DEVELOPMENT OF DRIVING CYCLE FOR METRO MANILA

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abstract: The Department of Energy(DOE) implemented a DOST-funded research project entitled *'Performance Testing of Selected Road Vehicles Using the Chassis Dynamometer Under Simulated Urban and Highway Traffic Conditions'* from 1994 to 1995. One of the target outputs under the subject project was a transport drive cycle which would simulate urban traffic conditions and would be used in the performance testing of passenger vehicles. The motivation behind the development of drive cycle was to provide a means of comparing fuel consumption of different vehicles and to measure exhaust emissions of vehicles in a fixed location. The author was tasked to develop the said drive cycle for Metro Manila. It was based on collection of speed versus time data using a fully instrumented test car. A computer program package was developed to perform processing, statistical analysis, and evaluation of the drive cycle.

1. INTRODUCTION

A drive cycle is a speed-time history which forms the basis of reproducible measurements of vehicle performance and characteristics such as fuel consumption and exhaust emissions(Watson, 1985). Vehicle performance varies in different conditions of temperature, altitude, road and traffic. A localized drive cycle can be used as a basis for improving vehicle fuel utilization by changing driving patterns through traffic engineering and management including road alterations and computer control of traffic signals to minimize stops and thereby improving travel time.

Drive cycles have existed for several decades as a means of assessing fuel consumption. The growing concern on exhaust emissions has led to proliferation of drive cycle emission measurement in the US, Europe, and Japan. The range of existing drive cycle reflects a variety of perceived needs:

a. The planning analyst desires/aims to devise statistically meaningful combinations of vehicles and driving patterns at various levels of aggregation to describe fuel use and population sources for particular geographic regions.
b. Vehicle manufacturers need cycles which are fixed and provide a long term basis for design, testing and marketing.

The problem in Los Angeles and San Francisco and later in Tokyo of increased smog levels made it imperative to test vehicles in a fixed location since it was impracticable to install a pollution measuring instrument in a vehicle tested on the track without altering its performance. Thus drive cycles which could be driven on a chassis dynamometer were developed.

The objective of the paper is to present a methodology for the development of city driving cycle for Metro Manila. The components of the computer package used to facilitate the development of the cycle are discussed.

2. DATA COLLECTION

Several possibilities exist for measuring driving patterns representative of a particular region. One approach followed to define driving behavior has been to instrument user driven cars and then to record car velocity and other information during their typical car usage. Another alternative approach followed has been to instrument few cars, detecting car, engine, and gear operating parameters. The main disadvantage of this approach consists in the scarce information on different users and cars effects on driving cycles(Della Ragione, et al). For this study, due to financial constraints, only a single car can be equipped with instrumentations and the 'chase car' technique has been adopted. This technique involves random selection of a car in the traffic stream which is followed by the instrumented car along a particular route, and another vehicle selected when the vehicle being followed turns, behaves suspiciously, or following becomes too dangerous(Khatib, 1985). As shown in Figure 1, the instrumented vehicle is used to chase cars in order to determine the second by second speed vs. time profiles, frequency and severity of acceleration/deceleration, and other pertinent parameters associated with typical city driving(Carlock, 1992).

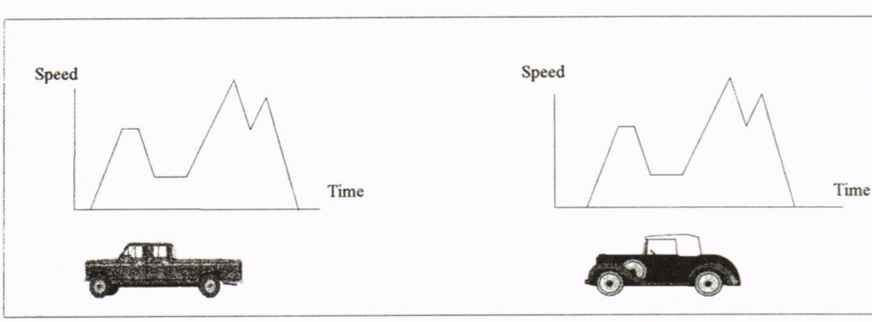

Figure 1. Chase Car Technique

In the survey of a city driving pattern, it is plainly not possible to consider every route. A rational approach is to survey routes in proportion to their usage. Based on the annual average daily traffic(AADT) flow map, routes to be included in the survey were selected.

The test car used has a fully automated on-board instrumentation. The system includes the following:

- On-board monitoring and data acquisition computer equipped with a 20 channel CF I/O board and disk drive for mass storage.
- Max series 210 positive displacement type flowmeter and transmitter for fuel flow measurement.
- Thermocouples for monitoring engine oil, gear box and final drive temperatures.
- Airpax magnetic pickup installed in the test car wheel to monitor vehicle speed, distance traveled, acceleration, and deceleration.

Data collection covers the period, July 10 until August 16, 1995. Due to severe congestion during the morning peak period, data were collected between 9 A.M. and 11 A.M. From time to time, malfunctioning of the on-board monitoring instruments (particularly the sensitive magnetic sensors) occurred due to excessive shock and vibration attributed to bad road condition in some parts of Metro Manila. Because of time constraint, only one run(or pass) per selected route was conducted. The data gathered using the on-board data logging/acquisition system consisted of velocity measured every 1 second. These were lumped into a single data file. The total number of data points is about 23,000 representing roughly 6.4 hours of travel along the major thoroughfares of Metro Manila. Careful scanning of the data had to be done to eliminate erratic/noisy entries.

3. DRIVING CYCLE DEVELOPMENT TECHNIQUE

A variety of techniques are available to translate, compile and analyze traffic data into representative cycles. Some of which are:

a. ACDI(Acceleration, Cruise, Deceleration, and Idle) - this is a cycle comprised of constant acceleration, cruise, constant deceleration, and idle. This cycle is not designed to represent an actual road route but rather to portray a representative mode involving constant or 'straight line' rates of vehicle movement. This cycle could be repeated a number of times to form any required length of test cycle.

b. Step-wise Mode Form - this is another cycle that involves 'straight line' rates of vehicle movements but these modes vary in number to represent the input data. Construction of such a cycle involves reviewing the basic summary statistical information such as percentage of time in various speed bands, percentages of idle time, acceleration rates and trip length. With these data on hand, one could arbitrarily construct a cycle having the same average statistical characteristics as the input data.

c. Microtrip Accumulation - this technique involves the following steps:
   - Collected data from all runs are added together to form one file; the speed-time trace that is represented by this file serves as the reference or target cycle.

- A joint velocity-acceleration probability density function matrix is produced for the target cycle.
- This matrix is normalized, i.e., each cell is divided by the number of samples.
- The total data file is divided into a number of driving segments that start and end with zero velocity and are of over 2 minutes each duration (i.e., microtrips).
- A number of microtrips are selected at random to form the required length of prospective cycle. It is assumed that all microtrips have equal probability of being chosen, hence a uniform distribution is utilized to generate random variates. A cycle formed by connecting the selected microtrips becomes a candidate cycle. A normalized joint velocity-acceleration probability density function matrix is produced for that cycle.
- Candidate cycles having similar characteristics with that of the overall data are saved for final selection.

The above steps can be done easily using microcomputers.

Other techniques used to develop and/or smoothen drive cycle are the following:

- Fourier series
- Time series analysis
- Curve fitting techniques using polynomial functions

The microtrip technique produces a representative cycle in a constrained form, i.e., the vehicle must be at a specific speed during the test. This results in a very precise and repeatable test on a fixed chassis dynamometer but has the drawback that it requires a strip chart recorder and possibly two operators (one steering and the other accelerating) if the cycle is to be driven on the test track in order to precisely follow the pattern.

4. THE DRIVE CYCLE ANALYSIS PACKAGE

A computer program package based on the microtrip accumulation technique was developed in order to perform all the tasks necessary to produce a drive cycle. The package consists of the following modules: a)processing of the target cycle, b)microtrip generation, c)generation of candidate drive cycles, and d)processing/ evaluation of candidate drive cycles.

4.1. Processing of the Target Cycle

All the time-velocity data are accumulated in a single file representing the target cycle. The following statistics for the target cycle are computed: a)percentage distribution (joint velocity-acceleration probability density function), b)percentage idle, c)maximum and minimum speeds, d)maximum and minimum acceleration, e)average travel speed, f)average acceleration, and g)average running speed.

4.2. Microtrip Generation

From the target cycle, 137 microtrips(small trips of at least 2 minutes in duration which have to start and end at zero velocity) were generated.

4.3. Generation of Candidate Drive Cycles

Candidate drive cycles were generated by combining the microtrips at random. It was decided to produce a 20 minute drive cycle. This duration is reasonable enough to be performed for dynamometer testing. (It was initially thought to base the duration of the drive cycle on the average trip time of more than 40 minutes but this will be impractically too long for testing on the chassis dynamometer.) More than 20,000 candidate cycles were generated.

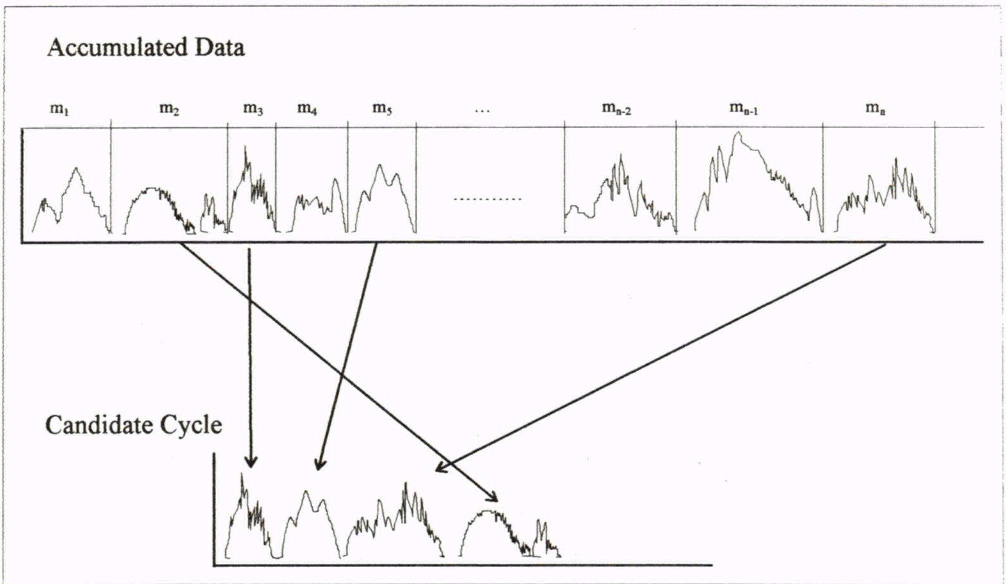

Figure 2. Construction of Candidate Drive Cycle Using Microtrip Technique

4.4. Processing/Evaluation of Candidate Drive Cycles

Screening was performed using the joint velocity-acceleration probability density function as the initial criterion. The absolute difference between the probability density functions of the candidate and the target cycles was computed. This difference should be kept as small as possible for the candidate to be considered acceptable. A difference of not more than 20% is generally acceptable(Watson, 1985). The eight candidate cycles with the least absolute difference are shown in Table 1.

Table 1. Characteristics of Some Candidate Cycles

Criteria	Target	c1113	c1500	c3011	c3532	c3638	c5949	c6607	c8594
Absolute Difference	0.00	12.39	12.59	12.42	12.91	11.93	12.81	12.51	12.42
Idle, %.	33.33	30.00	33.10	34.10	33.10	33.72	32.60	33.90	32.50
Max.speed, kph.	76.40	66.00	60.80	66.00	57.90	66.00	56.40	56.40	71.20
Min. speed, kph.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max. acceleration, m/s2.	2.10	1.90	1.70	1.90	2.10	1.90	1.70	1.90	1.70
Min. acceleration, m/s2.	-2.70	-2.10	-2.10	-2.50	-2.10	-2.10	-1.90	-2.10	-2.50
Ave. travel speed, kph.	14.60	14.20	14.30	14.60	13.30	14.30	13.60	12.70	14.80
Ave. acceleration, m/s2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ave. running speed, kph.	22.49	21.90	21.99	22.93	20.36	22.14	20.74	19.83	22.83

5. FINDINGS

Candidate #c3638 was found to be the most likely choice for the drive cycle to represent city driving in Metro Manila during morning peak. It has the least absolute difference of 11.93%. Except for the maximum velocity of 66kph.(which underestimates the target by 10kph.), almost all other parameters are similar to the target cycle. The maximum velocity is exceeded by a mere 0.72% of the data points in the target cycle. The graph of this drive cycle is illustrated in Figure 3.

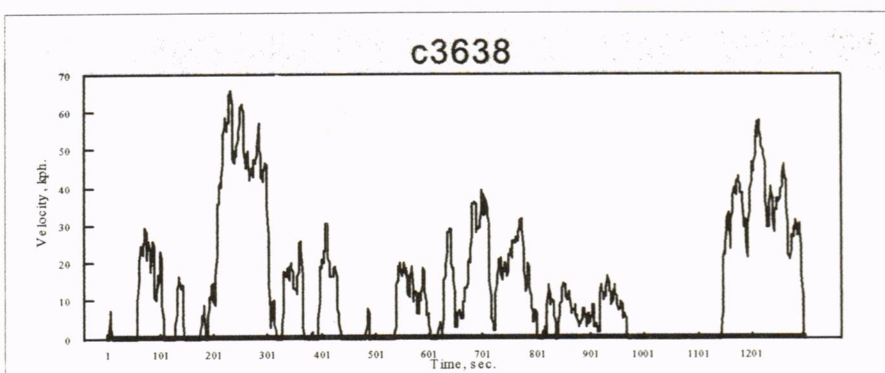

Figure 3. Candidate Drive Cycle #c3638

The similarity of this candidate cycle with the target cycle can be seen from their respective 3-dimensional graphs of the joint velocity and acceleration probability density function(Figures 4 & 5). Both graphs show concentration of data points within the envelope of 0 to 60 kph. velocity and -2.0 to +2.0 m/sec^2. acceleration ranges. Due to traffic congestion, there is a noticeable peaking of data at the zero velocity and zero acceleration region(more than 33% of the data points).

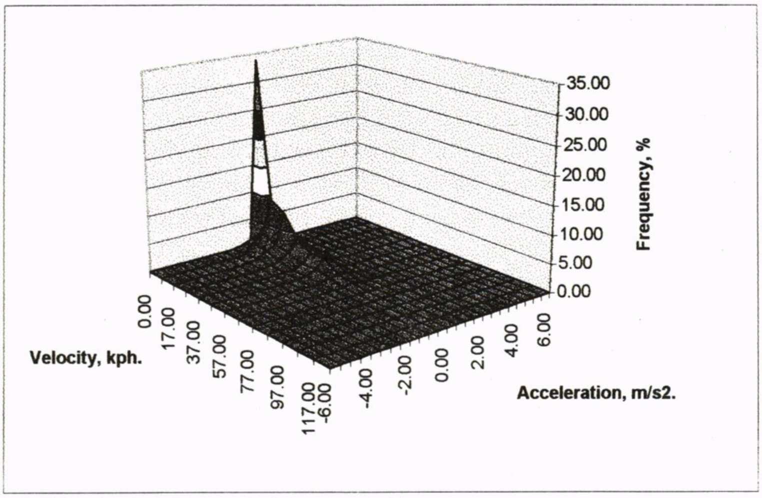

Figure 4. Joint Velocity and Acceleration Probability Density Function (Candidate Cycle #c3638)

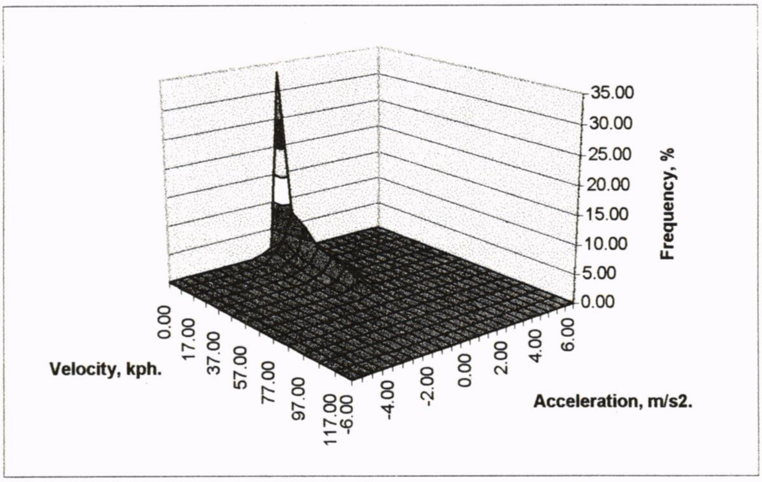

Figure 5. Joint Velocity and Acceleration Probability Density Function (Target Cycle)

The driving cycle developed can give indications on the air pollution problems in Metro Manila as emission of pollutants largely depends on operating characteristics of the vehicle(running speed, idling, acceleration, and deceleration). Long idling normally produces emissions of high concentration of carbon monoxide(CO). During acceleration and deceleration, large emission of NO_x is expected. The results of this study show a very high idling time(more than one third of total trip time) and frequent acceleration and deceleration due to stop and go situation of traffic flow. Improvement of the traffic situation in Metro Manila will have a positive effect on the environment.

6. CONCLUSION

A driving cycle for Metro Manila has been developed to simulate urban traffic conditions and to test performance of passenger vehicles. Due to heavy dependence of the transport sector on imported oil, the Department of Energy(DOE) has been performing experiments on the use of alternative fuels for vehicles. At the testing laboratory of the DOE, the driving cycle has undergone initial runs using dynamometer.

The Philippine economy has been improving in the fast years. A number of transportation infrastructures are now being put in place - light rail transit, new traffic signal control system, widening of roads, etc. Also, some travel demand management(TDM) measures are already being adopted. These projects and measures will definitely have positive impacts on the transportation and traffic situation in Metro Manila and hopefully, this would lead to improved air pollution levels.

Correspondingly, the driving pattern within the city may change and this will have to be reflected in the driving cycle. There is therefore a need to revise the driving cycle in the near future to account for this change. The methodology and the computer package developed in this paper can be used for the task.

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