# Design and assessment of Local Real-World Drive Cycles for Electric Vehicles

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**ABSTRACT**

Recently much research has been conducted, especially in Europe and the US, aiming to identify typical driving patterns on different road types. The main reason has then been to assess in which way, and to what degree, vehicle energy consumption is affected by different driving patterns and situations. to identify typical levels of speed, acceleration, and road grade attributed to different road types, such as; crowded driving roads (sub-city), urban driving roads (city), Rural and High-Way driving Roads (high-speed motorway driving), to design real-world drive cycles in Egypt and assess it with the comparison of real-world drive cycles such as United States (US) and Europe (EU) Drive cycles. typical driving distances, Speed, and acceleration will be investigated since the range is an important design factor for a BEV. it has been found that the acceleration parameters for the designed real-world drive cycle have significant change by comparing with the other cycles, for the distance and the speed are varying for all cycles.

**Keywords:** Design, assessment, Drive Cycles, Electric Vehicle, Egypt roads.

## 1. INTRODUCTION

Normal real-world driving is thus affected by many different factors such as driver behavior, weather conditions, street type, traffic conditions, journey type as well as vehicle type and specifications [1]. This makes it a highly challenging task to identify and specify typical real driving characteristics.

Much literature has been done under the sponsorships of American and European national emission regulatory organizations, such as the US Environmental Protection Agency (EPA), the California Air Resources Board, and the United Nations Economic Commission for Europe. In a fact, apart from the additional cycles, EPA has also considered such studies to identify other causes of fuel consumption during real-world driving, such as fuel energy density, wind, tire pressure, and road roughness

The purpose has been made to develop test procedures that describe repeatable standardized laboratory tests on passenger cars, as a part of the type approval procedure. Then the test is legal regulation of emissions, as well as fuel economy/efficiency, which is measured while the vehicle is driven according to a reference speed over time (called a drive cycle). To ensure that the legally set emission targets are not exceeded in typical real-world traffic, the laboratory test fallout should be fairly close to that. Another significant result of the test is that they represent a reasonable estimate of fuel economy/efficiency for customers. However, as acknowledged by the EPA, most test drive cycles were developed a few decades ago, and both legal speed limits and vehicle power specifications have increased since then, so performance has improved.[2] .

But instead of enhancing the test procedure to include such factors, EPA has developed a complex formula where the city and highway fuel economy label data are calculated based on specific weighting factors on sections of each test cycle. So far, the test procedures in Europe have remained on the continent since the year 2000. Yet, many projects have been conducted where driving data has been collected by using instrumented vehicles, and corresponding drive cycles have been developed. The common studies are the INRETS, HYZEM, ARTEMIS and the latest is the WLTP [3] .

In that way, Egypt is close to manufacturing a new electric car in cooperation with China, within the framework of the state's plan to reduce harmful emissions and reduce fossil fuel consumption during the coming period, coinciding with the global trend to expand the manufacture of these types of cars. To assess the energy consumption of these vehicles, it is necessary to design different real-world drive cycles to analyze their energy consumption behavior. Instead, in this paper sample, in-house measurements have been conducted, mostly covering the area in and around Cairo, but also longer highway sections. Data regarding speed and acceleration has been measured with an OBD II (ELM) and Car Scanner pro android application, see Appendix A.

## 2. DRIVE CYCLES

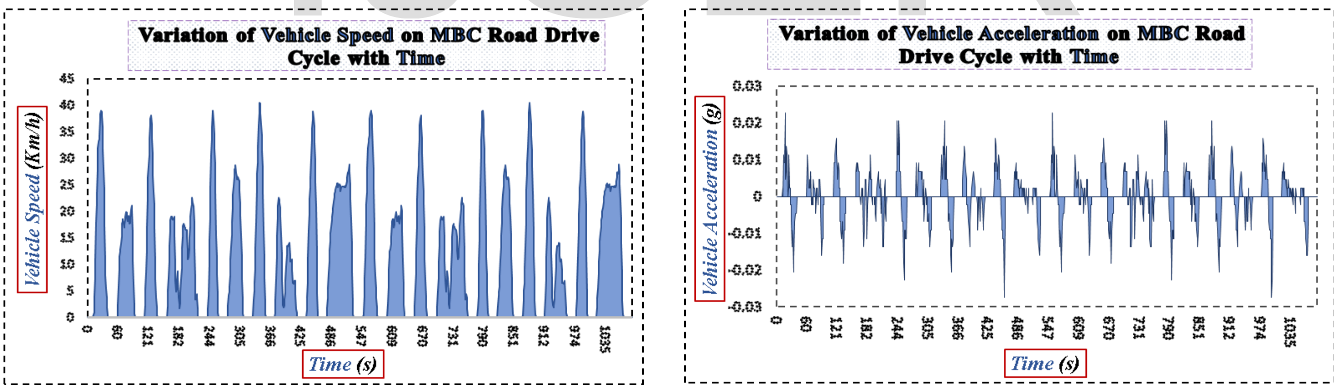
Some of the legislative and non-legislative United States and European drive cycles are used in comparison with the real Egypt-designed roads to use in evaluating vehicle emissions, fuel, and energy consumption. Only eight drive cycles of the US and EU are used in this research in comparison with the different designed cycles [3].

### 2.1 United States Drive Cycles (USDC)

USDCs are a series of data points representing the speed of a vehicle versus the time of its roads. Also, it is produced by different US countries and organizations to assess the performance of vehicles in various ways, such for instance fuel consumption, electric vehicle autonomy, and polluting emissions [4].

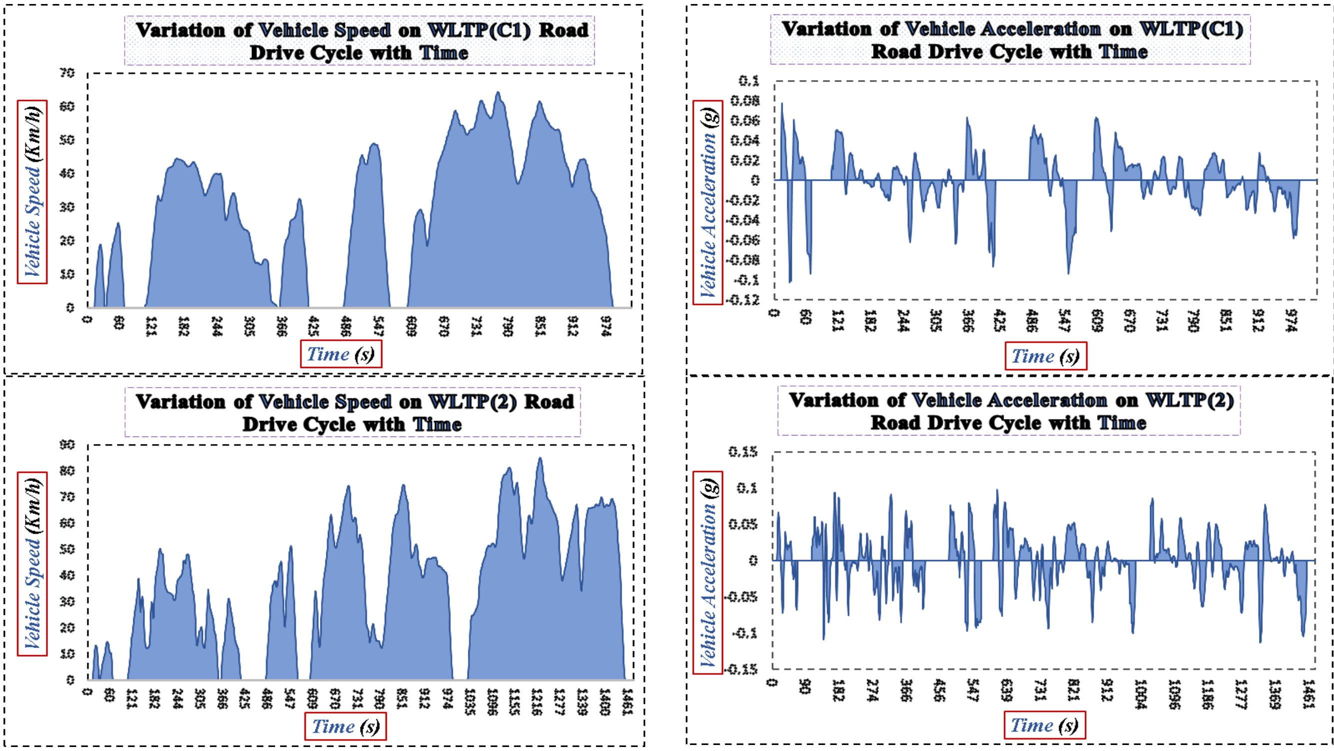


**2.1.1 Manhattan Bus Cycle (MBC):** The MBC was developed and supported observed driving patterns of urban transit buses within the Manhattan core of latest York City. The cycle is characterized by frequent stops and really low speed. Figure 1 represents MBC which is categorized as a legislative drive cycle [3].



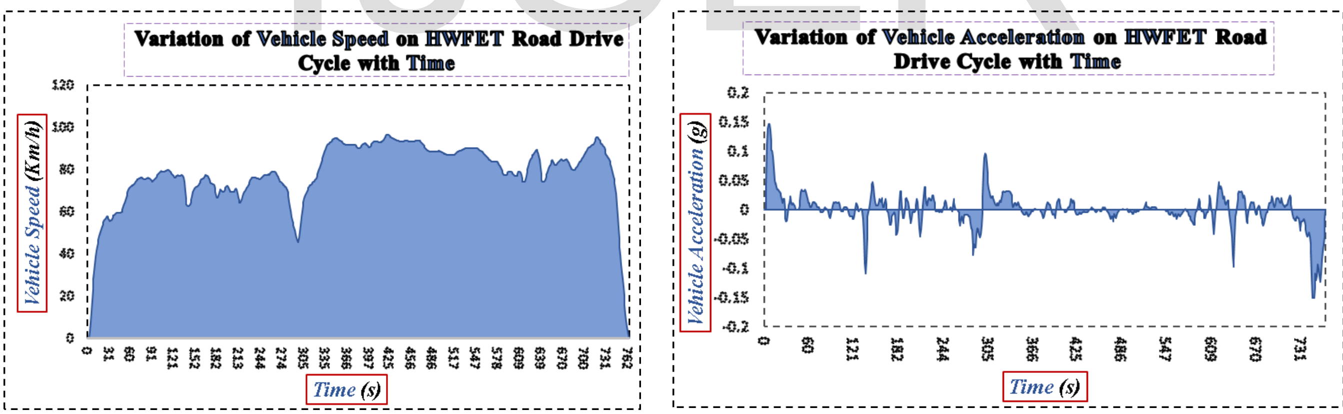

**Figures 1** variation of speed and acceleration on MBC road drive cycle over time

**2.1.2 Worldwide Harmonized Light Vehicle Test Procedure (WLTP):** Worldwide harmonized Light vehicles Test Procedures (WLTP) and Worldwide harmonized Light vehicles Test Cycles (WLTC) are sometimes used interchangeably, the WLTP procedures define another procedure, additionally to the WLTC test cycles that are needed to type approve a vehicle. WLTP will be used for type approval fuel consumption and emission tests. The cycle is aimed to represent typical driving on a world scale. Vehicle data has been collected from instrumented vehicles within the USA, it's categorized as a non-legislative cycle [3]. WLTP has three classes Urban, Rural and highway Roads, during this paper only two classes of WLTP are used Urban (WLTP C1) and Rural (WLTP C2) as stated in figure 2.




**Figures 2** variation of speed and acceleration on WLTP (C1 & C2) road drive cycle over time

**2.1.3 Highway Fuel Economy Test cycle (HWFET):** HWFET is exhibited in figure 3, it's a legislative cycle, The cycle could be a chassis dynamometer driving schedule developed by the US EPA for the determination of fuel economy of light-duty vehicles. The HWFET is employed to see the highway fuel economy rating, while the town rating is predicated on the EPA Federal Test Procedure FTP-75 test [3].

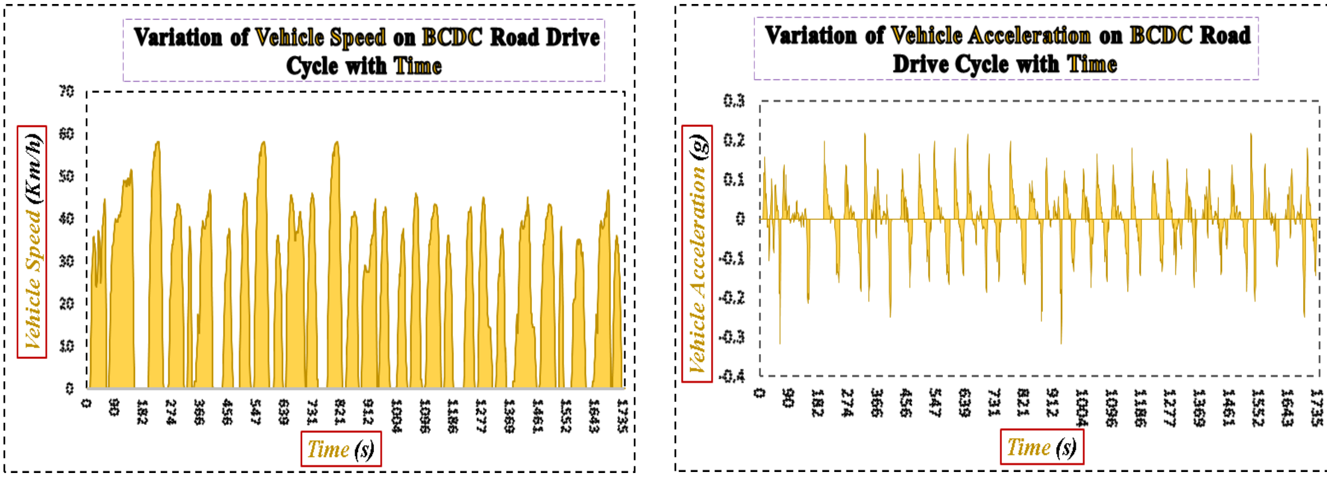



**Figures 3** variation of speed and acceleration on HWFET road drive cycle over time

## 2.2 European drive cycles (EDC)

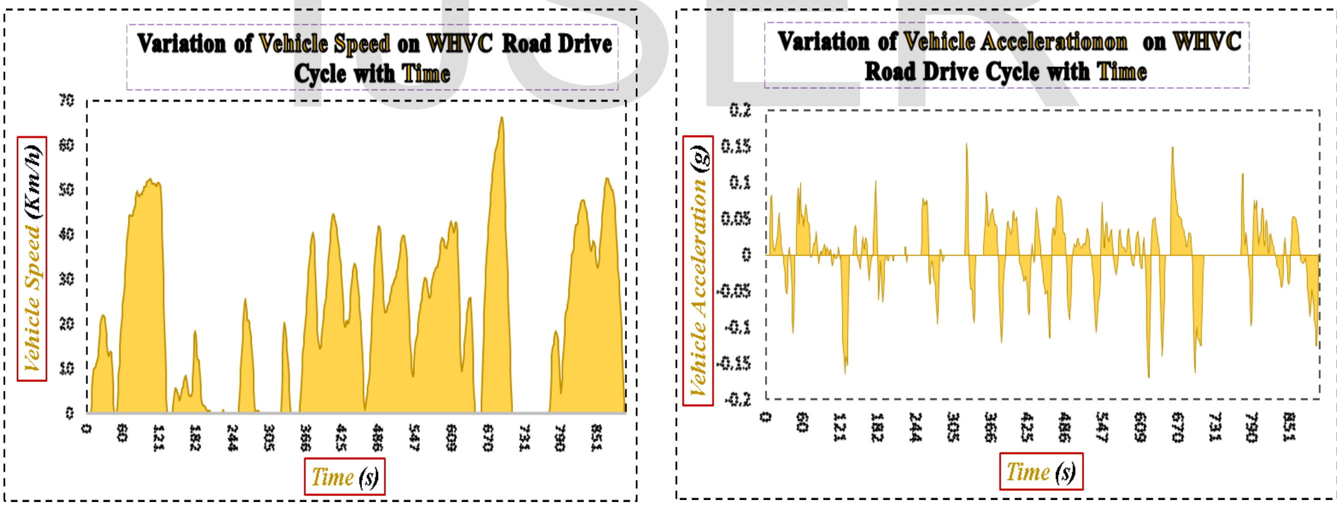
EDC are a driving cycle that is designed to assess the emission levels of car engines and fuel economy and energy consumption in passenger cars (which excludes light trucks and commercial vehicles). It is also referred to as the MVEG cycle (Motor Vehicle Emissions Group).

**2.2.1 Braunschweig City Driving Cycle (BCDC):** BCDC was developed at the Technical University of Braunschweig. It is a transient driving schedule simulating urban bus driving with frequent stops which can be used as a crowded road. The cycle is shown in figure 4, it is performed on a chassis dynamometer. had been frequently utilized in various research projects, as well as for some equipment certification programs. It is categorized as the EU legislative drive cycle with the introduction of the transient European Transient Cycle (ETC) cycle, the role of the Braunschweig cycle has diminished. [3].



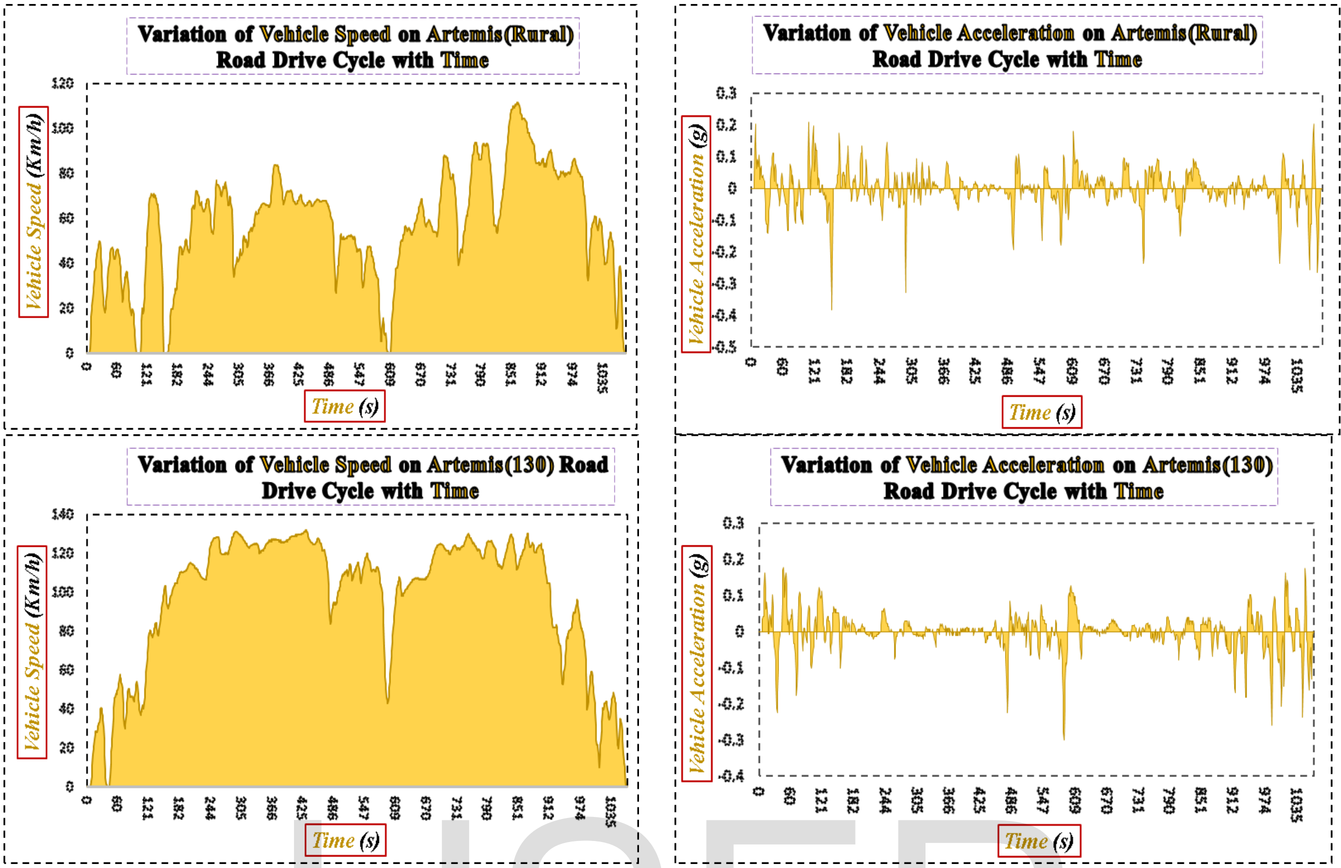

**Figures 4** variation of speed and acceleration on BCDC road drive cycle over time

**2.2.2 World Harmonized Vehicle Cycle (WHVC):** WHVC is a chassis dynamometer test developed based on the same set of data used for the development of the World Harmonized Transient Cycle (WHTC), which is represented graphically in figure 5. While the WHVC chassis dynamometer test isn't similar to the WHTC engine test, the WHVC results are occasionally used to compare the respective vehicle, engine emission levels, and battery energy consumption for research purposes. WHVC has also been developed, but is not a part of standard international testing procedures (non-legislative cycle), in this paper we use WHVC as an urban road for the EU drive cycle [5].




**Figures 5** variation of speed and acceleration on WHVC road drive cycle over time

**2.2.3 Assessment & Reliability of Transport Emission Models & Inventory Systems (ARTEMIS):** The Common Artemis Driving Cycles (CADC) is a chassis dynamometer procedure developed within the European Artemis project, based on a statistical analysis of a large database of European real-world driving patterns [6]. The ARTEMIS program built upon the earlier recommendations arising from the fourth framework project MEET and Cost Action 319. ARTEMIS is a non-legislative cycle that has three basic types of roads; ARTEMIS Urban, ARTEMIS Rural, ARTEMIS Motorway 130 or 150, in this paper we will use ARTEMIS Rural as a Rural Road and ARTEMIS Motorway 130 for High-way Road as it exhibited below in figure 6.




**Figures 6** variation of speed and acceleration on ARTEMIS (Rural & M130) road drive cycle over time



## 2.3 Designed Drive Cycles

Driving patterns in developing countries, particularly in metropolitan areas, differ markedly from those in developed countries or less-populated cities. However, the majority of vehicles driven in these areas are tested using driving cycles that do not correspond to those special driving characteristics, resulting in an underestimation or overestimation of energy consumption for electric or hybrid vehicles.in this study, four driving pattern cycles have been designed as a real-world drive cycle which can be used as a comparison with the other cycles to use as standard real-world drive cycles in Egypt. The device responsible to record data for measured route location track from the GPS for the designed cycle is stated in Appendix A.

**Figure 7** photo of Egypt Crowded Road

**2.3.1 crowded road drive cycle:** As mentioned previously, Egypt is a metropolitan city with high-populated people, and some roads have a high density of traffic, this is led to many stoppings' times with repetitive patterns of acceleration and deceleration that have a significant effect on energy consumption and driving behavior, other reasons refer to the bad condition of the road surfaces. A road was chosen that fits as a crowded road in slums in Egypt. the represented graphically data is shown in Appendix B.

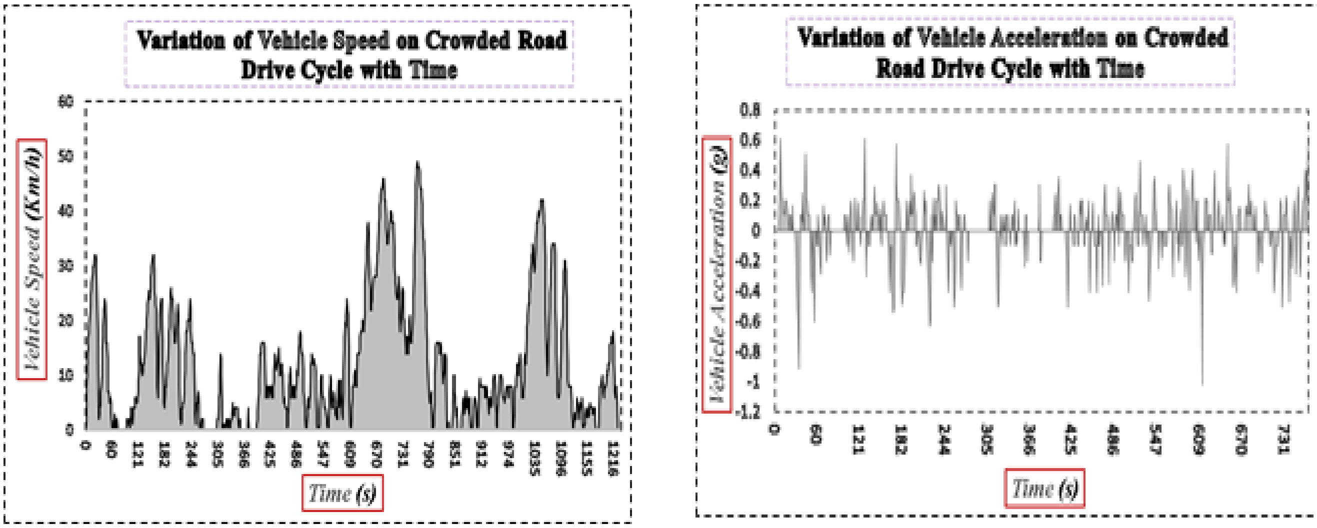



**Figure 7a** variation of vehicle speed and acceleration on Crowded test road drive cycle with time

**2.3.2 Urban Road drive cycle:** An Urban Road is a road located within the boundaries of a built-up Cairo area. Most of the urban roads in Egypt have been developed since 2014, which led to an increase in the efficiency of the road surface and relative ease in the rate of movement and traffic density. Therefore, the rate of stopping at the speed of the car and the rate of acceleration and deceleration have decreased compared to the crowded roads and this is due to the overcrowding in urban areas. the represented graphically data is shown in Appendix C.

**Figure 8** photo of Egypt Urban Road

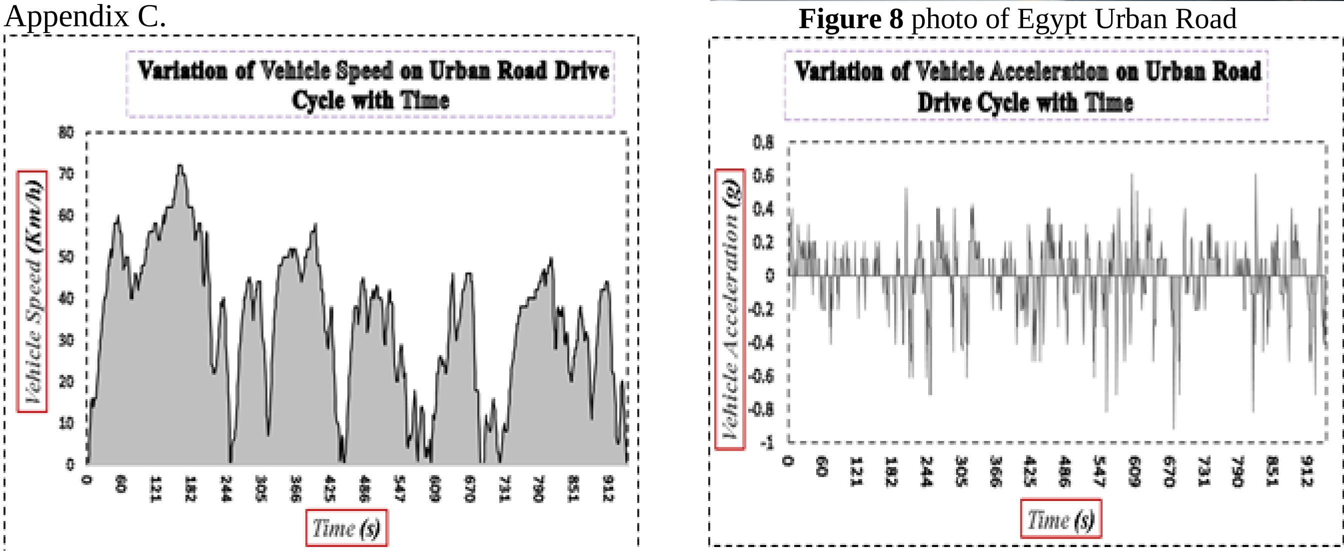
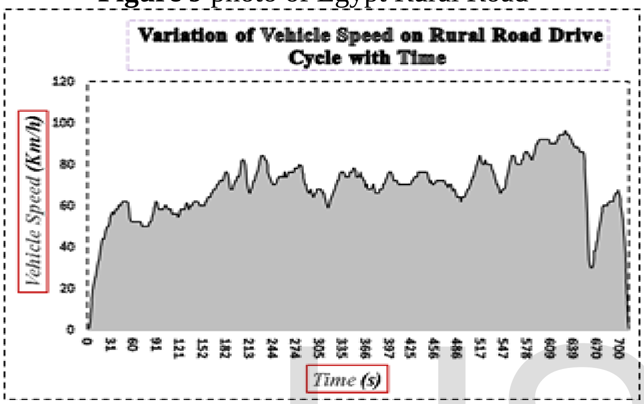



**Figure 8a** variation of vehicle speed and acceleration on Urban test road drive cycle with time

**2.3.3 Rural Road drive cycle:** Rural roads are defined as low traffic volume roads located in forested and rangeland settings that serve residential, recreational and resource management uses. They may have been constructed to relatively low standards with a limited budget. Cairo Alexandria Rural Road is one type the main Rural Road in Egypt, most of the road consists of two lanes, one to go and one to return, with each lane of only two cars. The road is entirely developed by the end of 2021. Part of the route road has been recorded and graphically represented in Appendix D.

**Figure 9** photo of Egypt Rural Road



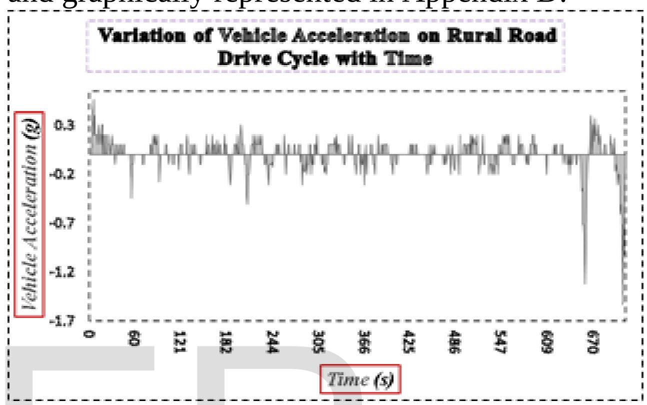
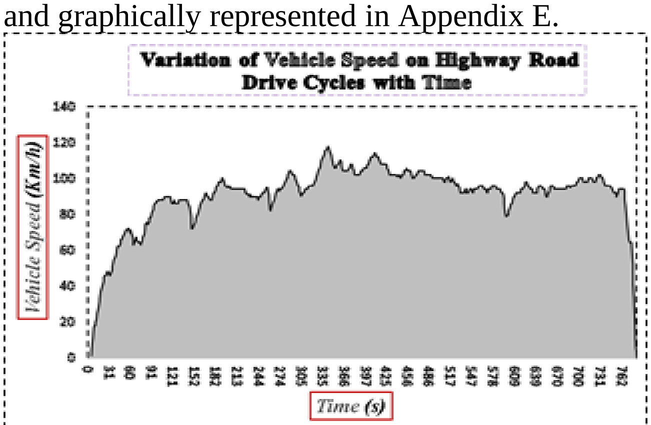




**Figure 9a** variation of vehicle speed and acceleration on Rural test road drive cycle with time



**2.3.4 Highway Road drive cycle:** The New Administrative Capital City Road is considered the best highway in Egypt, as it was built inside Egypt because it provides all the individual's requirements of suitable housing with standard specifications, as well as commercial and investment services, with the presence of major investment projects in the city, and it is located in a privileged location linking many areas within Cairo. a part of this road was measured and graphically represented in Appendix E.

**Figure 10** photo of Egypt Highway Road



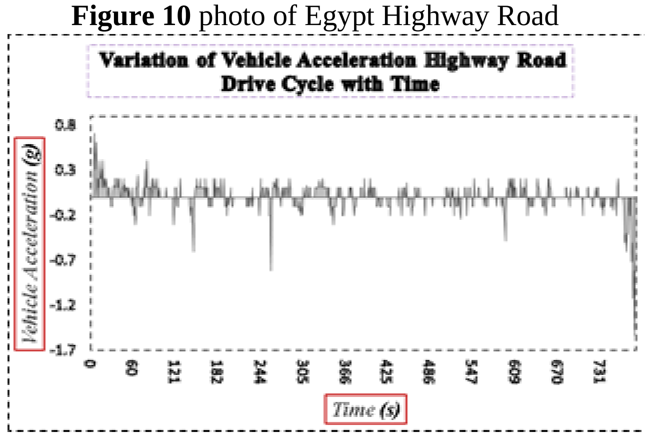




**Figure 10a** variation of vehicle speed and acceleration on HighWay test road drive cycle with time

## 3. METHODOLOGY

Again, the purpose of the design of the road driving cycles was to gain the best possible representation of the data basis in one representative trip per usage domain. The four domains, which have been defined as targets, are predominantly; crowded driving, urban driving, rural driving, and highway driving. some of the real drive cycles have mixed overall operation with a ratio of crowded to urban and urban to rural and rural to high-way segments as found in the data basis.

The first step to building up each driving cycle is a statistical analysis to define target vectors for the total length, the duration, and the number of driving sequences to get the best possible representation of the drive cycle data. however, the procedure that follows is based on the methodology used in [9]. Hereby 37 further statistical parameters are derived from the database to complete the target values for the driving cycle. The parameters are determined on the evaluation of [7, 8, and 9]. Table 1 provides a comprehensive overview of the parameters used. Table (1) represent the distance, speed, and acceleration parameters.

Table (1) test drive cycles parameter analysis for standard and measured cycle.

| Parameters | | Symbol | Equation | Unit |
|---|---|---|---|---|
| Time Duration | | T | - | s |
| **Distance Parameters** | Total Distance Travelled | TD | - | Km |
| | 1st Distance Phase | 1st DP | $= 0 : \frac{TD}{3}$ | Km |
| | 2nd Distance Phase | 2nd DP | $= \frac{TD}{3} : \frac{TD}{2}$ | Km |
| | 3rd Distance Phase | 3rd DP | $= \frac{TD}{2} : TD$ | Km |
| | Time Percent of 1st Distance Phase | T%. 1st DP | - | % |
| | Time Percent of 2nd Distance Phase | T%. 2nd DP | - | % |
| | Time Percent of 3rd Distance Phase | T%. 3rd DP | - | % |
| | Average Speed of 1st Distance Phase | aV. 1st DP | - | Km/h |
| | Average Speed of 2nd Distance Phase | aV. 2nd DP | - | Km/h |
| | Average Speed of 3rd Distance Phase | aV. 3rd DP | - | Km/h |
| **Speed Parameters** | Time Percent of Stopping Speed | T% SV | $= \frac{\sum s = 0}{T}$ | % |
| | Maximum Vehicle Speed | Max. V | - | Km/h |
| | Vehicle Average Speed | aV | $= \frac{TD}{T}$ | Km/h |
| | Vehicle Average Moving Speed | amV | | Km/h |
| | Maximum Average Moving Speed | Max amV | $= \frac{\Delta TD}{\Delta T}$ | Km/h |
| | Standard deviation of vehicle speed $n^t$ = Number of step time | Sd. V | $= \sqrt{\frac{\sum (V - \bar{V})^2}{n^t}}$ | Km/h |
| | Percent of Speed Phase ($V \leq 40$) | SP | - | % |
| | Percent of Speed Phase ($60 \leq V < 40$) | SP | - | % |
| | Percent of Speed Phase ($90 \leq V < 60$) | SP | - | % |

| | | | | |
|---|---|---|---|---|
| | Percent of Speed Phase (V > 90) | SP | - | % |
| Acceleration Parameters | Acceleration $= \frac{dv}{dt}$ | Acc | $= \frac{V(K+1) - V(K-1)}{T(K+1) - T(K-1)}$ | g |
| | Time Percent of Total Stopping Acceleration | T% Acc | $= \frac{\sum Acc = 0}{T}$ | % |
| | Maximum Positive Acceleration | Max $+^{Acc}$ | - | g |
| | Average Positive Acceleration | a. $+^{Acc}$ | - | g |
| | Standard Deviation of positive Acceleration | Sd. $+^{Acc}$ | - | g |
| | Time Percent of Stopping Positive Acceleration | T% $+^{Acc}$ | $= \frac{\sum +^{Acc} = 0}{T}$ | % |
| | Maximum negative Acceleration | Max $-^{Acc}$ | - | g |
| | Average negative Acceleration | a. $-^{Acc}$ | - | g |
| | Standard Deviation of negative Acceleration | Sd. $-^{Acc}$ | - | g |
| | Percent of Stopping negative Acceleration Time | T% $-^{Acc}$ | $= \frac{\sum -^{Acc} = 0}{T}$ | % |
| | Relative Positive Acceleration | RPA | $= \frac{\int V(T) * (+^{Acc})}{\int V(T)dt = (TD)}$ | g |
| GPS Tracker | Maximum Grade | Max G | - | % |
| | Minimum Grade | Mini G | - | % |
| | Maximum Elevation | Max E | - | m |
| | Minimum Elevation | Min E | - | m |
| | Elevation Gain | E Gain | - | m |

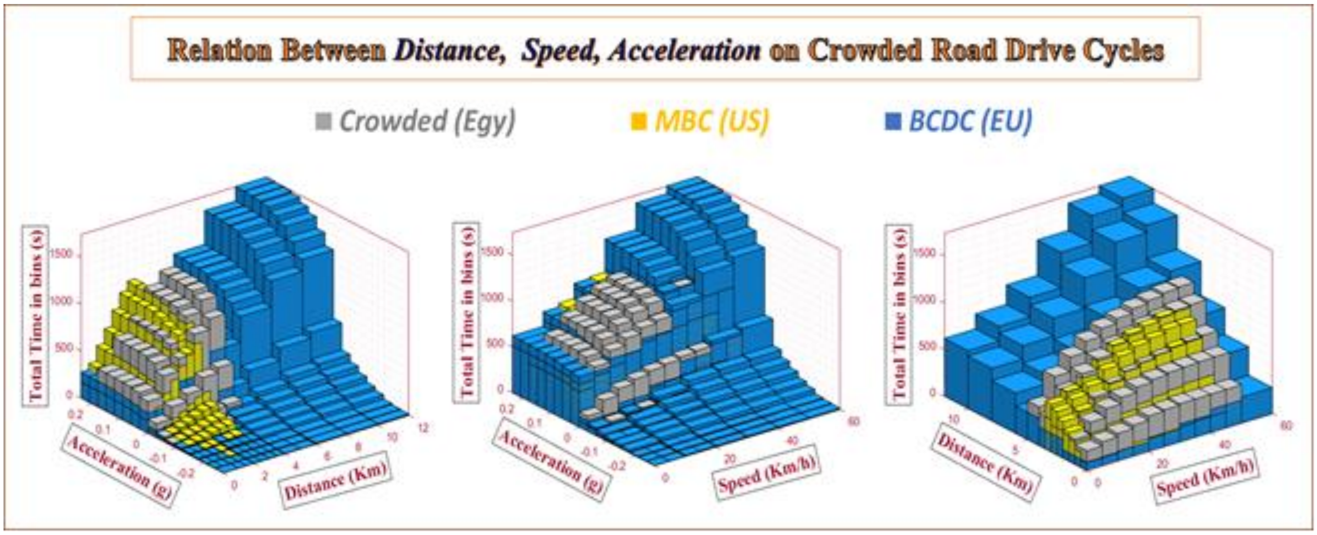


## 4. ROAD TYPE SPECIFICATION BASED ON DISTANCE, SPEED LEVELS, AND ACCELERATION DISTRIBUTER

The distance, speed, and acceleration levels experienced by vehicles are of great interest for finding the necessary parameters of distance and speed levels of the vehicles. It is also interesting to know what speed levels that typically occur on which road type in comparison to designed roads [1]. However, Since the peak force and power on the wheels often is due to the vehicle's acceleration, it is vital to analyze what levels of acceleration are to be expected to occur during normal driving on the different road types. acceleration levels will be analyzed as a function of speed and time. Logged real-world cycles will be compared with US and EU test cycles. All Cycles data regarding time duration, driven distance, and speed levels can be seen in appendix F, for both standard and Designed cycles. the purpose of this categorization is to find typical driving characteristics for the chosen road types, therefore the majority of the time spent at a certain distance, speed, and acceleration levels is dominating the categorization assigned to either of the road types categories; Crowded, Urban, Rural and Highway roads.

### 4.1 Crowded Roads Analyzing.

The time series of distance, speed, and acceleration for the Crowded drive cycles can be seen in Figure 11. To account for measured location track from the GPS for the designed cycle is stated in appendix A, For the test and Designed cycles, the significant speed parameters are for the BCDC cycle since maximum speed, average speed, average running speed and maximum average running speed are (58.2, 24, 31.9 and 18.3 km/h respectively). Distance traveled phases for the same cycle are higher at all the phases and the designed cycle comes in second place, this is due to the total distance for the BCDC being 10.9 Km while the designed and MBC cycles are 3.6 Km and 3.3 Km respectively. maximum positive and negative acceleration are (0.612 and -1.063 g) for the crowded road. The percent of negative and positive acceleration time is higher for BCDC roads due to the number of stooping times.

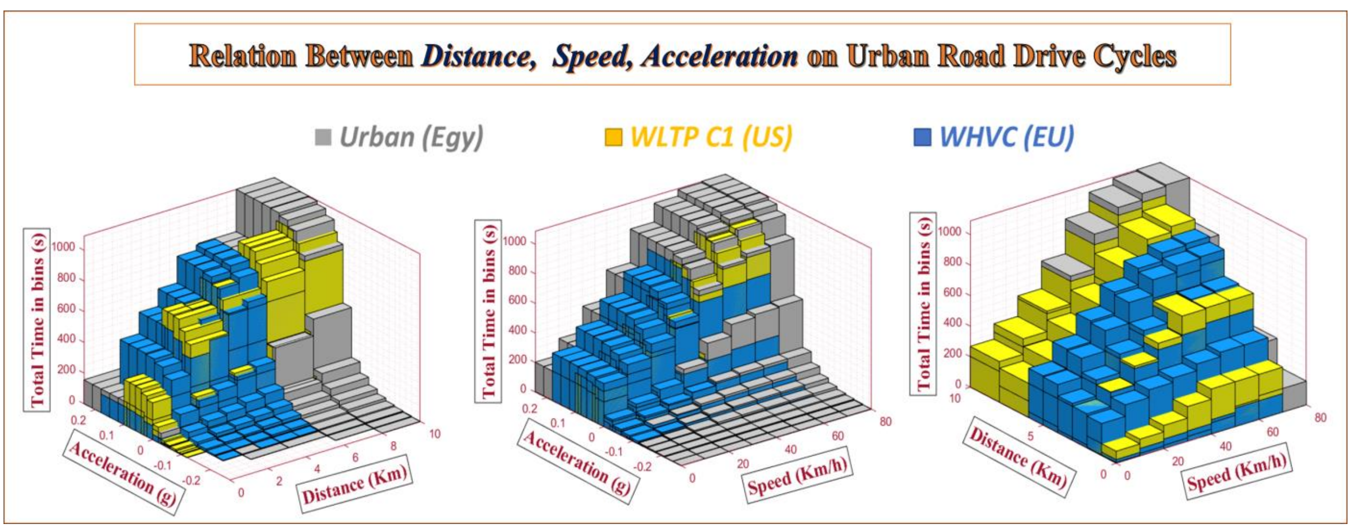



**Figures 11** Variation of distance, speed and acceleration parameters on different Crowded Roads drive cycles over time



## 4.2 Urban Roads Analyzing.

The time series of distance, speed, and acceleration for the Urban standard and designed cycles can be seen in Figure 12. Three urban cycles were excluded from the figure, since two of them represent real-world drive cycles, and the designed one was similar to the others. for both designed cycle and real-world drive cycles. speed parameters are little similar for all cycles, the highest value for the urban road by 72 Km/h, and the average speed and running speed are 34.2 and 51.1 (Km/h) while the maximum average moving speed for real-world drive cycles for the designed cycle. as well as the time standing are based on traveled distance levels at 8.1 k (1022 s) and below, for all cycles.



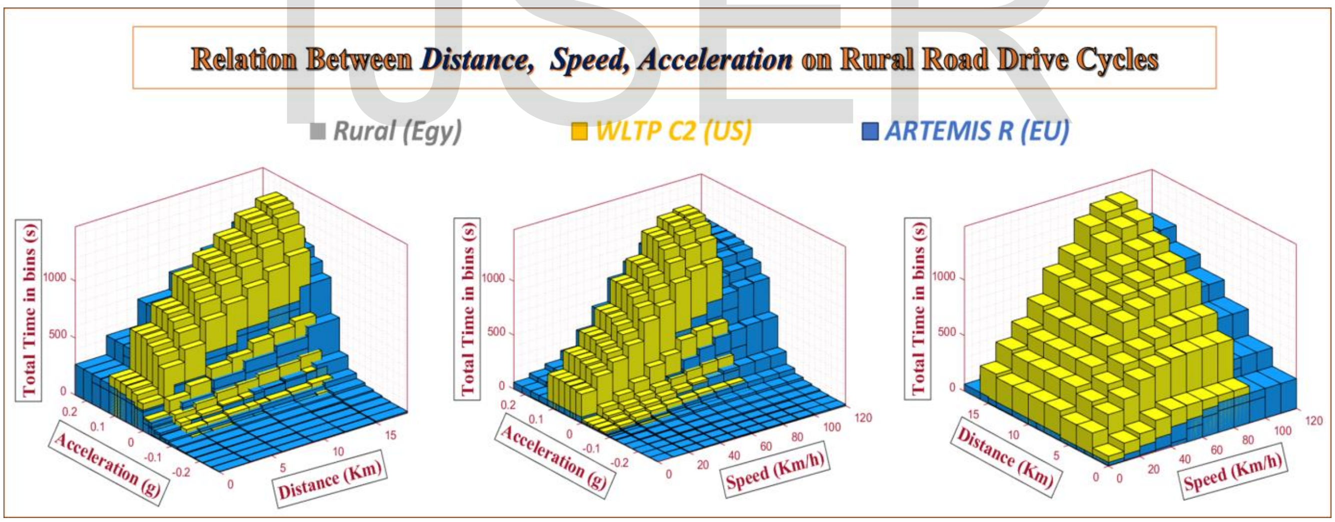

**Figures 12** Variation of distance, speed and acceleration parameters on different Urban Roads drive cycles over time

Regarding the time s within certain speed intervals, the traveled phases are little well for all cycles. The main difference is a longer at speed phases (S≤40) 58.8% for WHVC, and thus a shorter time at low speed, compared to the urban road. Most certainly some of the test cycles represent less dense traffic conditions than what was experienced in crowded cycles. The % of stopping acceleration time is high for WHVC at 22.1%. For the test cycles, the minimum positive and negative acceleration is (0.078, -0.102 g respectively) for the WLTP C1. Percent of stopping time for positive and negative acceleration is higher for the urban road by 31.1% (WLTP C1 and WHVC is varies between 18.3% and 19.9%).

### 4.3 Rural Roads Analyzing.

Cycle data for both designed road and Rural real-world cycles can be seen in appendix G, also in this case the time standing is higher for the WLTP C2 by 1477 s at 14.7 Km. Then the distance phases are little same for all cycles, the percent of speed level phases is pretty close at (S ≤40 and 40 ≤ S ≤ 60), while (60 ≤ S ≤ 90) is higher at Rural Road by 70.8 %. This is also reflected in the maximum speed levels which are higher for all cycles especially for the ARTEMIS Rural by 111.5 Km/h, while the average speed and average running speed are a little high for the rural road (68.1 and 47.6 Km/h). At the same time, the maximum average running speed has no significant change between the Rural and ARTEMIS M130 while the lowest value for the WLTP C2 by 36.5 Km/h .

Distance level phases are pretty close for all cycles at all phases, it has a slightly high value for ARTEMIS Rural and WLTP C2 by 17.3 and 14.7 % respectively in the 3rd phase, due to the total travel distance is high for ARTEMIS Rural BY 17.3 Km. from appendix F It can be seen that a maximum positive and negative acceleration is high for the Rural Road by (0.57 and -1.53 g respectively), in another way the high percent of stopping positive and negative acceleration by (55.2 and 42.5 %) for the ARTEMIS Rural as shown in figure 13.

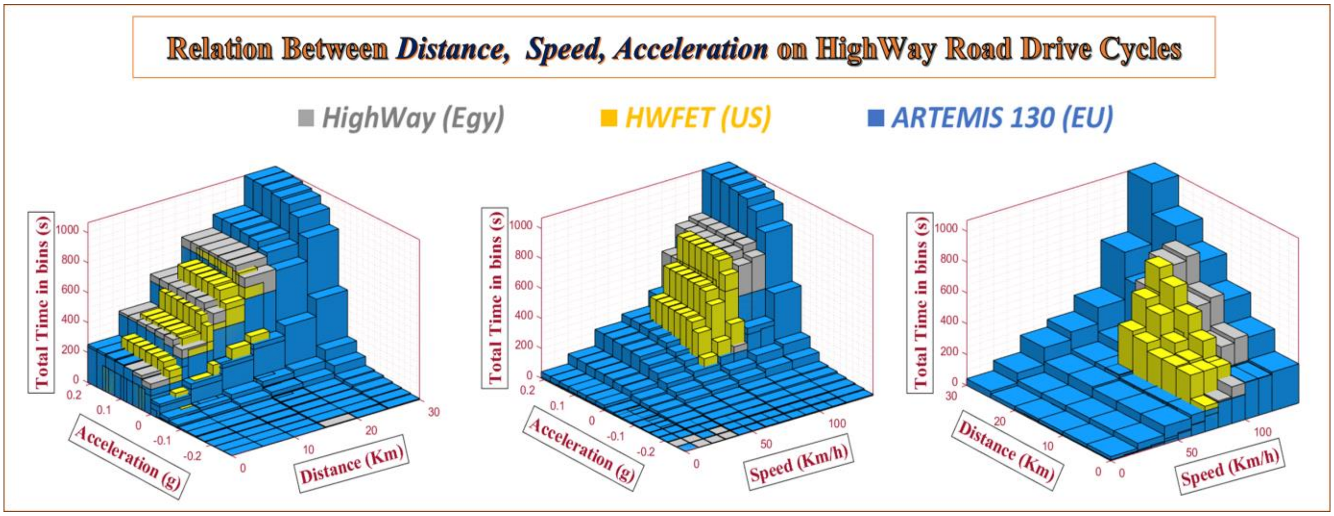



**Figures 13** Variation of distance, speed and acceleration parameters on different Rural Roads drive cycles over time

### 4.4 Highway Roads Analyzing.

The road-specific parameters for the three Highway cycles can be seen in Figure 14. for both designed and real-world drive cycles. speed parameters for all cycles are somewhat close, the maximum speed is 131.8 Km/h and the average running speed is 82.4 Km/h for the ARTEMIS M130, as well as the time standing, is based on traveled distance levels at 28.7 km (1068 s) and below for all cycles.

The three-level phases of the distance are only increased for the ARTEMIS M130 especially at the 3rd phase by 28.7 %. The main difference is the increase in the percent of speed phases ($60 \leq S \leq 90$) is 66.1% for HWFET, while ($S > 90$) is 70.1% for ARTEMIS M130 and 69.8% for Highway Road. Most certainly some of the test cycles represent too few dense traffic conditions than what was experienced in all cycles. For the test cycles, the minimum positive and negative acceleration is (0.146, and -0.15 respectively) for the HWFET. Percent of stopping time for positive and negative acceleration is higher for only Highway Road by 49.7% (HWFET and ARTEMIS M130 vary between 0.5% and 1.2%).




**Figures 14** Variation of distance, speed and acceleration parameters on different Highway roads drive cycles over time

## 5. CONCLUSION.

This work aimed to design and assessment the first representative road drive cycles of the driving patterns in Cairo as a developing metropolitan city. This was in response to the lack of such drive cycles for Egypt and the common use of non-representative driving cycles, developed originally for developed countries. Large-scale field activities have been made to identify the most suitable techniques, areas, and vehicles to represent the actual traffic conditions in Cairo. Recorded datasets were inspected, analyzed, and graphically represented for a feature. The designed cycles represented different types of Egypt roads, Crowded, Urban, Rural, and Highway. The designed cycles have been compared to the recorded data from different US and EU drive cycles to make the designed cycles more real and effective. The designed cycles were found more representative of the recorded data in terms of cycle parameters compared to the US and EU cycles. However, the designed cycles showed high stopping times of all accelerations from the collected data in terms of positive and negative accelerations. The designed driving cycle can be used in vehicle emission inspection, certification, and pollution evaluation, as well as energy consumption for electric vehicles. In future works, it is planned to develop the cycles using more advanced algorithms using data of newer vehicles exclusively.

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# APPENDIXES

## Appendix (A)

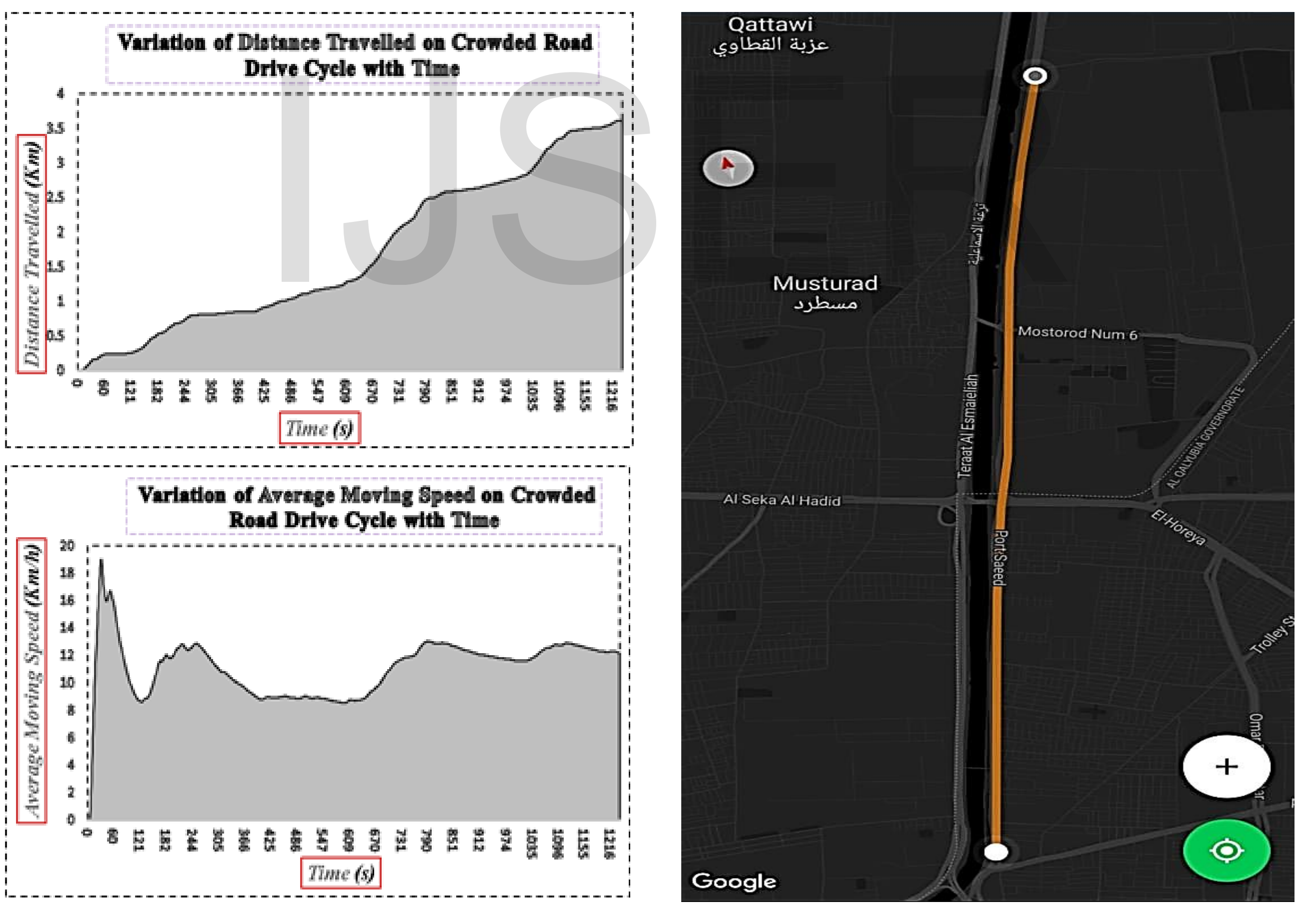

**OBD II android device scanner**

ELM327 Bluetooth devices provide an easy way to scan a vehicle's Onboard Diagnostics II (OBD-II) system for codes, reading, and recording data. They can also read PIDs and aid in diagnostics. These devices represent a low-cost way for DIYers and seasoned techs alike to tackle computer diagnostics. However. Scan tools that include an ELM327 microcontroller and a Bluetooth chip are capable of pairing with a variety of devices, but there are some important limitations. The primary devices you can use an ELM327 Bluetooth scan tool with are; Smartphones, Tablets, and Laptops.

**Car Scanner ELM OBD2 app pro**

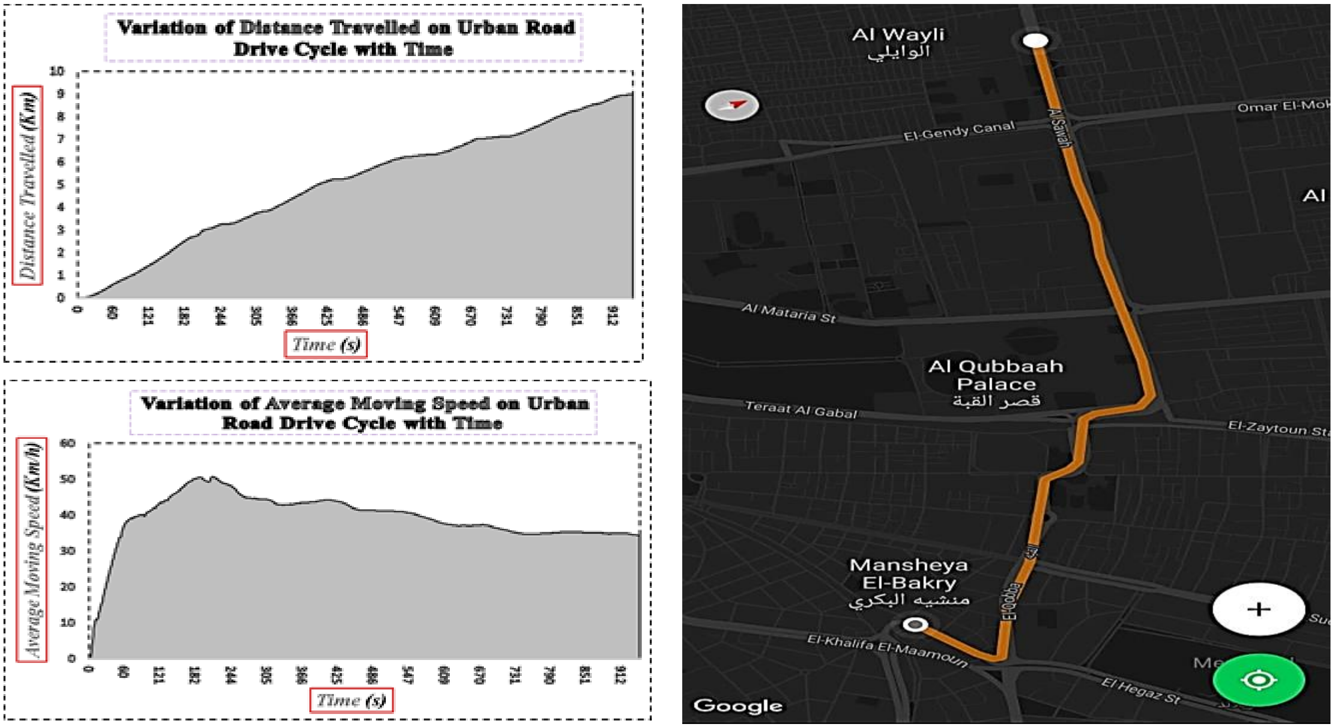
Simple, ELM OBD2 plugs into a car's OBD-II port, reading diagnostic data from the Electronic Control Unite and sending over Bluetooth to your phone within Car Scanner Android app. The vehicle that was used in this research is a lancer shark 2016, for more data go to [10]

**Appendix (B)** Crowded Road Graphical Data




Figures 15 Variation of distance and average speed on Egypt root Crowded test road drive cycle over time

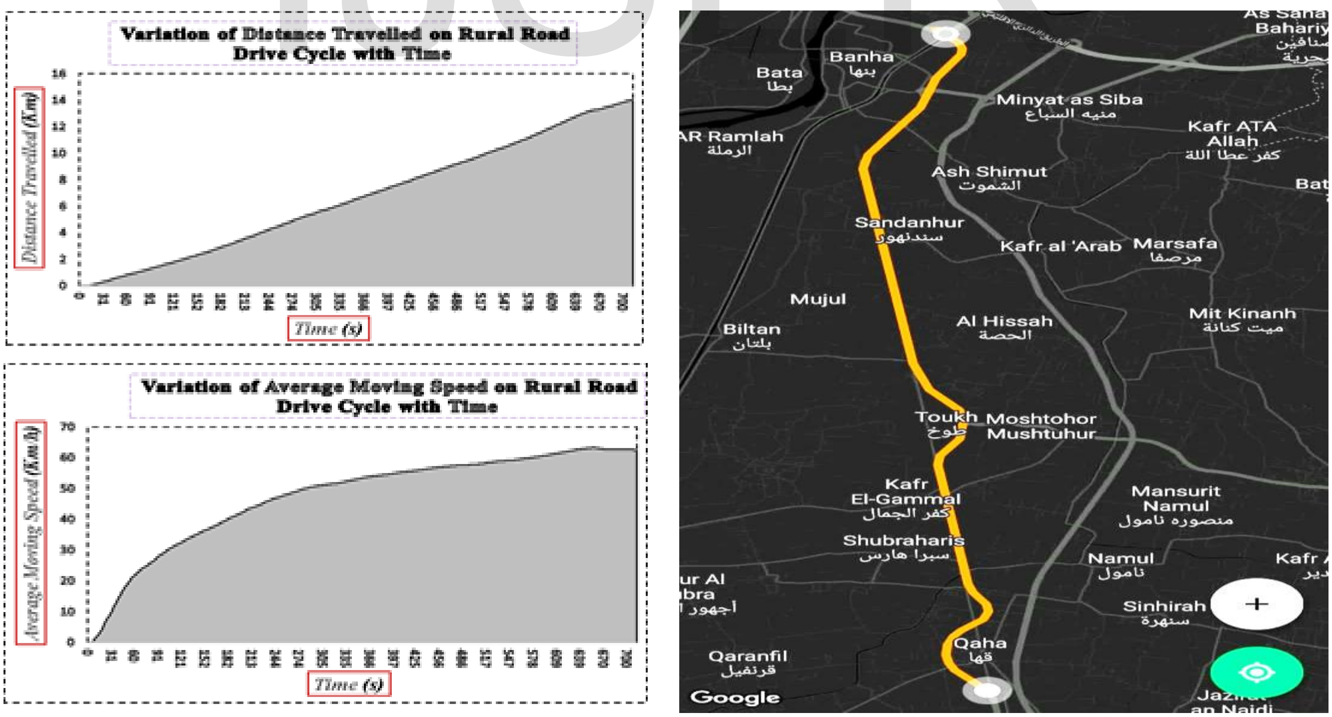
**Appendix (C)** Urban Road Graphical Data




Figures 16 Variation of distance and average speed on Egypt root Urban test road drive cycle over time

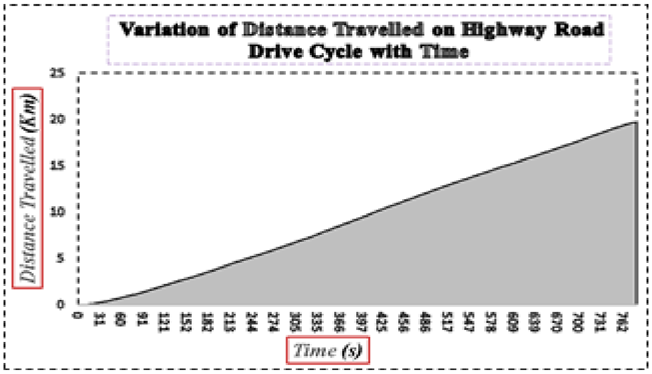


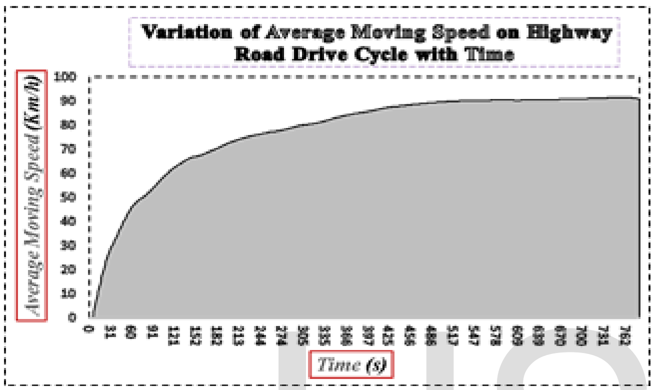
**Appendix (D)** Rural Road Graphical Data

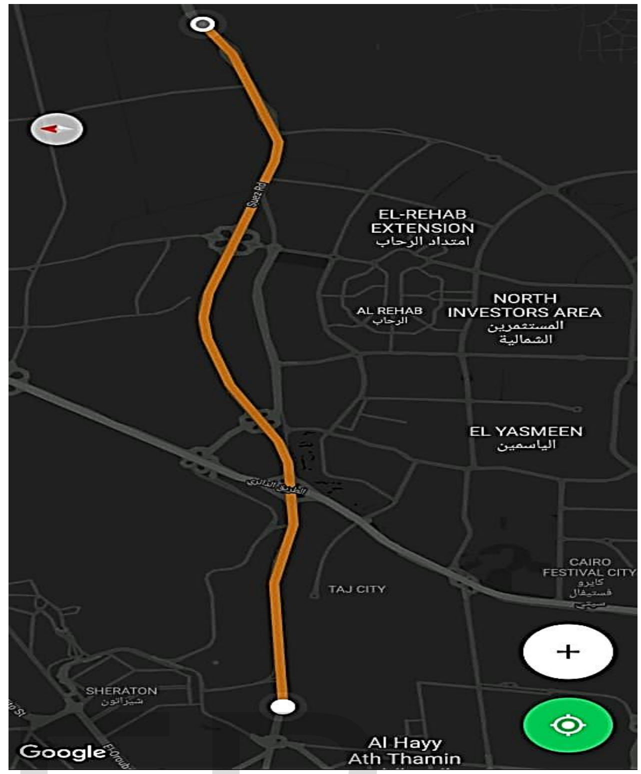



Figures 17 Variation of distance and average speed on Egypt root Rural test road drive cycle over time

**Appendix (E)** <u>Highway Road Graphical Data</u>




Figures 18 Variation of distance and average speed on Egypt root HighWay test road drive cycle over time



**Appendix (F)**: Table (a), Cycle data of Vehicle Speed for test drive cycles on different roads.

| **Drive Cycle Type** | | **T% 'SV'** | **Vehicle Speed (Km/h)** | | | | **Sd. 'V'** | **% Of Speed Phases (%)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Max. V** | **aV** | **amV** | **Max amV** | | **V ≤ 40** | **40 < V ≤ 60** | **60< V ≤ 90** | **V > 90** |
| **Crowded** | **Crowded (Egy)** | **13.9** | **49.1** | **12.1** | **11.1** | **18.8** | **11.7** | **82.7** | **3.5** | **0** | **0** |
| | **MBC (US)** | **36** | **40.5** | **11** | **10.7** | **17.2** | **11.8** | **63.7** | **0.4** | **0** | **0** |
| | **BCDC (EU)** | **25.2** | **58.2** | **22.5** | **24** | **32** | **18.3** | **53.3** | **21.6** | **0** | **0** |
| **Urban** | **Urban (Egy)** | **6.6** | **72** | **31.2** | **38.4** | **50.6** | **18.4** | **56.1** | **32.6** | **4.8** | **0** |
| | **WLTP C1 (US)** | **19.2** | **64.4** | **28.5** | **21** | **29.9** | **20.3** | **44.4** | **32.9** | **3.6** | **0** |
| | **WHVC (EU)** | **22.1** | **66.2** | **21.3** | **18.4** | **30.1** | **18.1** | **58.8** | **18** | **1.2** | **0** |
| **Rural** | **Rural (Egy)** | **0.6** | **96** | **68.2** | **59.3** | **70** | **15** | **4.1** | **17** | **73.5** | **5** |
| | **WLTP C2 (US)** | **15.8** | **85.2** | **35.7** | **23.2** | **36.5** | **24.7** | **37.1** | **25** | **22.2** | **0** |
| | **ARTEMIS R (EU)** | **3** | **112** | **57.4** | **46.2** | **58.9** | **24.6** | **17.8** | **30** | **42.1** | **7.1** |
| **HighWay** | **HighWay (Egy)** | **0.6** | **118** | **90.3** | **77.3** | **91.4** | **18.6** | **2.7** | **2.9** | **23** | **70.9** |
| | **HWFET (US)** | **0.8** | **96.4** | **77.6** | **68.7** | **79.1** | **16.5** | **2.7** | **7.2** | **66.1** | **23.3** |
| | **ARTEMIS 130 (EU)** | **1.6** | **131** | **96.8** | **82.6** | **104** | **35.2** | **8.5** | **10.3** | **9.6** | **70.1** |

Table (b), Cycle data of Vehicle Acceleration for test drive cycles on different roads.

| **Drive Cycle Type** | | T% Acc | Positive Acceleration (g) | | | | Negative Acceleration (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $+_{Acc}$ Max | $+_{Acc}$ a. | $+_{Acc}$ Sd. | $+_{Acc}$ T% | $-_{Acc}$ Max | $-_{Acc}$ a. | $-_{Acc}$ Sd. | $-_{Acc}$ T% | RPA |
| ***Crowded*** | Crowded (Egy) | **0.56** | **0.17** | **0.03** | **0.03** | **55.9** | **-0.24** | **-0.04** | **-0.04** | **43.6** | **0.7** |
| | MBC (US) | **1.01** | **0.218** | **0.03** | **0.04** | **69.5** | **-0.241** | **-0.07** | **-0.05** | **29.6** | **0.8** |
| | BCDC (EU) | **0.63** | **0.218** | **0.03** | **0.05** | **64.4** | **-0.242** | **-0.06** | **-0.06** | **35.1** | **0.6** |
| ***Urban*** | Urban (Egy) | **0.18** | **0.22** | **0.03** | **0.03** | **53.3** | **-0.24** | **-0.04** | **-0.05** | **46.6** | **0.2** |
| | WLTP C1 (US) | **1.17** | **0.08** | **0.01** | **0.02** | **58.3** | **-0.12** | **-0.02** | **-0.02** | **40.6** | **0.2** |
| | WHVC (EU) | **0.78** | **0.16** | **0.02** | **0.03** | **64.7** | **-0.18** | **-0.05** | **-0.04** | **34.7** | **0.5** |
| ***Rural*** | Rural (Egy) | **2.8** | **0.158** | **0.02** | **0.02** | **52.5** | **-0.245** | **-0.03** | **-0.05** | **47.4** | **0.2** |
| | WLTP C2 (US) | **8.8** | **0.102** | **0.02** | **0.02** | **59.6** | **-0.119** | **-0.03** | **-0.03** | **39.5** | **0.2** |
| | ARTEMIS R (EU) | **5.5** | **0.218** | **0.04** | **0.04** | **51.8** | **-0.247** | **-0.04** | **-0.05** | **47.7** | **0.4** |
| ***HighWay*** | HighWay (Egy) | **0.51** | **0.198** | **0.02** | **0.02** | **64.2** | **-0.243** | **-0.03** | **-0.05** | **35.4** | **0.3** |
| | HWFET (US) | **0.39** | **0.146** | **0.02** | **0.02** | **53.7** | **-0.15** | **-0.02** | **-0.03** | **46** | **0.2** |
| | ARTEMIS 130 (EU) | **0.66** | **0.195** | **0.03** | **0.04** | **53.8** | **-0.253** | **-0.04** | **-0.05** | **45.6** | **0.3** |

Table (c), Cycle data of Vehicle Traveled Distance for test drive cycles on different roads.

| **Drive Cycle Type** | | Time | **Distance Phases (Km)** | | | **% Of Phases Time (%)** | | | **Average Phases Speed (Km/h)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st DP | 2nd DP | 3rd DP | T%. 1st DP | T%. 2nd DP | T%. 3rd DP | aV.1st DP | aV.2nd DP | aV.3rd DP |
| ***Crowded*** | Crowded (Egy) | 1239 | 1.4 | 2.1 | 4.2 | 47.3 | 9 | 43.5 | 8.6 | 22.2 | 14 |
| | MBC (US) | 1089 | 1.1 | 1.7 | 3.3 | 34.5 | 16.9 | 48.6 | 10.5 | 11.8 | 11.1 |
| | BCDC (EU) | 1740 | 3.6 | 5.4 | 10.9 | 31.8 | 14 | 54.1 | 23.3 | 26.6 | 21 |
| ***Urban*** | Urban (Egy) | 945 | 3.2 | 4.7 | 9.5 | 21.9 | 13.6 | 64.5 | 43.3 | 36.2 | 24.5 |
| | WLTP C1 (US) | 1022 | 2.7 | 4 | 8.1 | 49.6 | 16.7 | 33.6 | 19.1 | 27.4 | 43.1 |
| | WHVC (EU) | 900 | 1.8 | 2.7 | 5.3 | 45.8 | 13.2 | 40.9 | 15.6 | 27.5 | 25.7 |
| ***Rural*** | Rural (Egy) | 713 | 4.5 | 6.8 | 13.5 | 37.3 | 16.1 | 46.4 | 61.1 | 71 | 73.3 |
| | WLTP C2 (US) | 1477 | 4.9 | 7.3 | 14.7 | 49.5 | 13.7 | 36.7 | 24.1 | 42.8 | 48.9 |
| | ARTEMIS R (EU) | 1082 | 5.8 | 8.6 | 17.3 | 39.2 | 20.2 | 40.5 | 49.1 | 46.7 | 71.2 |
| ***HighWay*** | HighWay (Egy) | 782 | 6.6 | 9.8 | 19.7 | 38.2 | 13.9 | 47.8 | 79.5 | 104.6 | 95.3 |
| | HWFET (US) | 765 | 5.5 | 8.3 | 16.5 | 37.9 | 15.6 | 46.4 | 68.5 | 83.2 | 83.6 |
| | ARTEMIS 130 (EU) | 1068 | 9.6 | 14.4 | 28.7 | 36.1 | 13.8 | 50.1 | 89.3 | 117.6 | 96.8 |

Table (d), Cycles data of Vehicle Traveled Distance for test drive cycles on different roads.

| **Drive Cycle Type** | | Max +Acc | Speed (Km/h) | Distance (Km) | Max −Acc | Speed (Km/h) | Distance (Km) | Max Speed | ±Acc. (g) |
|---|---|---|---|---|---|---|---|---|---|
| ***Crowded*** | **Crowded (Egy)** | **0.17** | **2** | **0.0016** | **-0.24** | **23.59** | **3.859** | **49.1** | **0.031** |
| | **MBC (US)** | **0.218** | **17.7** | **0.0089** | **-0.241** | **13.24** | **1.358** | **40.54** | **0.056** |
| | **BCDC (EU)** | **0.218** | **10.79** | **5.1831** | **-0.242** | **29.28** | **6.09** | **58.2** | **0.002** |
| ***Urban*** | **Urban (Egy)** | **0.22** | **7.53** | **9** | **-0.24** | **4.79** | **9.159** | **72** | **0.0568** |
| | **WLTP C1 (US)** | **0.08** | **3.09** | **0.0004** | **-0.12** | **0.005** | **0.212** | **64.4** | **0.0056** |
| | **WHVC (EU)** | **0.16** | **13.86** | **1.309** | **-0.18** | **21.43** | **3.452** | **66.2** | **0.01** |
| ***Rural*** | **Rural (Egy)** | **0.158** | **13** | **0.0047** | **-0.245** | **47.31** | **12.781** | **95.9** | **0.0283** |
| | **WLTP C2 (US)** | **0.102** | **29.59** | **0.557** | **-0.119** | **47.69** | **5.076** | **85.2** | **0.0028** |
| | **ARTEMIS R (EU)** | **0.218** | **13.85** | **0.834** | **-0.247** | **53.1** | **3.488** | **111.5** | **0.0226** |
| ***HighWay*** | **HighWay (Egy)** | **0.198** | **7.95** | **0.0013** | **-0.243** | **34.8** | **19.64** | **118** | **0.0283** |
| | **HWFET (US)** | **0.146** | **18.17** | **0.0092** | **-0.15** | **63.08** | **16.38** | **96.4** | **0.0045** |
| | **ARTEMIS 130 (EU)** | **0.195** | **32.17** | **28.66** | **-0.253** | **14.65** | **16.01** | **131.7** | **0.0226** |