, the driving cycles available obtained for countries or certain cities are not applicable to other countries and cities. Therefore, much targeted of research work is developing towards their own city driving cycles [4].

The types of worldwide urban driving cycles of vehicles are New European Driving Cycle (NEDC), West Virginia. University City Cycle (WVUCITY), Urban Dynamometer Driving Schedule (UDDS), Germany, Nuremberg bus cycle (Nuremberg R36), Extra Urban Driving Cycle (EUDC), and the New York City Cycle (NYCC).

In this study, four typical paths in the city center of Basrah were used to collect data and analyzed the time-speed in addition to the location of a gasoline vehicle. Data was collected and analyzed to obtain the essential parameters of the standard driving cycle. The previous standard driving cycles were compared with local driving cycles established. Based on the statistical analysis of the collection of the driving cycle time-speed data, the development of the Basrah city center driving cycle (BCCDC). An overview of the relevant available literature.

Fotouhi and Montazeri [4] developed a Tehran city driving cycle and gathering driving data using Advanced Vehicle Location devices. Driving data, including two characteristics, idle time and average speed, are analyzed, based on micro-trips and clustered into four groups using the method of k-means clustering.

It is compared to another vehicle driving cycle and shows a higher average speed and a lower idle time percentage, and it causes vehicle FC and emissions in the middle range.

Abu mallouh et al. [5] sophisticated Amman city driving cycle. A gasoline vehicle model with the developed driving cycle is employed to conduct a performance to estimate exhaust emissions and fuel consumption. Also, study the performance of the fuel cell and battery in hybrid vehicles.

Fei Zhang [6] investigated the Beijing driving cycle of the electric vehicle. Based on GPRS communication, collection a new data then divided the obtained data into the micro-trips. The driving cycle is achieved by k-means clustering method and principal analysis of the component. The results show the electric vehicle driving cycle represent the traffic conditions compared with the test data.

Wenyu et al. [7] developed the driving cycle using the principal component analysis, PCA and k-mean cluster in Shenyang. The k-mean cluster is employed to select a new form of a driving cycle and applied PCA to collect data of road conditions. Concluded that the developed driving cycle under certain driving conditions matches to overall road condition.

Hongwen et al. [8] proposed a prediction model of a real-time with the variable horizon and employed a real data to construct the driving cycle. Based on Marco Chain with the variable horizon, and cluster analysis with principal of component analysis, an online prediction model is established. And concluded that the accuracy is improved by 20 % compared to the time prediction model with the variable time prediction model.

2. Basrah City Specifications

Basrah is an oil and industrial city. It is located to the south of Iraq and facing the Arabian Gulf.
Pollution of air in Basrah city is increasing as a result of the extraction and refining of oil due to the development of the industry as well as the number of vehicles are an increase rapidly. The air pollution and emission sources in Basrah city due to vehicles. Therefore, it is important to study the overall pollution sources. Study and analysis of pollution need a real analysis of road and driving performance by developing a standard real-world driving cycle in Basrah city.

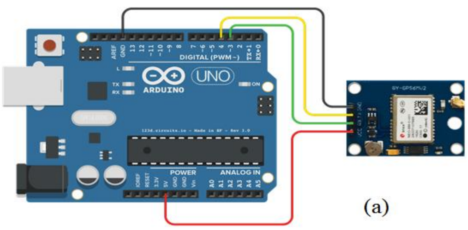
3. Experimental Work

3.1. Driving Cycle Data Collection

The first step is collecting data that represent the road conditions, which were collected by moving cars on the roads in the city center of Basrah. The routes divided into 4 paths started from the point and ending at the second point, each path, repeated 5 times on the same path. Driving cycle data were recorded with a 3 sec sampling rate during both light and peak traffic hours. The peak hours collect data duration is approximately between 4:00 to 6:00 pm and a total of 20 collects datasets were lasting for five weeks.
Measurement of the speed, time, and braking distance based on Arduino device and Global Positioning System GPS performance unit. Arduino microcontroller is the basic unit that used to construct the driving cycle. It works as a tool to collect the original data as shown in Fig. 1 which records an instantaneous speed at the one stop to the next beginning of the stop.

3.2. Hardware Setup of Control System

An Arduino UNO ATmega328 board is used for this project as the Central Processing Controller unit. The U-blox NEO-6M-0-001GPS tracking device with an external antenna is providing a function to get position latitude, longitude, altitude, in addition to time, speed, and course of using GPS devices. The system considered a microcontroller, a GPS sensor and UNO ATmega328 board connected to a PC through serial communication port with a simple C++ code.
The U-blox NEO-6M-0-001GPS module communicates with the Arduino via serial communication to vehicle speed, time measurement, and location, the Arduino 5V pin is connected to module VCC pin, the Arduino pin 3 (TX) is connected to module RX pin, the Arduino pin 4 (RX) is connected to module TX pin, and the Arduino GND pin is connected to the module GND pin. The rotation speed of the tire in RPM will be converted into vehicle speed.



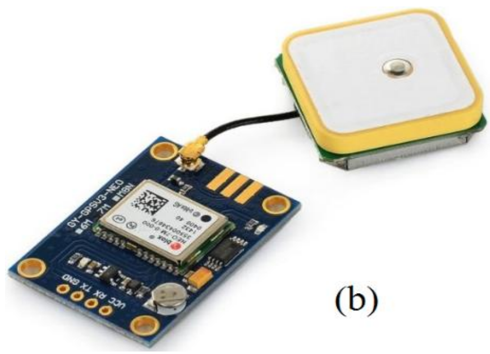


Fig. 1: (a) Arduino UNO ATmega328 board with U-blox NEO-6M-0-001, (b) U-blox NEO-6M-0-001 GPS tracking device

4. Methodology

In this paper, the principle of development the Basrah driving cycle depends on the method of Tzeng [9]. This method depends on selecting a dataset similar to that shown in Table 1.
The Statistical Package for the Social Sciences (SPSS) is used to develop a driving cycle for Basrah city.
Step 1: Describe characteristics of the driving cycles by defining the evaluation criteria
These criteria, the total distance of travel, total time of travel, and average speed of travel.
Step 2: Calculate the values of the 8 criteria for each driving cycle
Step 3: Calculate the mean values of the 8 criteria for all the driving cycle and consider as a single driving cycle
Step 4: Statistically by the factor analysis method derive factor scores
Step 5: Calculate by the factor scores the Euclidean distance between each driving cycle and the mean values of the 8 criteria
A statistical method is used to find out the variation of the samples defined as Euclidean distance. Therefore, equation (1) employs to estimate the Euclidean distance by the factor scores.

$$D_{ij} = (\sum_{k=1}^{m} (f_{ik} - f_{jk})^2)^{0.5} \tag{1}$$

Where Dij is the Euclidean distance between i and j driving cycle, f_{ik} is the kth factor score of i driving cycle and m is the number of factor score.
Step 6: Chose the smallest Euclidean distance for each driving cycle derived from step 5 and the cycle derived in step 3
The selection of driving cycle as a representative the smallest Euclidean distance and is the significantly similar to all the driving cycle.
The differences in the Basrah driving cycle parameters with the other driving cycles can be observed. Although the time per sec of the Basrah driving cycle is less than the NurembergR36 driving cycle, in addition, the distance per km of the developed cycle is close to the EUDC driving cycle. The maximum velocity of the developed cycle is higher than the WVUCITY driving cycle, the average velocity, a number of stops per km and number of stops of the developed cycle are those significantly different than the other driving cycle values.
The acceleration and deceleration maximum of the developed cycle are the same values as the NYCC and WVUCITY driving cycle respectively. Consequently, the developed driving cycle obtained is significantly different than the other worldwide driving cycles.
The evaluation of the 8 criteria is presented in Table 1.
Fig. 2 is shown the developed Basrah driving cycle representative the most similar to all the driving cycles collected.
Table 2 shows the comparison between the developed Basrah driving cycle with worldwide urban driving cycles criteria

Table 1: Sets of collecting data

Dataset	Distance (km)	Time (sec)	Max. velocity (km/h)	Average velocity (km/h)	Max. acceleration (m/s2)	Max. deceleration (m/s2)	Stops Number	Stop Number (km)	Euclidean distance
1	6.571	1107	60.39	21.271	2.045	-4.167	1	0.152	2.3679
2	6.871	798	61.37	30.934	2.864	-2.752	3	0.436	2.6940
3	9.589	924	67.42	37.408	3.049	-3.728	4	0.417	4.0670
4	6.506	909	60.28	25.668	2.318	-2.234	3	0.461	2.5762
5	6.553	870	60.1	27.138	2.157	-2.473	4	0.610	2.6441
6	5.807	1089	59.06	19.217	2.548	-3.789	4	0.513	1.6286
7	5.907	1359	58.54	15.638	1.998	-2.984	28	3.589	4.0868
8	6.027	1089	58.17	19.891	2.843	-3.093	4	0.513	2.5292
9	5.783	1194	60.6	17.498	1.993	-4.216	5	0.641	2.3510
10	5.865	1317	58.93	15.948	2.286	-2.711	10	0.78	4.5388
11	4.186	1293	55.1	11.633	1.910	-3.191	4	0.727	2.8190
12	4.321	684	54.21	22.574	2.465	-3.310	1	0.182	3.6260
13	4.221	1173	60.34	12.976	2.575	-3.383	4	0.727	2.6767
14	4.314	1056	62.23	14.641	2.349	-2.691	5	0.909	3.0772
15	4.186	1071	54.67	13.965	2.529	-2.842	7	1.273	3.4475
16	6.237	897	65.34	24.894	2.835	-2.906	2	0.253	2.2607
17	6.291	864	62.06	26.097	2.254	-3.883	1	0.126	2.5399
18	6.104	1083	60.49	20.204	2.79	-2.767	8	1.012	1.8750
19	**6.273**	**1041**	**63.62**	**21.632**	**2.661**	**-3.094**	**7**	**0.886**	**1.5187**
20	5.521	972	60.65	20.346	2.661	-3.094	11	1.392	2.0399
Average	5.649	1045.6	59.797	20.114	2.425	-3.136	5.895	0.799	

Table 2: Comparison driving cycle criteria

Criteria	BCCDC	NYCC	UDDS	NEDC	EUDC	WVUCITY	Nuremberg
Time (sec)	1041	598	1369	1184	400	1408	1084
Distance (km)	6.273	1.9	12.0	10.93	6.95	5.32	4.32
Max. Velocity (km/h)	63.62	44.3	91.2	120.0	120.0	57.65	53.7
Average Velocity (km/h)	21.632	11.3	31.5	33.21	62.44	13.59	14.33
Max. Acceleration (m/s2)	2.661	2.7	1.5	1.06	0.83	1.14	1.88
Max. Deceleration (m/s2)	-3.094	-2.6	-1.5	-1.39	-1.39	-3.24	-2.11
Stops Number	7	18	17	13	1	14	24
Stop Number (km)	0.886	10.0	1.4	1.2	0.143	2.63	5.5

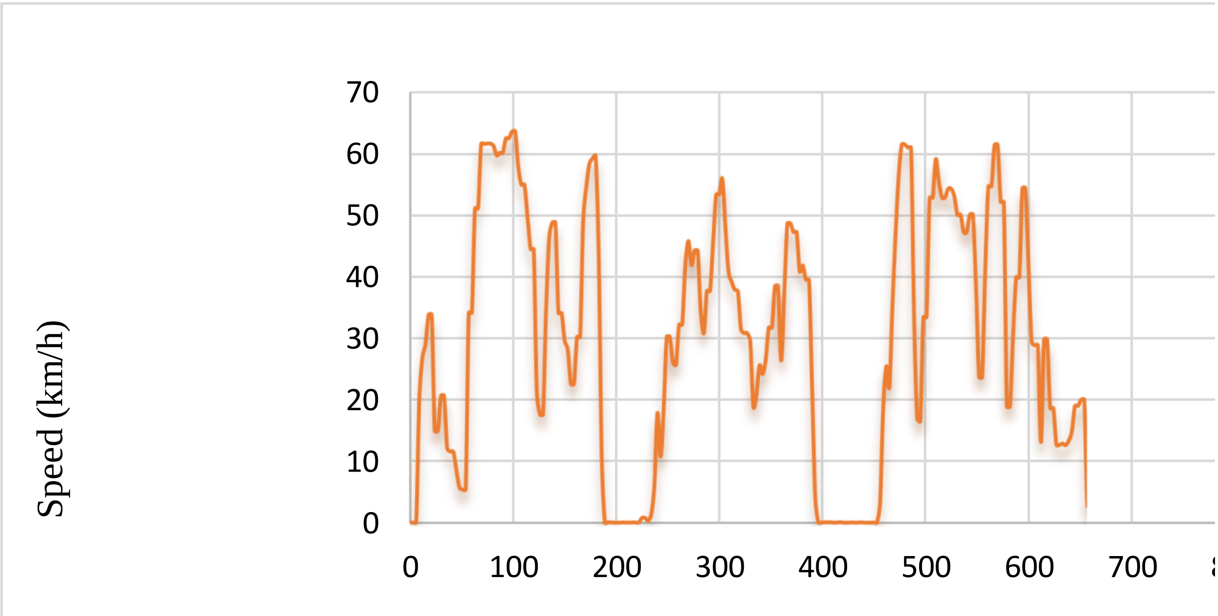


Fig. 2: The developed Basrah driving cycle.

5. The Advisor Software Package

ADVISOR, ADvanced VehIcle SimulatOR, is a software used to perform a comprehensive analysis of performances of a wide range of vehicles, and have a set of data, model, and script text files. ADVISOR is flexible enough to operate on most computer platforms in the Matlab/Simulink software environment. It is basic physics and designed for analysis and predicts of the performance and fuel economy use, tailpipe emissions, acceleration performance of electric, conventional, and hybrid electric vehicles.

6. Driving Cycle Effect on the Economic Performance

The advisor software package is shown in Fig. 3 is used to investigate the economic performance of the Basrah driving cycle of the internal combustion engine vehicle. Also, investigated the performance of the internal composition engine vehicle in terms of the fuel consumption and exhaust emission, as presented in Table 3, and Fig. 4 shows the parallel vehicle Simulation Model.

The exhaust emissions and fuel consumption for the developed cycle are significantly different values than the other cycles obtained and within the expected range of emissions.

The performance of the parallel hybrid vehicle with an internal composition engine for developed driving cycle was investigated, it's found that the fuel economy is 6.8 L/100 km is relative to the other worldwide urban driving cycles, the fuel economy is presented in Table 3, which denote that the suggested developed driving cycle is a delicate estimation of the vehicle driving cycle in the Basrah city. Fig. 5, 6, and 7 show the state of charge, the emission of the cycle, and the overall ratio result of Basrah driving cycle respectively.

7. Conclusions

In this work, a statistical method is used to develop a driving cycle for Basrah city and to find out the factor score and the Euclidean distance analysis. A simple electronic system is built to construct the driving cycle, the system considered a microcontroller and a GPS sensor connected to a PC through a simple C++ code. The development of the proposed driving cycle represents the first model driving cycle in the city of Basra. It was found that the Basrah driving cycle obtained is significantly different than the other driving cycles in terms of exhaust emissions and fuel consumption and within the expected range of emissions.

Table 3: The economic performance and emissions of Basrah driving cycle with different driving cycles

Driving Cycle	HC emission (g/km)	CO emission (g/km)	NOx emission (g/km)	Fuel economy (L/100 km)
BCCDC	0.562	8.059	0.365	6.8
NYCC	1.876	11.001	0.934	6.56
UDDS	0.343	1.607	0.271	6.6
NEDC	0.354	1.837	0.211	6.4
EUDC	0.493	2.102	0.307	4
WVUCITY	0.695	3.578	0.385	10.5
Nuremberg	0.872	3.606	0.434	10.8

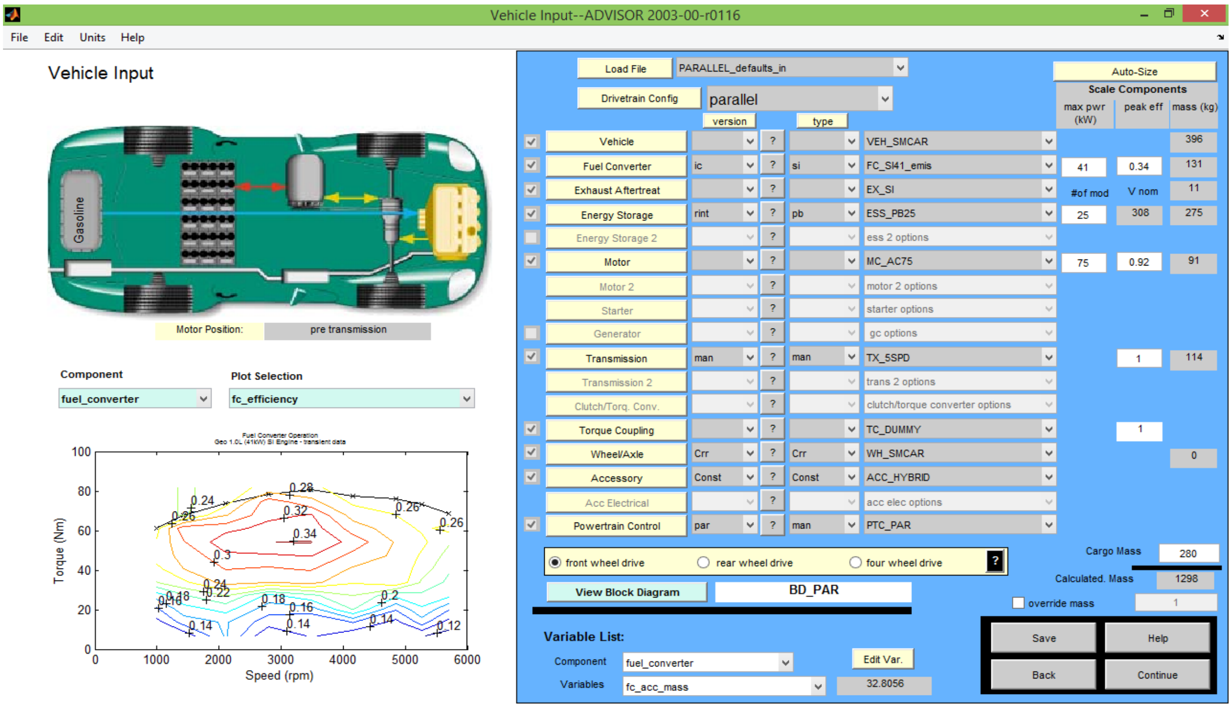


Fig. 3: The interface advisor software

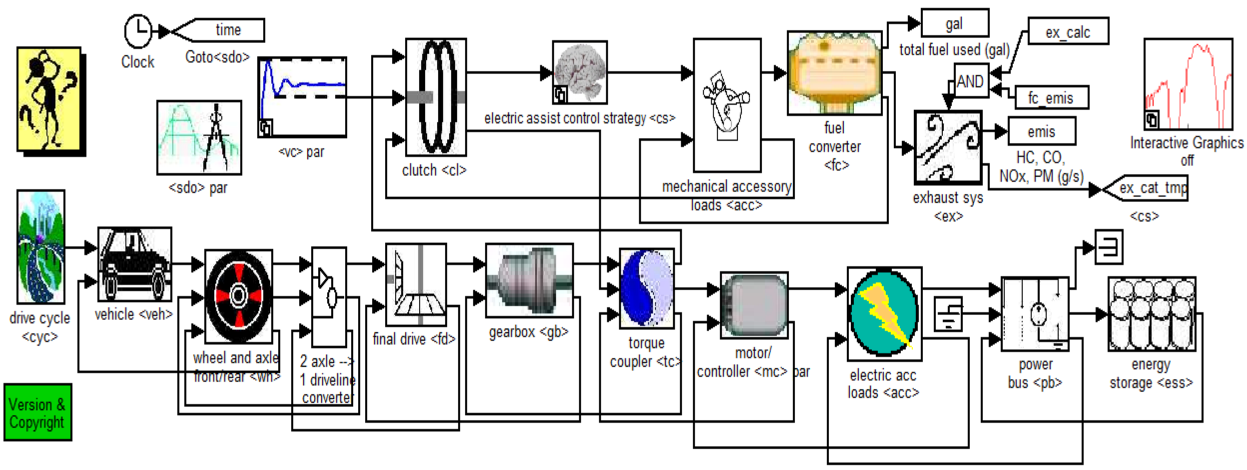


Fig. 4: The parallel vehicle simulation model

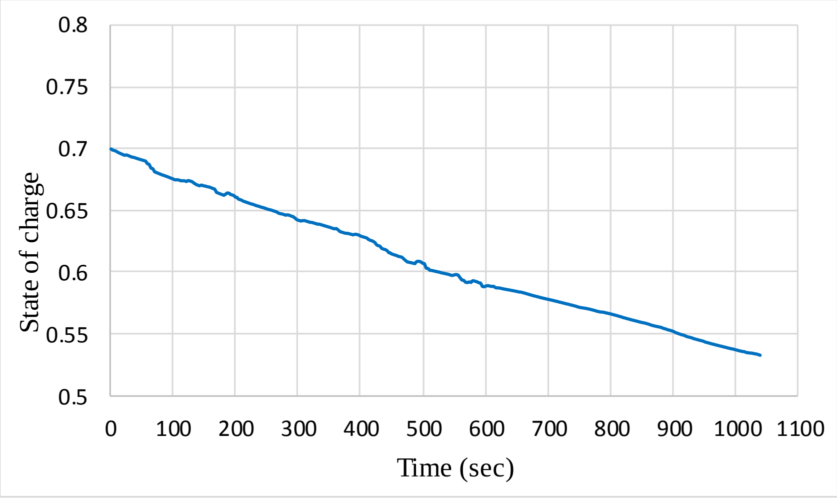


Fig. 5: The state of charge

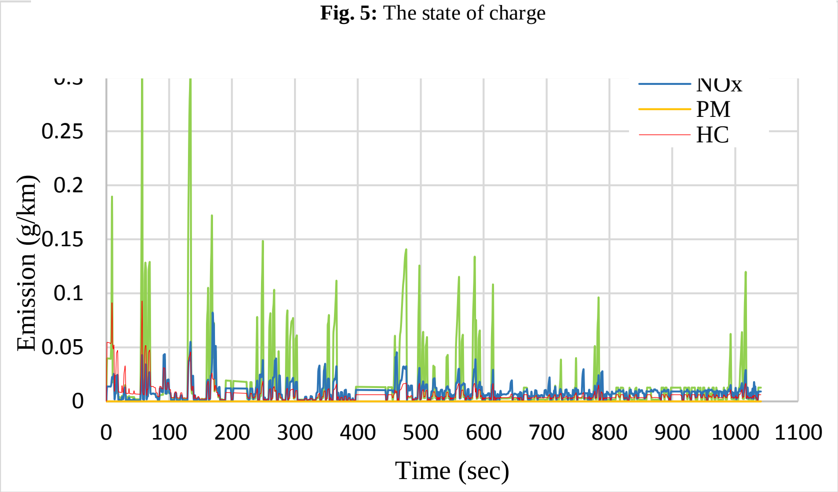


Fig. 6: The emission of cycle

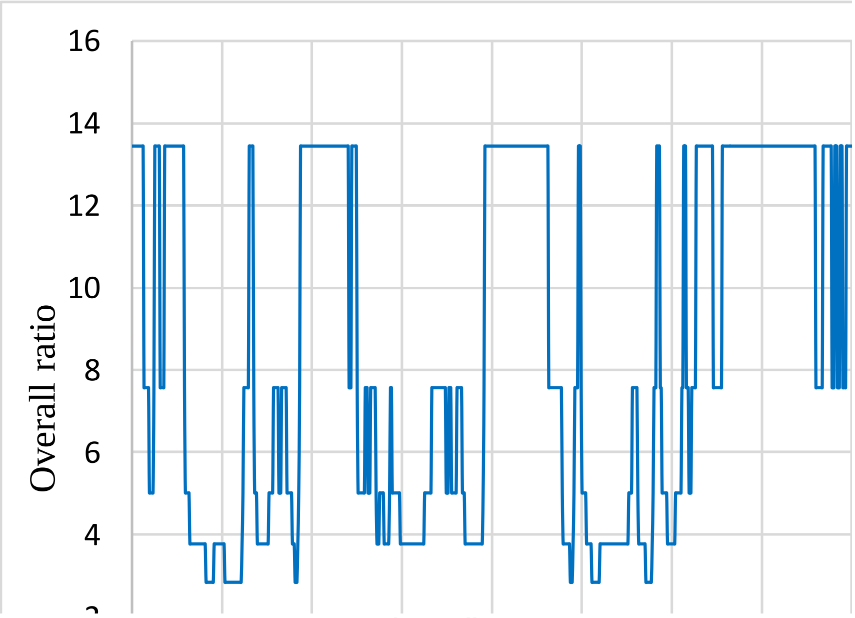


Fig. 7: The overall ratio

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