Investigation of Urban Driving Cycle and Relevant Geometric Factors in Abu Dhabi

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Abstract: Driving cycle is an important requirement in the evaluation of the driver's behaviour and the performance of vehicles for a number of applications. For example, fuel consumption and emissions need input information on the characteristic driving patterns of traffic. The development of the real-world driving cycle for the urban areas in the city of Edinburgh has been initially investigated as a pilot study, to set the procedures and design the measurement work for the driving cycle calibration in Abu Dhabi. In this study, the analysis of real-world data has been obtained from data recording of actual traffic conditions in Edinburgh using the Global Positioning System tracking of traffic. These data were collected from trips which have been done on one route. The assessment of various parameters of traffic (i.e. speed, time percentage spent on acceleration, deceleration, idling, cruising and cycle duration) and their statistical validity produced a real-world driving cycle for the private cars.

Keywords: Driving Cycle, Performance Box, Speed of Motor Vehicles, Micro Simulation Model

1 Introduction

The driving cycle is a series of data points representing the speed of a vehicle versus time. Driving cycles are produced by different countries and organisations to assess the performance of vehicles in various ways, for example, fuel consumption and polluting emissions. A driving cycle for a vehicle is a representation of a speed–time sequenced profile developed for a specific area or city. It is widely used to estimate transport air pollutant emissions and in the building of databases for emission inventories. For example, driving cycles for private cars and light goods vehicle are to enhance traffic management systems, determining fuel consumption patterns and reduce transport impacts on health (Hung et al., 2007; Saleh, 2007; Tzirakis et al., 2006).

The performance box device is a Global Positioning System (GPS)-based tracking tool for measuring vehicles' performance accurately. The performance box device has the capability to monitor vehicle speed, throttle position and mass air flow. The device automatically stores date and time. The data can then be downloaded to a desktop computer (PC) and analysed. During the data collection, the private vehicle will have two occupants, the driver and an assistant who records further information, such as, abnormal traffic or weather conditions, distances, as well as starting and end times at each segment of the route. All these parameters will be assessed during the pilot survey.

It is important to understand the factors which affect driving cycles in urban and rural areas. Speed is a critical element in transportation the systems. Planning, design, construction and maintenance of roads, traffic engineering and management affect speed. The speed has a critical impact on the capacity, safety, efficiency and the level of service of any road network. Driving cycle's characteristics in urban or rural areas change even for small variations in speed. Traffic and roadside characteristics, vehicular volume and number of intersections in a link, commercial land uses and pedestrian facilities and carriageway width have important effects on speed.

Speed of motor vehicles depends on a number of factors. These factors can be defined as four categories: traffic characteristics such as traffic density, flow, vehicle composition and the type of traffic management. Traffic management measures include speed limits, traffic lights, speed breaker and stop sign (Aerde and Yagar, 1983; Fitzpatrick et al., 2001; Galin, 1981; Polus et al., 1984). The second category is driver characteristics. Driver characteristics are classified as physical, mental, psychological and environmental (Ericsson, 2000; Holmen and Niemeier, 1997; LeBlance et al., 1995). The third category is roadside characteristics such as land uses abutting the road network, incidence of on street parking, bus stops and pedestrian facilities (Aerde and Yagar, 1983; Fitzpatrick et al., 2005; Galin, 1981; Koshy and Thamizharasan, 2005; Poe et al., 1996; Tignor and Warren, 1990). The forth category is vehicle characteristics such as model, age of the vehicle, size of the vehicle, power and quality of maintenance. The weather conditions (temperature, visibility, humidity and wind speed) may also have an impact on speed (Liang et al., 1998; Kilpelaninen and Summala, 2004).

Although there are a large amount of research on speed and other traffic characteristics, there are not much work on driving cycle characteristics and investigations in particular in the city of Abu Dhabi. The main aim of this research, therefore, is to investigate the urban and rural driving cycles and relevant geometric factors in Abu Dhabi.

Abu Dhabi is the capital and second most populous city in the United Arab Emirates (UAE) after Dubai and one of the world's largest producers of oil in the world. It is also the seat of government of the emirate of UAE. The city lies on a T-shaped island jutting into the Persian Gulf from the central western coast, with a population of approximately 1.45 million in 2008. Abu Dhabi has actively attempted to diversify its economy in recent years through investments in financial services and tourism.

First, a pilot study will be carried out in the city of Edinburgh. This paper presents the preliminary investigation of the driving cycle investigations in Edinburgh.

2 Literature Review

A driving cycle is a series of data points representing the speed of a vehicle versus time. Driving cycles are produced by different countries and organisations to assess the performance of vehicles in various ways, for example fuel consumption and polluting emissions. Fuel consumption and emission tests are performed on chassis dynamometers. Tailpipe emissions are collected and measured to indicate the performance of the vehicle.

Another use for the driving cycles is in simulations, for example, in propulsion system simulations (simulators designed specifically to model the drive system only and predict performance of internal combustion engines, transmissions, electric drive systems, batteries, fuel cell systems, etc.). In most cases, the driving cycles are derived theoretically, as it is done in Europe. Very little real-world driving cycle measurements have been undertaken.

The development of a driving cycle for the urban area of the city of Edinburgh has been investigated in literature (see, e.g. Esteves-Booth et al., 2001). The driving cycle in that study was obtained from data recorded under actual traffic conditions using the car chase techniques. New statistical methods of analysing the recorded data were also developed. The TRAFIX method enables the calculation of a representative driving cycle from data sets obtained from traffic measurements undertaken during two stages of experiments. Data from the City of Edinburgh Council traffic monitoring stations were weighted in proportion to traffic flows on the constituent driving routes. A comparison between the European Economic Commission of Europe (ECE) cycle and the Edinburgh driving cycle (EDC) had also been made. They also investigated the Edinburgh air quality forecast tools that predicted future levels of vehicular emission within the Edinburgh city centre to measure the effects of different levels of traffic control scenarios.

3 Traffic Characteristics

The term acceleration is defined as where there is an increase in speed. It is also defined as the rate at which a vehicle increases its speed. The accelerating vehicle constantly changes its speed, so the average acceleration can be calculated by

$$\text{Acceleration} = \frac{\text{Speed}}{\text{Travel time}}.$$

(a)

Figure 1(a) - Performance box "Performance Box Manual"

Deceleration is defined as the decrease in speed. It can be defined as the rate at which the vehicle reduces or decreases its speed. The average deceleration can be calculated by the speed at which the vehicle travels by the total time travel.

Idling is defined as a minimum operating speed by the vehicle on a road. In this case, the engine of the vehicle will be still on but the vehicle might be in a situation where it can move further on the normal speed due to traffic or the red traffic light. The stage where the vehicles speed is zero or near to zero normally refers to idling.

Cruising is a stage when the vehicle travels at same speed for a longer or constant time. The vehicle can travel at 20 km/h or maybe 40 km/h for 1 min or longer is called as cruising.

4 GPS Performance Box

The GPS is a global navigation satellite system developed by the United States Department of Defense which receives signals from the satellites and gives global location of moving vehicle on a second-to-second interval (Figure 1.a). Performance box is based on the Racelogic VBOX, which is used to assess performance. A GPS system is installed in the performance box with an update rate of 10 samples per second. By using performance box, it is easy to measure some important features like very accurate speed (±0.1 km/h), deceleration, acceleration, very accurate distance measurement (±10 cm in 400 m), lateral acceleration, latitude and longitude. The data are stored on a removable SD flash card, and a USB connection allows data to be downloaded to the computer for further in-depth analysis.

5 Micro Simulation Model

Micro simulation model enables the user to predict the outcomes of a proposed change to a road network before it is implemented, and it also helpful to evaluate the merits of the proposal. Micro simulation is one of the most common methods used to model the road traffic movements for the evaluation and development of road traffic management and control systems in United Kingdom. These movements are determined using simple car following, lane changing and gap acceptance rules. Micro simulation models are used when some analytical techniques or conditions are not represented using mathematical equations. In the traditional models, all vehicles of a particular group obey the same rules of behaviour because they provide an aggregated representation of traffic and typically expressed in terms of total flows per hour. But the micro simulation models give the actual driver behaviour and network performance with a better and purer representation.

Complex traffic problems like complex junctions, effects of incidents, intelligent transportation systems (ITSs) and shockwaves are effortlessly examined using micro simulation tools. New systems can be developed using micro simulation, and it will be simple to optimise their effectiveness. By producing outputs on a wide range of measures of effectiveness, it can be easy to estimate the impact of the scheme developed. Many of these impacts, such as the driver behaviour, queues and delays and amount of pollutions, are often difficult to measure in the field. It will be an essential part for any assessment toll to reproduce the individual driver behaviour; it can be measured easily in micro simulation models. For testing and evaluating of ITSs, micro simulation is particularly suited to its development. One of the main advantages of using micro simulation in ITSs is they interact with individual vehicles.

Because these models behave much faster than real time, it will be easy to predict about the future state of a road network. Many of these models are used for all the research work but only used for specific research task. In United Kingdom, the numbers of softwares available for commercial use is very less. VISSIM (PTV, Karlsruhe), Paramics (SIAS and Quadstone, Edinburgh), AIMSUN (developed by TSS, Barcelona), DRACULA (University of Leeds/WS Atkins), HUTSIM (Helsinki University of Technology) and SISTM (TRL, Crowthorne) are models which are commercially available in United Kingdom for the use.

6 Methodology

For achieving the aim and the objectives of this research, the following tasks have been identified:

- *Task 1:* Carry out literature review on a driving cycle and factors affect it, traffic and flow literature and traffic conditions in Abu Dhabi.
- *Task 2:* Define the set of variables which will be investigated in the driving cycle. These will be identified from the literature review.
- *Task 3:* Define a number of routes in Edinburgh first to carry out the pilot survey, then in Abu Dhabi. The City of Edinburgh Council and the Abu Dhabi City Municipality will be consulted for the identification of the routes.
- *Task 4:* Pilot the measurement of the private car driving cycle using the performance box in Edinburgh first, then in the case study (Abu Dhabi).
- *Task 5:* Carry out the main surveys in Edinburgh first, then in Abu Dhabi, and compare the results.
- *Task 6:* Analyse data and draw conclusions.

7 Data Collection

7.1 Description of the Corridor

To carryout the task, a number of traffic corridors in Edinburgh have been selected. They are Gorgie Road,Lothian Road, Leith Walk, Queen Street and West Maitland. So far, only Gorgie Road has been investigated to get an accurate measurements and results. After that, the same procedures will be carried out on the other routes and the case study as well.

The corridor is Gorgie Road – A71 (Edinburgh, Scotland). The length of the corridor is approximately 1.3 miles. The corridor is very busy during the rush hours because it has five junctions (see Figure 1.b): they are as follows.

The signalised junctions:

1. Gorgie Road/Robertson Avenue (Location number 175).
2. Gorgie Road/Westfield Road (Location number 117).

(b)

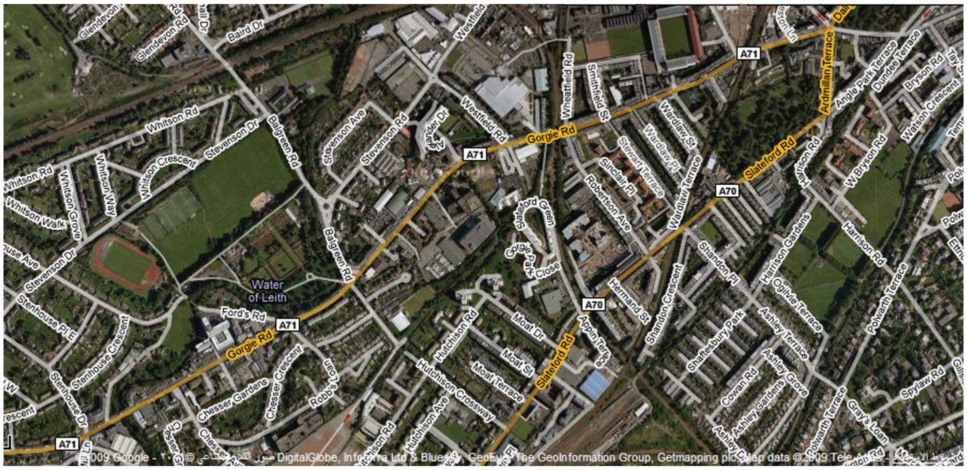


Figure 1(b) - Gorgie Road corridor "Google Earth"

3. Gorgie Road/Balgreen Road (Location number 124).
4. Gorgie Road/Chesser Avenue (Location number 98).

The priority junction:

5. Gorgie Road/Robb's Loan (Location number 259).

7.2 Description of Data Collection

An investigation of real-world driving cycles for private cars in Edinburgh has been carried out by analysing real-world data. These data in the driving cycle were obtained from data recorded under actual traffic conditions using the GPS Performance Box and were collected from trips which have been carried out on Gorgie Road in Edinburgh city. Pilot measurements of the private car driving cycle on the selected route have been conducted using the GPS Performance Box. The assessment of various parameters (e.g. speed, time percentage spent on acceleration, deceleration, idling, cruising and cycle duration) and their statistical validity over total trip length produced a real-world driving cycle for cars.

To collect the data, the following equipments have been used.

1. *Performance box:* The performance box device is a perfect tool for measuring vehicle or driver performance accurately and has the capability to monitor vehicle speed, throttle position and mass air flow. The device automatically stores date and time. The data can then be downloaded to a desktop computer (PC) and analysed. The private vehicle will have two occupants, the driver and an assistant who records further information, such as abnormal traffic or weather conditions, distances, as well as starting and end times at each segment of the route. All these parameters will be finalised during the pilot survey.
2. *Video camera:* The video camera is a useful tool for counting traffic flow along the selected corridors, especially in signalised junctions. This tool has been used to calculate the traffic flow in each direction of the four junction on Gorgie Road and also to calculate the traffic signals timing in each junction.
3. *Private car:* The researcher's private car has been used in to investigate the driving cycle in the selected route. The car was a Nissan QX, year 1999, 2.0 litre engine and automatic transmission. The car has been equipped with the performance box on the dashboard to collect the data.
4. *Stop watch:* This tool has been used to do some calculation during the data collection stage.

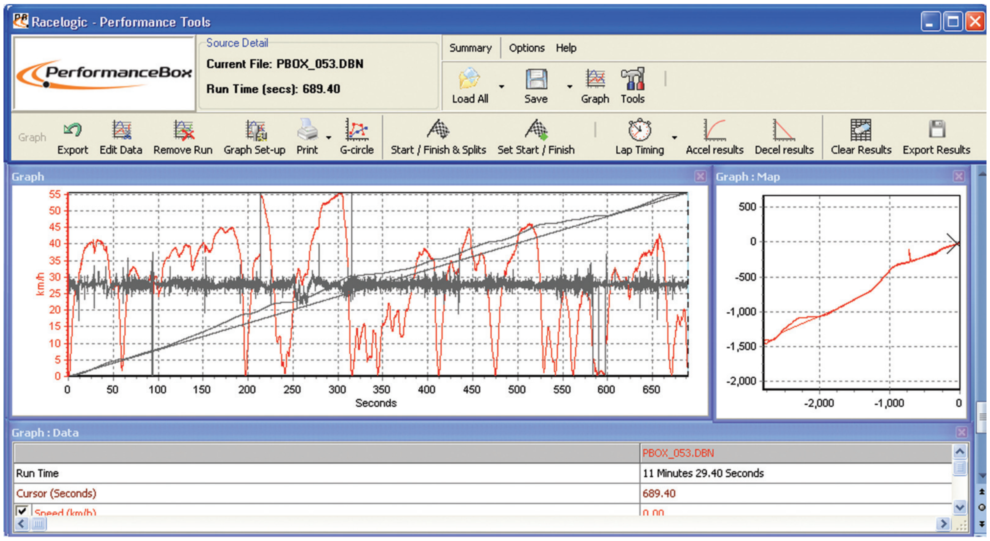


Figure 2 - Performance box software page

Driving cycle was recorded along the selected corridor during the morning traffic peak hour (8.30-9.30 a.m.), midday (12.00-1.00 p.m.), evening peak hour (4.30-5.30 p.m.) and off peak hour (9.00-10.00 p.m.). One car driver (the researcher) was used to carry out all the driving tasks during data collection. The car was driven along the corridor for a three runs for each corridor for each time period. Data were recorded then in the performance box.

The information obtained from the performance box includes the following (Figure 2):

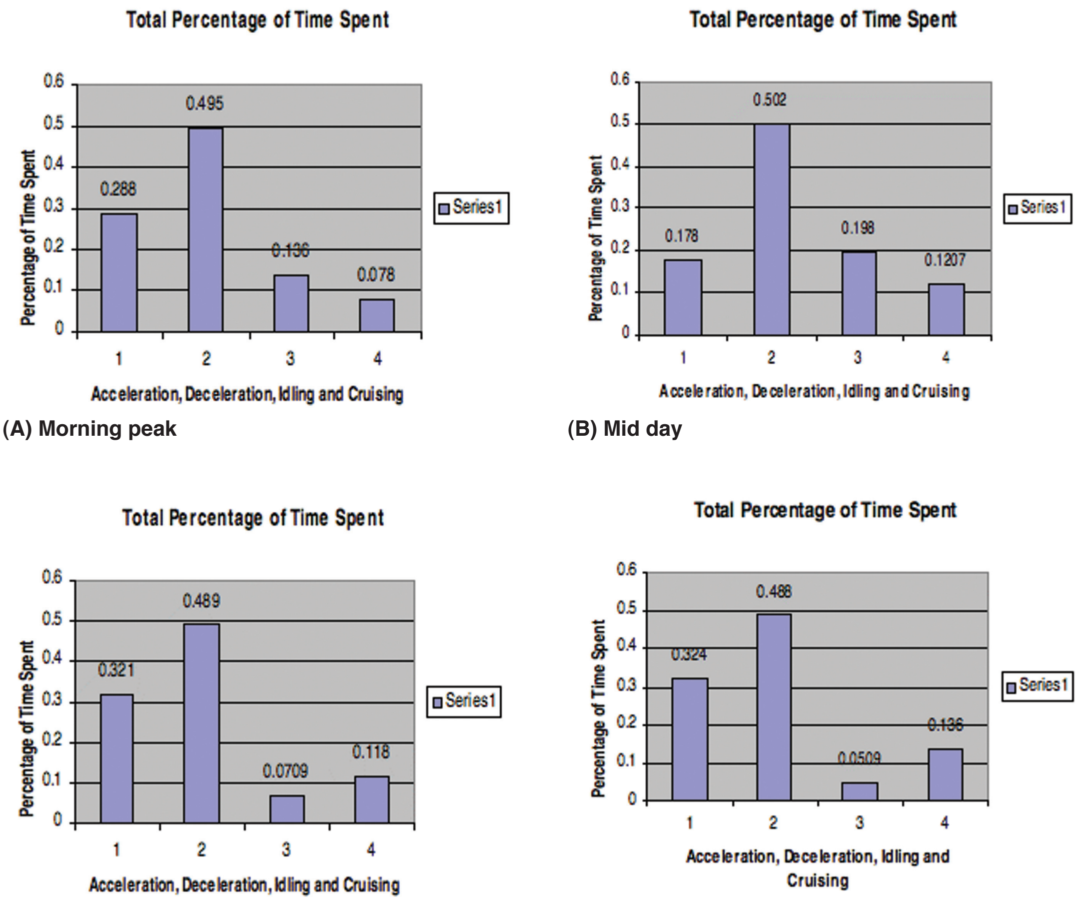
- Acceleration
- Deceleration
- Time
- Speed
- Distance

8 Data Analyses

The data file obtained from the performance box was further analysed to calibrate the driving cycle for the corridor as described in the following:

- The data were exported from the performance box software to excel file.
- The data in excel file were sorted out by acceleration/deceleration, to separate the acceleration, deceleration, idling and cruising values.
- The acceleration/deceleration column has been changed from km/s to m/s2.
- The acceleration values are the positive values.
- The deceleration values are the negative values.
- For the idling and cruising, tow conditions was made to define them.
- If speed is less than 10 km/h, and acceleration less than average acceleration, then it means idling.
- If speed is more than 10 km/h, and acceleration is more than average acceleration, then it means cruising.
- Measuring the percentage of acceleration, deceleration, idling and cruising.

Figure 3 shows the percentage of time spent on acceleration, deceleration, idling and cruising in all four periods (Morning peak, Midday, Evening peak and Night off peak).



(A) Morning peak **(B) Mid day**

(C) Evening peak **(D) Night off peak**

Figure 3 - Characteristics of driving cycle on the Gorgie corridor (A, morning; B, mid day; C, evening; D, night off peak)

9 Future Work

Future work on this research includes further investigations of the driving cycle characteristics in Edinburgh using microsimulation (VISSIM) and comparisons of the results from the field work and modelling. The investigation and calibration of driving cycles for urban and rural corridors in Abu Dhabi will then be undertaken. Microsimulation analysis will also be carried out using the analysis of the car following model. Results obtained from both cities will be compared and investigated. Recommendations for further research into this area will be concluded.

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