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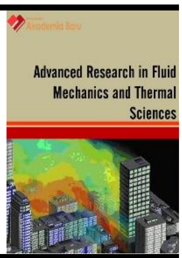

An Assessment of Power Demand for Electric Vehicles in Comparison to Conventional on Real and Standard Driving Cycles

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ABSTRACT

This paper was aimed to investigate the potential benefits of switch conventional vehicles to electrical vehicles. Vehicle activities were collected in Baghdad city, Iraq and analysed. The Autonomie simulation program was used to simulate electric vehicles on standard and real world driving cycles. The results showed that vehicle activities in Baghdad city were quite similar to most crowded cities such as New York. The expected energy consumption may decrease by about 67% as compared to the conventional vehicle. However, the decrease in energy consumption was about 35% on highway standard driving cycle.

1. Introduction

Clean energy is one of the key elements to maintain the environment safe and clean [1, 2]. Therefore, for cleaner environment with reduction in oil consumption, hybrid electric vehicles (HEVs) are one of the key elements of future technology [3]. Although, the hybrid electric vehicles have not yet gained the maximum popularity in the world, they offer more efficient, cost effective, new technology and very low emission vehicles comparing to the traditional one [4]. To make HEVs more popular, the government needs to take action such that the sales of hybrid electric vehicles need to be at least 20-30% of the whole vehicles sales [5]. Moreover, the government can reduce the taxes and free parking for the hybrid electric vehicles buyers.

The gasoline vehicle is the main source of harmful emission and air pollution which is the important factor that driving to change. Figure 1 clearly shows how the emissions (Particulate Matter, PM) was affected Paris due to the gasoline vehicles use [6]. Therefore, HEVs have obvious environmental benefits in reducing the harmful emission. Moreover, from economic point of view, using HEVs are not only reducing the air pollution but also eminently practical. Thus, most

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researchers strongly emphases to investigate alternatives to the gasoline vehicles by using HEVs which have low or zero greenhouse gases emissions [7].

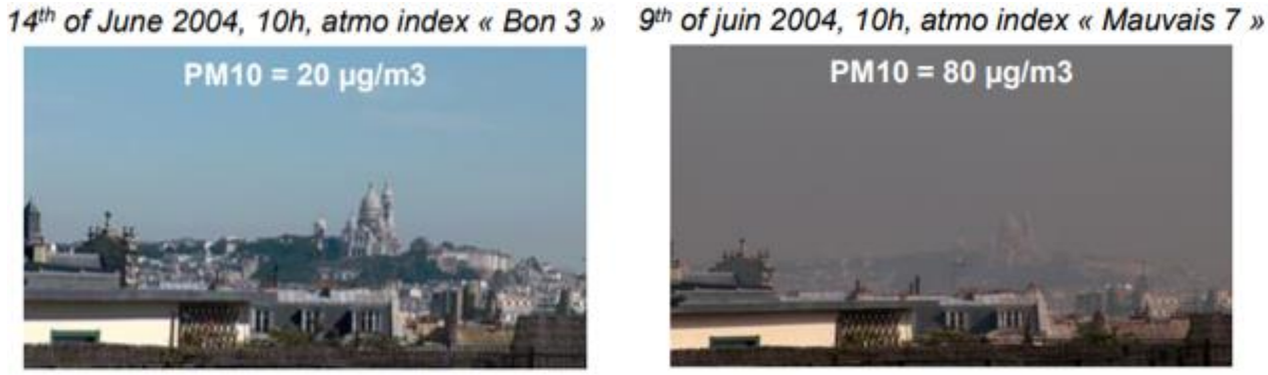


Fig. 1. Particulate (PM) emissions change in Paris during 5 days [6]

In brief, using HEV is not an easy task as it seems because there are other factors need to be considered such as distance, time to recharge and weight of storage. HEVs still facing many challenges, which need to be solved and therefore, not expected to be spread before 2040 as shown in Figure 2.

This paper aims to evaluate the power demand by different types of vehicles (electric and conventional) on several driving cycles. It is very obvious that the emission from electric vehicles is (none) basically zero. However, from the well to wheel assessment perspective there is emission from the power plants that supply the electricity for charging stations. Therefore, this paper is going to evaluate the decrease in total defect of vehicle on our environment due to use electric vehicles on our terrains.

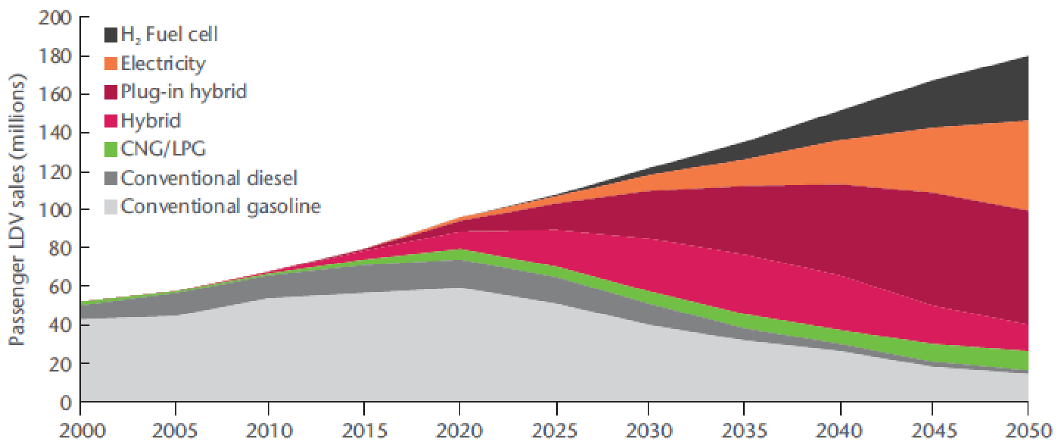


Fig. 2. Annual sales base on specific technology type [8]

2. Road Load Equation

Total power required at the wheels was stated by the road-load equation applied to a vehicle as

$$P_t = \left(m\frac{dv}{dt} + \frac{1}{2}C_D\rho A v^2 + \mu m g + mgZ\right)v \tag{1}$$

where, m is mass of the vehicle (kg), v is speed of the vehicle (m/sec) assuming no wind, A is frontal area of the vehicle (m^2), g is acceleration due to gravity (9.81 m/sec^2), CD is aerodynamic drag coefficient, μ is tire rolling resistance coefficient, ρ is air density, and Z is road gradient (%) [24-26]. Pt is the total power needed at the wheels and is stated in Watts (W). In this equation the first term was referred to as the inertia load, the second term as the wind drag, the third term as the rolling resistance, and the last term was the grade load. Summation of these loads resulted in the "total load or total power." This was also termed as 'tractive force' needed to propel the vehicle at any prescribed velocity and acceleration [9]. Moreover, there are other (accessories) power demands such as A/C, cooling and lights. The power demand for accessories did not account in this equation, but it accounted during the vehicle model simulation.

The aerodynamic drag in Eq. (1) was defined as the force required to overcome the aerodynamic resistance to vehicle motion. The value of drag coefficient, CD for a chassis heavy duty vehicle used in the literature varied from 0.40 to 0.79 [9].

The rolling resistance was defined as the force required to move a vehicle over a surface and stated as μ*m*g**v*. The rolling resistance coefficient, μ, was influenced by tire size and pressure, axle geometry, and the amount of load applied to the tires.

3. Electric Vehicle

3.2 Energy Storage System

3.2.1 Battery pack

It is important to choose the battery technology as the battery moves the hybrid electric vehicle in standings of price, reliability, mass and "greenhouse gas emissions" production [10, 11]. The battery technologies used widely in HEV include lead-acid, nickel-metal hydride (Ni-MH) and lithium ion (Li-ion) [12]. Lead-acid batteries were used in the initial period of HEVs, but most of the current vehicles operate with Ni-MH and Li-ion [10]. Table 1 compares and contrasts the two battery technologies [13]. The dominant battery type in the market for hybrid electric vehicle now is Li-ion [14].

Table 1
The comparison of two batteries [13]

	Ni-MH	Li-ion
Specific energy	50 Wh/Kg to 65 Wh/Kg	90 Wh/Kg-95 Wh/kg
Battery charging and discharging cycles	200-300 cycles	Above 1000 cycles
Cycle life of the battery	The calendar life of Ni-MH batteries can be improved by full discharging to prevent crystalline formation	Li-ion batteries are subject to aging, even if not in use
State of charge	There exists a constant voltage profile for this battery from 80%-30%	The battery should not be fully charged, high voltages stresses the battery
Temperature dependent performance	Shows unsatisfactory performance at high or low temperatures	The performance erodes drastically at extreme high/low temperature

3.2.2 Ultracapacitors

An ultracapacitor is an electrochemical capacitor that has high energy density while having the same features of a usual capacitor [15]. The ultracapacitor contains two electrodes, which are separated by an insulator. The current will be kept from moving between the electrodes, therefore an electric potential is allowed to develop. The electrodes are normally built from a layer of activated carbon with metal foil. As the charge builds up on the electrodes, ions are attached to the surface of the activated carbon [16]. Ultracapacitors have clear advantages when compared with batteries, as described below. The advantages of ultracapacitor are

i. Long life span, without degrading the performance with use, which extends the life of a HEVs' power source.
ii. Can be charged or discharged in a very short time, approximately ten times faster than a battery with the same weight, but unfortunately it can't maintain energy for a long time, and has a much lower energy storage capacity.
iii. Low weight and volume.
iv. Steady performance at temperatures as low as -40 ^{o}F [16].

The hybrid electric vehicle with the ultracapacitors is better controlled at quick power transient due to its high power density, which enables an HEV with ultracapacitors to increase existing power during acceleration [16]. However, the ultracapacitors have some limitations such as variable voltage, which is negative in some cases and also they can't store energy for long time. Most of the existing ultracapacitor hybrids are designed for use in transit buses where their frequent stop-and-go duty cycles are conducive to the use of [16].

3.3 Control Unit

It is important to explore in details to understanding of the drivability for both conventional and electric vehicles. Drivability is associated with the driver's sensitivity to the dynamic responses of the vehicle [17, 18]. Drivability is frequently evaluated by qualified drivers that evaluate the vehicle performance under precise dynamic conditions for example engine idling, launch, acceleration, cruise (low/high speed), pedal tip-in/tip-out, gear changes and engine on/off. The general evaluation of automobile drivability can be inefficient and is subject to human error. Lately, auto builders moved towards the use of special software sets to evaluate drivability in an independent way [19]. These software sets use methods (for example neural networks) that process a combination of sensors and data gained from several driving conditions.

4. Driving Cycles

The amount of emission and oil consumption need to be evaluated for both hybrid electric vehicles against traditional vehicles using a few driving cycles (standard and real-world). These driving cycles are briefly explained with their affecting parameters in Table 1. In the current study, a standard driving cycles was applied for both highway and city (UDDS, FTP and US06HWY), while real-world driving cycle was applied for vehicle activity in Baqubah city / Iraq. The driving cycle of Baqubah city was created a part of driving information and they processed based on their frequency as clearly clarified in [20]. Emissions and fuel consumption were investigated on Tuesday with the help of real-world driving cycle.

5. Simulation of Vehicles

Using different driving cycles (i.e standard and real-world) cause very big challenge when simulating a vehicle model due to the dynamic interaction between the system components. The vital parameters to indicate the best strategy of simulating any system is the repeatability and accuracy of the results. Additionally, the theoretical and experimental outcomes validation represents the main requirement for any simulation software to be considered. All these conditions can be fulfilled by simulation program named Autonomie (authorized to Ahmed Al-Samari at West

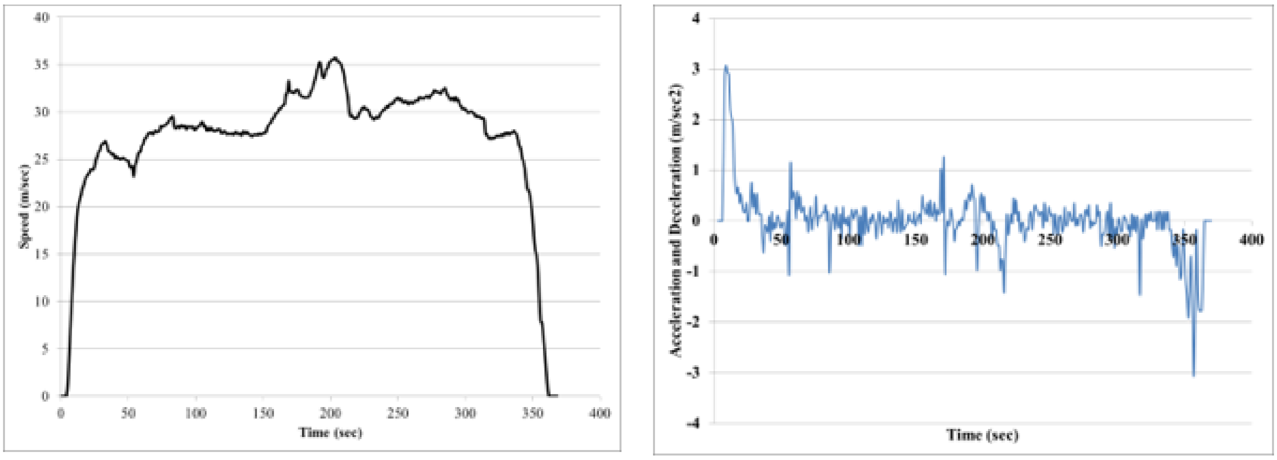
Virginia university, USA) [20]. This program has a great ability of simulating vehicles in real live conditions like climate conditions, driver, ability of the engine and driving cycle [21-24]. It has also the ability to estimate the fuel economy, emissions, equipment performance in addition to the evaluation of the results accuracy.

5.1 Simulation Validation

The previous studies showed that simulation vehicles model with Autonomie program showed high accuracy in comparison with the experimental data such that Autonomie model can reach 99% of the experimental results [20]. Additionally, this program has been considered in more than 780 vehicles producer companies such as Ford, General Motor to estimate the emissions, fuel economy and size of equipment [22]. Moreover, in each single simulation results can be also validated using this program (i.e. whether a driving cycle is run by vehicle model).

6. Results and Discussion

The major privilege of electric vehicle is capturing the lost energy while using brake system. Therefore, the percentage of deceleration during any activity will give a very first impression about the expected benefit from using electric vehicles on these terrains. Figure 3(a) and (b) shows the activity and the acceleration-deceleration for the standard high way driving cycle. It is obvious that the amount of deceleration is relatively small.



(a) (b)

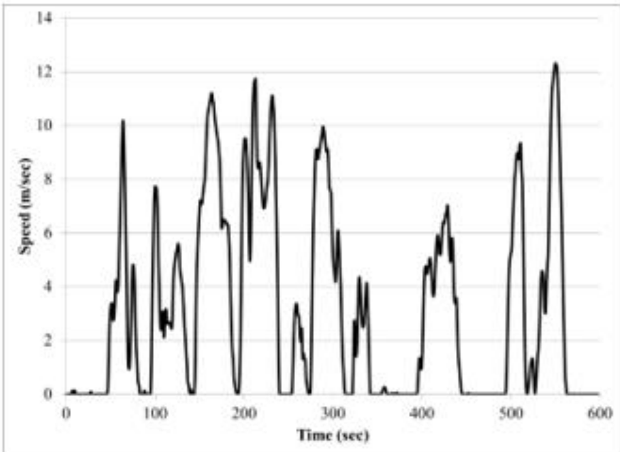
Fig. 3. (a) and (b) represent the standard driving cycle and acceleration/deceleration on Highway

Furthermore, Table 2 shows the parameters of each driving cycle used in this study and these parameters can give the brief expectation about which activity can save energy the most. Actually, the characteristic of highway driving cycle can't give a correct impression about the activity because the real life world usually last for much longer time than this activity. Basically, these standards driving cycles used for assessing engines and emissions. The real world driving cycle used in this study was longer than the most standard driving cycles (2036 second) to make a sort of real impression about the expected benefits.

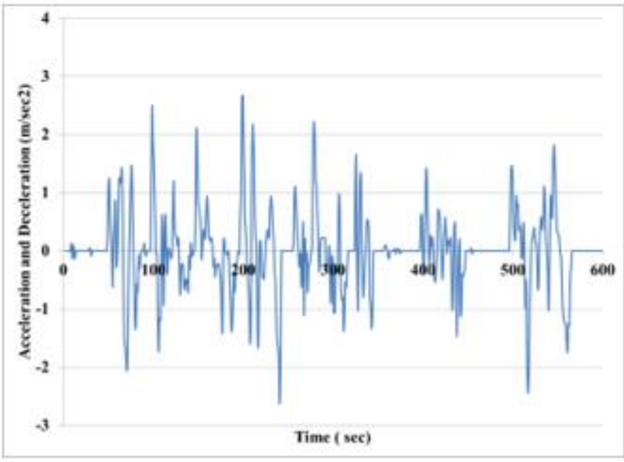
Figure 4 and 5 show the activity and acceleration-deceleration for New York standard and real world (Baghdad-Iraq) driving cycles which is represents city activities. The acceleration rate means the increasing in velocity rate and the deceleration rate is in contrast represent the velocity decreasing rate. The most energy saving was found on the New York driving cycle about 68% which is expected. Moreover, the energy saving percentage on the real world driving cycle was about 67% and the saving on high way driving cycle was the least about 32% as shown in Figure 6. The final outcome of this study shows that Baghdad city activity worth to employ electric vehicles on its terrains.

Table 2
Real world and standard driving cycle's parameters

	HWY	NY	Real world
Duration (Sec)	369	599	2036
Distance (km)	9.977	1.887	10.914
Max velocity (km/h)	128.48	44.32	77.24
Average velocity (km/h)	97.338	11.343	19.29
Maximum acceleration (m/sec^2)	3.129	2.88	2.197
Maximum deceleration (m/sec^2)	-2.825	-2.403	-2.68
Average acceleration (m/sec^2)	0.1504	0.202	0.187
Average deceleration (m/sec^2)	-0.1504	-0.202	-0.187
Deceleration (%)	47.155	37.56	38.06
Idle time (%)	2.71	53.422	48.43
Cruise time (%)	80.7	0	0

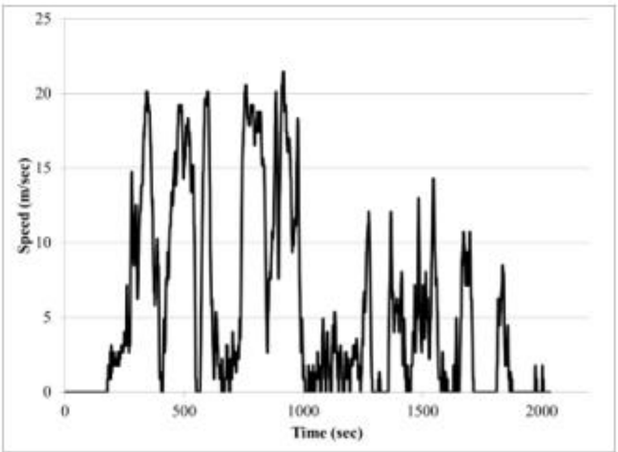


(a)

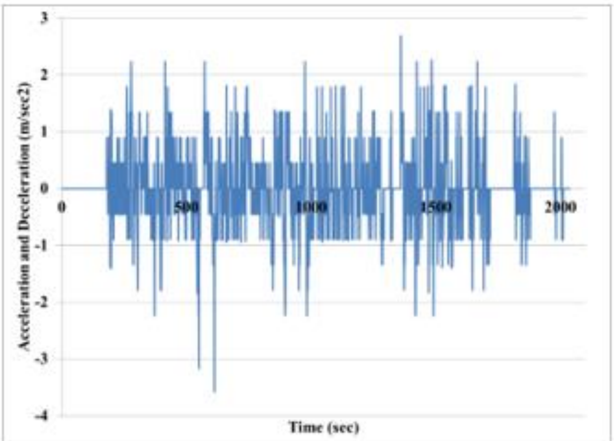


(b)

Fig. 4. (a) and (b) represent the standard driving cycle and acceleration/deceleration in New York city



(a)



(b)

Fig. 5. (a) and (b) represent the real world driving cycle and acceleration/deceleration cycle in Baghdad

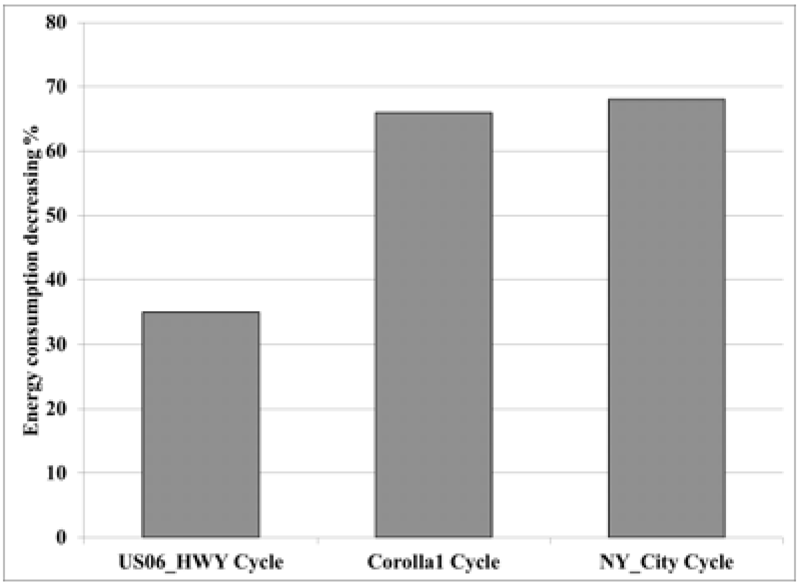


Fig. 6. Energy consumption decreasing in comparison to conventional vehicles

7. Conclusions

The outcome of this work shows that the vehicles activities in Baghdad city is pretty much similar to the most crowd cities such as New York. The expected energy consumption may decrease about 67% in comparison to the conventional vehicle. However, the energy consumption decreasing was about 35% on highway standard driving cycle. However, the standard highway may not precise enough to assess electric vehicle on it and that because it is short. The short trip can't simulate the actual activity on highway in the perspective of energy management.

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