International Journal of Energy Production and Management
Vol. 8, No. 1, March, 2023, pp. 21-25
Journal homepage: http://iieta.org/journals/ijepm

Kinta District Driving Cycle Analysis by Using DC-TRAD Conceptual Model

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https://doi.org/10.18280/ijepm.080103

Received: N/A
Accepted: N/A

Keywords:
DC-TRAD, driving cycles, emissions, fuel economy, hybrid electric vehicles, IoT, Simulink

ABSTRACT

An accurate technique of driving cycle development is important. Such a technique should be dominantly based on real-world driving behavior to ensure it represents the profile of the selected route. A driving cycle often is the combination of analyses of huge numbers of micro-trips under different conditions of traffic. This research is an initiative to improve the accuracy of the method of data collection; this contributes directly to one of the major procedures of driving cycle development, namely data collection. A driving cycle tracking device (DC-TRAD) is a device developed to improve the data collection strategy with integration of Internet-of-Things to manage the huge amount of data collected. A conceptual design of DC-TRAD is developed, and the flexibility of the device is made use in this research to compare and analyze the driving cycle of Kinta district.

1. INTRODUCTION

A driving cycle is a relation profile of speed versus time of a vehicle on a specified route. Driving cycles are often used by environmentalist and traffic engineers to estimate and conduct studies on vehicle emission and fuel consumption. However, the biggest challenge in developing an accurate driving cycle is to manage the huge amount of data required for the development and feature extraction. Past research on a driving cycle tracking device (DC-TRAD) had proven an increase of the accuracy of data capturing by 80%; in that work, the device is able to capture cruises where the speed of the vehicle is nonzero when the acceleration is zero [1]. Such a device was also developed with Internet-of-Things (IoT) implementation, which is in line with Industrial Revolution 4.0 (IR 4.0). In this case, DC-TRAD captures and records the data collected in the MySQL database, which was constructed using Personal Home Page codes [2].

Malaysia is at its initial stage of developing a driving cycle, which matches the real-world road conditions of Malaysia [3]. To construct an accurate driving cycle, three major modes of driving must be taken into count; these are low, idle, and medium speed. There are a few measured driving cycles that are used worldwide namely, the worldwide harmonized light vehicle test cycle (WLTC), the new European drive cycle (NEDC), and the federal test procedure (FTP). However, the criticality of development and manufacturing is solely depending on the quality of data and information obtained. In automotive industries, it has always been a challenge to manage the production cost, which is shooting high and contributed by other factors such as parts failures, inaccurate data, low efficiencies, and system corruption [4].

This research is an initiative to implement the usage of DC-TRAD in driving cycle development strategies. The focus is on improving the accuracy of the development [5]. This research also focuses on conceptually designing a DC-TRAD in MATLAB/Simulink, which is widely utilized by industries, mainly the automotive sectors [6-8]. This software is widely used in industry due to its flexibility and automotive supporting blocks and toolboxes, which are easily integrated to form a complex simulation system. The model of DC-TRAD was developed in this environment to simulate and output features extracted by a click through which it calculates 10 main parameters that are important for a driving cycle development and analysis. The prototype and conceptual model of DC-TRAD was successfully implemented on Kuala Terengganu driving cycle, and this research is focusing on the Kinta district driving cycle to strengthen the validity of DC-TRAD and, at the same time, analyze the features on Kinta district.

2. METHODOLOGY

Three methods adopted in this research are discussed.

2.1 Route selection and data collection

The routes for this research were selected based on traffic report from Road Traffic Volume Malaysia (RVTM) 2019 [9]. Based on this report, there are 10 routes shortlisted as the busiest routes in Kinta district due to population compactness as per Figure 1.

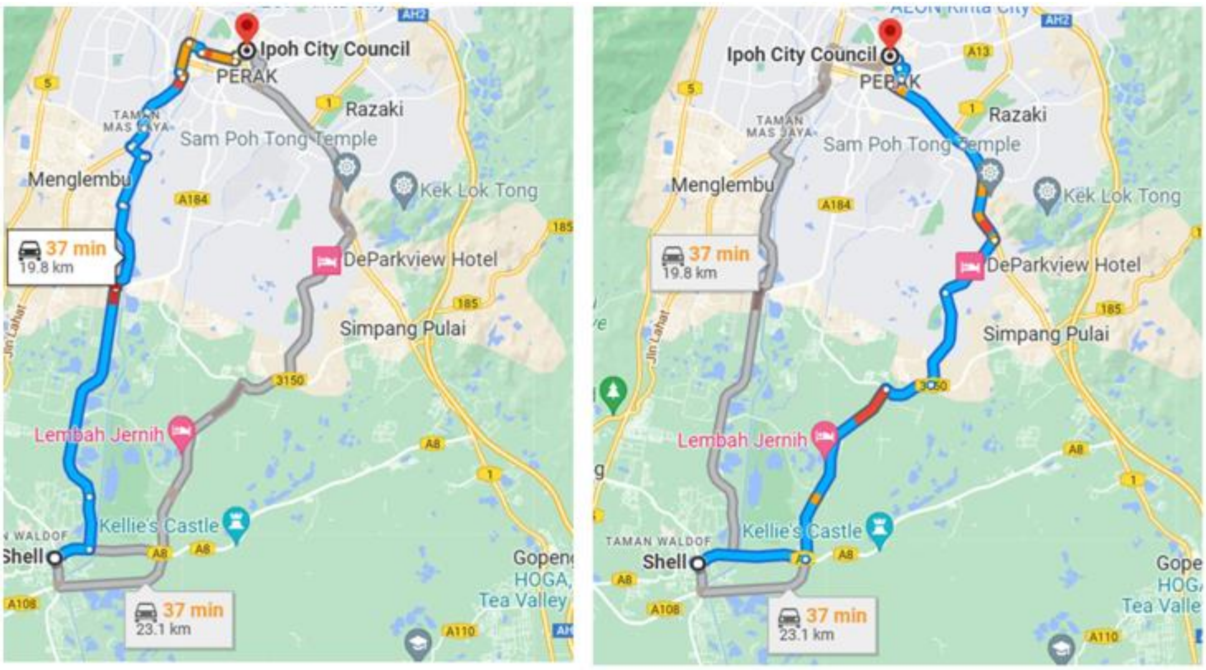
Firstly, the 10 routes were classified according to the vehicle composition, 16-hour traffic volume, peak hour traffic volume, peak hour time, and level of service [10]. Among the 10 routes listed in RVTM, AR311 is dominating the others; in this route, the car percentage is at the highest at 68.7% at 17:00-18:00 hours. AR311 also records the highest percentage of vehicle growth at 9.03% per year. Figure 2 shows the growth percentage of vehicles in Kinta district.

Census Station Number	Survey Type	Route Number	Description of Location	GPS Coordinate (WGS84) (Latitude,Longitude)		Type of Carriageway
AR303	0	1	Ipoh – Gopeng	4.5619270	101.1123780	K2-2
AR304	0	1	Ipoh – Kuala Kangsar	4.6565660	101.1088160	K2-2
AR305	2	1	Ipoh – Kuala Kangsar	4.7565397	101.1160351	K2-2
AR306	0	A13	Ipoh – Tanjong Rambutan	4.6323436	101.1540097	K2-2
AR307	0	A1	Ipoh – Jelapang	4.6274420	101.0606160	K3-3
AR308	2	5	Ipoh – Lumut	4.5168330	101.0270620	T1-1
AR309	3	73	Ipoh – Siputeh	4.4643500	100.9880300	T1-1
AR310	2	5	Ipoh – Lumut	4.4331400	100.9984800	K2-2
AR311	2	A8	Ipoh – Batu Gajah	4.5012750	101.1414950	K2-2
AR312	2	A15	Batu Gajah – Tanjong Tualang	4.4525210	101.0407790	T1-1

Figure 1. Routes listed in RVTM 2019 (Source: RVTM, 2019)

Station Number	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Normal Growth (%/yr)	R^2
AR303	84135	73487	85819	77195	78210	78316	77483	87006	87711	53711	-1.65	0.09
AR304	80595	70470	82923	73024	64750	76894	81402	73829	74715	51083	-2.29	0.21
AR305	26251	29168	39267	29117	25116	25904	22594	22113	22476	23622	-3.86	0.38
AR306	41786	23758	38194	48879	41249	42366	41382	34601	34427	24116	-4.02	0.36
AR307	34204	38115	51996	49227	60125	62591	47598	37986	40508	33817	-1.61	0.03
AR308	24336	46163	27970	28020	25443	29775	29482	28334	29351	20584	0.49	0.01
AR309	6207	22253	6303	6209	5734	5303	4851	6489	6346	6524	-0.72	0.04
AR310	15378	19306	15522	14681	19823	18624	21533	20474	20916	21496	3.66	0.59
AR311	8087	7280	8636	10312	8614	10475	13546	13119	21039	14522	9.03	0.69
AR312	11750	8286	13356	13361	12964	11647	12463	18572	19099	15040	4.14	0.48

Figure 2. Vehicle growth in Kinta district (Source: RVTM, 2019)



(a) (b)

Figure 3. Road map from Shell Batu Gajah to MBI with the two different routes drafted highlighted in (a) and (b). (Source: Google Maps, 2022)

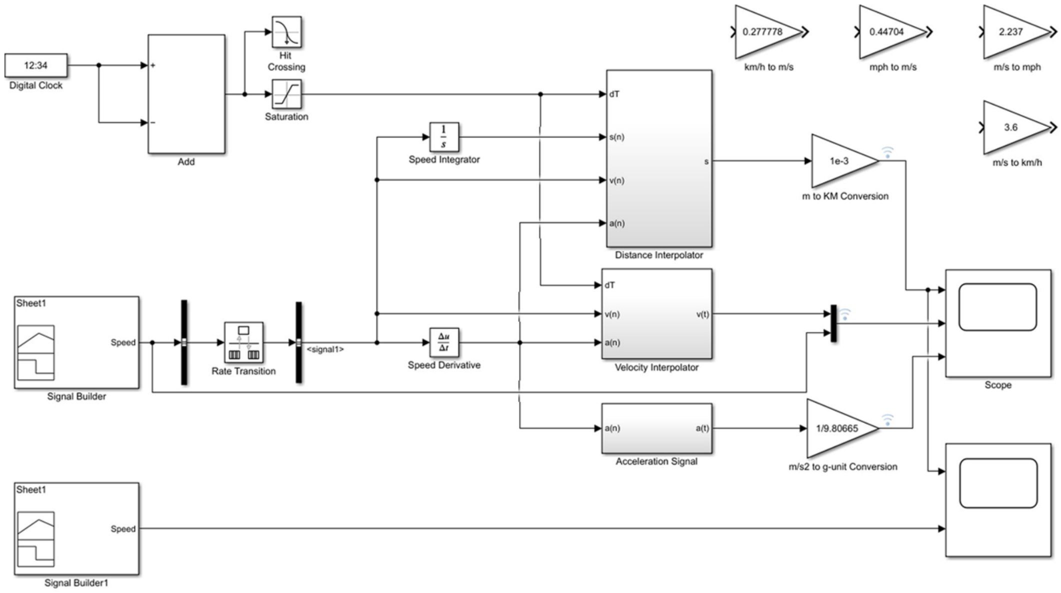


Figure 4. DC-TRAD conceptual model (Source: Arun et al. [1])

On AR311, a starting and ending point was selected to facilitate the data collection process. By using DC-TRAD, the speed and time data were collected from Shell Batu Gajah to Majlis Bandaraya Ipoh (MBI). Each of these start and end points was selected due to its strategic location in the middle of the town with several nearby landed houses and governmental offices and buildings. This is to ensure the real-world traffic condition rule is satisfied as the traffic at these points are at peak at the selected time. Two different routes were drafted, which are mainly used by citizens back and forth on daily basis. Figure 3 shows the selected routes' map.

Data were taken for 10 times on each route at 5:00 pm on weekdays. The captured speed time data were then stored in a MySQL database for further extraction and simulation.

2.2 Driving cycle simulation

The collected data are then simulated in DC-TRAD conceptual model. The results obtained from the simulation are then analyzed and compared with the real-world based, developed driving cycle of Kinta district. Figure 4 shows the developed DC-TRAD conceptual model in MATLAB/Simulink.

Table 1. Assessment of parameters for validation

No	Variable	Unit	Formula
1	Average speed, V_1	m/s	$V_1 = 3.6\frac{\text{dist}}{T_{\text{total}}}$
2	Average running speed, V_2	m/s	$V_2 = 3.6\frac{\text{dist}}{T_{\text{drive}}}$
3	Average acceleration, a	m/s^2	$a = \left(\sum_{i=1}^{n}\begin{cases}1(a_i > 0)\\ 0(\text{ else })\end{cases}\right)^{-1}\sum_{i=1}^{n}\begin{cases}a_i(a_i > 0)\\ 0(\text{ else })\end{cases}$
4	Average deceleration, d	m/s^2	$d = \left(\sum_{i=1}^{n}\begin{cases}1(a_i < 0)\\ 0(\text{ else })\end{cases}\right)^{-1}\sum_{i=1}^{n}\begin{cases}a_i(a_i < 0)\\ 0(\text{ else })\end{cases}$
5	Acceleration P_a, v(t) ≥ 0.83 m/s, a(t) ≥ 0.1 m/s^2	%	$\%\text{acc} = \frac{T_{\text{acc}}}{T_{\text{total}}} \times 100$
6	Deceleration Pd, v(t) ≥ 0.83 m/s, a(t) <–0.1 m/s^2	%	$\%\text{dec} = \frac{T_{\text{acc}}}{T_{\text{total}}} \times 100$
7	Total distance travelled	km	-
8	Total time taken	s	-
9	Root mean square (RMS)	m/s^2	$\text{RMS} = \sqrt{\left[\frac{1}{T}\right]\int_0^T (a)^2\, dt}$
10	Cruising P_c, v(t) ≥ 0.83 m/s, −0.1 ≤ a(t) < 0.1 m/s^2	%	$\%cruise = \frac{T_{\text{cruise}}}{T_{\text{total}}} \times 100$
11	Idling P_i, v(t) = 0 m/s	%	$\%\text{idle} = \frac{T_{\text{idle}}}{T_{\text{total}}} \times 100$

n=number of data, T=time

The DC-TRAD model was verified with two measured driving cycles; these are Kuala Terengganu BasKITE and HWFET. The verification gives an error below 5% [11]. This justifies the accuracy of the constructed model and its suitability to be used in other research to simulate driving cycles. In addition to that, 11 parameters were chosen for justification as that implies the exact feature extraction for driving cycle development.

2.3 Driving cycle analysis

As mentioned previously, 11 parameters were chosen to be compared and analyzed; these are the distance, time taken, average speed, average running speed, average acceleration, average deceleration, root mean square (RMS) of acceleration, percentage idle, acceleration percentage, deceleration percentage, and cruise percentage. Table 1 shows the parameter details.

The Kinta district driving cycle was previously developed using deep learning in which a neural network algorithm was involved [12]. The constructed driving cycle was simulated in the DC-TRAD conceptual model to further analyze the result of simulation and later to conduct a comparative study on the cycle.

3. RESULTS AND DISCUSSION

The total distance for Kinta district driving cycle is 22.52 km and with a total of 15 microtrips. Figure 5 shows the developed final Kinta district driving cycle.

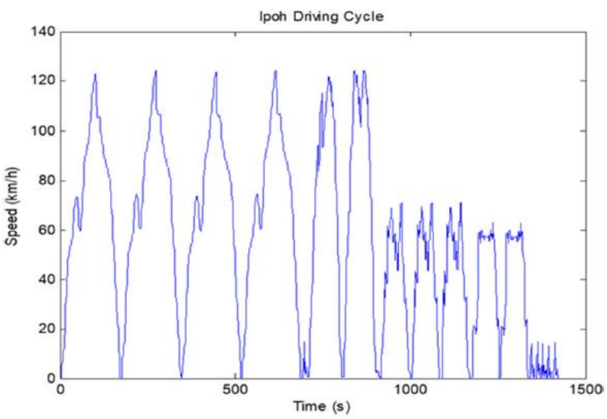


Figure 5. Kinta district driving cycle (Source: Arun et al. [12])

Table 2. Assessment parameters of Kinta district driving cycle

Items	Measured	Simulation	Error (%)
Distance (km)	22.52	22.52	0.00
Time (s)	1425	1425	0.00
Avg speed (m/s)	15.88	15.79	0.57
Avg run speed (m/s)	16.74	16.72	0.12
Avg acc (m/s^2)	0.65	0.66	1.54
Avg dec(m/s^2)	0.69	0.68	1.45
RMS	1.02	1.05	2.94
Idle %	4.56	4.52	0.88
Acc %	48.70	48.90	0.41
Dec %	45.47	45.40	0.15
Cruise %	1.26	1.30	3.17

The data points of the final cycle are then simulated in the conceptual model of DC-TRAD and 11 assessment parameters were drawn out for comparison as per Table 2.

According to Table 2, the average speed travelled by vehicles on route AR311 ranges approximately 15.88 m/s. From this, it can be concluded that the route in Kinta district is on medium traffic mode and on certain roads, clear traffic mode. However, the micro-trips recorded are below average speed, and thus, it can also be concluded that the fuel consumption on this route is high due to frequent stops, which may be caused by bad road conditions or high number of traffic lights. This may be also caused by driving behaviors of individuals where frequent braking is done. Figure 6 shows the comparison of measured and simulated driving cycle.

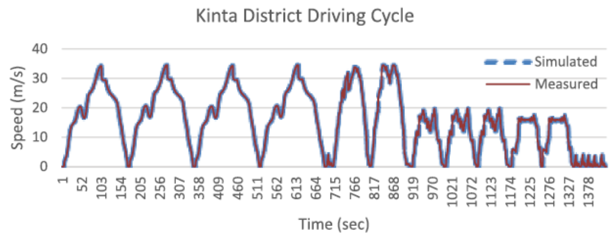


Figure 6. Measured and simulated Kinta district driving cycle

According to Figure 6, the simulated driving cycle is overlapping with the measured driving cycle with minimal error. The error between measured and simulated driving cycle is below 5%; this confirms that the conceptual model of DC-TRAD can keep track and simulate the entire driving cycle system thus matching the developed real-world driving cycle.

4. CONCLUSION

To summarize, a conceptual design of DC-TRAD was designed in MATLAB/Simulink and validated with the KT BasKITE driving cycle and the HWFET driving cycle; the validation resulted in an error of less than 5%. This developed DC-TRAD conceptual model is made use of in this research to simulate the measured Kinta district driving cycle, which was initially developed by means of neural network algorithm.

As previously discussed, 11 assessment parameters were chosen to be analyzed; these are distance, time taken, average speed, average running speed, average acceleration, average deceleration, RMS of acceleration, percentage idle, acceleration percentage, deceleration percentage, and cruise percentage. The Kinta district driving cycle was then simulated in DC-TRAD conceptual model and the features were compared and analyzed. In this research, it can be concluded that the Kinta district route is on medium traffic at 15.8 m/s average speed. Even though the traffic condition is medium, the fuel consumption is relatively high since micro-trips fall below average speed and this typically means there is frequent braking which may be caused by various factors namely, bad road conditions, traffic lights, and driving behavior of individuals themselves. Through simulation, it can also be concluded that the DC-TRAD conceptual model gives a reliable result with the simulated result matching the measured driving cycle; the predicted cycle curve overlaps the original curve with errors below 5%. Therefore, it is proven that the DC-TRAD conceptual model can be used to simulate driving cycles in future to further enhance fuel economy by reducing consumption and to ensure that the data obtained are reliable and trustable.

DATA AVAILABILITY STATEMENT

The model required to reproduce the above findings is available to download from Arun, S.K., Anida, I.N., Norbakyah, J.S., Salisa, A.R. (2022). A comparative study of conceptual design and prototype of DC-TRAD using EV powertrain for RTW DC in KT City. International Journal of Energy Production and Management, 5(4): 59-72.

ACKNOWLEDGMENTS

The authors would like to thank the Ministry of Education Malaysia for providing financial assistance under MG3+1 2022 (MG3+1/ 2022/ 53495/ UMT) grant and the Faculty of Ocean Engineering Technology and Informatics, UMT for all their technical and research support for this work to be successfully completed.

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