REPRINT

Estimation of Car Fuel Consumption in Urban Traffic

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REFERENCE:

NOTE:
This paper is related to the intersection analysis methodology used in the SIDRA INTERSECTION software. Since the publication of this paper, many related aspects of the traffic model have been further developed in later versions of SIDRA INTERSECTION. Though some aspects of this paper may be outdated, this reprint is provided as a record of important aspects of the SIDRA INTERSECTION software, and in order to promote software assessment and further research.
ESTIMATION OF CAR FUEL CONSUMPTION
IN URBAN TRAFFIC

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ABSTRACT

The concept of a hierarchy of fuel consumption models is discussed where models of different levels of detail are applicable to the various scales of traffic systems. Fuel consumption models of four levels of detail are described and easy to use functions and graphs are presented to assist in their application. The areas of use of each model are described and the appropriate fuel consumption model for various traffic models is given. The fuel consumption models range from a detailed energy-related instantaneous model to the aggregate average travel speed model. They are interrelated, forming part of the same modelling framework with an aggregate model being derived from a more detailed model. The vehicle parameters are explicit at all model levels but, for simplicity here, models are presented with a set of default parameters. The more detailed models are structured and calibrated so that the various components of fuel consumption are estimated separately. This allows the incremental effect on fuel consumption of changes in traffic management to be estimated. Examples of the use of each model are given.

INTRODUCTION

1. In recent years attention has focused on the use of traffic management as a means of reducing car fuel consumption. A large body of analytical aids exist to assist in the estimation of fuel consumption in urban traffic. However, recent research, particularly that reported by Bowyer et al. (1984), has revealed the need for careful selection of these aids for a particular management task to ensure their cost effective use.

2. There are two primary means of deriving estimates of fuel consumption for use in urban traffic management. These are on-road measurement and using fuel consumption models. The use of models has many advantages over direct on-road measurement. Firstly, model estimates of fuel consumption are unaffected by weather conditions and changes in vehicle fuel consumption characteristics. Secondly, when combined with traffic models, fuel consumption models can be used for comparing different traffic management schemes or policies in advance. Finally, direct on-road measurement is often costly, especially if various traffic management schemes are to be evaluated, and it is difficult, if not impossible, to ensure similar operating conditions for the various schemes. It has therefore been necessary to establish rigorous models to estimate car fuel consumption which are applicable to the range of traffic management applications.

3. Models which are applicable for a particular area of use may be unduly complicated or of insufficient accuracy for another area of use. Akcelik et al. (1983) have shown that a hierarchy of vehicle fuel consumption models exists which includes models ranging from a basic energy-related model to the more aggregate average travel speed model.

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The choice of model depends on the intended application, the available data and the accuracy required.

4. In this paper, fuel consumption models of four levels of detail are described and easy to use functions and graphs are presented to assist in their application. The areas of use and the data requirements of each model are described and the appropriate fuel consumption model for various traffic models is given. The functions and graphs have been drawn out of a comprehensive guide to fuel consumption models by Bowyer, Akcelik and Biggs (1985) and are presented here for a 'default car' in urban driving conditions.

**FUEL CONSUMPTION MODELS**

5. Fuel consumption models have applications in widely diverse areas. These include automotive engineering, design of traffic management schemes, transport management and analysis of transport infrastructure and urban form. No one model is suitable for use in all areas. For a model to be applicable in a particular area, it must be able to predict the incremental effects on fuel consumption resulting from changes in parameters or designs applicable in that area. Thus, an instantaneous model is required to determine the difference in fuel consumption between stop and give-way control at an intersection while the average travel speed model is suitable for determining the effect on fuel consumption of various urban planning policies. Akcelik et al. (1983) showed that the existing fuel consumption models form a hierarchy and that each model is appropriate to a particular scale of traffic system.

6. Fuel consumption models of four levels of detail will be described. These are, in increasing order of aggregation:

(a) an energy-related instantaneous fuel consumption model,

(b) a four-mode elemental model of fuel consumption,

(c) a running speed model of fuel consumption, and

(d) an average travel speed model of fuel consumption.

All four models are inter-related and form part of the same modelling framework. A simpler model is derived from a more complicated model, e.g. the elemental model from the instantaneous model, keeping the vehicle characteristics such as mass, drag function and energy efficiency as explicit parameters at all model levels. Vehicle characteristics are likely to change over time and from country to country, and therefore this is a particularly useful property of the models. The more detailed models are structured and calibrated so that the various components to fuel consumption are estimated separately. This allows the incremental effect on fuel consumption of changes in traffic management to be estimated.

7. For simplicity here, only the instantaneous fuel consumption model is described in any detail. However, because of the derivation procedure, many of the features and properties of this model are present in the more aggregate models. Easy to use functions and graphs are given for the more aggregate models based on a 'default car' in urban driving conditions. The default car is defined by the parameters given in Table I and all parameters related to the speed profile and driving environment were calibrated using on-road data collected in Sydney. Use of the models is illustrated by estimating the fuel consumption for the trip segment shown in Fig. 1. A full description of all models, together with details of model calibration and worked examples, are given in a guide to fuel consumption analyses by Bowyer, Akcelik and Biggs (1985).

**AN INSTANTANEOUS MODEL OF FUEL CONSUMPTION**

**AREAS OF USE AND DATA REQUIRED**

8. The instantaneous fuel consumption model is suitable for use in the detailed assessment of the impacts of proposed traffic management schemes for individual intersections, road sections or small sub-area networks. A model of this level of detail is particularly useful when the management schemes produce only small differences in the speed profile and when grades are variable. Instantaneous traffic data must also be available. These include instantaneous values of speed, v, and grade, G, for a car when driven through the particular traffic system. The unit of time is typically one second and the speed data must be of sufficient accuracy to calculate instantaneous acceleration rates, a.
TABLE I
DEFAULT VEHICLE PARAMETERS APPLICABLE TO ALL MODELS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>0.444</td>
<td>Idle fuel rate in mL/s</td>
</tr>
<tr>
<td>$I_i$</td>
<td>1600</td>
<td>As $a$ but in mL/h</td>
</tr>
<tr>
<td>$M$</td>
<td>1200</td>
<td>Mass in kg</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.090</td>
<td>Energy efficiency parameter in mL/kJ</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.045</td>
<td>Energy-acceleration efficiency parameter in mL/(kJ m/s$^2$)</td>
</tr>
<tr>
<td>$b_1$</td>
<td>0.333</td>
<td>Drag force parameter in kN, mainly related to rolling resistance$^*$</td>
</tr>
<tr>
<td>$b_2$</td>
<td>0.00108</td>
<td>Drag force parameter in kN/(m/s)$^2$, mainly related to aerodynamic resistance$^*$</td>
</tr>
</tbody>
</table>

$^*$ $b_1$ and $b_2$ are also related to the component of drag associated with the engine.

![Fig. 1 — Speed-time trace and estimated instantaneous fuel consumption](image)

DESCRIPTION OF MODEL

9. The instantaneous fuel consumption model relates fuel consumption to:

(a) the fuel to maintain engine operation, estimated by the idle rate, $a$,
(b) the energy consumed (work done) by the vehicle engine to move the vehicle,
(c) the product of energy and acceleration during periods of positive acceleration.

The energy consumed in moving the vehicle is further separated into drag, inertial and grade components. Part (c) allows for the inefficient use of fuel during periods of hard acceleration.

10. The fuel consumption rate per unit time, $f_t$, can be estimated by:

$$ f_t = a + \beta_1 R_D \nu + (\beta_2 M a^2 \nu^2 / 1000) \quad \text{for } R_T > 0 $$

and

$$ f_t = a + \beta_1 R_T \quad \text{for } R_T < 0 $$

where

$\nu = $ speed in m/s,

$a = $ instantaneous acceleration rate in m/s$^2$,

$R_T = $ total force required to drive the vehicle, which is the sum of drag force ($R_D$), inertial force ($R_I$) and grade force ($R_G$) in kN:

$$ R_D = b_1 + b_2 \nu^2 $$

$$ R_I = M a / 1000 $$

$$ R_G = 9.81 M (G / 100) / 1000 $$

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where

\( G \) is the per cent grade which is negative for downhill, and

\[ a, b_1, b_2, M, b_1, b_2 \] are vehicle parameters defined in Table I.

Eqn (1) for the default car, with parameters given in Table I, becomes:

\[
f_t = 0.444 + 0.090 R_T v + (0.054 a^2 v)a > 0 \quad \text{for} \ R_T > 0
\]

\[ = \alpha \quad \text{for} \ R_T < 0 \quad (5)\]

where the total tractive force is

\[ R_T = 0.333 + 0.00108 v^2 + 1.20 a + 0.1177 G \quad (6)\]

11. The instantaneous model has been found to estimate the fuel consumption during constant speed driving and acceleration (including hard accelerations) to within 10 per cent of measured values and to within 5 per cent over acceleration-cruise-deceleration cycles. Further details on the model and calibration procedures are given in Bower et al. (1985) and Biggs and Akcelik (1985a).

EXAMPLE

12. The speed time trace in Fig. 1 represents the instantaneous speeds for a car travelling over a road section comprised of 0.65 km prior to a traffic signal and 1.05 km after the signal. The total micro-trip takes 118 seconds and involves a cruise-deceleration-idle-acceleration-cruise cycle. Assume that there is zero grade. Estimate the total fuel consumption during this micro-trip for the default car.

13. Even with this simple example, eqn (5) must be applied 118 times. Thus, a computer program has been used to calculate the instantaneous fuel consumption rates. These rates are also plotted in Fig. 1. For example, consider the simple case at the point where \( t = 30 \) seconds at which the speed is constant. The fuel consumption rate is calculated as follows:

\[
v = 60 \text{ km/h} = 16.7 \text{ m/s}
\]

\[
a = 0 \text{ m/s}^2
\]

\[
R_T = 0.333 + 0.00108 \times 16.7 \text{ m/s} \times 16.7 \text{ m/s} = 0.6331 \text{ kW}
\]

\[
f_t = 0.444 + 0.090 \times 0.6331 \times 16.7 \text{ m/s} = 1.39 \text{ mL/s}
\]

By summing the instantaneous values, the total fuel consumption over the complete micro-trip is found to be 231 mL.

A FOUR-MODE ELEMENTAL MODEL OF FUEL CONSUMPTION

AREAS OF USE AND DATA REQUIRED

14. The areas of use of the elemental model are similar to those of the instantaneous model. In particular, it is suitable for predicting the incremental effects of delays and number of stops/stops due to traffic control devices. Hence, it is useful for the design of traffic control and management schemes. The elemental model requires only macroscopic data such as cruise speeds, \( v_c \) number of stops and stopped time, \( t_s \). The section distance, \( x_s \), and average grade prior to and after the intersection for each road section in the traffic system are also required. More accurate estimates will be obtained if initial and final speeds (\( v_i \) and \( v_f \)) in each acceleration and deceleration are known and if acceleration and/or deceleration times and/or distances are known, rather than estimated values, can be used.

DESCRIPTION OF MODEL

15. The elemental model estimates the fuel consumed over any road section by the sum of the fuel consumed during each mode of driving over that section. The total fuel consumption over a cruise-deceleration-idle-acceleration-cruise cycle (as for example, in Fig. 1) is therefore estimated by summing over each mode as follows:

\[
R_s = f_{C_1}(x_{S_1} - x_d) + F_d + at_i
\]

\[
+ f_s + f_{C_2}(x_{S_2} - x_a) \quad (7)
\]

where

\( f_c, f_{C_2} \) = cruise fuel consumption per unit distance (mL/km) for the initial and final cruise speeds, \( v_c \) and \( v_{C_1} \),

\( x_{S_1}, x_{S_2} \) = known section distances (km) prior to and after the intersection, respectively,

\( x_d, x_a \) = deceleration and acceleration distances (km), respectively,

\( F_d, F_a \) = total deceleration and acceleration fuel consumption (km), respectively,

\( \alpha \) = idle fuel consumption rate (\( \alpha = 0.444 \text{ mL/s} \) for the default car), and

\( t_i \) = idle or stopped time (s), assumed known.
The elemental model is comprised of a set of equations for estimating the cruise fuel consumption, and the acceleration and deceleration fuel consumptions. These functions were derived by integration of the instantaneous model and include vehicle parameters, initial and final speeds, acceleration and deceleration times and distances, average grades, etc. The full set of functions, including equations for calculating unknown parameter values, are given in Bowyer et al. (1985).

16. The cruise fuel consumption for a given cruise speed and the acceleration and deceleration fuel consumptions and distances for given initial deceleration and final acceleration speeds are shown in Figs 2 to 5 for the default car. It has been assumed that the final deceleration and initial acceleration speeds are zero, thus Figs 2 to 5 are only applicable for cycles involving a complete stop. In addition zero grade has been assumed. Fig. 2 includes the fuel consumption rates for constant speed travel and for cruising which involves some speed fluctuations. The cruise fuel consumption function was calibrated to include all speed fluctuations above 20 km/h. Figs 2 to 5 can be used in conjunction with eqn (7) to estimate the fuel consumption for the default car over a cruise-deceleration-idle-acceleration-cruise cycle.

17. The excess fuel consumed during a deceleration and an acceleration from speed $V_c$ to zero and back to $V_c$ compared to cruising the same distance at $V_c$ is shown in Fig. 6 for the default car. For example, for a stop-start from 60 to 0 and back to 60 km/h, the excess fuel consumption is 19 mL. Using the full set of functions given in Bowyer et al. (1985), it is possible to estimate deceleration and acceleration fuel consumption from and to any speeds, thus allowing the effect of slow-downs and move-ups in a queue to be modelled. In addition, excess fuel consumption for stops or slow-downs involving different initial and final cruise speeds can be estimated.

18. Estimates based on the elemental model have been found to be within 10 per cent of the instantaneous model values in 85 per cent of cases over idle-acceleration-cruise-deceleration cycles when only cruise speed, section distance and stopped time were known. On average the difference in estimates between the two models is less than 2 per cent.

EXAMPLE

19. Estimate the total fuel consumed by a car over sections of road, $X_{81}$ and $X_{82}$, prior to and after a traffic signal. The vehicle follows the speed-time trace given in Fig. 1.

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![Fig. 2 — Cruise fuel consumption rate as a function of average cruise speed](image-url)
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20. From Fig. 1 the required speeds for each drive mode are:

Cruise: \( v_{C1} = 60 \) and \( v_{C2} = 90 \text{ km/h} \)
Deceleration: \( v_i = 60 \) and \( v_f = 0 \text{ km/h} \)
Acceleration: \( v_i = 0 \) and \( v_f = 90 \text{ km/h} \)

Section distances are \( x_{a1} = 0.65 \text{ km} \) and \( x_{a2} = 1.05 \text{ km} \). Using the values found from Figs 2 to 5, total fuel consumption is calculated as follows:

\[
F_s = 92(0.65 - 0.16) + 10 + 0.444 \\
\times 20 + 96 + 113(1.05 - 0.44) \\
= 229 \text{ mL}
\]

This compares with 231 mL calculated using the instantaneous model.

A RUNNING SPEED MODEL OF FUEL CONSUMPTION

AREAS OF USE AND DATA REQUIRED

21. The running speed model is suitable for estimation of fuel consumption for a trip, but not for short road sections or for the design of traffic management schemes. A trip will typically be longer than 1 km. The minimum data required to apply the running speed model are travel time, \( t_s \), distance, \( x_s \) and stopped time, \( t_i \), over the total trip. Increased accuracy can be achieved if the initial and final speeds in each acceleration are known. Functions for estimating the running speed, \( v_r \), and stopped time from average travel speed, \( v_s \), allow the running speed model to be used when only \( v_s \) is known.

DESCRIPTION OF MODEL

22. The running speed model estimates the fuel consumed during the idle and non-idle (or running) modes separately. The form of function used to estimate the 'running' fuel consumption is similar to the cruise
fuel consumption function of the elemental model, but with speed fluctuations down to zero allowed. The total fuel consumption, \( F_s \), in mL, over a road section is estimated by:

\[
F_s = \frac{F_r}{x_s} + \alpha t_i
\]

where

\( f_r \) = fuel consumption per unit distance (mL/km) excluding stopped time effects, and

\( \alpha \) = idle fuel consumption rate in mL/s (\( \alpha = 0.444 \) mL/s for the default car).

The values of distance, \( x_s \) (km), and stopped time, \( t_i \) (s), are known. The fuel consumption rate, \( f_r \), is a function of the average running speed, \( v_r \), which is given by:

\[
v_r = \frac{3600 x_s}{(t_s - t_i)}
\]

The general equation giving \( f_r \) as a function of the vehicle parameters, average grade and the change in positive kinetic energy (calculated from the initial and final speeds during each acceleration) is given in Bowyer et al. (1985). The relationship between \( f_r \) and running speed is shown in Fig. 7 for the default car and zero grade.

Such a restriction is necessary for the average travel speed model. Fig. 8 shows the relationship between the fuel consumption per unit distance, \( f_x \), and \( v_x \) using the running speed model for urban driving in Sydney. Total fuel consumption is then estimated by \( F_s = x_s f_x \).

24. The running speed model was found to predict fuel consumption within 10 per cent of the instantaneous model estimate on 67 per cent of cases for idle-accelleration-cruise-deceleration cycles of at least 0.7 km when only the running speed was known. When initial and final speeds during each acceleration are also known, this increased to 97 per cent. For trips over 10 km, estimates were within 10 per cent on 99 per cent of cases.

**EXAMPLE**

25. Estimate the total fuel consumed for the micro-trip depicted in Fig. 1 using the running speed model.

26. From Fig. 1, section distance, \( x_s = 0.65 + 1.05 = 1.7 \) km, \( t_s = 11.0 \) s and \( t_i = 66 - 46 = 20 \) s. The average running speed is therefore,

\[
v_r = \frac{3600 \times 1.7}{(118-20)} = 62.4 \text{ km/h}
\]

and using \( f_r = 106 \) from Fig. 7, the section fuel consumption is:

\[
F_s = 1.7 \times 106 + 0.444 \times 20 = 189 \text{ mL}
\]
In this example the running speed model underestimates total fuel consumption considerably (189 compared to 231 mL for the instantaneous model). This is due, in part, to the default estimates of the total positive kinetic energy change. Generally, the model is suited to estimating fuel consumption over trips, rather than short road sections as in this example.

**AN AVERAGE TRAVEL SPEED MODEL**

**AREAS OF USE AND DATA REQUIRED**

27. The average travel speed model is suitable for estimation of total fuel consumption in large urban traffic systems and for assessing the impacts of transport management schemes which are likely to impact on average travel speeds and the level of travel demand. This model is accurate only for average travel speeds less than 50 km/h. The only data required is the vehicle travel distance, $x_s$, and either the average travel speed, $v_s$, or the travel time, $t_s$.

**DESCRIPTION OF MODEL**

28. The average travel speed model relates fuel consumption per unit distance, $f_x$, to the inverse of average travel speed:

$$f_x = f_1/v_s + b$$  \hspace{1cm} (10)

where

$f_1 =$ idle fuel consumption rate in mL/h ($f_1 = 3600 \times a$), and $v_s =$ average travel speed ($v_s = 3600 x_s/t_s$),

$b =$ parameter related to the drag, inertia and grade components of fuel consumption and is dependent on the vehicle parameters and driving environment.

The fuel consumption rate for the default car was found to be

$$f_x = 1600/v_s + 73.8$$  \hspace{1cm} (11)

using calibration data collected in urban driving in Sydney. Total travel fuel consumption, $F_S$ (mL), is then estimated by:

$$F_S = x_s f_x$$  \hspace{1cm} (12)

The dependence of $f_x$ on the driving environment is shown in Fig. 8. When average travel speeds are greater than 50 km/h the running speed model, with running speed and idle time estimated from average travel speed, should be used (see Fig. 8). The fuel consumption rate is also dependent on car size as shown in Fig. 9. The method of adjusting the $b$ parameter for different vehicle parameters is described in Bowyer et al. (1985) and a full discussion of the average travel speed model is given in Biggs and Akcelik (1985b).

29. The average travel speed model was found to predict fuel consumption to within 5 per cent of the instantaneous model estimate on 84 per cent of cases for trips over 10 km with $v_s$ less than 50 km/h.

![Fig. 9 — Fuel consumption per unit distance as a function of average travel speed for a small, medium and large car in general urban driving](image)

**EXAMPLE**

30. Estimate the total fuel consumption for the micro-trip shown in Fig. 1 assuming only the average travel speed is known.

31. Applying the average travel speed model,$$v_s = 3600 \times 1.7/118 = 51.9 \text{ km/h}$$

and $f_x = 105$ mL/km from Fig. 8 assuming the 'other urban' driving environment. Trip fuel consumption is therefore,$$F_S = 1.7 \times 105 = 179 \text{ mL}$$
However, as the average travel speed is greater than 50 km/h, the running speed model based on average travel speed should be used. Trip fuel consumption is estimated from Fig. 8 to be:

\[ F_s = 1.7 \times 110 = 187 \text{ mL} \]

These estimates are significantly less than the instantaneous model estimate (231 mL) and, in general, models using average travel speeds are too coarse to give accurate estimates of fuel consumption in this micro-trip context.

### TABLE II

<table>
<thead>
<tr>
<th>Fuel Consumption Model</th>
<th>Required Traffic Variables*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Speed</td>
<td>( x_{i,j} ) for each trip or network</td>
</tr>
<tr>
<td>Running Speed</td>
<td>( x_{i,j} ) for each trip or road section</td>
</tr>
<tr>
<td>Option a.</td>
<td>( y_{i,j} ) for each trip or road section</td>
</tr>
<tr>
<td>Option b.</td>
<td>( y_{i,j} ) for each trip or road section</td>
</tr>
<tr>
<td>Option c.</td>
<td>( y_{i,j} ) for each acceleration, for each trip or road section</td>
</tr>
<tr>
<td>Element</td>
<td>( x_{i,j} ) number of stops for each road section</td>
</tr>
<tr>
<td>Option a.</td>
<td>( x_{i,j} ) for each road section</td>
</tr>
<tr>
<td>Option b.</td>
<td>( x_{i,j} ) for each acceleration/deceleration, for each road section</td>
</tr>
<tr>
<td>Instantaneous</td>
<td>( v ) for each second over a road section</td>
</tr>
</tbody>
</table>

* Variables defined in Annotations and Definitions section at start of report.

### TABLE III

<table>
<thead>
<tr>
<th>Traffic System Scale</th>
<th>Traffic Model</th>
<th>Fuel Consumption Module Specification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro</td>
<td>UTPS</td>
<td>(a) No freeways: use average speed model, calculated at the total network level.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) With freeways: use running speed model (option a), calculated at the trip level.</td>
</tr>
<tr>
<td></td>
<td>LATM</td>
<td>Running speed model (option b), calculated at the route section level.</td>
</tr>
<tr>
<td></td>
<td>SATURN</td>
<td>Elemental model (option a), calculated at the route section level.</td>
</tr>
<tr>
<td></td>
<td>TRANSYT</td>
<td>Elemental model (option a), calculated at the link level.</td>
</tr>
<tr>
<td></td>
<td>SCATSIM</td>
<td>Elemental model (option b).</td>
</tr>
<tr>
<td></td>
<td>SIDRA</td>
<td>Elemental model (option b), calculated at the lane level.</td>
</tr>
<tr>
<td></td>
<td>MULTSIM</td>
<td>Instantaneous model, calculated at 1 second intervals.</td>
</tr>
<tr>
<td></td>
<td>INSECT</td>
<td>Instantaneous model, calculated at 1 second intervals.</td>
</tr>
</tbody>
</table>

### CONCLUSIONS

34. Easy to use functions and graphs have been given for four fuel consumption models and examples have been given to illustrate their use. These models cover the range of applications of fuel consumption models in the areas of traffic and transport management. The areas of use and data requirements of each model have been described. Traffic models are a primary means of obtaining data for fuel consumption models and the appropriate fuel consumption model for various traffic models has been given. The fuel consumption models are all inter-related and form part of the same modelling framework. Vehicle parameters are explicit at all model levels. This allows the user to choose vehicle parameters for a particular application. The changes in vehicle characteristics over time and from country to country are allowed for without need to derive new sets of regression equations. Full details on the four models are given in a guide to fuel consumption analyses by Bowyer, Akcelik and Biggs (1985).
REFERENCES


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David Biggs graduated from Monash University in 1978 with a Master of Science degree, majoring in Statistics. After graduating, he worked in Canada as a statistical consultant and research analyst for National Health and Welfare, the Atomic Energy Control Board and Industry, Trade and Commerce. He joined the transport work area at the the Australian Road Research Board in 1981 and has worked in the areas of urban system indicators and fuel consumption in urban traffic. He is currently studying the effect on fuel consumption of different forms of traffic management.

D.C. Biggs

Rahmi Akcelik graduated as a Civil Engineer (M.Sc.) from Istanbul Technical University, Turkey, in 1968, and received his Ph.D. degree in Transportation Engineering from the University of Leeds, England in 1974. He worked as a lecturer at the Black Sea University, Turkey, before he migrated to Australia in 1975. He worked as a traffic engineer with the National Capital Development Commission in Canberra for four years before he joined the Australian Road Research Board in 1979. He is a Principal Research Scientist in the road users work area of ARRB. His main interests have been in the traffic signal and fuel consumption areas of research and development.

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