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Real-World Driving Cycle: Case Study of Nasiriyah, Iraq

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Abstract

The driving cycle is a critical factor in measuring fuel consumption and exhaust emissions. Because vehicle exhaust emissions from road transport are the primary contributors to emissions around the world, so the study of the driving cycle is a vital way to solve the difficulties of environmental pollution. This paper presents a new real-world driving cycle for Nasiriyah, Iraq. A simple electronic device is designed to build the driving cycle after collecting speed data; the system consists of Arduino and a Global Positioning System (GPS) sensor connected to a computer. The technique involves producing micro-trips extracted from real-world driving. Using the K-means clustering method, the Statistical Package for the Social Sciences (SPSS) was used to design this driving cycle. The built driving cycle has a 1568 s speed time series, with an average velocity of 26.7 km/h and a distance of 11.64 km, according to the results. The effectiveness and accuracy of the proposed method were verified when the drive cycle was compared to other types of driving cycles. These results findings strongly support the use of hybrid electric vehicles (HEVs) in Nasiriyah city.

Keywords: Fuel consumption, Exhaust emission, driving cycle, Statistical method, Micro-trip, K-means clustering, SPSS.

1. Introduction

A drive cycle is a speed-time series designed for specific vehicles in a specific area. It is a test for analyzing the effects of fuel consumption and emissions. In simulations of vehicles, the drive cycle is often used to forecast the performance of various powertrain configurations, and because of its crucial significance in vehicle design and energy management strategy, there has been a lot of concern about it**[1].**

It is critical to develop a truthful world drive cycle for traffic and transportation management, vehicular emissions measurement, and power management, especially in HEV studies **[2]**.

The two most popular forms of driving cycles are legislative and non-legislative. Governments use legislative driving cycles to implement exhaust emission standards for vehicle emission certification. Legislative driving cycles in the United States, Europe, and Japan include The Federal Test Procedure FTP-75, The New European Driving Cycle NEDC, and The Five Typical Japanese Driving Cycles J10-15 respectively. In research for power management and emissions assessment, non-legislative driving cycles, such as the Hong Kong driving cycle, are used **[3]**.

A driving cycle can be developed in two ways. One is stated such as polygonal or modal that is made up of different driving modes of the continuous accelerated period, decelerated period, and speed (like the NEDC and Extra-Urban driving cycle ECE). The "real world" cycle, on the other hand, is derived from actual driving data. The FTP-75 and The Athens Driving Cycle ADC are two such cycles. The real-world cycles are more dynamic, as they reflect the faster acceleration and deceleration patterns seen on the. road**[4]**.

In recent years, the development and implementation of driving cycles have accelerated. The majority of the work on driving cycles was completed about ten years ago.

Al-Samari**[5]**, in 2017, developed a real-world driving cycle for the city of Baqubah, Iraq. A car-chip device is used for data collection while using micro-trips with Matlab code to construct it.

Najem et al. **[6]**, in 2018, developed a driving cycle for Basrah, Iraq. A simple Arduino with GPS was used to collect data, which was then used to choose the best route using the factor score and the Euclidean distance analyses method in the SPSS package.

Tong **[7]**, in 2019, created a driving cycle for a specific bus route for a Hong Kong supercapacitor electric bus route. The mobile device "MyTracks," which is a simple GPS tracking application, was used to record the user's route parameters. The drive cycle was created by using the micro trip approach.

Norbakyah et al. **[8]**, in 2020, created and defined a driving cycle for myBAS which is a heavy-duty car used in Kuala Terengganu city, Malaysia. The fuel consumption and emissions were analyzed using Advisor after micro-trips were clustered using the k-means clustering approach in Matlab.

Huzayyin et al. **[9]**, in 2021, proposed the first driving cycle of passenger cars in Greater Cairo, Egypt. Matlab was used to develop the driving cycle using K-means and K-medoid clustering techniques.

However, based on the literature review, it can be inferred that there could be major variations in data collection techniques and instruments, as well as data analysis and computational methods used, resulting in different driving cycles. The technique to be used in a specific case is determined by factors such as the intent of the driving cycle, the quality and quantity of data, and the data collection capabilities **[10]**.

Since driving patterns differ significantly by region, drive cycles are established for an area that doesn't look like another within the same country **[11]**. Unlike regions that have unlike driving features, so it's serious to establish a characteristic drive cycle for individual location based on its circumstances **[12]**.

For a variety of causes, countries, metropolises, and areas lack their own DC, so it has adopted famous drive cycles from other countries, especially those from the USA and Europe, for objectives like emission analysis and vehicles certification. However, since the adoption of these cycles isn't always indicative of local driving patterns, it's important to track how drive cycles have evolved in these areas **[7]**. As a result, it's important to be able to predict energy consumption and driving range with greater accuracy.

A drive cycle is an excellent tool when it comes to developed HEVs that have been produced, as it related to the developed HEV technique. Although the world's first powerful HEV (Toyota Prius) has been on the market since 1997, Furthermore, electrified vehicles are uncommon on Iraqi highways. Until the last month of 2019, only 22 electrified vehicles (9 EVs and 13 HEVs) were registered, compared to over 1 million conventional vehicles **[13**]. Additionally, the findings of this study may be useful for Iraqi hybrid electric vehicle research.

This paper uses a new methodology focused on factor analysis, Euclidean distance approach, and micro-trip clustering using K-mean cluster techniques to develop a vehicle driving cycle for Nasiriyah. This paper is organized as follows. The Methodology and The numerical analysis are discussed in Section 2. Then section 3 describes the detail of the result and discussion. Section 4. shows the validation of the Nasiriyah driving cycle. Finally, a conclusion and suggests future study directions are included in section 5.

2. Methodology

The key procedures were included in this study: Measuring Techniques, Route Selection, Data Collection, Data Statistics, and Numerical Analysis. This paper proposed a drive cycle construction method based on the K-means clustering technique is used for micro-trips clustering by use (SPSS) package. **Figure (1)** show the flowchart of the DC developed approach.

2.1 Measuring Techniques

To build a drive cycle, traffic data from vehicles is required, such as speed, distance traveled, geographical location, fuel and energy usage, and so on. These necessitate data collected by many methods such as installing an Onboard measurement device OBD on the experimental vehicle to monitor its driving details along a predetermined route or installing a simple electronic system with a GPS tracking tool in a car to gather the car speed and travel distance while passing over areas. MyTracks application **[7]**, A primary GPS that has been used as the mobile app to monitor the user's direction, speed, distance, and altitude as it travels, can also be used to collect data. It is also possible to the track data from the Google Waze application when capturing **[9]**.

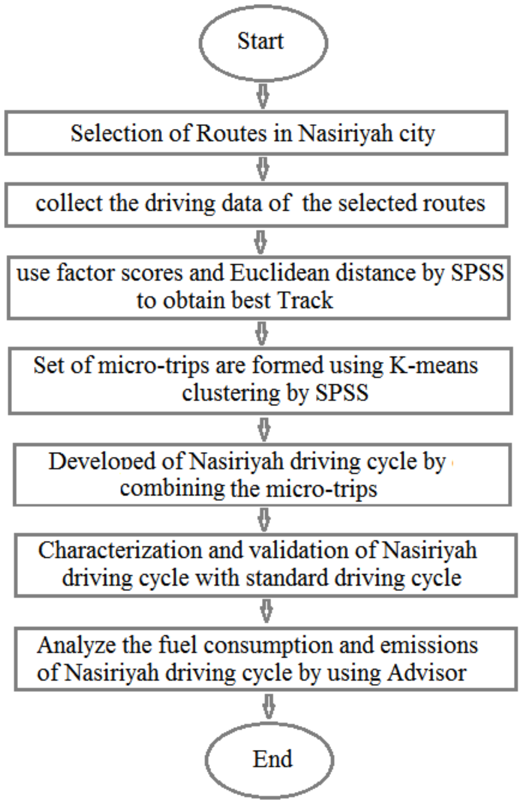

Fig.1 The flowchart of the developed driving cycle to Nasiriyah.

In this paper, a simple electronic system consisting of a Mega Arduino and a GPS sensor (ATmega 2560 type) is connected to a computer through the communication port, where a simple code is used to collect data necessary to build the driving cycle, as shown in **Figure (2**).

Fig.2 Scheme for an Electronic Measurement System.

2.2 Route selection and data collection

This paper aims to establish a passenger car drive cycle in the city center of Nasiriyah, which is the metropolis of the Thi Qar Governorate and is located alongside the river of the Euphrates, approximately 360 kilometers south of Baghdad, nearby the ruins of the olden city of Ur. It is Iraq's fourth most populous city.

One of the most important aspects of the drive cycle is route selection. The travel routes chosen should reflect the real transport network and characteristic traffic movement conditions, which are influenced by locative and temporal aspects as terrestrial use, street type, terrain, signaled intersection abundance, and residents concentration in the region.

All of the routes were chosen because they are the most commonly used by Nasiriyah residents in their automobiles. Starting from the same fixed starting point and ending at the same final destination, the routes have been chosen as shown in **Figure (3).**

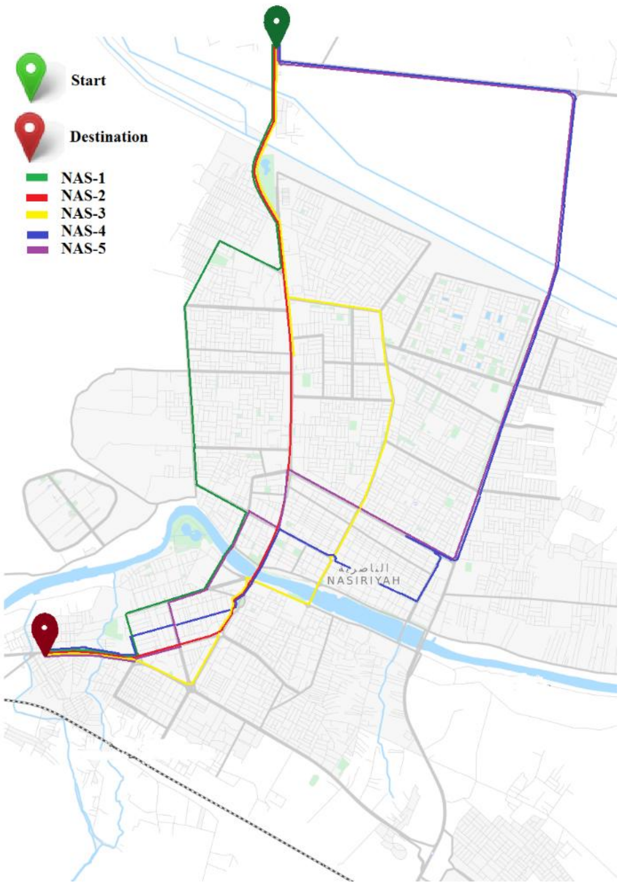

Fig.3 The selected route in Nasiriya city

The number of routes is limited to five, which are replicated five times to obtain precise data. For a month, a private vehicle equipped with the aforementioned device was driven on these chosen routes to collect road data. Driving data was collected at a 2 seconds sampling rate during peak and light traffic hours. A total of 25 data sets with a total time of 10.9 hours and a total distance of 348.8 km were collected. All data was arranged in Microsoft Excel as a raw data format, and all work was completed in the SPSS program.

2.3 Data statistics

There are many approaches to developing driving cycles. In this paper, the Nasiriyah driving cycle is developed using the same approach introduced in **[14][15][6]** to select the best-repeated route where the statistical method is employed, which is based on a better range of data determined by eight characteristics (distance, time, maximum speed, average speed, maximum acceleration, maximum deceleration, stop number, and idle time) for each of the five routes, each of which is repeated five times.

The driving cycle is defined by at least two vectors: the time vector and the vehicle speed vector sampled from a vehicle on a given road. The time (taking into account the sampling rate) and speed data are then entered into an Excel file, and simple Excel functions such as Max, Min, and Average are used to determine the driving characteristic, e.g. Max, Min, and Average Speed. This function is also used to determine the maximum acceleration and maximum deceleration, average acceleration, and average deceleration after calculating the instantaneous acceleration and deceleration from the speed of a vehicle based on the instantaneous kinematic equations.

The average values of the five iterations of the initially recorded driving data are determined separately for each route in this method.

The statistical approach to factor analysis is then used to determine factor scores for each characteristic in a data set. The Statistical Package for Social Sciences SPSS analyzes the Euclidean distance after deciding the factor score, allowing the difference between all driving data to be found. Finally, the smallest Euclidean distances among the average and each other driving data for five routes are calculated and chosen the best five tracks[16].

Following the best track, another well-known approach relies on the K-means, which, laterally used to build the DC. The datasets of the selected tracks of five routes were used for further processing.

2.3 Numerical Analysis and Data preprocessing

Two conventional methods for constructing DCs are the micro-trips-based technique and the Markov analysis-based technique. The micro-trips method has been used to establish the majority of current driving cycles [**10].** The K- means clustering methodology is used in this study for micro-trips clustering because of its uncomplicatedness and reliability for extensive datasets **[8].**

Cluster analysis is used to classify events with similar characteristics into one category and events with different characteristics into another category. One of the most commonly used clustering techniques in the literature is the k-means algorithm.

In the K-Means clustering method, K-clusters are formed according to the understanding of the clustering problem. A representative sample of each class is selected as the initial focal point, and the other samples are classified according to their distance from this focused point. Generally, squared Euclidean distance was used to analyze the data, which has the following formula[**17]**:

$$d_{ij} = \sum_{k=1}^{p} (\mathrm{x_{ik}} - \mathrm{x_{jk}})^2$$

where each micro trip has p parameters, x_{ik} is the micro trip of number i in parameter k, and d_{ij} is the distance of each micro trip.

Each micro-trip begins with the car in idle mode (speed = 0 km/h) and comes to an end when the car returns to its idle mode. The process of developing a drive cycle entails many complicated steps, beginning by dividing the original track into small-duration micro-trips and calculated its parameters and ended by choosing the number of microchips to construct the drive cycle, most steps accomplish by use of a specially coded Matlab program or SPSS technique.

In this paper, the steps include establishing micro-trips from the best five-track selected from real driving routes as shown in figure 3. This micro-trips cluster utilizes the k-means clustering method and SPSS which exploit in developing this driving cycle. The five repeated tracks by micro-trip-based method divide into many micro-trips, the number of useable records equal to 44 micro-trips. After transfer text files contain data files SPSS, for each micro-trip, the principal characteristic parameters of distance, time, maximum speed, average velocity, maximum acceleration, maximum deceleration, average acceleration, average deceleration, and idle percentage are calculated, all parameters must be standardized using Z-scores, which are used in SPSS to normalize the characteristic parameters for micro-trips. All micro-trip is compared with other micro-trips so that eventually trips with similar characteristics are grouped in terms of selected parameters to form micro-groups. As a consequence, with a K cluster value equal to 7, seven groups are logically obtained. **Figure (4)** shows flowchart of micro-trips technique.

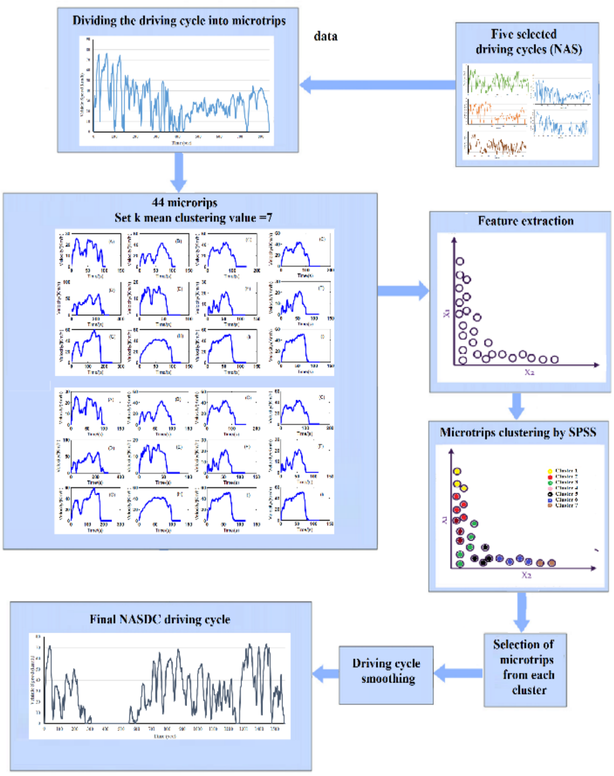

Fig.4 Flowchart of micro-trips technique.

Data centroids for all micro-groups were discovered using K-means clustering techniques, which were based on nine parameters last mentioned. The micro-trips that are nearest to cluster centers are chosen for the final driving cycle. The distance from the cluster center for all micro-trips, as well as a selected micro-trip, is shown in **Table (1).**

Table 1 The distance from the cluster center for all micro-trips, and selected micro-trip.

NO.	Cluster Member-ship	Distance from the Cluster center	NO.	Cluster Member-ship	Distanc e from the Cluster center
1	1	1.83245	24	2	2.66851
2	7	1.26875	25	2	1.47811
3	6	0.77468	26	5	1.54276
4	4	1.22346	27	7	1.47394
5	5	2.08012	28	6	1.64380
6	1	0.94613	29	4	1.39250
7	7	1.15353	30	2	1.55892
8	7	1.32824	31	2	1.72626
9	2	1.74477	32	5	2.24308
10	2	1.19899	33	5	1.16840
11	2	2.38440	34	6	1.15010
12	2	0.98895	35	6	1.62818
13	2	1.33814	36	6	1.03383
14	7	1.25081	37	6	2.06421
15	7	1.52887	38	3	1.32201
16	2	1.13911	39	2	1.01287
17	6	1.73028	40	3	1.32201
18	6	1.75749	41	2	0.73074
19	6	1.26879	42	6	0.92781
20	4	0.79952	43	2	0.55385
21	6	2.29417	44	2	1.46417
22	1	1.83245	24	2	2.66851

3. Result and discussion

The most representative DC is assembled by combining the seven micro-trips that are nearest to cluster centers in series, after that the DC is smoothed to meeting the expectation express of real drive in all situations. The developed real DC of Nasiriyah city is shown in Figure (5).

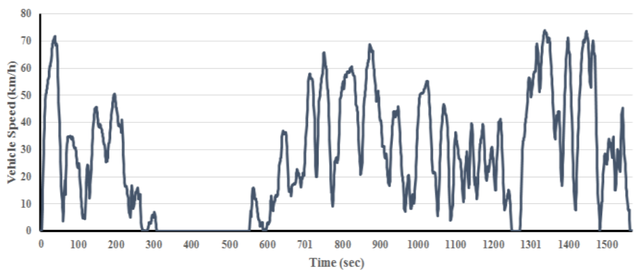

Fig.5 Developed Nasiriyah driving cycle

4. Validation of Nasiriyah driving cycle

The developed real DC of Nasiriyah city was validated by comparison to other DCs: Baqubah, Basrah, Tehran, UDDS, and US06 driving cycles as shown in Table (2).

Table2 Comparison between Nasiriyah with other rivingcycles.

parameter	Nas.	Baq.	Bas.	Teh.	UDDS	FTP
Duration (Sec)	1568	1052	1041	1533	1369	2477
Distance (km)	11.64	6.33	6.27	14.41	11.99	17.77
Max velocity (km/h)	73.85	68	63.63	91.06	91.25	91.25
Average velocity (km/h)	26.7	21.63	21.68	33.83	31.51	25.82
Max acceleration (m/sec2)	2.08	3.31	2.66	2.15	1.48	1.48
Max deceleration (m/sec2)	-3.14	-4.12	-3.1	−1.88	-1.48	-1.48
Average acceleration (m/sec2)	0.46	0.237	0.5	0.47	0.5	0.51
Average deceleration (m/sec2)	-0.5	-0.24	-0.48	−0.49	-0.58	-0.58
Idle time (s)	267	265	11	233	259	360
Nas. = Nasiriyah; Baq.= Baqubah ; Bas. =Basrah ; Teh.=Tehran						

4. Fuel consumption and emissions analysis

The hydrocarbons HC, carbon monoxide CO, and oxides of nitrogen NOx are three types of exhaust pollutants besides fuel consumption that are taken into account in the simulation procedure. For the simulations, advanced vehicle simulator Advisor software was used. Advisor software, which is famous in the simulation field, exploits to analyze fuel consumption and pollution emissions to this developed drive cycle. The model of the Toyota Prius hybrid vehicle was used to investigate this DC. The result shows that the fuel consumption is 5.36 L/100 km when compared to the standard drive cycles, Table (3) shows the characteristics of the developed real drive cycle of Nasiriyah city comparison to standard drive cycles, which is a path with various characteristics that indicate that the final driving cycle is a delicate estimation of the road driving condition in Nasiriyah city.

Table 3 Comparison Nasiriyah DC with standard DCs in terms of the fuel consumption FC (L/100 km) and gas emissions(g/km).

Driving Cycle	HC emission (g/km)	CO emission (g/km)	NOx emission (g/km)	Fuel consumption (L/100 km)
Nasiriyah	0.713	1.027	0.27	5.36
UDDS	0.704	0.791	0.152	4.9
US06	0.588	0.942	0.31	6.1
FTP	0.542	0.615	0.135	5

In addition, the Nasiriyah DC was simulated in conventional CV, hybrid (series, parallel, and Toyota Prius), and electric vehicle models with all parameters (engine, electric motor, generator, and battery) set to default in Advisor. In reality, set the number of cycles to three while simulating to get a reasonable simulation distance and a practical fuel consumption value for both the Nasiriyah and UDDS driving cycles. Although some specifications, such as the size of the engine of different models, must be equivalent, which requires changing the default settings for each model separately, for the comparison to be valid. However, the results can be observed and compared to the UDDS cycle as shown in **Table (4),** and the results showed that the HC, CO, Nox, and fuel economy values for the Nasiriyah driving cycle are close to the relative change in the results of the UDDS cycle. Whereas, the UDDS driving cycle has proven effective in reducing emissions and fuel consumption when using the equivalent model for different vehicles type. This means Nasiriyah's DC also effectively reduces emissions and fuel consumption for the equivalent models.

Table 4 Comparison of Nasiriyah's and UDDS driving cycle for different types of vehicles.

parameters	CV	S-HEV	P-HEV	Toyota Prius	EV
HC emission (g/km)					
NAS*	0.216	0.242	0.222	0.39	-
UDDS*	0.186	0.197	0.183	0.351	-
CO emission (g/km)					
NAS	1.055	1.138	1.297	0.448	-
UDDS	0.71	0.863	0.876	0.389	-
NOx emission (g/km)					
NAS	0.192	0.428	0.215	0.13	-
UDDS	0.161	0.319	0.19	0.109	-
Fuel consumption (L/100 km)					
NAS	6.7	6.7	7.9	6.1	2.4**
UDDS	5.8	5.3	6.6	5.2	2.1**

* NO. of driving cycles =3 **Gasoline Equivalent)

As a note from **Table (3) and Table (4)** results, Fuel consumption and emissions are higher in the Nasiriyah driving cycle than in other cycles due to traffic congestion and frequent stops, so using hybrid or electric cars is strongly recommended.

5. Conclusions and future works

In this paper, a methodological approach for creating driving cycles is presented, which is based on the k-means method of clustering micro trips with the SPSS package. Data was collected using Arduino and GPS in a private vehicle driving along selected routes in Nasiriyah city. The results of driving features such as distance, time, maximum speed, average speed, maximum acceleration, maximum deceleration, stop number, and idle time of Nasiriyah driving cycle are 11.64 km, 1568 s, 73.85 km/h, 26.7 km/h, 2.08 $\mathrm{m/s^2}$, -3.14 $\mathrm{m/s^2}$, 7, 267 s respectively. According to these results, the Nasiriyah driving cycle's fuel consumption and emission values are found to be substantially different from those of other driving cycles. This study encourages using hybrid or electric cars in the city and recommends more studies in other cities in Iraq or to take other paths to improve the driving cycle, as it is based primarily on real-world driving behavior.

Abbreviation:

ADC	The Athens Driving Cycle
ADVISOR	Advanced Vehicle Simulator
CV	Conventional Vehicles
EVs	Electric Vehicles
FTP-75	Federal Test Procedure
GPS	Global Positioning System
ECE	Extra-Urban driving cycle
HEVs	Hybrid Electric Vehicles
J10-15	Five Typical Japanese Driving Cycles
NEDC	The New European Driving Cycle
OBD	On- Board-Diagnostics
SPSS	Statistical Package for the Social Sciences
UDDS	The Urban Dynamometer Driving Schedule
US06	The United States 06 Driving Cycle

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