An Approach to Fuel Consumption and Emissions Modelling of the South Australian Vehicle Fleet

Mr Rocco Zito
Research Engineer
Transport Systems Centre
University of South Australia

Prof Michael A.P. Taylor
Director
Transport Systems Centre
University of South Australia

Abstract : The Transport Systems Centre (TSC) of the University of South Australia (UniSA) have an instrumented VS Holden Commodore that has the ability to output time, distance, speed, fuel consumption, rpm, manifold pressure, throttle position and geographical position using GPS at one second update rates. It is proposed that this vehicle undergo a process of engine mapping that will enable the real time emissions variables to be calculated in combination with the previously mentioned vehicle variables. Once this has been achieved, the car can be used to collect real time emissions data.

The driving of the various routes in the different socio economic regions will occur during different times of the day, ideally during the AM and PM peaks together with some interpeak driving. It is important to cover all aspects of metropolitan driving since recent trends (Oxlad 1997) are showing that the journey to and from work is becoming a smaller percentage of total commuter trips. Therefore the interpeak trips need to be represented in any sort of standard driving cycle.

Once the GPS and other data has been collected it will be imported into a Geographical Information System (GIS) were it can be displayed and analysed spatially as well as analytically. The TSC already has the Adelaide metropolitan street centre line data that will be added as a layer to the GIS so that the exact route, speed profile and time data can be determined on a link by link basis. This data will then be used as the basis for deriving the standard driving cycle. The paper will go on to describe how this drive cycle data will be used to extrapolate fuel consumption and emissions predictions for the South Australian vehicle fleet.

1 INTRODUCTION

This paper will concentrate on the derivation of fuel consumption and emissions models for the South Australian vehicle fleet. To this end the Transport Systems Centre (TSC) of the University of South Australia (UniSA) has an instrumented VS Holden Commodore that has the ability to output time, distance, speed, fuel consumption, rpm, manifold pressure, throttle position and geographical position using GPS at one second update rates. It is proposed that this vehicle undergo a process of engine mapping that will enable the real time emissions variables to be calculated in combination with the previously mentioned vehicle variables. Once this has been achieved, the car can be used to collect the drive time, fuel consumption and emissions data. Once this data has been collected the next stage will be to extrapolate the data for the rest of the South Australian vehicle fleet enabling representative on road emissions models to be created from actual driving conditions. This will allow transport professionals to change parameters in the model such as vehicle fleet composition, travel times on roads or even the road network itself and be able to determine the effect it will have on fuel consumption and emissions.

2 ENGINE MAPPING

In order to be able to obtain real time emissions from the TSC's instrumented car one of the first processes to take place will be the engine mapping process. It would be preferable if this occurred before any drive cycle data is collected since it will allow real time on road emissions to be collected as a part of the drive cycle data. The engine mapping process will require the vehicle to be set up on a full chassis dynamometer and measurements of engine RPM and manifold pressure correlated with the emissions of interest. RPM and manifold pressure will be recorded using the existing instrumentation that has already been fitted to the TSC car. The emissions will be obtained from an emissions trolley that has been developed by the Energy and Engines Research Group E2RG of the University of South Australia. The emissions trolley is capable of measuring the following: hydrocarbons, oxygen, C02, CO and N0x. Once these have been mapped with respect to manifold pressure and RPM, a mathematical model of these emissions can be formulated. The calculation of real time emissions as part of the output of the TSC's instrumented car will then be possible.

Figure 1 shows the look of a typical engine map, basically a three dimensional surface with manifold pressure as the x axis rpm as the y axis and in this situation the amount of hydrocarbon output from the engine in parts per million (ppm). As stated previously the TSC car is capable of outputting manifold pressure and rpm on a second by second basis. Therefore the amount of hydrocarbon emitted from the engine can be calculated from the equation of the surface. Table 1 shows the functional form of the equation of the surface, a polynomial surface was chosen, as the best type of fit, since the surface tends to be smooth and continuous. The polynomial is of fourth order and so has some 44 coefficients these are listed in Table 1. With this information it is a simple matter of programming the equations of the desired emissions and adding them as part of the real time output. Or collecting the data and then running the data through a spreadsheet or software package with the appropriate equations programmed in it to come up with the emission parameters.

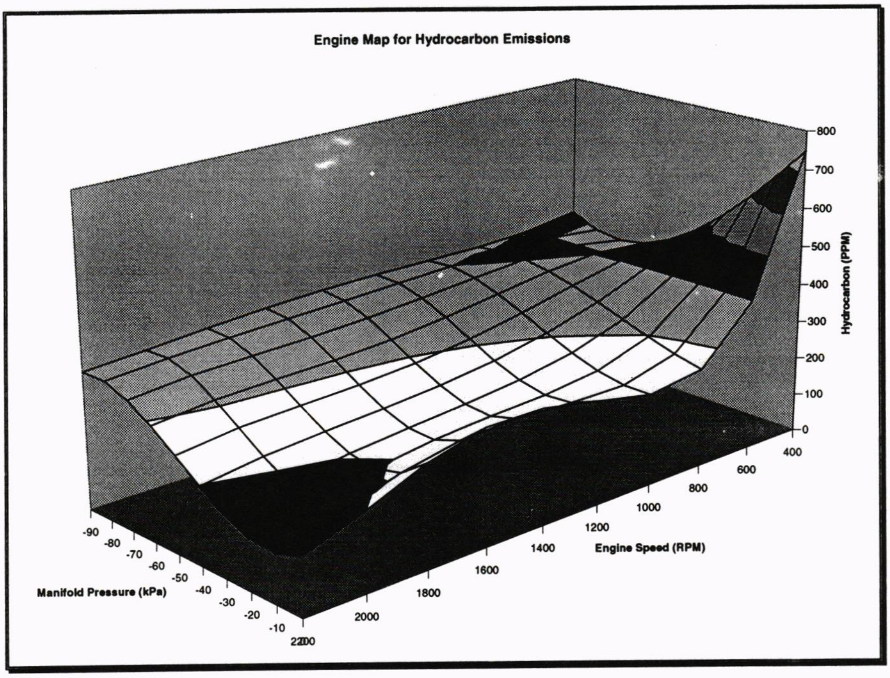

Figure 1 Typical Engine Map for Hydrocarbons

Table 1 Equation and Coefficients of hydrocarbon Engine Map

z=a00+a01*y+a02*y^2+a03*y^3+a04*y^4+a10*x+a11*x*y+a12*x*y^2+a13*x*y^3+a14*x*y^4+a20*x^2+a21*x^2*y+a22*x^2*y^2+a23*x^2*y^3+a24*x^2*y^4+a30*x^3+a31*x^3*y+a32*x^3*y^2+a33*x^3*y^3+a34*x^3*y^4+a40*x^4+a41*x^4*y+a42*x^4*y^2+a43*x^4*y^3+a44*x^4*y^4

a00	2557	**a23**	-1.21E-09
a01	-7.054	**a24**	2.03E-13
a02	0.007618	**a30**	-0.00126
a03	-3.43E-06	**a31**	1.83E-06
a04	5.43E-10	**a32**	9.21E-10
a10	65.32	**a33**	-9.40E-13
a11	-0.2362	**a34**	1.72E-16
a12	0.000285	**a40**	-2.70E-11
a13	-1.36E-07	**a41**	1.14E-13
a14	2.23E-11	**a42**	-1.56E-16
a20	0.3642	**a43**	8.59E-20
a21	-0.00165	**a44**	-1.63E-23
a22	2.39E-06		

3 DATA COLLECTION

Obtaining the data to calculate typical driving will be based around the use of Global Positioning System (GPS) receivers to record the time position and speed data at a update rates of once per second in conjunction with the instrumentation in the TSC car. The TSC has a wealth of experience in using GPS for travel time studies and congestion analysis (Zito and Taylor 1995 and Zito and Taylor 1994). The TSC already has a number of GPS receivers that can be used to obtain the positional data together with an available laptop that can be used to store the data. Both the positional data and the engine data that will be collected on a second by second basis, if the engine maps have been derived the total data set will include:

Table 2 Vehicle Parameters Logged in Real Time

Variable	Measurement Units	Variable	Measurement Units
Time	Sec	Air Conditioning	On/off
Distance	Km	Power / Economy mode	On/off
Speed	Km/h	Engine Gear	Gear (1 to 4)
Fuel Consumption	L	HC	ppm
RPM		NOx	ppm
Manifold Pressure	Pa	CO	ppm
Throttle Position	Ratio	CO2	ppm
Engine Temperature	°C	O2	ppm
		GPS position	Latitude / Longitude

The driving of the various routes will occur during different times of the day, ideally during the morning and evening peaks together with some interpeak driving. It is important to cover all aspects of metropolitan driving since recent trends (Oxlad 1997) show that the journey to and from work is becoming a smaller percentage of total commuter trips. Therefore the interpeak trips need to be represented in any sort of standard driving cycle.

4 SOCIO ECONOMIC REGIONS IN ADELAIDE

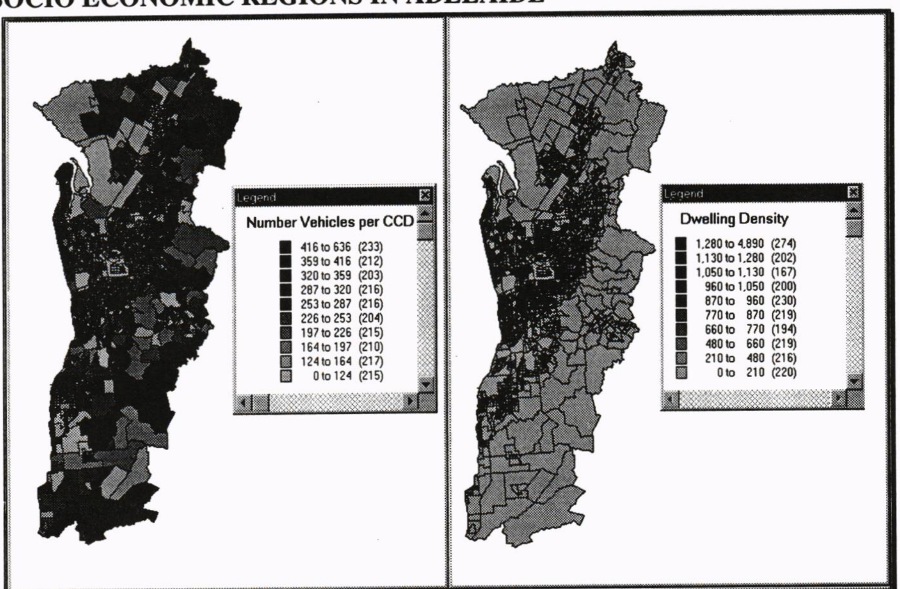

Figure 2 Typical Demographic Features of the Adelaide Statistical Division

Figure 2 shows some typical demographic maps of the Adelaide statistical division. This data was derived from the CDATA96 product that has all of the 1996 Census data in a GIS format, ready for mapping and analysis. The map on the left-hand side shows the total number of cars per census collection district. The other map shows the dwelling density of the same region. In both maps the darker colours reflect the higher values while the lighter represent the lower values. Kenworthy and Newman (1982) suggested these and other parameters to try and spilt a region into various socio demographic areas that could possible represent different driving patterns within them. Typically in all of the demographic variables suggested by Kenworthy and Newman (1982) when applied to the Adelaide situation showed the same sort of characteristics as in Figure 2. Namely three distinct regions northern, southern and central, this result thus shows that the driving characteristics should be based within these three regions.

Now that the regions have been established it is a matter of determining which roads in those regions should be driven on to obtain a representative sample of driving in that region. Figure 3 shows a map of the main arterials in the Adelaide regions with the traffic volumes shown as darker for the higher volumes and lighter for the lower volumes. It is envisaged that the proportion of driving within these regions will be proportioned with respect to the traffic volumes shown in Figure 3, for each of the three regions identified.

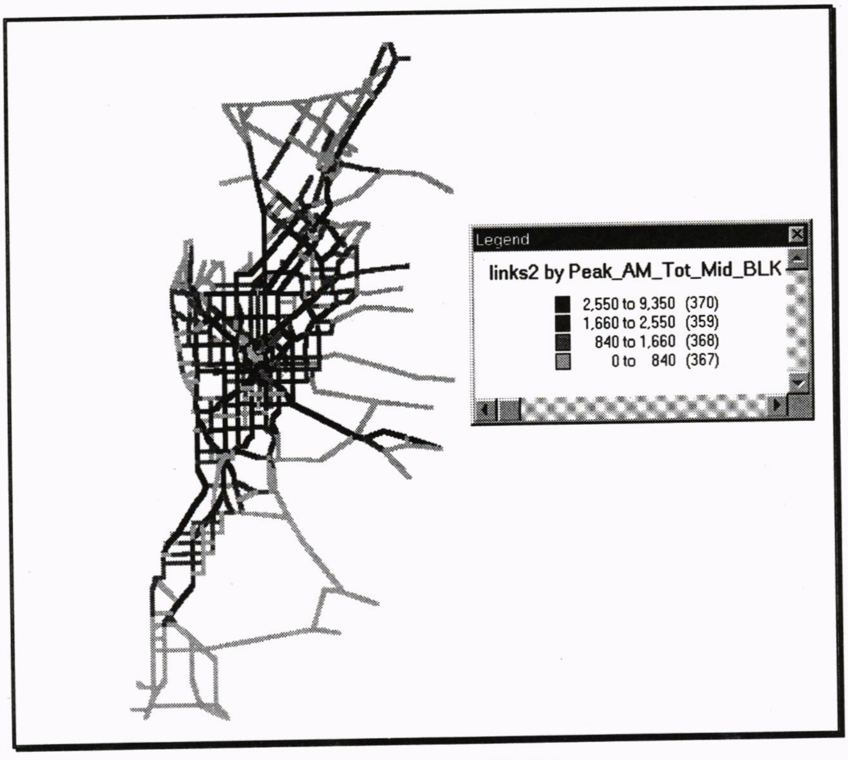

Figure 3 Adelaide Traffic Volumes

5 ANALYSIS OF TRAVEL TIME DATA

Once the GPS and other data has been collected, it will be imported into a Geographical Information System (GIS) were it can be displayed and analysed spatially as well as analytically. The TSC already has the Adelaide metropolitan street centre line data that will be added as a layer to the GIS so that the exact route, speed profile and time data can be determined on a link by link basis.

A combination of chase car and floating car techniques will be used to collect on-road data and hence obtain speed time profiles. This involves using the TSC instrumented vehicle (fitted with GPS) travelling behind a targeted vehicle or blending in with the traffic stream. As Figure 4 shows this will enable a detailed picture of time, speed and position to be obtained at update rates of up to once per second. Therefore not only will a detailed picture of speed profile and time information be obtained but also when imported into a GIS, a spatial distribution of where these speeds occurred can be obtained. The other advantage of using a GIS is that spatial and numerical analysis of the data can be performed. It is envisaged that differential GPS will be used to track the vehicles thereby enhancing positional accuracies to at least ±5m and instantaneous speed accuracies to at least ±2km/h, (Zito et al 1995), using the existing GPS receivers possessed by the TSC. Differential GPS is available in all capital cities in Australia and some regional centres. Through the Triple J radio network; the TSC has subscribed to this service and has the capability to receive the differential correction in such areas.

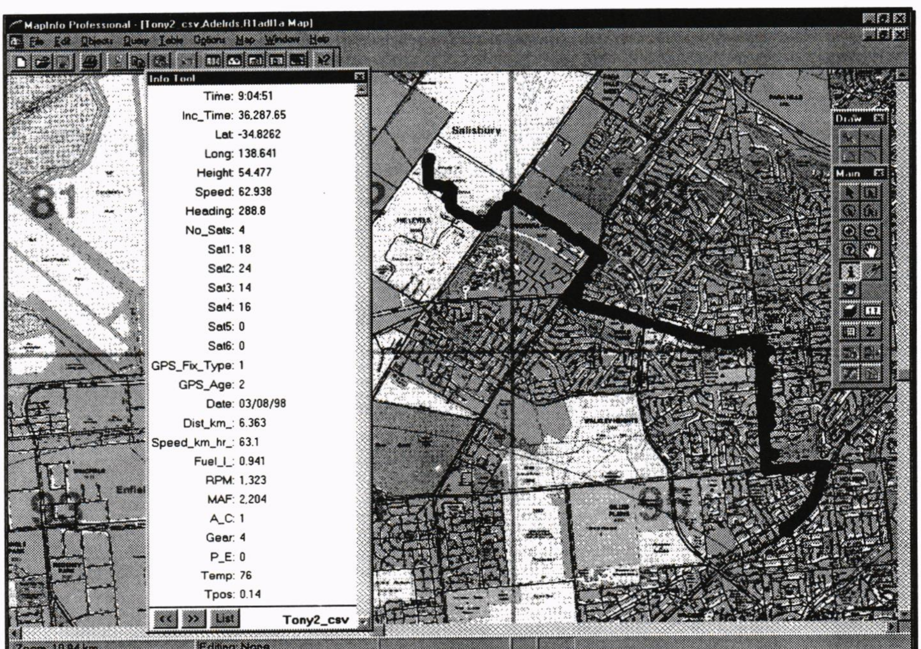

Figure 4 TSC Instrumented Car Travelling through Street Network

Figure 4 shows the ability of GIS to display the position of the car in the street network with the circles as well as the ability to associate the above mentioned variables to each circle as shown by the Info Tool dialog box. In this way data can be queried using standard database techniques and also queried spatially. To give the data collected added value GIS has the ability to over lay different databases. Figure 4 shows how the collected data has been overlaid with a raster street directory image allowing the user to read directly off the map the street names. In addition another vector layer of street centrelines had been added the attributes associated with this database include the geographic coordinates of the links as well as the address ranges for each side of the road. This database allowed the raster image to be georeferenced so that it is spatially correct, hence GPS positions can be overlaid on the map.

6 EXTRAPOLATION OF DATA

Since the raw data includes fuel consumption and possibly emissions it will be a matter of correlating these figures to the driving data collected to come up with the appropriate emissions models. The next stage of this process will be to extrapolate this data so that it is representative of the South Australian vehicle fleet. This can be achieved by the use of the Federal Office of Road Safety's 1996 report on in-service vehicle emissions (FORS 1996) which includes results of dynamometer tests on a number of in-service vehicles. These results could then be used to scale the emission and fuel consumption data obtained from the instrumented vehicle to get a representative picture of the South Australian vehicle fleet. The TSC already has the ABS TRANSTATS program, which will be used to determine the numbers of each type of vehicle in the vehicle fleet. This will allow the correct weighting factors to be given to each of the different types of vehicles tested by FORS consequently allowing a representative picture of fleet fuel consumption and emissions to be obtained.

7 CONCLUSIONS

The advantages of using GPS and GIS include:

- The ability to obtain second by second speed profile data
- The spatial display and analysis of data in a GIS
- The ease of transferability of GPS equipment from vehicle to vehicle

Some of the major research questions that will be addressed as a part of this research project include:

- Analysis of GPS driving data in a GIS environment
- Engine map of the TSC instrumented vehicle
- Derivation of fuel consumption and emissions models from on road data
- Extrapolation of data for the South Australian vehicle fleet
- Ability to perform "what if" scenarios with the emissions models i.e. changes to vehicle fleet and or travel times etc

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