METHODOLOGY TO DEVELOP A DRIVING CYCLE FOR A GIVEN MODE AND TRAFFIC CORRIDOR; CASE STUDY FOR GALLE ROAD, COLOMBO, SRI LANKA

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Abstract:A driving cycle is a speed time profile which represents the driving characteristics of a selected area. This can be of use to both legislative and non legislative purposes such as development of emission inventory, determination of fuel consumption etc. As driving cycles are dependent on the traffic constituents, driver behaviour and road conditions established driving cycles cannot be used in Sri Lanka. Hence the objective of this research is to develop a methodology and to constructa driving cycle(s) which represent given set of conditions in Sri Lanka such that it can be use to establish emission inventory in future. To achieve these objectives, it is necessary to collect and analyse the on road speed-time data on selected routes which will represent the driving patterns of urban or rural conditions. Due to the restriction of time and resources, study was limited to one transport corridor, anurban condition and for light vehicles only. A sample driving cycle was developed based on the data collected on the Galle Road, section from Katubedda to Fort using on board method. Cycle was developed using micro trip based cycle construction and computer application was developed to aid this purpose. In this study we observed average speed 21.37km/h, average running speed 25.78km/h, average acceleration 2.03km/h/s and average deceleration 2.02km/h/s with acceleration, deceleration, cruising and idling proportions of 27.37%, 23.70%, 31.43% and 17.49% respectively for selected urban condition. This study would facilitate the further studies on development of driving cycles for other conditions and could be of use for traffic engineering studies as well as sustainable development.
Keywords: Driving cycle, Emission, On board method, micro trip, cycle construction

1. Introduction

A driving cycle is a speed time profile which represents the driving characteristics of a specified area. This can be of use to both legislative and non legislative purposessuch as development of emission inventory and determination of fuel consumption. Vehicle manufacturers need these cycles to provide a long term basis for design, tooling and marketing.As Sri Lanka has stepped into this industry this would be of use for the development of such industry. Traffic engineers require driving cycles in the design of traffic control systems and simulation of traffic flows and delays(Hung et al., 2007).

1.1 Objective of the Study

Established driving cycles such as European driving cycle and United States driving cycle cannot be used in Sri Lankan context as the traffic constituents, driver behaviour and road conditions vary significantly that from the conditions of those countries. For example, use of the European test cycle to predict total exhaust emissions in

Turkey did not produce accurate results (Tong et al., 1999). Hence the objective of the research is to find an appropriate method and develop a sampledriving cycle which represents Sri Lankan urban conditions and toestablish emission inventory in future based on such cycle.

2. Methods Available for Cycle Development

Basically two methods are available to develop driving cycles. One is to derive from the on-road driving data. The other is modal or polygonal driving cycle, which is constructed from various representative constant acceleration and speed driving modes (Tong et al., 1999). First method has been used in this study as it is experimental and more representative of the existing condition and widely adopted around the world. This procedure consists mainly of four sections.

1. Route Selection
2. Data collection
3. Cycle Construction
4. Cycle Assessment

2.1 Route Selection

A representative route is necessary to reflect normal traffic conditions of the interested area. Mainly following factors are considered in selection of the test route. Annual Average Daily Traffic (AADT), land use patterns, route classification, population density, travel activity pattern, vehicle composition, average trip length, number of signalized/un-signalized intersectionsroad profile and etc. The weightage given for each factor is subjective.It isbased on the purpose of driving cycle development and also the researcher (Tong and Hung, 2010).

2.2 Data Collection

There are three main methods adopted for on- road data collection (Tong and Hung., 2010).

- Chase car method
- On board measurement method
- Hybrid of the above two methods

In chase car method a vehicle is targeted and chased in the traffic stream. When selecting atarget vehicle, attention should be given to easy identification of the target vehicle among traffic since pursuer needs to track the vehicle continuously. The reason is, if not some times the targeted vehicle can be lost because of the traffic congestion of the road (Tong and Hung., 2010). The speed data is recorded at desired intervals (distance/time). Most practised method in driving cycle construction is recoding speed at every second of the trip.

On board measurement is another method which used to collect data for driving cycle construction. In this method,instruments are installed on a selected vehicle and let the vehicle travel along the traffic stream at an average speed. And then per second speed data is recorded as they travel along the predetermined routes (Tong et al., 2011).

First method requires less resource but can be complicated because of the behaviour of the targeted vehicle. Hence can be time consuming, less accurate and less cost effective but ideal to monitor true driving behaviour. Second method may not represent the true driving behaviour (depends on the driver) but fewer complexities in the data collection process.

2.3 Cycle Construction

Method of cycle construction varies with the intended use such as emission inventory development or traffic engineering purposes. Each cycle method has inherited features that serve the intended purpose. Hence a driving cycle developed for emission study purposemay not suits for traffic engineering purposes. Basic methods available for cycle construction are (Dai et al., 2008)

- Micro-trip based cycle construction
- Segment-based cycle construction
- Cycle construction with pattern classification
- Modal cycle construction

Micro-trips are defined as the driving activity between adjacent stops, including the leading period of idle. In first method the collected data is divided to micro trips and they are added to construct the driving cycle of the desired duration (20-30 minutes cycles are widely used). The addition is usually done in three ways: random selection, best incremental (incrementally searching for and adding a micro-trip with specific characteristics) or a hybrid of both approaches. This method is suitable for cycles developed for emission study purposes but has very limited use for traffic engineering purposes as micro-trip does not differentiate by various types of driving conditions such as roadway type or Level of Service (LOS)(Dai et al., 2008). In second method, trip segment is attained by splitting vehicle speed-time data considering changes in roadway type or LOS hence cycle can be used to represent driving activity for specific roadway types and traffic conditions. Adding of segment is done as in the case of micro trip cycle construction, how ever, tolerance limits are introduced to connect successive segments start and end unlike in the previous method. Ideal for traffic engineering studies but has limited use in emission related studies (Dai et al., 2008).In Cycle construction with pattern classification, data is segmented according to kinematic sequences using statistical methods and in modal cycle construction data is divided considering the mode (idling/acceleration/ deceleration/cruising). And they are used for cycle construction.

2.4 Cycle Assessment

In early stages of driving cycle development the main consideration was given to the average speed, maximum speed, number of stops etc. They were much related to traffic engineering studies but less related to emission. Hence with time, new parameters were introduced to incorporate the contribution from emission and fuel consumption. For the assessment, both the cluster analysis and the principal component analysis (PCA) is used as segments have arbitrary speed values for Table 1: Methods of Established Cycles (Tong, 2010)(Andre, 2004).At present and following are some of the parameters that arebeen used for assessment.(Tong et al., 2011)

Table 1: Methods of Established Cycles (Tong, 2010)

- average speed of the entire driving cycle
- average running speed
- average acceleration and deceleration
- maximum speed
- average micro-trip duration
- time proportions of driving modes for idling, acceleration, deceleration and cruising
- root mean square acceleration
- positive kinetic energy
- speed acceleration frequency distribution

The parameters used for a certain study may vary according to the intended purpose of the constructed cycle.

Following are the adopted methodology for cycle development in various countries and the intended use.

Driving cycle	Route selection	Data Collection	Cycle Construction Method	Assessment Parameters
FTP72, FTP75	Home-to-work trips	On-board measurement	Select the whole trip best fit the whole population	Stop per distance Average speed Maximum speed Number of stops
LA01	Mixture of routes by road types and areas	Chase car method	Modal cycle construction to match speed acceleration frequency distribution(SAFD)	Average speed Maximum speed Minimum speed 95th percentile speed SAFD Road power 95th percentile power
Improved European cycle	Mixture of routes in European cities	On-board measurement	Match with the population according to the assessment parameters	Average speed Average running speed Average acceleration and deceleration Mean length of micro-trips Average number of acceleration and deceleration changes Proportions of idling, acceleration SAFD
Sydney cycle	Road classification High emission Traffic density	Chase car method	Random selection of 2-mindriving segments	Average speed Root mean square acceleration Percentage idle
Melbourne peak cycle	Central business area Arterials Highway	Chase car method	Random selection of 100 m driving segments	Average speed Root mean square speed Root mean square acceleration Positive kinetic energy Percentage idle SAFD

3. Methodology for the Case Study

3.1 Route Selection

For the case study the Galle Road, section from University of Moratuwa to Colombo Fort was selected as the test route. When selecting the route consideration was given to several facts as the aim is to construct a driving cycle representing the urban condition and to setting up an emission inventory based on the developed driving cycle.

Therefore, when route was selected, consideration was given to the land use pattern and intention was to select a route which goes through both commercial and residential areas. In the selected route commercial use also differs from high end uses to normal commercial uses. The residential areas that are connected also consist of various social levels that are typical in Colombo and urban areas. This section is highly dense and it make this section affects many people. And most of the vehicles entering or leaving the City use at least a part of the selected route. And thusit's more appropriate to use this road section for our data collection.

Selected route has signalized intersections since it is usual condition in the Colombo area. When driving in Colombo one cannot avoid signalised intersections. At the same time manual traffic control can also be seen frequently in Colombo city. This affects the driving behaviour significantly.

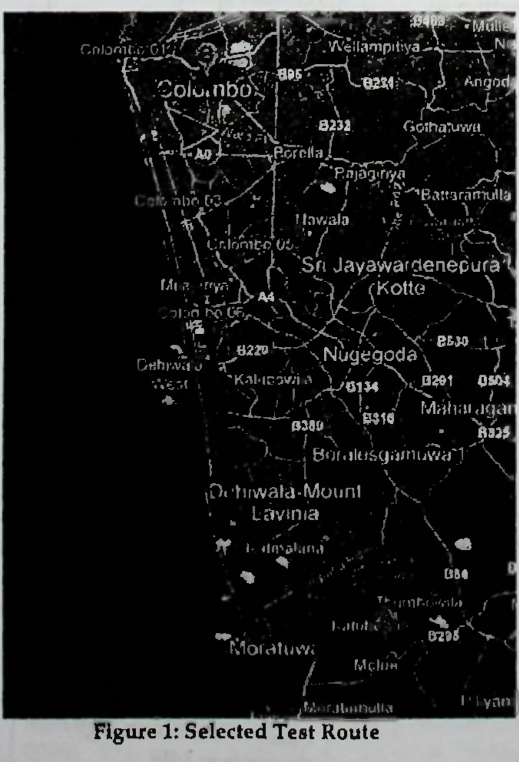

Figure 1: Selected Test Route

The selected route has both these control types and consists of junctions connecting to major parts of the city.

It is required to select a road which has high traffic density as it is the typical condition in Colombo and the length of the route was determined taking this in to account and the average trip length. Further, consideration was given when selecting a road which has at least one fly over, because major roads in Colombo city have flyovers and may come a cross in any typical journey.

Considering all these facts it was decided to use above route as the test route for the case study but this route containslittle portion of local roads. In actual case it is necessary to select the route that contains some more local roads, but due to time and resource constraints, the above route was selected.

3.2 Data Collection

For the case study it was decided to use the on board method for data collection. There were many reasons to adopt the on board method as data collection method in this study. The route which was selected is congested mostly during day time due to the fact that it is one of the main corridors feeding Colombo. Therefore if the chase car method is adopted, possibilities are high to miss the target vehicle due to various reasons, such as irregular driving pattern of the vehicles, presence of number of intersections, etc. Therefore, on board data collection method was used, thus convenient and accurate.

Not only that, it requires minimum amount of equipment and it is a very cost effective method compared to other methods available. Also it is possible to take direct measurement of the speed time measurement. Though the road is highly congested, the driving patterns of the drivers are irregular and therefore difficult to follow a targeted vehicle at the speed of the targeted vehicle. The major problem encountered from chase car method is that the data collected will not be accurate because there is always a delay due to driver's response time between two vehicles and it is significant in a highly congested area especially with irregular behaviour of traffic. But adopting on board method it is possible to overcome the delay due to driver's response time.

3.3 Cycle Construction

Micro trip based cycle construction approach is adopted in this case study by considering the cycle construction methods used in development of various driving cycles on the past. Literatures indicate that, this approach has been commonly adopted worldwide to develop driving cycles to study emission related activities. The aim of this research is also focused on setting up emission inventories for Sri Lankan context. To aid the cycle construction process a computer application was developed as the manual handling of a large set of data is time consuming and could lead to errors.

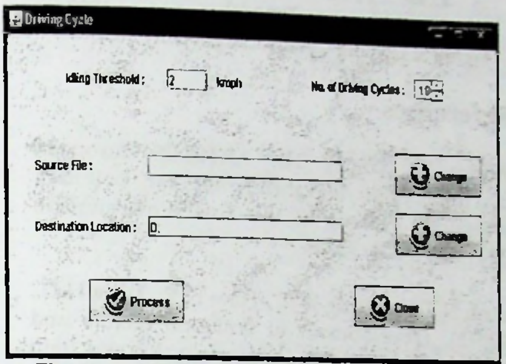

Figure 2: Interface of the Developed Computer Application

First, the application will filter the points that are having unusual characteristics. Under this step,points are having instantaneous acceleration greater than 1.4 ms^{-2} and points having instantaneous speed greater than 100kmph will be filtered. Under normal Sri Lankan road and traffic conditions, it is not possible to have that much of speed and also engine power is not capable of providing accelerations of greater than this value.

The whole filtered data are then separated into micro trips as described earlier to determine the predominant patterns occurred in the actual driving situations. The driving parameters of each micro trip are calculated and micro trips are grouped into speed ranges based on their average velocities.

These speed ranges are given an equal probability to be selected randomly during cycle construction process. Similarly in the selection of a micro trip from any speed range, each micro trip in the speed range is given an equal probability which can be calculated based on the number of micro trips in the bin. To commence the cycle construction, first the application will select a bin randomly then, again randomly select a micro trip from that bin. Thereafter, average speed of that micro trip and target average speed will be compared and depending on that, next speed range will be decided.

If the average speed of selected micro trip is less than the target average speed, next micro trip will be chosen from the bins having average speed greater than target average speed. From the bins having greater average speed, application will again randomly choose another bin and micro trip, and vice versa. Whenever a new micro trip is selected and added to the previously selected ones, the average speed for new set of micro trip is calculated to check whether it is lower or higher than target value before selecting next new micro trip. So that new average speed would become closer to the target value. Depending on that, application will repeat the above steps until the desired total driving cycle duration is reached.

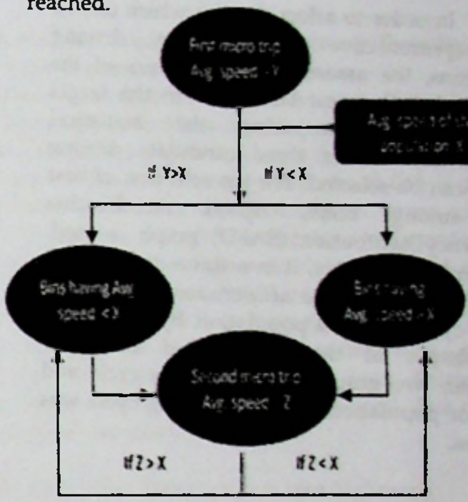

Figure 3: Process of the Developed Application

The total duration of the driving cycle is determined considering the fact that it should be long enough to describe all traffic situations and obtain the emission effectively as chassis dynamo meter test is costly. The total driving cycle duration in this study is taken as 20 minutes, which is compatible with various well known driving cycles. The selected micro trips might not cover the cycle duration of 20 minutes, if so the remaining period will equally distributed among idle periods in between selected micro trips. Desired number of candidate driving cycles can be generated using the application developed.

3.4 Cycle Assessment

By definition, a driving cycle is a speed time profile designed to represent a real world driving pattern. So the developed driving cycle should best fit with the real world driving situations. In order to minimize the effect of uncontrollable bias due to random selection of micro trips, a number of candidate driving cycles are generated. Then among those a best candidate driving cycle is selected by means of assessment parameters. Following parameters were used for the principal component analysis in this study.

- Average speed of the entire population and driving cycle
- Average running speed
- Average acceleration and deceleration of all acceleration and deceleration phases
- Time proportions of driving modes (idling, acceleration, cruising, deceleration)
- Root mean square acceleration

In order to select the one which can be best representative to the actual driving conditions, the assessment parameters of the generated cycle must be closest to the target statistics. By comparing the statistical parameters, two or three candidate driving cycles can be selected. For the selection of best one among them, Speed Acceleration FrequencyDistribution (SAFD) graph is used. As mentioned above, it is a three dimensional graph showing speed acceleration distribution of the cycle and data population. By comparing the shapes of the graphs and difference between two graphs where one for cycle and one for population, the best driving cycle was chosen.

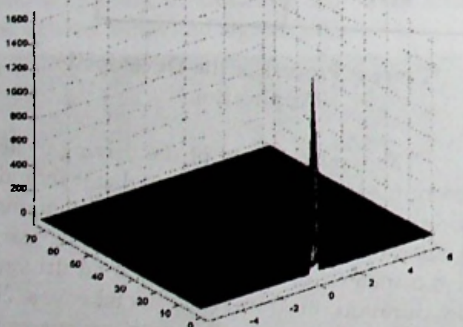

Figure 4: SAFD for the Whole Test Population

4. Results

Based on the model driving cycle developed for urban condition in Sri Lanka the following out puts can be seen. The average speed 21.37km/h, average running speed 25.78km/h, maximum speed 72km/h, average acceleration and deceleration 2.03km/h/s and 2.02km/h/s. And the test population showed acceleration, deceleration, cruising and idling proportions of 27.37%, 23.70%, 31.43% and 17.49% respectively. Following graph is the developed drivng cycle for emmision in urban condition.When compare, these values differ from the existing driving cycles, hence insists to develop a cycle for Sri Lankan context.This study can be considered as the starting point of driving cycle development for Sri Lanka, which truly represents the local conditions.

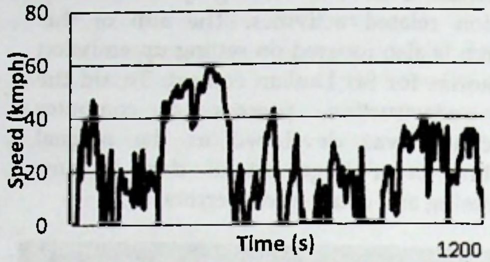

Figure 5: Driving Cycle for Light Duty Vehicle

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