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Investigation of Driving Behavior on Performance and Fuel Consumption of Light-Duty Vehicle

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ABSTRACT

This manuscript instrumented two light-duty passenger cars to construct real-world driving cycles for the Baghdad-Basrah highway road in Iraq using a data logger. The recorded data is conducted to obtain typical speed profiles for each vehicle. Each of the recruited vehicles is modelized using Advanced Vehicle Simulator and conducted on the associated created driving cycle to investigate fuel economy and analyze performance. Moreover, to inspect the influence of driving behavior on fuel consumption and emissions, the simulation process is re-implemented by substituting the conducted real-world driving cycle. The analyses are done for the first and second stages of simulation predictions to explore the fuel-penalty of aggressive driving behavior. The analysis for substitution predictions showed that fuel consumption could be reduced by 12.8% due to conducting vehicle under the more consistent real-world driving cycle. However, conducting vehicle under the more aggressive one would increase fuel consumption by 14.6%. The associated emissions change prediction due to the substitution is also achieved and presented.

1. Introduction

Fuel economy simply means that a vehicle is traveling a specified distance in a reasonable time and consumes fuel as less as possible. The fuel economy depends basically on the engine load, furthermore, the load demand is influenced by many parameters like; vehicle's weight, engine's size, aerodynamic resistance, rolling resistance, and terrains (i.e. uphill, downhill, or flat) [1]. Hence, fuel economy is strongly affected by the engine load which also yields the driver pedal press. Unfortunately, there are no inclusive standard limits for GHGs in Iraq, but for HC and CO emissions that were reported beaten by a 30% increased concentrations [2]. However, rough statistics revealed that the Iraqi transportation sector along with the electricity-production generators and the heavy-duty machines consume approximately 21 million liters of gasoline and a similar quantity of diesel fuel daily [3]. In practice, Test cycles are standard driving cycles that introduce speed and elevation profiles versus time, the standard driving cycles were firstly used to judge the gaseous emissions of tested vehicles. The test cycles are often conducted on chassis dynamometer so that the process of energy conversion at the wheel so-called wheel-to-miles imitates the conducted standard test cycle. Having useful findings had been proven, the standard driving cycles were also utilized to

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compare the fuel economy for different internal combustion engine vehicles (ICEVs). Predefined initial conditions are taken into account like (temperature, humidity, hot and cold start) while testing. The pollutant emissions are significantly influenced by the cold-start conditions, however, fuel economy is also affected by the cold-start but not highly as the pollutant emissions [4].

Regarding the proposal of repeating the speed profile, that strategy was adopted frequently. For instance, the “motor vehicle expert group in 1995 (MVEG-95)” proposed a combined cycle by repeat the urban driving cycle (ECE) four times, This European urban test driving cycle involves three stop-and-go operations as well as the first one which is cold-start. Another assembled cycle namely (Japanese combined 10-15 mode) which consists of four repeated urban driving cycles in addition to an extra-urban portion was also managed to test vehicles [4]. Inevitably, the real-world driving cycles are often more power-demanding and more complicated than the standard ones in terms of speeds, accelerations, driving conditions, etc. [5, 6]. Thus, all automakers implement their own-crated standard speed profiles that better emulate the real driving conditions [4].

The published report [7] revealed that aggressive driving pattern strongly affects vehicle performance on the highway than on city activities. The associated analysis showed that aggressive driving on the highway could reduce powertrain efficiency by 28% for a powerful car, and 33% for the average car. Another study [8] implemented GPS driving data from the Southern California Association that gathered in 2003 to investigate PHEV performance. The analysis of that 621 samples-included data showed that the power and speed values associated with the GPS driving data are higher than those associated with the standard UDDS cycle. The analysis also demonstrated that 94% of vehicles consume higher energy under real-world driving cycles than under UDDS and HWFET cycles [8].

Conducting tests under real-world driving conditions results in improvements for fuel economy and emissions lower than those attained under the comparable standard cycles since many disturbing factors like traffic conditions, driving patterns, weather conditions, and terrains might adversely affect fuel economy and emissions. The performance of some propulsion systems is more sensitive to definite driving cycles than others [5]. It was proved that the fuel economy of the hybrid school bus was considerably influenced by the road traffic conditions, driving behavior of the driver, and the fulfilled services of maintenance [9].

The study [10] showed that rising in vehicles' weight average by 30% between (2000-2006) increased the combined fuel consumption by approximately 15%. The vehicle weight affected the fuel consumption of the ICEVs in a way that each additional 100 kg in vehicle weight (separately from system power) can increase the fuel consumption by 0.7 l/100 km. That increase proves that a significant technological improvement was realized in the field of the fuel converter industry. The study also revealed that the ICEVs weight is more sensitive than the system power in city conditions. However, under highway driving conditions, the ICEVs fuel consumption differences are mainly affected by the vehicle weight rather than the system peak power. The vehicle weight differences primarily attribute the fuel consumption differences for the ICEVs under both city and highway driving conditions [10].

The simulator models or subsystems are constructed with a combination of experimental data, engineering postulates, and hypotheses, in addition to algorithms that are based on physics. The Advanced Vehicle Simulator (ADVISOR) software which is a combination of script text files that processed using MATLAB-Simulink is considered in this study for the simulation process. The used simulator models are utilizing empirical data that represent the results of testing processes for each powertrain component. Although utilizing quasistatic control strategy-in ADVISOR-has a disadvantage of lower accuracy in comparison to the dynamic strategy, its main advantage is the significant quick analysis [11].

This study aims to investigate the influence of driver behavior on the fuel economy in the first place. This work aims also to demonstrate the characteristics of the studied road. Furthermore, what driving limitations are more economical and environmental to be employed while traveling on such a highway road? Therefore, the researcher managed to investigate the fuel economy achieved on the Basrah road by substituting the two constructed driving cycle with each other, viz., simulate the Chrysler model under the speed profile of the Charger model and verse versa.

2 Theory and calculation

2.1 Performance and drivability

Vehicles perform differently according to their prime movers' capabilities, techniques used in the drivelines, and the efficiencies of components. Three main indications are referred to when one compares the passenger cars performance and drivability [4]:

- Top speed.

- Acceleration time, which is the time that vehicle takes while accelerates from rest to a referenced speed such as 60 mph or 100 km/h for example [4]. This indicator is associated with the powertrain performance rather than the driving behavior since imposing such an inefficient ICE to accelerate rapidly could lessen fuel economy. Eco-driving can improve fuel economy through training drivers on how to drive more consistently, and hence mitigates the economic and environmental implications of aggressive driving conditions [6].

Maximum grade that the vehicle propulsion system can climb at the legal top limit of speed with fully loaded cargo.

The top speed indicates the maximum speed that has been reached at wheels and it mainly affects the aerodynamic part of the road load equation since the speed value is cubed as shown in the equation. To sense this affection, calculations illustrate that the demand of increasing the top speed by 25% impose the engine to double its produced power [4]. However, the quantifier of vehicle gradability is eliminated since the studied case is of driving on a flat road.

2.2 Models description

The performance of the IC engine is indicated by three main parameters; engine displacement (liter), maximum engine power (kW), and engine efficiency (%). The engine displacement is somewhat considered when estimating fuel consumption and CO_2 emission, but the thermodynamic efficiency of the engine is the most important parameter. The engine speed and torque are the most important variables that the thermodynamic efficiency of the IC engine is dependent on. Hence, the engine efficiency is instantly varying and can be inferred from the torque-rpm map for the engine performance as shown in Figure 1. The torque-rpm map is indicated as an output sketch for the mathematical model (Eq. 1). When the engine is operated at low torque, its efficiency drastically drops since the engine efficiency substantially depends on engine torque, while the engine speed reveals less affection. As a consequence of operating the IC engine at low torques or operating other fuel converters at low loads, the efficiency may drop to zero, hence, the fuel converter efficiency cannot be inferred from the torque-rpm map. Thermodynamic efficiency of the engine yields the equations [4];

$$\eta_e = \frac{P_e}{P_c} = \frac{\omega_e \,.\, T_e}{P_c} \tag{1}$$

$$P_c = \dot{m}_f \,.\, lhv \tag{2}$$

A conventional vehicle model has been configured (Figure 2) and conducted on the studied speed profile to calculate the overall energy consumed over the cycle, hence, the fuel consumed is obtained. The pollutant emissions such as HC, CO, and NOx are also predicted based on transient conditions while the engine undergoes the transient points introduced by the constructed driving cycle.

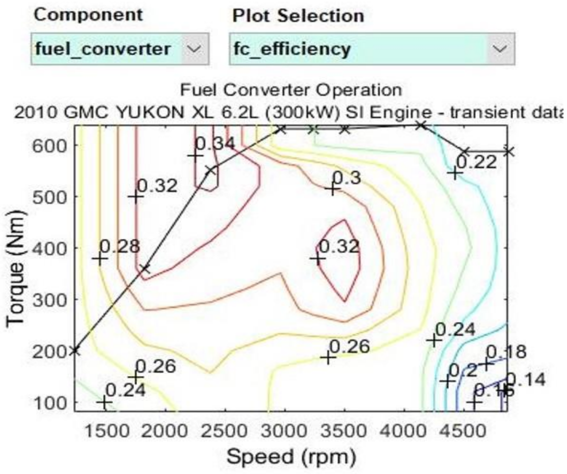

Fig 1. Torque-rpm map for ICE

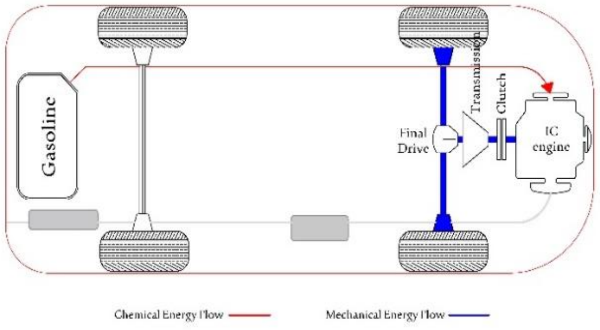

Fig 2. Conventional vehicle architecture

2.3 Road load equation

The power demand calculated is affected by factors such as; vehicle mass, vehicle speed, vehicle acceleration, frontal area, drag coefficient, rolling contact coefficient between the tires and road surface, and grade of the road (uphill, downhill, or flat) [1]. Accordingly, the load demand is analyzed and processed at the power management system to respond to the road load, the load demand is mathematically modeled by the road load equation. This equation (Eq. 3) is sufficiently employed in both the forward and backward-looking approaches to judging the powertrain performance [12].

$$p = \left(ma + \frac{1}{2}C_d\rho Av^2 + \mu mg\cos\theta + mg\sin\theta\right)v \quad (3)$$

Table 1 Nomenclature

Symbol	Description	Units	Value
t	The total time of the driving cycle	Second	
P_e	Mechanical power of ICE	kW	
P_e	Chemical power of ICE	kW	
η_e	Engine efficiency	%	
P	Total power demand	kW	
m	Calculated vehicle mass	kg	
a	Vehicle acceleration	m/s^2	
C_d	Coefficient of drag	-	
ρ	Air density	kg/m^3	1.2
A	Frontal area of a vehicle	m^2	
v	Vehicle speed	m/s	
μ	Coefficient of rolling resistance	-	0.012
g	Gravitational acceleration	m/s^2	9.81
θ	Slope angle of the road	%	
lhv	Lower heating value	MJ/kg	42.6
T_e	The torque of engine	N.m	
ω_e	The angular speed of engine	Rad/s	
$\dot{m}_{fuel}$	Fuel mass flow rate	Kg/s	
FC	Fuel consumption	l/100 km	

The adopted density of gasoline is 0.749 kg/l.

3. Materials and methods

The first step of this study is constructing a real-world driving cycle that emulates the speed profile of a specified route need to be analyzed and studied. This created speed profile is considered the backbone of the simulation process. The main three instruments utilized in this study are: first, two light-duty vehicles, second, OBD-II data logger, and third, computer with associated applications.

3.1 Instrumentation

The vehicles that recruited to gather the wanted parameters were the primary laboratory in this work, their specifications are listed in Table 2. The instrument “Davis Instruments 8226 CarChip Pro” is used to gather data [13]. Then, for downloading and processing the saved data, a PC with the compatible software is used. More than 23 engine and drivetrain parameters can be logged for tracking the performance of the overall propulsion system as well as the fuel economy, and emissions, etc. CarChip is programmed to record several parameters such as; engine speed, engine load, vehicle speed, coolant temperature, throttle position, fuel pressure, intake manifold pressure, and airflow rate, etc. Identifying of speed threshold, acceleration threshold, and deceleration threshold is also allowed [14]. The trips also can be viewed as tables or reports other than as plots, more features of CarChip usage is viewed in Figure 3.

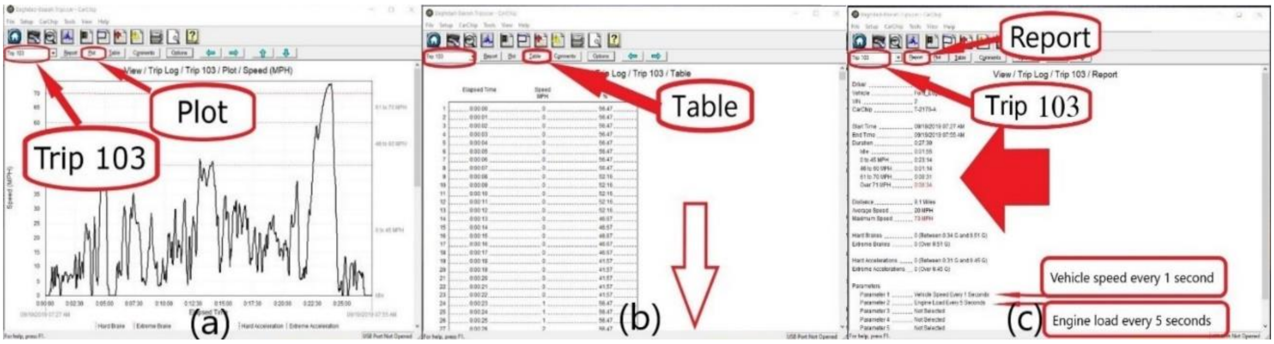

Fig 3. The CarChip "Davis Instruments 8226 CarChip Pro" software (a) plot view, (b) table view, (c) report view

3.2.1 Data gathering

The "Davis Instruments 8226 CarChip Pro" data logger which is used to gather data was implemented before in the published manuscripts [1, 15] and a similar data logger was used by [6, 16]. Two sedan vehicles were recruited to gather the wanted data on the studied road "Baghdad-Basrah highway road" in a daily repeated scenario to transport passengers, the road is marked on map Figure 4. The vehicles are "Chrysler 300 2012" and "Dodge Charger 2013" with the specifications listed in Table 2. The CarChip is plugged-in to the OBD-II (On-Board Diagnostic port) and it was set to record the vehicle speed every second that represents the key parameter for the driving cycle.

The step next to the full recording for the complete two-way trip is detaching CarChip from the OBD-II of the vehicle then connecting it to the PC for displaying and downloading the saved data using compatible software. The reports include the start time and date of the trip, duration of the trip, distance traveled, max speed reached, time spent in the preset top speed band in addition to other parameters. There is also data for the hard brakes and accelerations as well as some other features showing the troubles and the accidents that occurred during the driving of the vehicle.

Fig 4. The sketch of the route (Google Maps)

Table 2 Specifications of the recruited vehicles

Parameters	Unit	Metrics
Vehicle body style	-	Large car
IC engine max power	kW	218 @ 6350
IC engine max Torque	N.m	352 @ 4800
Engine displacement and configuration	Liter	3.6 -V6
IC engine max efficiency	%	34
Transmission	-	Auto
Drive type	-	RWD
Frontal area	m^2	2.1
Coefficient of drag	-	0.3
Calculated mass	kg	2096

3.2.2 Selecting of driving cycle

The drivers of both vehicles were asked to let the CarChip connected while driving from Baghdad to Basrah for three sequent two-way trips. Every recorded trip consists of many sub durations. The researcher managed to consider one of them to be processed rather than accumulating all the recorded trips. The considerations that are depended to select the eligible trip are; the most realistic one as well as that of the highest speed reached. This strategy was on the one hand used to select the most accurate real-world speed profile that can be considered as representative for the Baghdad-Basrah road. On the other hand, to avoid immensity and loading of the huge dataset [4]. The Excel software is a vital tool-owing to arithmetic functions and other features-to be used to conduct recorded data for evaluating the statistical metrics and creating the typical real-world driving cycle. The statistics of the created driving cycles are listed in Table 4. The speed profile crated by the Chrysler300 is entitled as “BGD-BSRH2” and that created by the Dodge Charger is entitled “BGD-BSRH1”, both of them are sketched in Figure 7. The trusted trips have been selected and assembled, the typical real-world driving cycles are constructed then inserted into the ADVISOR database and ready to be simulated for obtaining result predictions.

3.2.3 Simulation procedure

Other than the driving cycle, many more inputs can be also inserted into the open-source simulation program like; the engine size and efficiency, the overall mass of the vehicle, drivetrain configuration, powertrain control, the body style of vehicle, several standard global driving cycles, and other accessory options. The quasistatic model utilized to analyze performance, and hence fuel economy in ADVISOR is block-diagrammed in Figure 5.

The strategy of back-to-back or extended period was followed in this work to create repeated standard driving cycles (e. g. New York City Cycle (NYCC), Urban Dynamometer Driving Schedule (UDDS), Highway Fuel Economy Test (HWFET), and (US06)). This approach is used to achieve the lowest variance when contrasting the duration of the real-world and standard driving cycles, thereby, the results are more acceptable since the higher the duration is simulated, the better is the correspondence of results [4, 17]. The simulation results of the repeated drive cycles are deemed as references for the constructed real-world drive cycle studied in every single case. The drawback of the quasistatic method is the shortcoming of a hundred percent precise predictions because this approach assumes that vehicle speed and acceleration are constant over each single time interval. Inevitably, the propulsion system behavior cannot be 100% accurately described by a mathematical model [4]. For that, this procedure may not match (miss trace) some segments of the cycle duration in which the input variables are not constant, hence, a considerable discrepancy is documented for those short time intervals as revealed in Figure 6. Nevertheless, the total fuel consumption predictions are still highly accepted.

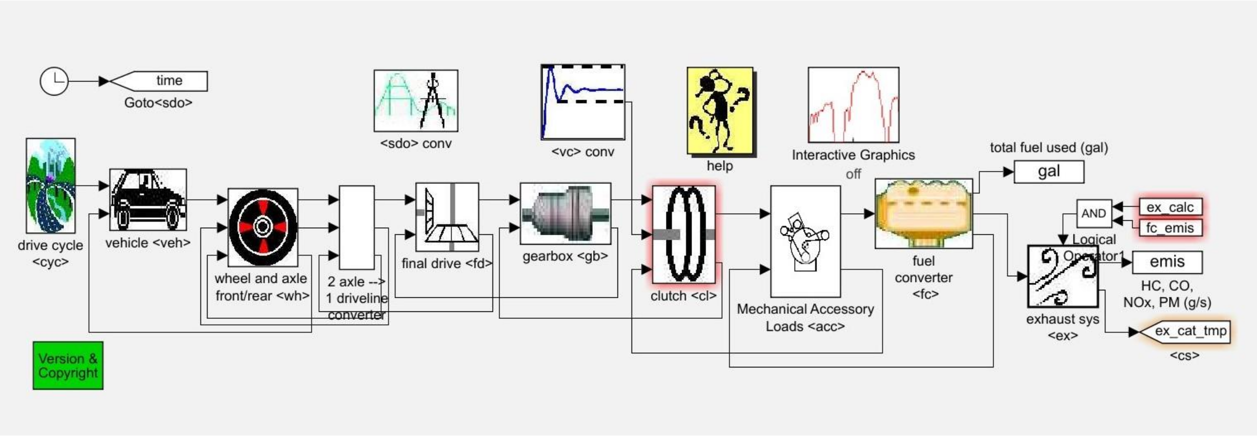

Fig 5. Block-diagram of the conventional powertrain.

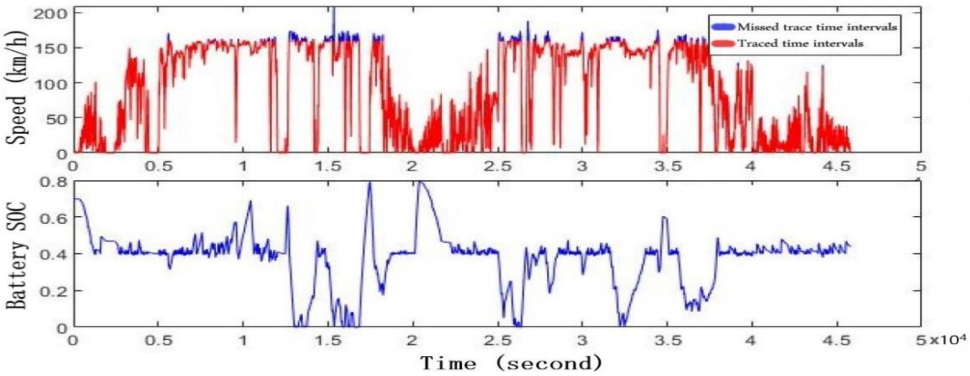

Fig 6. Simulation output of the driving cycle

3.3 Fuel consumption validation

Even though the ADVISOR software was recently validated-in terms of fuel consumption-by [15] at a precision of about 99%, the validation process has been done accurately. The precision of the simulation process for the vehicles was approximately 98% and 97% for Chrysler300 and Dodge Charger respectively; in which the traditional approach that has been explained in detail [18] was used to investigate the fuel consumption manually. This approach is dependable as the most de facto approach for investigating fuel consumption [19]. The recorded gasoline refueled by the drivers and the traveled distances are listed in Table3. The precision of ADVISOR predictions-regarding fuel consumption-is determined for the recruited vehicles using Equation 4

$$\text{precision} = \left(\frac{\text{FC from the simulation process}}{\text{actual value of FC}}\right) \qquad (4)$$

Table 3 Comparison of actual and predicted fuel consumption

Vehicle	Unit	Chrysler -300	Dodge Charger
No. of passengers	person	4	4
A/C status	-	ON	OFF*
Avg. distance traveled	Km	1106	1167
Avg. fuel consumed	Liter	138	148
Actual consumption	l/100 km	12.48	12.68
ADVISOR fuel consumption	l/100 km	12.3	12.3
Induced simulation precision	%	98.55	97.00

The AC was OFF during the real test, whereas in the simulation process it is actuated, so, fuel consumption prediction is hence increased.

$$\text{ADVISOR P.P for Crysler} = \frac{12.3\ \text{lit/100 Km}}{12.48\ \text{lit/100 Km}} = 98.6\ \%$$

$$\text{ADVISOR P.P. for Charger} = \frac{12.3\ \text{lit/100 Km}}{12.68\ \text{lit/100 Km}} = 97\%$$

Thus, simulation of the vehicles is validated considerably

4 Results and Discussion

4.1 Real-world driving data analyzing

Although both the vehicles were driven on the same road, the driving data shows that the driving behaviors are variant clearly. The Chrysler driver's behavior is more consistent than that of the Charger driver as shown in Figure 7 since the Charger speed profile involves more aggressive responses due to the hard to extra-hard accelerator pedal press. On the other hand, higher vehicle speed (209 km/h) is reached by Charger, however, moderate speed of 164 km/h is attained by Chrysler. Consequently, higher driving speed involves higher fuel consumption, and hence harder brake is required when coasting the vehicle. Analyzing the two real-world driving data shows that the recurrent maximum acceleration (7.15 m/s^2) and maximum deceleration (-9.39 m/s^2) of the Charger speed profile are quite higher than those of the Chrysler speed profile (3.58 m/s^2) and (-4.92 m/s^2), Table 4.

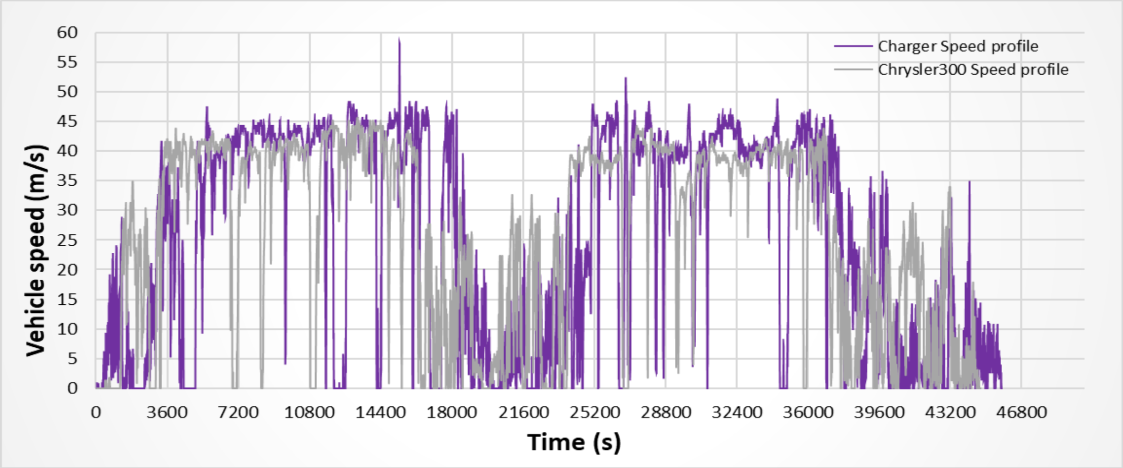

Fig 7. The constructed real-world driving cycles

Table 4 Characteristic parameters of Baghdad-Basrah driving cycles

Item	**Unit**	**Statistics**	
		Chrysler	**Charger**
Duration of the trip	seconds	44770	45836
Distance of the trip	km	1168.24	1133.92
Maximum speed	m/s km/h	45.6 164	58.12 209
Average speed	m/s km/h	26.1 93.94	24.74 89.06
Maximum acceleration	m/s^2	3.58	7.15
Maximum deceleration	m/s^2	-4.92	-9.39
Average acceleration	m/s^2	0.57	0.69
Average deceleration	m/s^2	-0.75	-0.77
Idle time	seconds	5056	6024
Acceleration time	seconds	7808	9467
Deceleration time	seconds	5958	8384
No. of stops	-	128	196
Traction time	Seconds	33885	31625
Traction ratio	%	76	69

Regarding the acceleration mode time, Figure 8 reveals that the acceleration time composes approximately 38% of the total trip duration in the case of Charger, whereas only about 17% is involved in the case of Chrysler. The deceleration time during the Charger' trip (18%) is also higher than that during the Chrysler' trip (13%). The number of stops counter refers that the Charger stops are more than the stops of Chrysler by 68 stops, and hence the Charger IC engine is more stop-and-go undergoing. All these extra values are associated with IC engine transient operations that in turn lessen fuel economy.

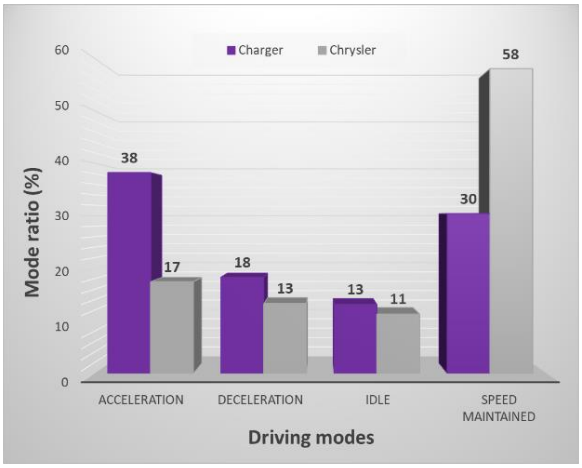

Fig 8. Driving modes ratios

4.2 Performance analyses

A comparison of the two real-world driving cycles results with the simulation results of the standard driving cycles in Figure 9 illustrates a kind of corresponding for the BGD-BSRH1 and BGD-BSRH2 cycles to the repeated US06 cycle. The comparable aggressiveness of the two cycles (BGD-BSRH1 and US06) mentioned before results in somewhat correspondent fuel consumption predictions. The simulation results for the Charger fuel consumption are 14.1 l/100 km and 12.9 l/100 km under the BGD-BSRH1 and repUS06 cycles respectively, under the same cycles, the Chrysler fuel consumption predictions are identical.

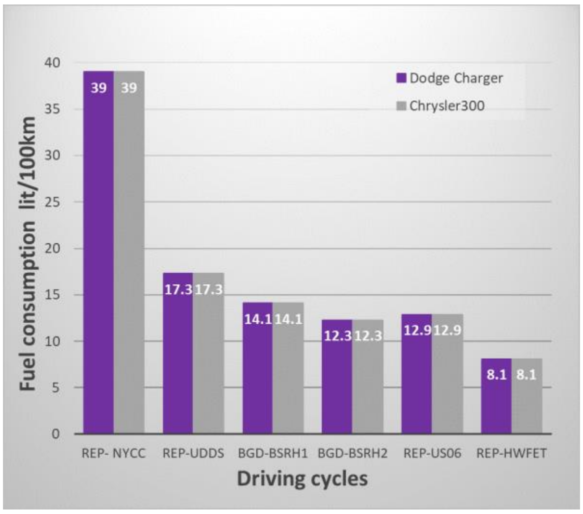

Fig 9. Fuel consumption comparison

The average efficiency of both the vehicles' ICEs is the same (23%), however, the overall system efficiency of the Chrysler is higher than that of the Charger. The simulation results analyses stated that the Chrysler performed higher overall system efficiency than that of the Charger, those improved efficiencies in the case of Chrysler could be attributed in the first place to the gear shifting that done over a sufficient time unlike for the case of Charger.

4.3 Fuel consumption and emissions

Table 5 illustrates the simulation results of the studied two models "Chrysler300 2012" and "Dodge charger 2013" when conducted on both real-world driving cycles "BGD-BSRH1" and "BGD-BSRH2". The results of conducting models on the repeated standard NYCC, UDDS, US06, and HWFET cycles are also implemented as in Figure 9. The predictions show that the reported fuel economy for the Dodge charger on the speed profile created by itself was 14.1 lit/100 km, whilst on the comparable speed profile created by Chrysler, the fuel economy was documented as in Figure 9 at 12.3 lit/100 km.

Thus, there is a 12.8% reduction owing to such a proposed substitution Figure 10. Contrarily, simulation of the modeled Chrysler on the other speed profile created by Dodge Charger reported a 14.1 lit/100 km fuel economy instead of 12.3 lit/100 km deduced by conducting on self-created speed profile. As a consequence of that switch for the simulated driving cycle, an increase in fuel consumption of 14.6% is involved, Figure 10.

Table 5 Simulation predictions

Parameters	**Unit**	**Chrysler 300**	**Dodge Charger**
Final drive ratio	-	9 : 1	9 : 1
Fuel consumption	l/100 km	12.3	14.1
Acceleration time (0-96.6 km/h)	second	7.5	7.5
Acceleration time (64.4-96.6 km/h)	second	3.2	3.2
Acceleration time (0-137 km/h)	second	16	16
Max acceleration across the driveline	m/s^2	4.3	4.3
Max speed across the driveline	km/h	215.8	215.8
HC emissions	grams/km	0.234	0.252
CO emissions	grams/km	0.765	0.854
NO_x emissions	grams/km	0.585	0.694
Total energy usage during the trips from tank-to-wheel (power mode only)			
Energy to ICE	MJ	4578.51	5103.02
Energy-penalty of weight	MJ/kg	2.18	2.43
ICE productivity	MJ/liter	1272	1417
Avg. ICE Eff.	%	23	23
To torque converter	MJ	1022.32	1131.35
Avg. Torque converter Eff.	%	99	98
To wheel/Axle	MJ	913	1010.03
Auxiliary load	MJ	31.34	32.08
Loss Vs. aero load	MJ	597.73	653.87
Loss Vs. rolling load	MJ	216.24	209.95
Overall system Eff.	%	17.8	16.9

Regardless of the deviation between the actual fuel consumption for both the vehicles which is attributed to the different driving conditions and a different driver. The variant fuel economy for each vehicle on the two real-world driving cycles created on Baghdad-Basrah road is mainly influenced by the driving behavior since the "BGDBASRAH2" speed profile (created by Chrysler) is more consistent and less transient points than that created by Dodge Charger as in Figure 7.

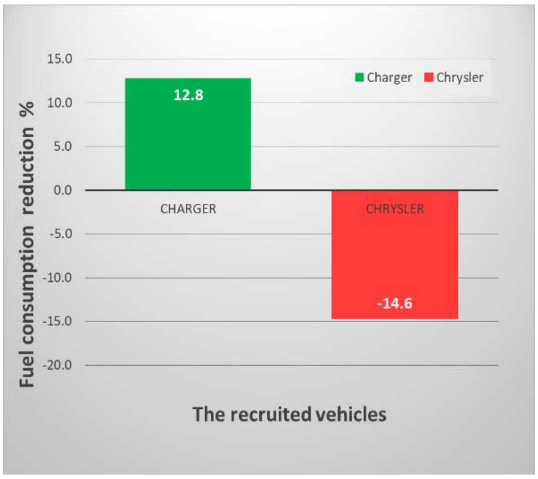

Fig 10. Fuel consumption change due to driving cycle substitution

The pollutant emissions are basically attributed to the transient conditions of the gasoline engine and other issues such as incomplete combustion. For that, and due to the aggressiveness of the Charger driver, the emissions released by that vehicle are higher than those released by the latter one in particular for CO and NOx as shown in Figure 11.

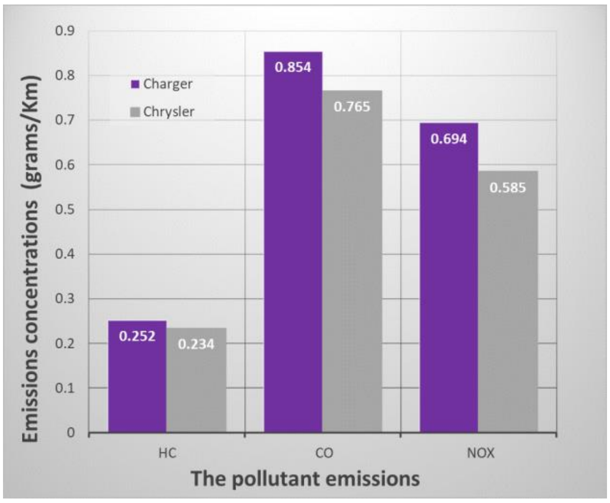

Fig 11. Emissions comparison

It's by substituting the simulated driving cycles and as consequences of the Charger driver's misbehavior, the pollutant emissions released by the Chrysler under the swapped speed profile are increased by 8%, 12%, and 19% for the HC, CO, and NOx respectively. In contrast, the Charger model achieves; HC emission reduction of 7%, CO emission reduction of 10%, and NOx reduction of 16% when it is conducted under the speed profile created by the comparable vehicle Figure 12.

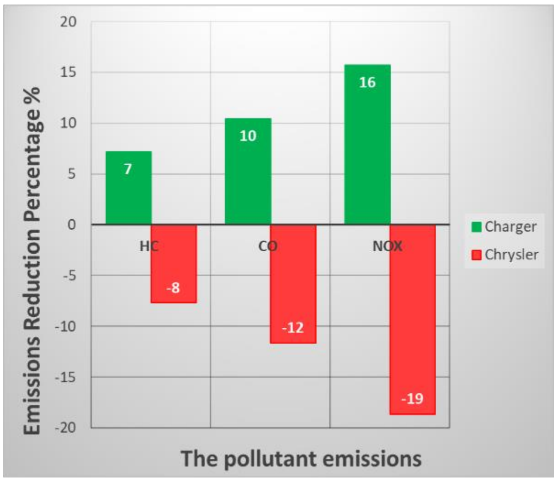

Fig 12. Emissions change due to driving cycle substitution

4.4 Energy consumption

Figure 13 states how much energy consumed during both trips of the two vehicles over each powertrain component. The Charger is more energy consuming because it accelerates more than the Chrysler while traveling. The higher energy consumed is attributed to the highest affection of acceleration term among the other terms in the road load equation.

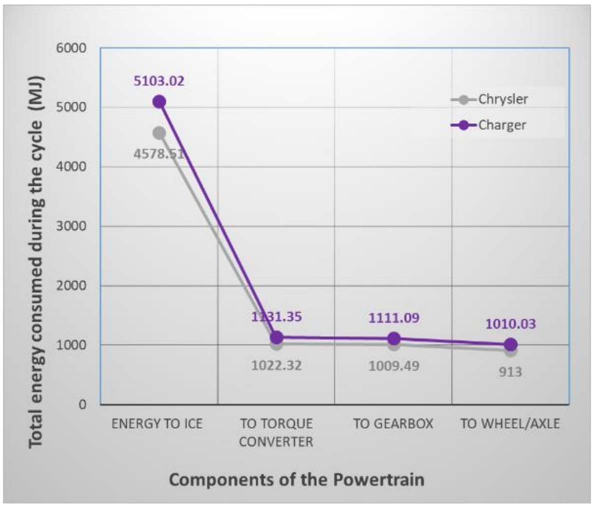

Fig 13. Energy consumed over the powertrains of vehicles

A comparison between Figure 14 and Figure 15 states that the two vehicles consume almost the same proportions of energy against aerodynamic and auxiliary loads, whereas no significant difference is involved in the rolling resistance. However, the proportional energy consumed by the Charger due to acceleration, slip, and other losses is higher than that consumed by the Chrysler. For that, the penalty of consumed energy per unit weight for the Chrysler is less as mentioned in Table 4.

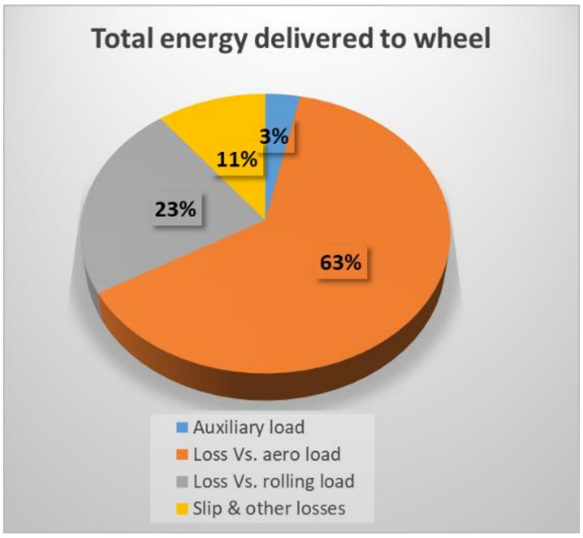

Fig 14. Energy consumed at wheel (Chrysler).

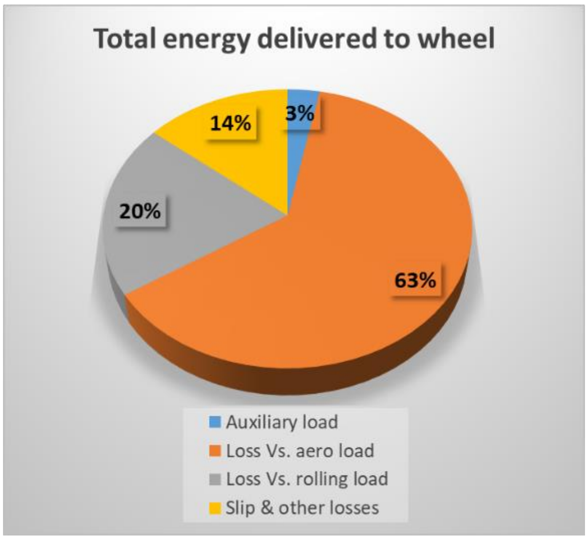

Fig 15. Energy consumed at wheel (Charger)

Figure 16 and Figure 17 show the most operating points of both the vehicles IC engines on the torque-rpm map. The engine performance points for the Charger are widely spread throughout the different areas of efficiency wider than that of Chrysler, viz., the Charger engine is more transient operation points. Hence, more energy loss is involved and more fuel is consumed due to the frequent-hardly accelerator and brake pedals pressing.

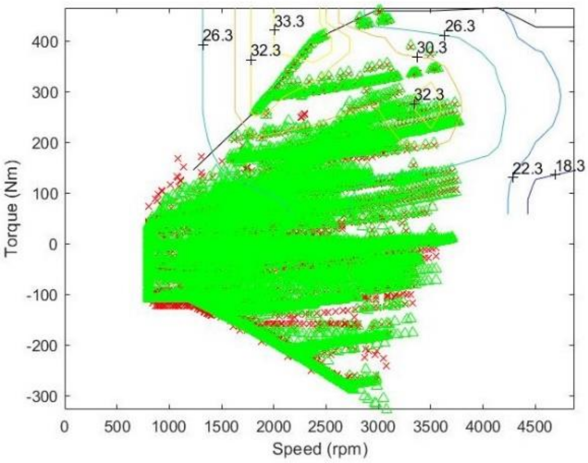

Fig 16. ICE operation points of Chrysler

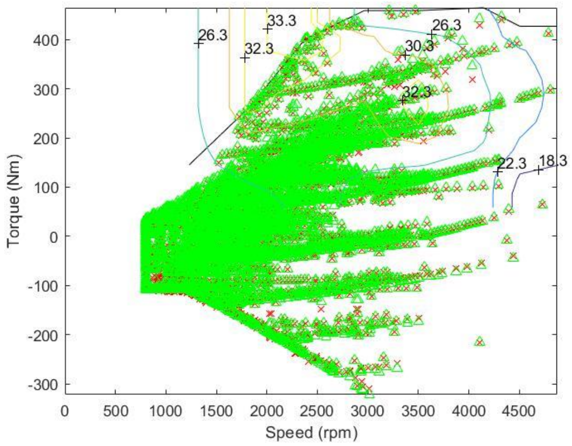

Fig 17. ICE operation points of Charger

5 Conclusion

The route of Baghdad-Basrah is extremely highway; it is apparently shown through its statistics with some exception of the existence of the checkpoints, the maximum and average speed showed the nature of the express route. Whereas the vehicle specifications and body style are similar, the passenger capacity is identical as well. Nevertheless, the induced logged speed profiles are different in which the speed profile of Chrysler is somehow more consistent and stabilized than that of the Charger. That is attributed to the hard acceleration and deceleration implemented in the conducted speed profile of the Charger. The driver's misbehavior is a critical factor for this variance. Such kind of fuel-consuming vehicle (large car body style, and 6-cylinder ICE) is spendy to be recruit on the low-medium speed cycles “NYCC” and “UDDS”. Driving behavior like that of the Chrysler driver is economic and environment-friendly in comparison to that of the Charger driver, and subsequently better fuel economy due to more regular gear-shifting. For that, using the Dodge Charger for traveling from/to Baghdad to/from Basrah is a more economical choice than the heavy-duty and all-wheel-drive vehicles but with a driving style like that of the Chrysler’ driver. Better driving modes and fuel consumption implications might be achieved at a speed range of 120-170 km/h.

References

[1] A. Al-Samari, "Study of emissions and fuel economy for parallel hybrid versus conventional vehicles on real-world and standard driving cycles," *Alexandria Engineering Journal*, vol. 56, no. 4, pp. 721-726, 2017/12/01/ 2017.

[2] Abd Al-Razaq and F. Fuad, "Study and Analysis Emissions Specifications for Iraqi Automobiles," Journal of University of Babylon for Engineering Sciences, vol. 26, no. 8, pp. 309-322, 2018.

[3] Dijla TV, "Interview with Ex-minister of Transport in Iraq ", ed. https://www.youtube.com/watch?v=d_bWCyhxtUo&list=WL&index=29&t=1097s, 2020.

[4] L. Guzzella and A. Sciarretta, *Vehicle propulsion systems*. Springer, 2005.

[5] O. Karabasoglu and J. Michalek, "Influence of driving patterns on life cycle cost and emissions of hybrid and plug-in electric vehicle powertrains," *Energy policy*, vol. 60, pp. 445-461, 2013.

[6] S. A. H. Zahabi, L. Miranda-Moreno, P. Barla, and B. Vincent, "Fuel economy of hybrid-electric versus conventional gasoline vehicles in real-world conditions: A case study of cold cities in Quebec, Canada," *Transportation Research Part D: Transport and Environment*, vol. 32, pp. 184-192, 2014/10/01/ 2014.

[7] U. S. D. o. E. Energy Efficiency and Renewable Energy. (2001). *Energy and Environmental Analysis, Owner related fuel economy improvements*. Available: https://www.fueleconomy.gov/feg/pdfs/OwnerRelatedFuelEconomyImprovements.pdf

[8] E. D. Tate, M. O. Harpster, and P. J. Savagian, "The electrification of the automobile: from conventional hybrid, to plug-in hybrids, to extended-range electric vehicles," *SAE international journal of passenger cars-electronic electrical systems*, vol. 1, no. 2008-01-0458, pp. 156-166, 2008.

[9] S. Hallmark, B. Sperry, and A. Mudgal, "In-use fuel economy of hybrid-electric school buses in Iowa," *Journal of the Air Waste Management Association*, vol. 61, no. 5, pp. 504-510, 2011.

[10] C. Reynolds and M. Kandlikar, "How hybrid-electric vehicles are different from conventional vehicles: the effect of weight and power on fuel consumption," *Environmental Research Letters*, vol. 2, no. 1, p. 014003, 2007.

[11] V. Dawood and A. Emadi, "Performance and fuel economy comparative analysis of conventional, hybrid, and fuel cell heavy-duty transit buses," in *2003 IEEE 58th Vehicular Technology Conference. VTC 2003-Fall (IEEE Cat. No. 03CH37484)*, 2003, vol. 5, pp. 3310-3315: IEEE.

[12] N. Kim, A. Rousseau, and H. Lohse-Busch, "Advanced Automatic Transmission Model Validation Using Dynamometer Test Data," 2014. Available: https://doi.org/10.4271/2014-01-1778

[13] D. Instruments. (2019). *Davis Instruments 8226 CarChip Pro Driving/Engine Performance Monitor*. Available: http://www.davis.com/Product/Davis_Instruments_8226_CarChip_Pro_Driving_Engine_Performance_Monitor/DO-68511-69

[14] A. Al-Samari, "Real-world driving cycle: Case study of Baqubah, Iraq," *Diyala Journal of Engineering Sciences* vol. 10, no. 2, pp. 39-47, 2017.

[15] L. M. Mubarak, A. Al-Samari, D. A. Alazawi, and M. Fadel, "Comparison study of fuel consumption and emissions of HEVs and conventional vehicle in Iraq using real-world cycle," *Journal of Mechanical Engineering Research and Developments*, vol. 43, no. 5, pp. 185-203, 2020.

[16] F. Orecchini *et al.*, "Energy consumption of a last generation full hybrid vehicle compared with a conventional vehicle in real drive conditions," *Energy Procedia*, vol. 148, pp. 289-296, 2018.

[17] K. J. Kelly and A. Rajagopalan, *Benchmarking of OEM hybrid electric vehicles at NREL*. Citeseer, 2001.

[18] wikiHow. (2019). *How to Calculate Fuel Consumption*. Available: https://www.wikihow.com/Calculate-Fuel-Consumption

[19] Y. Huang, E. C. Ng, J. L. Zhou, N. C. Surawski, E. F. Chan, and G. Hong, "Eco-driving technology for sustainable road transport: A review," *Renewable Sustainable Energy Reviews*, vol. 93, pp. 596-609, 2018.