APPENDIX A: TEST CYCLES

- The USA, Australia, Canada and Sweden use the US 1975 Federal Test Procedure (FTP) for urban driving and the US Highway Fuel Economy Test (HWFET) for highway driving. (Australia changed from the earlier US 1973 FTP in 1986).

- Most EC countries use the ECE cycle for urban driving and constant speed 90 kph and 120 kph tests as highway cycles.

- Japan uses a "10-mode" cycle for fuel consumption testing an "11-mode" cycle for emissions testing. Japan also uses a constant 60 kph test.

As a result it can be difficult to make international comparisons. The IEA has estimated the following conversion factors:

FIGURE 1:

$FC_{ECE} = FC_{75FTP} \times 1.12$

$FC_{ECE\ 90kph} = FC_{HWFET}$

$FC_{ECE\ 120kph} = FC_{ECE\ 90kph} \times 1.33$

$FC_{ECE} = FC_{10\ mode}$

$FC_{73\ FTP} = FC_{75\ FTP} \times 1.07$ (Australian testing, however, indicates a conversion factor of 1.05)

National average fuel consumption (NAFC) figures are derived by weighting the results of urban and highway drive cycle tests. Countries using the US 75 FTP and HWFET weight the results 55% urban and 45% highway. Most EC countries weight the urban, 90 kph and 120 kph tests one third each, while the UK weights are 40% urban, 50% 90 kph and 10% 120 kph.

All of these factors mean that statistical comparisons of vehicle fuel consumption between countries can only be used with caution.

Test procedures do not necessarily provide a good measure of expected on road fuel consumption. Actual driving is influenced by such factors as driver behaviour, terrain, traffic conditions and so on. Nevertheless, they give a good indication of trends in vehicle fuel use and a sound basis for comparison between different vehicles.

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Note: For additional references specifically relevant to the ITS models, see Appendix C.

APPENDIX C - EVALUATING ALTERNATIVE STRATEGIES DESIGNED TO IMPROVE THE FUEL ECONOMY OF PASSENGER VEHICLES IN AUSTRALIA: 1988-2005

Evaluating Alternative Strategies Designed to Improve the Fuel Economy of Passenger Vehicles in Australia: 1988-2005

David A. Hensher
Rhonda Daniels
Paul G. Hooper

Institute of Transport Studies
Graduate School of Management and Public Policy
University of Sydney
N.S.W. 2006

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1 Introduction

Household-based road transport accounts for 22 per cent of final energy consumption in Australia, and is the most heavily concentrated sector in terms of the type of fuel used, with virtually only petroleum products being consumed. 72.9 per cent of the total energy consumed in the road transport sector is consumed by light vehicles such as cars and station wagons (Donaldson et.al.1991). Over the period up to 2004-05, energy consumption in the Australian road transport sector is projected to grow at an average annual rate of 1.7 per cent (Donaldson et.al. 1990), a slowing down from the more optimistic 3.4 per cent per annum of the past fifteen years.

Existing econometric models of the household sector's demand for transport energy in Australia are macroeconomic in form, with energy demand per vehicle per unit of time explained and forecast in terms of real gross domestic product, real fuel prices and total vehicle registrations per person. A traditional time series specification is adopted with independent equations for vehicle registrations and fuel consumption(Hensher and Young 1991).

The approach developed in the current study adopts a much more comprehensive approach designed in particular to be sensitive to a very broad set of sources of influence on energy demand. A policy-sensitive modelling system should be capable of representing the role of macroeconomic effects such as government taxes on vehicles, fuel and maintenance; demographic trends such as the aging of the population and household downsizing; vehicle technology such as improvements in fuel efficiency, vehicle fleet depreciation and new vehicle downsizing; spatial opportunities such as distance from the central area of cities and access to public transport; and financial constraints such as income and access to a company car.

This paper presents a number of empirical forecasts of energy demand derived from the application of the model system outlined in Hensher et. al. (in press). Although the central focus is on forecasting household automobile energy demand other useful planning outputs are provided such as the demand for vehicle use and vehicles. In addition we evaluate the impact on government revenue and consumer welfare of a number of strategies to improve the fuel consumption of new passenger vehicles. The application uses the period 1985-88 as the base; the forecast years are 1995, 2000 and 2005.

2 Setting the Context

The next fifteen years present new challenges to the automobile industry. The environmental implications of previously economic-based decisions as embodied in the notion of sustainable development has elevated the energy dimensions of automobile engineering and demand to the place on political and planning agendas that it held in the early eighties following the fuel "crises" of the seventies.

The concern over greenhouse and ozone issues and the Toronto and Montreal goals has sent a number of signals to the Governments of the world to seek out ways of developing effective control strategies for achieving global solutions to atmospheric preservation. The Toronto greenhouse initial goal is to reduce CO_2 emissions from all sources by approximately 20% of 1988 levels by the year 2005. About one half of this reduction would be sought from energy efficiency and other conservation measures. The other half should be effected by modifications in supplies.

A major source of greenhouse emissions is pollutants produced by automobile use. In 1987-88 the private car was responsible for 54 percent of total carbon dioxide emissions from domestic transport (Cronin 1991), light commercial vehicles contributed another 11 percent. The consumption of petroleum products is currently forecast to grow at between 1 percent (low growth scenario) and 1.7 percent (high growth scenario) over the period 1990-2000. Strategies designed to reduce emissions and to conserve energy include improved fuel efficiency, alternative fuels (especially non-fossil fuels and bio-mass fuels), and the introduction of vehicle use reduction measures. While alternative fuels are likely to be a major contribution to a cleaner society, the scientific evidence coupled with the markets inability to make conventional fuels economically unattractive strongly points to little likelihood of any significant fuel substitution before 2005. Consequently the challenges for efficiency and conservation over the next 15 years are directed towards both technological modification of conventional automotive designs fuelled by automotive gasoline and diesel oil.

The emissions associated with greenhouse are correlated with both vehicle fuel economy and the rate of vehicle use for a given fuel type. Strategies designed to improve the fuel economy of automobiles have to be evaluated in the context of vehicle use and the incidence of new vehicles in the overall stock of vehicles on the road, otherwise the potential benefits of technology-based strategies may be more artificial than real. Some policies such as Corporate Average Fuel Economy (CAFE) standards impact on only new vehicles, whereas pricing policies can impact on all vehicles. At any point in time the new vehicles in the fleet typically represent 6% of on-road passenger vehicles, a small contribution to the automobiles overall emission of greenhouse gases.

The objective is to outline the way in which the household-based automobile demand modelling system can be used to evaluate the fuel consumption and energy demand implications of technology possibilities and a number of policy instruments. The major policy instruments tested by the model are:

1. Elimination of the 20 percent wholesale sales tax to increase sales volume and scrappage rates;
2. Compensating loss of revenue from elimination of the 20 percent sales tax by raising fuel levy;
3. A variable sales tax which reintroduces the idea of higher sales taxes on vehicles with relatively high fuel consumption. Targetted levels of undesirable fuel inefficiency will be identified, and

4. Increased fuel taxes affecting the unit fuel cost of vehicle use, as well as affecting the type of automobile purchased.

These broad types of policy instruments provide alternative and/or complementary ways of achieving fuel economy improvements, although the net impact on overall emission reductions is uncertain, depending on the extent to which the policies impact on both the fuel efficiency of the vehicle and the rate of vehicle use. Policies which impact on the technology of the vehicle without significantly affecting vehicle use in a way that yields no major savings in total energy demand and which may produce concomitant losses in consumer surplus are not desirable. A household-based automobile demand modelling system linked to the population of automobiles in the market can evaluate the implications of any technological or non-technological strategy in respect of sales-weighted fuel economy, vehicle use, total energy consumed and change in consumer surplus.

Although there is much still to be undertaken to achieve the 2005 target, much has already been achieved during the 1980's which enables industry experts to suggest that the passenger vehicles of the 1990's are expected to continue to be lighter than the current fleet and new vehicles (Automotive Industry Authority 1988,1990). Weight is one of a number of physical and performance attributes of vehicles which influence fuel economy (the partial correlation with the fuel efficiency of new 1988 vehicles is 0.70, the equivalent correlation for the total fleet in 1988 is 0.78). World forecasts associated with downsizing and material substitution expect the average car to reduce in weight from 1,210 kgs in 1988 to 1,065 kgs in 1995, with the value of each kilogram saved in 1988 doubling by 1995 (Automotive Industry Council 1988). The sales weighted average weight of new vehicles sold in Australia during the calendar year 1988 was 1,197 kg; this suggests that new vehicles in Australia are only marginally lighter than the world average. The trend in vehicle weight in Australia from 1981 to 1988 has not been encouraging; for both new and used vehicles the vehicle weighted average weight has remained almost constant or increased. A summary of key data for each class of vehicle (by manufacturer) is given in Table 1 for 1988 using the PAXUS 5-class system. Trends from 1981-1988 in market shares, fuel consumption, weight and prices are summarised in Figure 1.

Table 1 Trends in Fuel Efficiency ,Weight and Price 1981-1988

(i) All Vehicles

Fuel Consumption (70:30) **(litres/100 km)**

	Small	Medium	UMed	Lux	Ulx	Total
1981	8.75	10.59	14.39	12.77	13.70	11.86
1982	8.59	10.53	14.19	12.64	13.83	11.67
1983	8.54	10.44	14.11	12.55	13.68	11.56
1984	8.51	10.34	14.00	12.48	13.55	11.44
1985	8.44	10.24	13.90	12.30	13.26	11.32
1986	8.37	10.19	13.81	12.16	12.98	11.23
1987	8.33	10.13	13.68	12.05	12.81	11.14
1988	8.29	10.06	13.53	11.94	12.58	11.04

Fuel Consumption (55:45) **(litres/100 km)**

	Small	Medium	UMed	Lux	Ulx	Total
1981	8.41	10.21	13.78	12.20	13.00	11.39
1982	8.25	10.13	13.58	12.08	13.12	11.19
1983	8.19	10.05	13.50	12.00	12.97	11.08
1984	8.16	9.94	13.38	11.94	12.85	10.96
1985	8.09	9.84	13.27	11.77	12.57	10.84
1986	8.03	9.79	13.18	11.65	12.30	10.74
1987	7.99	9.73	13.05	11.55	12.15	10.66
1988	7.95	9.67	12.90	11.44	11.95	10.56

Weight (kg)

	Small	Medium	UMed	Lux	Ulx	Total
1981	848	1070	1379	1366	1501	1165
1982	856	1076	1375	1358	1507	1162
1983	857	1076	1376	1350	1500	1159
1984	860	1078	1376	1341	1492	1158
1985	862	1079	1375	1331	1471	1157
1986	865	1082	1375	1326	1456	1156
1987	867	1087	1374	1322	1452	1158
1988	872	1094	1373	1317	1447	1160

Nominal Price **($A, 1988)**

	Small	Medium	UMed	Lux	Ulx	Total
1981	3883	4961	4045	8839	23115	4645
1982	4212	5276	4827	9734	23696	5232
1983	4320	5517	4999	10097	24422	5452
1984	4634	6068	5427	10999	26134	5973
1985	5081	6538	5750	11804	29223	6529
1986	5651	7050	5720	12455	34806	6942
1987	6469	7730	6461	13789	39679	7818
1988	7227	8430	8906	15459	44891	9404

(ii) New Vehicles

Fuel Consumption (70:30) **(litres/100 km)**

	Small	Medium	UMed	Lux	Ulx	Total
1981	7.45	10.35	12.07	12.52	13.60	10.29
1982	7.54	10.09	12.01	11.72	14.24	10.14
1983	7.81	9.59	12.10	11.85	12.97	9.96
1984	8.25	9.35	12.31	11.94	13.00	10.21
1985	7.78	9.37	12.70	10.90	12.08	10.13
1986	7.67	9.42	12.50	10.58	11.53	10.03
1987	7.79	9.18	11.61	10.47	11.57	9.86
1988	7.80	8.99	11.24	10.22	11.27	9.62

Fuel Consumption (55:45) **(litres/100 km)**

	Small	Medium	UMed	Lux	Ulx	Total
1981	7.11	9.88	11.38	11.94	12.89	9.78
1982	7.19	9.62	11.34	11.25	13.49	9.64
1983	7.43	9.16	11.42	11.39	12.31	9.47
1984	7.84	8.94	11.59	11.47	12.30	9.71
1985	7.44	8.98	11.95	10.47	11.43	9.64
1986	7.35	9.02	11.77	10.20	10.93	9.55
1987	7.51	8.78	11.06	10.08	11.04	9.44
1988	7.52	8.60	10.71	9.85	10.78	9.20

Weight (kg)

	Small	Medium	UMed	Lux	Ulx	Total
1981	910	1129	1303	1377	1485	1145
1982	907	1111	1335	1304	1523	1142
1983	879	1084	1388	1286	1468	1125
1984	888	1096	1376	1271	1456	1147
1985	875	1088	1367	1254	1389	1139
1986	899	1132	1368	1273	1379	1157
1987	901	1180	1367	1272	1425	1189
1988	936	1200	1362	1236	1418	1197

Nominal Price **($A, 1988)**

	Small	Medium	UMed	Lux	Ulx	Total
1981	7075	8472	9931	15568	28769	9332
1982	7749	8877	12426	16728	32755	10594
1983	8424	10664	16533	19399	37279	12739
1984	9074	12460	16557	19678	39001	14059
1985	11060	13954	17265	22436	47376	15932
1986	11298	15518	15535	25628	59732	16601
1987	13952	16981	20743	32584	71359	19943
1988	14979	17895	25692	30893	71575	22782

Note: The 70:30 versus 55:45 split of the 'city' and 'highway' cycle are both presented. While the 70:30 split is empirically a more realistic mix, the 55:45 drive cycle is the internationally accepted FTP standard weighting for reporting comparative fuel consumption.

(ii) Market Share by Class for All and New Vehicles (percent)

	Small	Medium	UMed	Lux	Ulx	Total
New Vehicles						
1981	26.2	37.3	27.5	6.4	2.6	100
1982	27.9	33.9	27.9	7.7	2.5	100
1983	27.2	39.0	23.7	7.7	2.4	100
1984	24.2	37.2	27.6	8.2	2.7	100
1985	23.3	38.0	27.9	7.7	3.2	100
1986	28.9	28.9	30.8	7.5	3.8	100
1987	26.2	27.6	36.3	6.4	3.6	100
1988	26.8	28.9	34.4	5.8	4.2	100
New and Used Vehicles						
1981	22.6	30.7	41.0	5.0	0.7	100
1982	23.0	31.0	39.8	5.3	0.9	100
1983	23.4	31.7	38.4	5.5	1.0	100
1984	23.5	32.2	37.5	5.7	1.2	100
1985	23.5	32.7	36.6	5.9	1.4	100
1986	23.8	32.5	36.1	6.0	1.5	100
1987	24.0	32.3	36.0	6.1	1.7	100
1988	24.2	32.1	35.9	6.0	1.8	100

Automobile manufacturers are continually striving to improve the overall corporate average fuel efficiency of new vehicles while at the same time seeking to produce increasingly more sophisticated vehicles in terms of styling, comfort and electronic assistance for an increasingly discerning market of potential consumers. Product competition in the automotive market is intense among manufacturers' product lines. The manufacturers and their retail distributors have to understand the reasons that different passenger vehicle models have different market shares. This requires a knowledge (quantitatively or qualitatively) of consumer demands or tastes for vehicle attributes (price, fuel economy, styling, performance, reliability etc.) and the constraints which limit the translation of unconstrained tastes into actual purchase decisions.

Technological options in the main can only impact on vehicles yet to appear in the market, whereas the broader set of pricing options can influence the ownership and utilisation profiles of all vehicles both currently on the road and available for purchase today and in the future. In recognition of the fact that only 6% of all on-road passenger vehicles are less than one year old, it is clear that the effect of any major change in the technology of vehicles yet to come onstream will take some years to penetrate the market and hence benefit any policies geared towards fuel conservation or a slowing of the rate of growth of fuel consumption. The greatest determinant of the growth in fuel consumed is the rate of growth in the number of households after adjusting for household size (Train 1986).

Given the decision processes of manufacturers with respect to car designs and prices both at present and up to the year 2005, the analytical focus of our contribution is on competition among passenger vehicle models, based on consumer's demands for vehicle attributes and their choices among vehicle models.

Two important variables in this investigation are annual vehicle utilisation and vehicle fuel consumption (in litres per 100 kilometres). Manufacturers can influence both dimensions of the energy equation via the design of vehicles by appealing to the tastes of potential users as well as modifying the fuel efficiency of vehicles. Fuel efficiency per se however is not desired for its own sake but influences consumers' decisions because it affects the cost of operating an automobile.

Automobile attributes (e.g. weight, interior volume) and fuel consumption are related through a technical transformation function which can be estimated econometrically or documented exactly as a series of engineering mappings. Trade-offs between fuel consumption and the attributes of vehicles which are direct sources of consumer utility have to be identified in order to establish the relationship of fuel efficiency strategies to consumer demand for models of vehicles and levels of utilisation. Aside from fuel savings per km and possible changes in purchase price, fuel economy gains can be expected to lead to changes in other vehicle attributes which might reduce the perceived value to consumers. Valued attributes which might change include "style" (e.g. the longer, lower, wider look), acceleration, luxury, comfort, reliability and "image" (e.g. fully imported, European). Therefore consumer acceptance of passenger vehicles of the nineties and beyond, and changes in consumer welfare due to changes in vehicle attributes will depend critically on the degree to which manufacturers can, at competitive costs, maintain the levels of attributes relevant to purchase decisions in more fuel-efficient vehicles.

This recognition of the role of consumer demand makes it unavoidable that the tastes of the population must be accommodated within the overall approach to projecting fuel consumption of both new vehicles and the entire fleet. Manufacturers are not blind to consumer tastes and tend historically to introduce new vehicles with marginal changes to the critical attributes influencing consumer demand. Manufacturers are also aware that consumer tastes can be moulded by supply-side considerations, although it is a brave manufacturer who attempts to go against the general technological trend of the industry as a whole. Thus a knowledge of industry-wide trends is sufficient to guide likely scenarios of incremental change on an annual basis in vehicle design with respect to style, technology, performance and luxury.

The application phase of this study uses the demand model system parameterised on Sydney data and applies the models to all of urban Australia using Australia-wide data on the socioeconomic profile of the population of urban households and the profile of all passenger vehicles. That is, the models are estimated using Sydney data, but the parameters are assumed to be transferable to all of urban Australia. Thus the socioeconomic and demographic data represents all of urban Australia. To enable us to report best estimate projections for Australia as a whole, we introduce a number of assumptions on the profile of vehicle ownership, composition and utilisation for non-urban Australia. Our discrete-continuous choice model system is readily transferable to urban Australia, but not to non-urban Australia. The decision to apply the model system to Australia rather than Sydney alone is influenced by the richer information of important socio-demographic and automobile technology data available for the nation as a whole, plus the greater interest in the evidence at the national level.

1988 has been selected as the base year with the model system utilising data for 1985-88. 1988 is a national vehicle census year and is the year in which the most recent data on actual demand for automobiles and their energy requirements is most complete. Thus we are able to provide a benchmark base year model forecast which can be confirmed by observation.

3 A Synoptic Outline of the Application Strategy

The approach set out below involves two data bases:

1.**A Household Data Base (HDB).** A vehicle-level data set for a sample of households. We have available an urban areawide data base for 1985 which contains details of 2081 vehicles in a sample of Sydney households. Vehicle attributes and household socioeconomic characteristics are available for each vehicle. This enables us to estimate models which study the role of vehicle attributes in influencing choice of vehicle (hence fuel economy of the vehicle) and the annual kilometres travelled in the vehicle, allowing for the household context in which travel is demanded.

2.**A Population of Vehicles Data Base (PVDB).** A population wide data base of total registrations (new and used) of every make and model of vehicle registered in the base year (1988). This is also available for years 1981-1987, enabling us to calibrate the 1985 household model with the 1985 population of vehicle registrations. This data base identifies the PAXUS class of each model (small, medium, upper medium, luxury, upper luxury) and a full set of vehicle attributes (including fuel economy and price) together with scrappage rates.

The two data sets are jointly used in the following sequence of tasks:

1. The vehicle-level econometric models are estimated. The model system comprises two equations: annual kilometres travelled per vehicle and the unit fuel cost (cents per km.).Vehicle attributes including unit fuel cost and household constraints influence the amount of annual kilometres of each vehicle. Vehicle fuel efficiency and other variables influence unit fuel costs.The make/model and PAXUS class of each vehicle is known. Weights are applied to each vehicle in the sample to ensure that each sampled vehicle in the household data set represents the full set of registrations of the model and class on the road in 1985. The weight for each vehicle in class c is

% of all registrations in class c in year t / % of sampled vehicles in class c in year t.

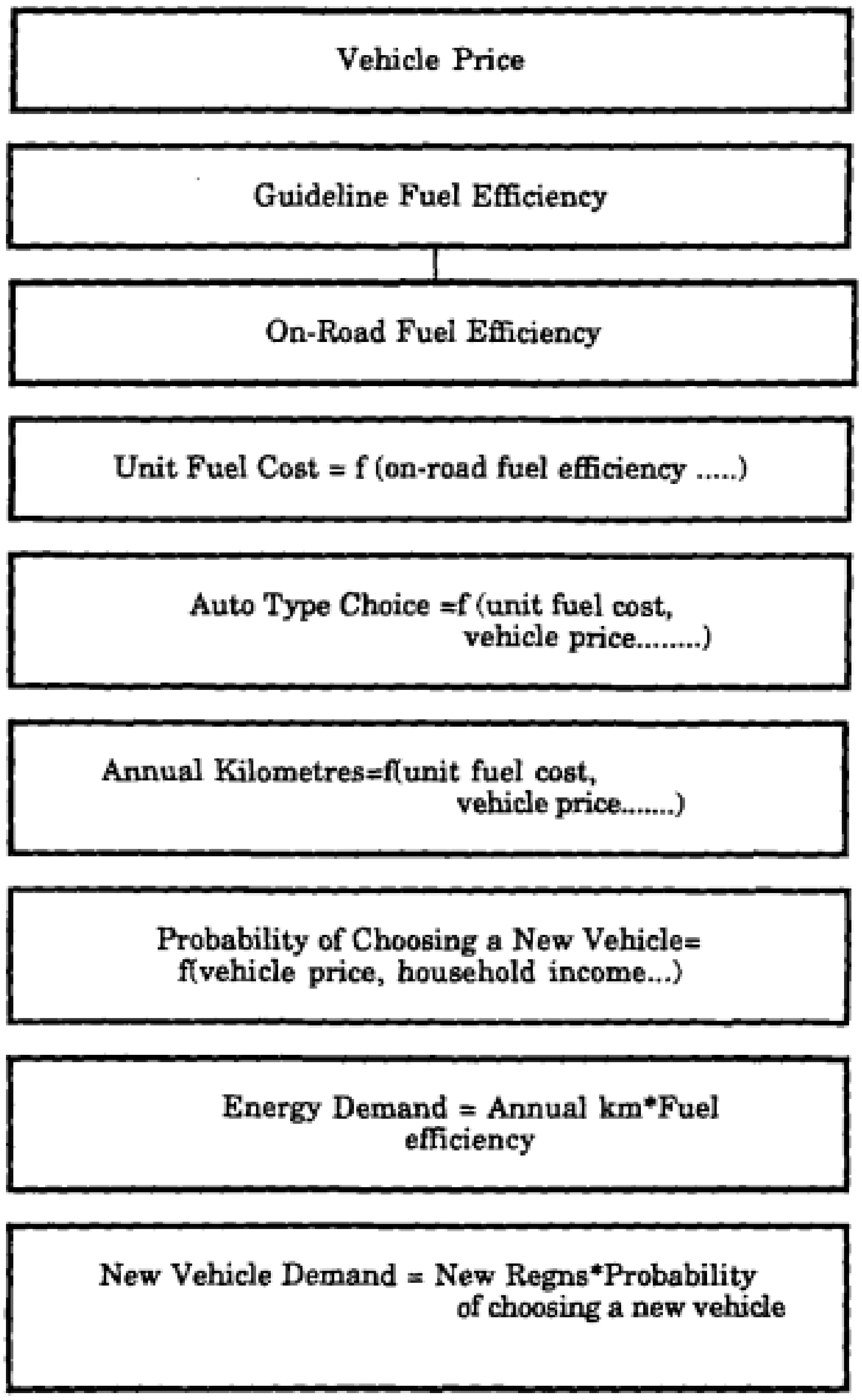
This weight ensures that the estimate of average annual vehicle kilometres for each class and the average fuel efficiency of each class are fully represented by the sampled vehicles. The resulting parameter estimates of the vehicle use and unit fuel cost models reflect the tastes of the population of households choosing the full set of vehicles on the road (assuming that the sampled households are representative of the population of households).

The known population registrations include all passenger vehicles. The econometric demand model is transferable to all major urban contexts, namely capital cities plus major provincial centres. Estimates of the split of registrations and vehicle use between urban and non-urban contexts in Australia are given in Table 3.3 of Working Paper no. 4.

3 The Critical Links in the Population-Based Applications System

The central models summarised in Figure 1 are an automobile type choice model, a vehicle price model, a vehicle fuel efficiency model and a vehicle use model. Interconnecting models are used to establish a mapping between the on-road fuel efficiency (VEFF) and the Federal guidelines on fuel efficiency based on the testing of representative new vehicles of each model according to Australian Standard 2077. This test has some weaknesses and has led researchers to suggest that it could be 15-20% optimistic. We have assumed a 70:30 split on the city and highway cycles to reflect observed driving cycles. Other interlinking equations are used to identify the relationship between vehicle prices, vehicle fuel efficiency and vehicle attributes. Throughout the modelling system, changes can be made at the vehicle model level to the technology of vehicles as well as the vehicle prices and household socioeconomic characteristics (the latter representing taste distributions within the population). Scrappage rates derived from the scrappage model are used to keep track of available used vehicles. In recent years scrappage rates have declined quite substantially, and are currently predicted to be 3% per annum on a registration-weighted basis. This is attributed to both higher relative prices of vehicle purchases, improved reliability of vehicles and a slowing down of the economy.

Figure 1. The Overall Model System for New Vehicle Market Analysis



The model system operates in an intuitive manner. Given the exogenous levels of influences on new vehicle prices, some of these influences being fuel economy related such as vehicle weight and acceleration, new vehicle prices are predicted. Likewise, given the influences on the fuel efficiency of new vehicles (assuming a 70:30 split on city and highway cycles) guideline fuel efficiency is predicted (or as an alternative directly adjusted into the future). The on-road fuel efficiency is predicted from the Federal guidelines fuel efficiency by the application of a mapping equation. The predicted on-road fuel efficiency together with the exogenously determined fuel price is used to obtain an estimate of the unit fuel cost. The predicted vehicle price and unit fuel cost enter the auto type choice and vehicle use models together with other vehicle and socioeconomic characteristics, notably household income, household size and vehicle weight. A final model identifies the probability of a household choosing a new or used vehicle, which is required to accommodate the substitution between new and used vehicles in response to vehicle price and household income changes. This same model is used to adjust the demand for used vehicles in response to changes in the overall demand for new vehicles.

Fuel efficiency is determined from the technical transformation equation which feeds in an exogenously determined fuel efficiency via the VEFF mapping equation above. The mix of new and used vehicles is established via the aggregate model share and class share models for new vehicles and the used vehicle model and class share from the used fleet plus scrappage.

The two key generic types of information required to establish forecasts of energy demand are the nature of vehicle technology (including vehicle prices) and the socioeconomic profile of future populations. Together with the demand modelling system we are able to obtain estimates of automobile demand, vehicle use and energy demand. The estimated models are summarised in the Appendix.

In identifying the nature of vehicle technology up to the year 2005, a knowledge of the product plan of each manufacturer is required In the context of the challenge to reduce the fuel efficiency of automobiles in line with the Toronto and Montreal goals, it is necessary to establish a maximum technology scenario in respect of technologically feasible improvements in the fuel economy of automobiles beyond the aspirations of the product plan. Given the complexities of identifying such scenarios at the individual-vehicle level, the forecasts of vehicle technology were developed at the class level, with due allowance for the composition of each class as defined by a number of representative vehicles for each manufacturer. The class-specific weighted averages for fuel economy, weight and price increment (over a 1988 vehicle in the same class) were used together with relevant socioeconomic projections in the application of the model system. All of our results are reported at the class level.

The classes selected for the application differ for new and used vehicles. We have adopted the 1988 PAXUS classes for used vehicles (small, medium, upper medium, luxury and upper luxury). The PAXUS classification is detailed in Working Paper 7.

For new vehicles in 1988 and each subsequent forecast year we have modified the PAXUS classes on the advice of K.Duleep of Environmental and Energy Analysts to accommodate the move to smaller vehicles. Seven classes have been selected (mini, small, sports, medium, upper medium, luxury and upper luxury). The PAXUS small car class was divided into a mini and a small class to accommodate the increasing popularity of an essentially new class of vehicle which has entered the market since 1988 (see Table 2).The mini vehicle is priced from $12,500 to $16,000 in 1991 and weighs 780-880 kg (Table 7) with engines smaller than 1.5 litres. Sports cars, included in the luxury vehicle class up to 1988 were separated to account for their unique performance and physical characteristics. Sports cars are smaller and more fuel efficient than the other upper luxury vehicles

Table 2 The 1990 Vehicle Class Mix using the Projection Classes for New Vehicles

Mini
Holden Barina
Daihatsu Charade
Hyundai Excel
Mazda 121
Suzuki Swift

Medium

Holden Apollo
Toyota Camry
Toyota Camry V6
Ford Corsair
Telstar
Mitsubishi Magna
Mitsubishi Nimbus
Mitsubishi Galant
Mazda 626 (incl Turbo)
Nissan Pintara
Honda Accord
Hyundai Sonata 4,6
Subaru Liberty

Upper Luxury
Mercedes
Porsche
Rolls Royce
Volvo 740/760
Saab 9000
BMW 500 Series
BMW 700 Series
Jaguar/Daimler
Rover
Range Rover
Honda Legend
Ford LTD
Holden Caprice

Small
Mazda 323
Holden Nova
Daihatsu Applause
Honda Civic
Mitsubishi Lancer
Mitsubishi Colt
Toyota Corolla
Ford Laser
Nissan Pulsar
Subaru Leone

Sport

Ford Capri
Toyota Celica
Toyota MR-2
Honda Integra
Honda Concerto
Honda Prelude
Mazda MX-5
Nissan EXA

Upper Medium
Holden Commodore 6
Holden Commodore 8
Ford Falcon
Ford Fairmont
Toyota Lexcen
Nissan Skyline

Luxury

Holden Statesman
Ford Fairlane
Toyota Cressida
Peugeot
BMW 318
Mazda 929
Nissan Maxima
Volvo 240
Saab 900

The small car class corresponds closely to the original small class minus the mini vehicles. The average new vehicle price in 1988 was just over $15,000. The Ford Laser and Toyota Corolla were the popular new models in 1988 capturing nearly 60 percent of the class sales. The medium class is very similar to the original PAXUS class with some individual models moved from the luxury classification to reflect their price and fuel efficiency. These include the Honda Accord, Mazda 626, Toyota Camry V6 and Hyundai Sonata (4 and 6 cylinder). Engine sizes range from 2 to 2.6 litres with an average weight of 1200kg. The upper medium class is essentially the two most popular vehicles supplied by the local manufacturers, General Motors Holden and Ford Australia. The Nissan Skyline has recently been phased out. This class is very dependent on company purchases. The average price in 1988 was $25,700 for a vehicle weighing on average 1363 kg. (although the base Falcon weighs 1480kg). The Ford Falcon Fairmont utilises a 3.9 litre engine while the Holden Commodore uses a 3.8 litre V-6 engine, as well as offering a 5 litre option. High levels of acceleration are offered by vehicles in this class relative to other non-luxury vehicles. This class is the least fuel efficient excluding the upper luxury class. With 34.1% of the new vehicle sales in 1988, the upper medium class is the real challenge for fuel efficiency gains.

The luxury class, with the exception of the Ford Fairlane is dominated by imports in respect of the number of unique models, although sales of the Ford Fairlane in 1988 represent 43% of total class sales. The average purchase price in 1988 was $32,500. Imports were noted for their 3 litre engines and 6 cylinder configuration. Upper luxury vehicles are essentially imported vehicles (the exception being the Ford LTD and Holden Caprice, the latter since 1990), although 95% of the vehicle sales are imports. There is a large price difference relative to the luxury class, with a mean price of $72,000.

4 The Base Situation in 1988

The discrete-continuous choice model system has to be capable of reproducing the 1988 best estimate of vehicle class share, vehicle use and total fuel consumed by the automobile fleet of Australian households. The Australia-wide data required to calibrate the model system to reproduce the 1988 class shares was assembled from various sources. A summary at the class level is given in Table 3 for all vehicles and households (see also Table 1). Control totals for the population of individuals, vehicles, and energy demanded are given in Table 4. Projections of three key exogenous variables - household size, income and fuel prices are given in Table 5.

Table 3 The Profile of the 1988 Market by Size Class ($Aus1988). Registration weighted average vehicle attributes

	Min/Sm	Spt	Med	Umed	Lx	Ulx
Household income	40143	45031	40399	39848	45031	57227
Age of driver	39.3	43.2	41.1	42.1	43.2	42.1
Propn vehicles:						
Hhld business reg'd	0.511	0.236	0.075	0.127	0.236	0.455
Other business reg'd	0.033	0.121	0.058	0.191	0.121	0.191
Front leg room (cm)	111.3	116.7	114.8	115.7	116.7	117.6
Rear internal vol (m^3)	0.171	0.141	0.188	0.251	0.245	0.217
Seating capacity	4.37	4.03	4.82	5.27	4.93	4.70
Luggage capacity (m^3)	0.371	0.412	0.538	0.781	0.512	0.409
Torque (Nm)	125	166	171	277	183	244
Engine Capacity (cc)	1421	1699	2048	3377	2133	2627
Insur rating (NRMA)	4.79	8.47	5.46	3.29	7.47	12.12
Acceleration 1-100 (secs)	13.71	11.18	13.64	10.99	11.19	11.03
Unit recurrent km-dependent cost (c/km)	1.46	1.46	1.35	1.67	1.36	1.15

Table 4 Key Exogenous Descriptors

Year	Population ('000)	Total Fleet	New Regns	FCons (bill lit)	Fcpervrh litres pa
70-71	13,067.3	3,990,938	417,224		
71-72	13,230.3	4,141,300	412,522		
72-73	13,565.4	4,361,600	429,739	8.639	1,981
73-74	14,785.5	4,604,000	464,990	9.212	2,001
74-75	13,968.9	4,858,500	502,720	9.575	1,971
75-76	14,033.1	5,072,800	454,637	10.158	2,002
76-77	14,192.2	5,243,000	447,103	10.606	2,025
77-78	14,359.3	5,462,200	432,439	10.952	2,009
78-79	14,515.7	5,657,200	463,453	11.237	1,992
79-80	14,695.4	5,799,300	451,950	11.273	1,952
80-81	14,923.3	6,021,000	456,593	11.442	1,910
81-82	15,543.6	6,293,800	455,523	11.877	1,900
82-83	15,393.5	6,462,700	426,416	11.792	1,839
83-84	15,579.4	6,636,200	428,658	12.155	1,850
84-85	15,788.3	6,942,700	483,222	12.463	1,842
85-86	16,018.4	6,985,400	450,893	12.759	1,851
86-87	16,263.3	7,072,800	365,112	12.934	1,855
87-88	16,538.2	7,243,600	410,473	13.452	1,885
88-89	16,833.1	7,442,200	448,514	13.919	1,903
estimated	max		forecast	forecast	forecast
89-90	17,083.0	7,616,263	467,493	14.151	1,858
90-91	17,337.4	7,835,358	472,993	14.291	1,824
91-92	17,592.2	7,910,707	471,184	14.182	1,793
92-93	17,846.7	8,210,217	469,106	14.459	1,761
93-94	18,100.8	8,461,456	466,746	14.629	1,729
94-95	18,354.2	8,667,684	463,681	14.702	1,629
95-96	18,606.7	8,806,257	470,915	14.645	1,663
96-97	18,857.0	8,948,490	477,437	14.580	1,629
97-98	19,104.9	9,153,316	484,323	14.602	1,595

98-99	19,350.2	9,348,099	491,317	14.588	1,561
99-00	19,593.4	9,503,223	496,010	14.494	1,611
00-01	19,834.1	9,634,226	501,016	14.347	1,489
01-02	20,072.4	9,792,030	498,308	14.225	1,453
02-03	20,308.3	9,922,973	498,181	14.050	1,416
03-04	20,541.7	10,169,315	498,081	14.014	1,378
04-05	20,772.4	10,256,635	497,935	13.741	1,340

Sources:
Population: ABS Projections of the populations of Australia, States and Territories, 1989 to 2031, November 1990 release.
Total fleet: Donaldson et.al. (1990), Table 6.
New vehicle registrations: 70-71 to 86-87, from AIC (1988), Appendix A3, page 65. 87-88 to 88-89 from AIA (1990) Table 1 Appendix 1, page 84. 1989-90 to 04-05 NELA (1991).Total annual fuel consumed (billions of litres): Donaldson et al (1990), Table 6, page 15, with forecasts based on high oil price, rising to $US32 a barrel by mid-2005.
Fuel consumed per vehicles (litres per annum); Donaldson et al (1990), Table 5, page 14 with forecasts based on high oil price.

Table 5 Scenarios and Assumptions imposed on Exogenous Factors
All dollar items are in $Aus 1988

	1988	1995	2000	2005
Household size	2.88	2.87	2.87	2.71
Real Hhd income growth		1%pa	1%pa	1%pa
Real fuel price	49.0	55.8	58.6	62.3

Since the sampled households are to be used to represent the population of households in 1988, they have to be weighted by their incidence in the population. At the level of the core socioeconomic variables - stage in the lifecycle and household income, the 1988 weights (proportion of the population/proportion of the synthetic sample) are those summarised in Table 6. Some households on the core socioeconomic effects are over-represented, notably households in lifecycle category 4, a typically high kilometre cluster. Likewise there are a number of situations of under-representation such as households of retired persons on low incomes, a typically low mobility cluster. The 500 synthetic households have similar weights to reflect their representation in the population. The final weights are a composite of the weights associated with the core socioeconomic strata criteria and the non-core criteria used for the development of the within-core syndicate households.

Table 6
Scaling Weights for sampled households in 1988

	Hinc1	**Hinc2**	**Hinc3**	**Hinc4**	**Hinc5**
Lcy1	1.47	1.96	2.08	2.69	3.23
Lcy2	1.29	1.04	1.38	1.42	2.52
Lcy3	1.72	1.32	1.58	1.14	1.79
Lcy4	0.43	0.32	0.30	0.24	0.24
Lcy5	3.53	1.47	1.02	0.91	2.35

Lcy1 = household with age of head less than 35 years and no children
Lcy2 = household with age of head less that 35 years and at least 1 child
Lcy3 = household with age of head 35-64 years old and no children
Lcy4 = household with age of head over 34 years and at least 1 child
Lcy5 = household with age of head over 64 years and no children
Hinc1 = household income ($88) less than $14001 per annum
Hinc2 = household with income ($88) in range $14001-$26,000 per annum
Hinc3 = household with income ($88) in range $26,001-$38,000 per annum
Hinc4 = household with income ($88) in range $38,001-$64,000 per annum
Hinc5 = household with income ($88) over $64,000 per annum.

5 Projecting to the Future

The vehicle technology of interest centres on the energy related changes which the manufacturers have included in their product plan (P) and the additional changes which are technologically feasible but which will require some additional incentives to encourage manufacturers to adopt a "maximum technology" (M) strategy in the interest of fuel economy. The product plan and the maximum technology scenario for each forecast year are summarised in Table 7 for the key attributes.

Table 7 Summary of Base Situation in 1988, 1995, 2000, and 2005

	1988	1995	2000	2005
Base new registrations	410,473	463,681	496,010	497,935
Base used registrations	6833127	7994456	9007213	9758700
Base Scrappage	218757	290350	345943	372340
Ave fuel price (c/litre)	49.0	55.8	58.6	62.3
New vehicle:				
Fuel Efficiency (G):P	9.21	9.01	8.42	7.87
Fuel efficiency (G):M	9.21	8.17	7.27	6.37

New vehicles:

	1988	1995		2000		2005	
Mini:		P	M	P	M	P	M
Weight (kg)	826	882	882	860	840	838	795
Power (hp)		75	75	75	72	73.5	67
Price inc. over 1988		108	108	259	329	421	586
1988 price	13,697						
Fuel efficiency (G)		6.26	5.79	5.84	5.13	5.42	4.47
Small		P	M	P	M	P	M
Weight (kg)	952	1055	1055	1027	1007	998	945
Power (hp)		103	103	98	95	93	86.4
Price inc. over 1988		250	250	421	498	616	773
1988 price	15,262						
Fuel efficiency (G)		7.41	6.80	6.89	6.03	6.39	5.25
Sports		P	M	P	M	P	M
Weight (kg)	1114	1212	1212	1180	1151	1151	1090
Power (hp)		129	129	125	122	120	116
Price inc. over 1988		107	107	277	455	458	817
1988 price	30,511						
Fuel efficiency (G)		7.96	7.97	7.54	7.14	7.11	6.37
Medium		P	M	P	M	P	M
Weight (kg)	1198	1295	1295	1258	1230	1220	1165
Power (hp)		181	125	181	119	111.5	113
Price inc. over 1988		169	169	389	522	620	892
1988 price	18,094						
Fuel efficiency (G)		8.88	8.07	8.30	7.21	7.72	6.35
Upper Medium		P	M	P	M	P	M
Weight (kg)	1363	1425	1425	1404	1344	1383	1263
Power (hp)		181	181	181	175	181	165
Price inc. over 1988		223	223	472	1133	743	1514
1988 price	25,708						
Fuel efficiency (G)		10.35	9.15	9.70	8.15	9.14	7.14
Luxury		P	M	P	M	P	M
Weight (kg)	1355	1355	1355	1307	1269	1259	1182
Power (hp)		177	177	170	168	163	159
Price inc. over 1988		228	228	748	1083	1268	2256
1988 price	32,551						
Fuel efficiency (G)		9.73	9.18	9.07	8.12	8.40	7.06

Upper Luxury		P	M	P	M	P	M
Weight (kg)	1421	1421	1421	1410	1400	1330	1300
Power (hp)							
Price inc. over 1988		228	228	748	1083	1268	2256
1988 price	71,978						
Fuel efficiency (G)		10.50	9.91	9.78	8.77	9.06	7.63

Market Shares 1988	New	Used
Mini	4.85	
Small	21.9	24.04
Sports	2.24	
Medium	29.6	32.07
Upper Medium	34.1	36.0
Luxury	3.1	6.04
Upper Luxury	4.1	1.83

Notes:
1. The product plan and maximum technology scenario do not include the effect of the 1994 USA emission/safety standards which require an additional weight of 30kg.
2. The maximum technology plan assumes that calibrating cars to best practice in the USA has no price effect.
3. The Federal Guidelines (G) are based on a 55:45 City:Highway drive cycle. The 70:30 drive cycle is used in the simulations.

Fuel consumption is based on the federal guidelines for city and highway conditions and a 70:30 split for the city and highway cycle. There is ambiguity in the literature on what is the correct split and indeed in which studies have different assumptions been imposed. A 55:45 split (the 'G' estimates) is recommended for descriptive comparisons with the US CAFE compliance data. The decision is further complicated by ambiguity with respect to the relationship between city and highway cycles and urban and non-urban travel contexts. We are assuming that the city:highway distinction is determined by the nature of the road environment regardless of the spatial context.

Because the fuel efficiency of vehicles on the road is influenced by the quality of driving, the state of the roads and the traffic, the fuel consumption levels recommended by the Federal Government and reported in their guidelines are likely to be on the low side. We have developed a mapping between the guideline efficiencies (FUELEFF) and the on-road efficiencies (VEFF) for our sample of household vehicles.Assuming a 70%:30% on-road split between city and highway cycle kilometres (split advised by NELA, 16 March 1991) the equation is (t-values in parenthesis):

$$\text{VEFF} = \underset{(9.8)}{0.988462} + \underset{(101.06)}{0.871080} * \text{FUELEFF} \qquad r^2 = 0.84$$

The technological assumptions underlying the product plan and the maximum technology scenario up to the year 2005 developed for Australia by K. Duleep of Environment and Energy Analysts are as follows:

Weight reduction: P = 5% for all automobiles except Holden Commodore.
M = 10% for all except 5% for Holden Commodore.
Drag reduction: P = C_D = 0.30 ~ 0.31
M = C_D = 0.28 ~ 0.29.
2-Stroke engine: P= 20% of mini and small vehicles
M = 80% of mini and small and 40% of medium.
4-valve engine: P= all other vehicles except V8, some mini vehicles
M = all other vehicles.
CVT (replacing automatic transmission):
P = 10% of mini, small and 20% of medium
M = all mini, small and 30% of medium vehicles.
5-speed auto transmission:
P = 50% of upper medium and luxury
M = all upper medium, luxury and 40% of medium.
Variable valve timing:
P = 50% of 4-valve engines rated over 75 kilowatts
M = all 4-valve engines rated over 75 kilowatts.
Advanced engine friction reduction:
P = all engines
M = all engines
Electric power steering:
P = replaces 50% of power steering in mini and small vehicles
M = replaces all power steering in mini and small cars.
Improved tyres: P = all vehicles
M = all vehicles.

The penetration rates in 1990 for various technologies are summarised below as a guide to the success to date in introducing new technologies linked to improved automobile fuel efficiency (NELA 1991).

Technology	Min	Sm	Med	UMd	Spt	Lux
Front wheel drive	100	100	100	0	100	13
Drag reduction (C_D <0.34)	70	35	20	55	77	23
M-5 transmission	80	60	30	10	75	10
A-4 transmission	5	5	70	90	25	90
Total auto transmission	20	40	70	90	25	90
Torque converter lock-up	5	20	70	90	20	90
Electronic trans. control	0	5	35	0	0	18
Overhead cam engine	100	100	100	45	100	85
Roller cam followers	0	6	2	55	0	4
Low friction pistons/rings	0	5	50	100	10	45
4-valve cylinder	22	62	36	0	100	34
3-valve cylinder	0	7	19	0	0	0
Central fuel injection	0	12	0	25	0	0
Multipoint fuel injection	40	36	80	75	100	100
10W-30 oil	0	0	0	0	0	0
Accessory improvements	0	0	0	0	0	0

Our first task is to implement the model system under the assumption of the product plan and the maximum technology scenario. Vehicle attributes influencing auto type choice, fleet size and vehicle use are assumed initially at the mean to reflect the 1988 class averages through to 2005, with all dollar items remaining constant in 1988 dollars except for vehicle price. The latter increases according to the product plan and maximum technology scenarios for new vehicles and decreases for used vehicles to reflect the real decline in asset value. The interaction of the demand system, the scrappage model and the equilibrating role of used vehicle prices for given new vehicle prices provides the framework for evaluating the energy implications of the two technology scenarios. The results are summarised in Table 8 for the base situation in 1988, 1995, 2000 and 2005. For both new and used vehicles the table summarises the class shares and the change in consumer surplus associated with the move from the product plan to the maximum technology plan for new vehicles. The concept of consumer surplus is explained in Appendix B.

The change in the benefits to the population of vehicle owners and users in the main is determined by the complex relationship between all the sources of indirect utility associated with the choice of vehicle types, appropriately weighted by sales/registrations of each vehicle type. In deriving an appropriate index of the change in consumer surplus as the generally accepted measure of change in benefit to consumers, we recognise that the "price" of a vehicle is multi-dimensional in nature, with the importance of each attribute defining the composite price being measured by weights with values such that the vehicle with the lowest composite price is the one actually chosen (Cardell and Dunbar 1980, 424). In practice the composite price index cannot be estimated with certainty and so we resort to a probabilistic choice rule.

The expected maximum utility associated with the auto type choice model form is the measure of consumer surplus (see Hensher and Johnson 1981). The change in the expected maximum utility is the measure of change in consumer surplus, assuming a negligible income effect. This index of change in consumer surplus is derived as the difference in the natural logarithm of the denominator of the auto type choice model (before and after a technology or policy change). To convert the surplus measure to dollars it is scaled by the inverse of the coefficient of vehicle price. In the current application this coefficient varies according to the level of household income, making the result sensitive to household tastes. The base comparison for new vehicles is between the consumer surplus associated with the product plan and the maximum technology scenario for each forecast year.

The multi-dimensional nature of composite price recognises that any changes in vehicle attributes designed to change vehicle fuel efficiency often result in changes which are perceived by motorists as being desirable or undesirable for other reasons such as comfort, reliability, safety and styling. The weights which each individual attaches to these attributes are used in the composite price to capture all (up to a probability of choice) of the adjustments which would be made in consumer vehicle choices and rates of use as a result of externally imposed policy strategies. For example, changes in vehicle mass associated with improved fuel economy affects not only the type of vehicle a person may choose (in respect of styling, safety etc) after allowing for other correlates with weight such as vehicle price, it also affects the rate of vehicle use.

The maximum technology plan if implemented can produce a fuel consumption of 6.35 litres per 100kms for new passenger vehicles by the year 2005, very close but still short of the 6 litre/100 km target. Additional strategies are required to both assist the technology strategy and to move further towards the 6 litre/100 km target. A large number of pricing and taxing strategies have been evaluated and are discussed below. Before doing so we need to interpret the results in Table 8. This is our reference benchmark for a pure technology "solution". The estimated scrappage of used vehicles in the context of the base product plan is given in Table 9 for each year up to 2005.

The product plan and/or maximum technology scenario represent weight and fuel efficiency changes up to 2005. To date weight and fuel efficiency gains have been achieved by changing vehicle designs to essentially preserve interior volumes and other desirable dimensions of comfort and styling (Greene and Liu 1988). The differences in the class shares over time amount to quite significant shifts in the absolute number of vehicle sales in each class and sizeable savings in energy demanded. The savings in energy demanded when moving from the product plan to the maximum technology scenario are tempered by the increase in the rate of vehicle utilisation, reflecting the lowering of unit fuel costs consequent on improved fuel economy. The net impact on government revenue from sales tax and fuel tax is an increase in revenue, equivalent to $26m in 2005. This is achieved together with the gain in consumer surplus of $1.597 billion in 2005. Even if we recognised the reasonable assumption that consumer preferences for smaller vehicles will change over time and that the indirect utility expressions underlying the choice models applied in this study are those of the 1980's, a discounting of the gain of consumer surplus to accommodate the bandwagon effect is likely to give a gain greater than the increases in government revenue. When the impact of new vehicle technology change on used vehicle owners is taken into account, there is a loss of consumer surplus to used vehicle owners due to the price effect. The adjustment in scrappage rates and hence the number of used vehicles on the road leads to a further adjustment in government revenue from fuel purchases. Over time the "downsizing" of the new fleet sales is translated into a downsizing of the total fleet. However the impact that this has on the fuel economy of the total fleet is still a long way above the desired 20% reduction sought up to 2005. See Working Paper No.4 (Table 6.9) and the Final Report for more details.

Table 8 Base Projections of Major Study Outputs Under Technology Strategies ($Aus1988), P -> M

(i) New Vehicles

Market Share	**1988**	**1995**		**2000**		**2005**	
		P	M	P	M	P	M
Mini	4.78	4.95	4.65	5.04	4.83	5.10	4.84
Small	20.9	21.3	20.5	21.6	21.2	21.8	21.4
Sports	1.95	2.54	2.21	2.54	2.27	2.53	2.24
Medium	32.35	30.7	30.5	30.6	31.3	31.1	31.33
Upper Medium	33.12	33.7	35.6	33.7	34.0	33.0	34.4
Luxury	2.84	2.84	2.70	2.74	2.63	2.66	2.37
Upper Luxury	4.04	4.02	3.85	3.76	3.76	3.75	3.39
Change in Consumer Surplus ($m pa)		1,152		1,168		1,597	

(ii) Used Vehicles
(Projections based on the product plan)

Market Share	**1988**	**1995**	**2000**	**2005**
Small	25.0	24.4	24.1	24.2
Medium	32.3	34.8	31.9	32.3
Upper Medium	30.2	31.97	31.3	31.1
Luxury	10.3	7.35	10.3	10.2
Upper Luxury	2.2	1.44	2.2	2.17
Change in Consumer Surplus ($m p.a.)		-410	-480	-510

Table 9 Estimated Scrappage of Automobiles: Base Situation

Year	Scrapped Vehicles
1988	218,757
1989	249,180
1990	262,100
1991	269,174
1992	275,243
1993	280,803
1994	285,843
1995	290,350
1996	301,201
1997	312,203
1998	323,324
1999	334,571
2000	345,943
2001	351,545
2002	357,125
2003	362,395
2004	367,464
2005	372,340

Tables 10-12 summarise the major implications of pricing strategies designed to complement the technology strategy. We limit the reporting to the only strategies we believe are feasible strategies in respect of further improvements in fuel economy. The range of strategies clearly is dictated by the capability of the model system, which although extremely rich it is not able to consider all potential strategies. For example, a promotion campaign to encourage fuel conservation cannot be handled by our model system. The reported changes in consumer surplus are equivalent to the nominal consumer surplus referred to in the main report (page 88) (in contrast to the laterally discounted consumer surplus).

We considered a number of strategies related to specific markets such as the company car, and although this is a sector which can be easily identified and a number of taxing strategies evaluated (e.g. eliminating the depreciation allowance on cars and/or increasing the sales tax on such vehicles while maintaining or even decreasing levels on privately-registered vehicles), the overall impact would be quite negligible in respect of fuel economy and overall energy demand. Vehicle registration fees (including compulsory insurance) as currently structured are not a source of influence on automobile purchase decisions, and thus has not been evaluated. Very large changes such as a 50 cents/litre fuel tax are discussed in the main report, but are argued to be taking the model beyond its limits of acceptable confidence in the results. Such results are not reported in this paper.

In Table 10 we report two types of consumer surplus change. The first is based on a change involving the same variation in sales tax and fuel tax under both technology regimes (for example P20 --> M20); the second is based on a sales and fuel tax adjustment which only applies to the maximum technology scenario (for example P --> M20). The former is discussed in the text on pages 26-27, the latter is commented on under item 5 of Section 6.

The sales tax reduction of 20 percent on all vehicles (preserving 10 percent on luxury and upper luxury vehicles) and the fuel tax increase are assumed to be introduced in 1995. The sales tax reduction provides a 'one-hit' impact on the price of used vehicles (which affects the demand for used vehicles) which translates into a significant loss of consumer surplus in 1995 only for used vehicle owners. The fuel tax increase also provides a 'one-hit' impact in 1995 on both new and used vehicle owners.

Table 10 Pricing Strategies to Complement Technology Strategy ($Aus1988): Elimination of 20% sales tax in 1995 (maintaining 10% on luxury and upper luxury vehicles). No fuel tax increase to establish revenue neutrality

(i) New Vehicles : P20 --> M20

Market Share	**1995**		**2000**		**2005**	
	P	M	P	M	P	M
Mini	4.56	4.26	4.60	4.39	4.66	4.40
Small	19.8	18.9	20.1	19.65	20.3	19.82
Sports	2.76	2.36	2.71	2.41	2.69	2.38
Medium	29.2	29.0	29.2	29.8	29.7	29.8
Upper Medium	34.5	36.6	34.6	35.1	33.9	35.6
Luxury	3.08	2.92	3.00	2.88	2.92	2.64
Upper Luxury	6.13	5.84	5.81	5.77	5.81	5.32
Registrations	519521		555744		557901	
Increase in Regns	55840		59734		59966	
Change in Consumer Surplus ($m pa)	1319		1373		1899	
Govt Revenue ($m):						
Sales Tax	182	173	190	189	193	183
Fuel Tax	216	202	228	205	226	193
Change in Consumer Surplus ($m pa) for P --> M20	2290		2741		3195	

(ii) Used Vehicles: P20 --> M20

(Projections based on the product plan). Elimination of Sales Tax on new vehicles impacts on demand for used vehicles (scrappage rate and price).

Market Share	**1995**	**2000**	**2005**
Small	24.2	23.8	22.8
Medium	34.7	31.8	31.5
Upper Medium	31.6	30.9	32.2
Luxury	7.68	10.8	10.7
Upper Luxury	1.83	2.8	2.8
Registrations	7938616	8947479	9698734
Decrease in Regns	55840	59734	59966
Change in Consumer Surplus ($m pa)	-2006	-480	-410
Change in Consumer Surplus ($m pa) for P -- > M20	-2006	-480	-410

Table 11 Pricing Strategies to Complement Technology Strategy ($Aus1988): Elimination of 20% sales tax in 1995 (maintaining 10% on luxury and upper luxury vehicles) and 12c/litre fuel tax increase from 1995 onwards to establish revenue neutrality.

(i) New Vehicles: P20/12 --> M20/12						
Market Share	**1995**		**2000**		**2005**	
	P	M	P	M	P	M
Mini	5.02	4.64	5.04	4.74	5.08	4.70
Small	20.9	19.9	21.2	20.6	21.4	20.6
Sports	2.83	2.40	2.79	2.43	2.76	2.38
Medium	29.3	29.2	29.4	29.9	29.8	29.8
Upper Medium	33.0	35.5	33.1	34.1	32.5	34.7
Luxury	3.00	2.83	2.94	2.79	2.87	2.58
Upper Luxury	5.80	5.51	5.54	5.48	5.57	5.09
Change in Consumer Surplus ($m pa)	1558		1731		2345	
Change in Consumer Surplus ($m pa) for P --> M20/12	173		2741		3195	
(ii) Used vehicles: P20/12 --> M20/12						
Change in Consumer Surplus ($m pa)	-4993		-480		-510	
Govt Revenue ($m):						
Sales Tax	174	164	182	180	186	176
Fuel Tax	285	268	298	268	293	250
Fuel Tax Increase:						
10c/litre:						
Sales Tax	175	166	184	182	186	177
Fuel tax - new vehicles	274	258	286	257	282	240
Fuel tax - used vehicles	4215	4215	4782	4782	5518	5518
Total	4664	4639	5252	5221	5986	5935
15c/litre:						
Sales Tax	172	162	180	178	184	174
Fuel tax - new vehicles	303	284	314	283	308	263
Fuel tax - used vehicles	4637	4637	5252	5252	6043	6043
Total	5112	5083	5746	5713	6535	6480
Change in Consumer Surplus ($m pa) for P --> M20/12	-4993		-480		-510	

Table 12 Special Treatment of Upper Medium, Luxury and Upper Luxury Vehicles: The Fuel Efficiency Implications of Sales Tax and New Vehicle Price Increases (From Base): The Maximum Technology Scenario for 2005.

Market Share	**Base**	**80% Increase in Retail Price**	**Sales Tax of 100%**
Mini	4.84	7.3	5.9
Small	21.4	32.15	26.5
Sports	2.24	3.4	2.7
Medium	31.33	47.0	38.7
Upper Medium	34.4	9.7	23.6
Luxury	2.37	0.4	1.38
Upper Luxury	3.39	0.07	0.94
Change in Consumer Surplus ($m)		-461	-473
Govt. Revenue ($m)			
Sales Tax	1588	1532	7808
Fuel Tax	173	170	167
Fuel Efficiency:			
On-Road (VEFF)	6.52	6.16	6.35
Guidelines (70:30)	6.37	5.94	6.15

The application of a number of pricing and taxation regimes to build on the technology strategy has substantial impact on government revenue and consumer surplus. The first taxing strategy involved the elimination of the 20% sales tax on all new passenger vehicle sales from 1995 up to 2005. The 10% sales tax addition on luxury and upper luxury vehicles was preserved. A priori this treatment is expected to increase the demand for new vehicles, leading to a substitution out of used vehicles (hence increasing the rate of vehicle scrappage), and resulting in a lowering of the resale price of used vehicles. The scrappage model has an implied elasticity of scrappage rate with respect to new vehicle prices of -0.66. The direction of new vehicle class shares favours currently more expensive vehicles, as borne out by a comparison of Tables 8 and 10.

The gain in consumer surplus in moving from the product plan to the maximum technology scenario is greater in the presence of the sales tax reduction (Table 10). In 2005, the **additional** gain associated with new vehicles is $302m (i.e. $1899m-$1597m). There is however a one-time loss of consumer surplus to used vehicle owners of $2,006m. This arises as a consequence of the lower prices of new vehicles leading to a reduction in the demand for used vehicles which results from a lowering of used vehicle prices which increases the scrappage rate. Furthermore the overall new vehicle average fuel economy has deteriorated from 6.35 litres per 100km to 6.42 litres per 100km in 2005 (maximum technology scenario). This is attributable to the net impact on increased new car sales of an increase in the class shares in the top three classes (especially upper medium which has increased from 31.33 %- Table 10.8 to 35.6% - Table 10). Government revenue from sales tax has reduced substantially. For example in 2005 it has reduced from $1,588m to $183m. When combined with the change in fuel tax from new and used vehicles, there is a shortfall in total tax revenue of $1.46 billion in 2005 under the maximum technology scenario and $1.394 billion under the product plan (Table 10).

In the interests of revenue neutrality, an increase in the fuel tax is required. The fuel tax would have to increase by approximately 12 cents per litre (in 1988 dollars) to achieve revenue neutrality (Table 11). This translates into a retail fuel price in 1991 (in current dollars) of $1.15 assuming a 7% rate of inflation. The loss of consumer surplus is substantial under this regime, even after discounting the impact on consumer preferences of downsizing (due to the bandwagon effect which is likely to occur over time).

The combined impact of the elimination of the base sales tax and the introduction of a 12c/litre increase in fuel tax in 1995 is that the overall average fuel economy of new vehicles improves from 6.35 litres/100km (pure technology strategy), to 6.42 litres/100km (sales tax elimination) to 6.29 litres/100km (combined sales tax and fuel tax treatment). The increase in the class share for the smaller vehicles is also observed; a comparison of Tables 8, 9 and 10 shows that the lower classes recover some of their share which was lost by the sales tax treatment in the absence of a revenue-compensation fuel tax.

In an effort to establish more severe measures capable of achieving an average fuel consumption of 6 litres per 100 km in 2005, we investigated a large number of regimes. The most promising involved substantial increases in the retail price of new vehicles and sales tax in the upper medium, luxury and upper luxury classes. It is particularly important to note that efforts to eliminate the luxury classes per se will be ineffective because of the relatively small market share of 7.2% in 1988 which is expected to increase to no more than 8% in 2005 under the maximum technology scenario (or 9% under the product plan and only 10% sales tax on luxury vehicles).

The results of severe pricing and taxing treatments in 2005 are summarised in Table 12. The imposition of a sales tax double the wholesale price of new passenger vehicles for the three top vehicle classes will not have the desired impact on the overall average fuel economy. It will however generate substantial government revenue without a major additional loss of consumer surplus. In contrast however, an 80 percent increase in the retail price of a vehicle (which is substantially higher than the retail price associated with the doubling of the sales tax) will achieve an average fuel consumption much closer to 6 litres per 100kms. The guideline definition of fuel efficiency is below the 6 litre target at 5.94 litres/100 km; however the on-road fuel efficiency is 6.16 litres/100km. The impact of this pricing treatment is revealed in the massive reduction in the class share for upper medium vehicles (from 34.4% to 9.7%) and a significant increase in market share for all of the lower classes.

Finally, a 50 cents per litre fuel tax increase was evaluated, although the caveat is imposed that such an application is "stretching" the econometric model well outside the range of experience available to any sampled member of the population. As an indicative measure, this translates into 10.73 cents per km in 1988 dollars in the year 2005, with a reduction in consumer surplus of $184 billion in 1995, $203 billion in 2000 and $218 billion in the year 2005 if these were the respective initial years of introduction of the 50 cents/litre increase. The increase in government revenue in the year 2005 alone is substantial. Major shifts in market share occur, especially in the upper medium class for used vehicles (from 31.1 per cent based on technology change only to 25.2 per cent). Because the application over-extends the model system, the results must be treated carefully. Such large variations from current experience are best evaluated in the context of a stated preference experiment.

6 Conclusions

This paper has applied the discrete-continuous choice model system to evaluate the role of technology modification and financial instruments in improving the demand for energy in the passenger vehicle market. The major empirical findings from the application of the model system are:

1. The maximum technology scenario for the year 2005 can achieve an average of 6.37 litres per 100km using the federal guideline definition of fuel consumption based on laboratory tests and 6.52 litres/100 kms based on the on-road adjustment procedure. This is achieved under the assumption of projected new vehicle prices and weight reductions with minimal impact on the dimensions of vehicles which influence consumer choice of vehicle type. That is downsizing is more akin to changes in the mix of vehicles on the road rather than on an across-the-board reduction in the size of vehicles and a concomitant loss of quality (styling, comfort, performance etc.).

2. While this is a significant improvement in the fuel economy of new vehicles, the efficiency of the used-vehicle fleet is improving at a much slower rate (see the main report). This is well short of any 20% overall improvement. It represents a 5.3% improvement only.

3. To achieve a further improvement in the fuel efficiency of new vehicles, the only strategy we have identified to achieve this which is consistent with the scope of the model system, involves a substantial increase in the retail price of a vehicle in the upper medium/luxury and upper luxury classes (80% increase - Table 12). This is predicted to achieve a 5.94 litres/100 km sales-weighted average in 2005 (based on the guidelines definition with a 70:30 drive cycle) or 6.16 litres/100 km on the road. Such a price increase is more draconian than a 100% sales tax which doubles the wholesale price The sales-weighted fuel efficiency in 2005 from this treatment is predicted to be 6.15 litres/100km on the guidelines definition (70:30) and 6.35 litres/100km on the road. The increase in revenue to government from these strategies is positive for sales tax increase and negative for the retail price increase.

4. A taxing regime involving sales tax elimination from 1995 onwards to encourage the purchase of new vehicles and the disposal of relatively fuel inefficient older vehicles is appealing. However if it were combined with a fuel tax from 1995 onwards as a means of achieving revenue neutrality, the loss of revenue from the sales tax would require an increase initially of 12 cents per litre (in 1988 dollars) applied to all vehicles on the road. In 1995 this is equivalent to a retail fuel price of approximately $1.15 per litre.

Since it is unlikely that a pricing policy directed at new vehicles will have a significant impact on the overall fuel efficiency of the total fleet of used and new vehicles up to 2005, a policy directed specifically to used vehicles may be the only possibility of increasing the turnover of older vehicles so as to take advantage of the improved fuel economy of new vehicles.

5. An overall summary of the main empirical findings on consumer surplus are given in Table 13. This Table combines information reported in Tables 8, 10 and 11 together with further information on changes in consumer surplus associated with other change scenarios. The sales tax reduction of 20 percent on all vehicles (preserving 10 percent on luxury and upper luxury vehicles) and the fuel tax increase are assumed to be introduced in 1995. The sales tax reduction provides a 'one-hit' impact on the price of used vehicles (which affects the demand for used vehicles) which translates into a significant loss of consumer surplus in 1995 only for used vehicle owners. The fuel tax increase also provides a 'one-hit' impact in 1995 on both new and used vehicle owners.

Table 13
Summary of Main Results in Consumer Surplus changes ($88m)

Strategy	Yr	Change in Consumer Surplus New	Used
P---> M	95	1152	-410
	00	1168	-480
	05	1597	-510
P20---> M20 Sales Tax Reduction (20%) Impacting Used vehicles in 1995	95	1319	-2006
	00	1373	-480
	05	1899	-510
P ---> M20	95	2290	-2006
	00	2741	-480
	05	3195	-510
P20/12---> M20/12 Sales Tax Reduction (20%) from 1995 on plus 12c/litre Fuel Tax Increase	95	1558	-4993
	00	1731	-480
	05	2345	-510
P ---> M20/12	95	173	-4993
	00	2741	-480
	05	3195	-510

Note: The $173m figure for new vehicles in 1995 is small, equivalent to $333 per vehicle. Its magnitude is the consequence of a positive implication for the sales tax reduction and a negative implication for the fuel price increase, of similar surplus impacts but in opposite directions. After 1995, the only factor causing change to consumer surplus is technology change under the new tax regime. The same rationale applies to used vehicles which are associated with a substantial fall in consumer surplus in 1995. This one-off fall is associated with a decrease in the price of used vehicles due to the elimination of sales tax on new vehicles, together with the rise in fuel tax, both reinforcing each other. After 1995, consumers' expectations are for high fuel taxes and normal rates of depreciation in used car prices; and hence the changes in consumer surplus associated with used cars are due to the flow through of the maximum technology scenario. See page 88 of the main report for further details.

Appendix A. The Model System

The unit price of a new vehicle is a function of:

1. Gross vehicle weight (kg) (unladen but ready to run with full fuel tank)
2. Acceleration from 0 to 100km/hr in seconds
3. Body type (sedan/hatch/coupe/sports vs station wagon)
4. Foreign manufacturer status, requiring a knowledge of whether a vehicle was manufactured in Japan, Germany, UK or Sweden.

New vehicle Federal Guideline fuel efficiency (70:30 mix) is a function of:

1. Gross vehicle weight (kg)
2. Carburation type (carburation or fuel injection)
3. Number of cylinders

It should be noted that for both the vehicle price and fuel efficiency equations, extensive investigations were undertaken with a rich data base to identify sources of influence, while recognising the high degree of multicollinearity present in vehicle attribute data. The price model has an adjusted r-squared of 0.80, and the fuel efficiency model's adjusted r-squared is 0.61. These two equations were jointly estimated with the population-based model-share equation to recognise the endogeneity of prices in the model share model and the correlation between the unobserved components of all three equations.

The factors influencing automobile type choice (for total fleet, new and used vehicles) are:

1. Unit fuel cost (c/km) which is itself derived from a knowledge of fuel efficiency and the price of fuel
2. Vehicle price ($)
3. Household income ($)
4. Insurance rating (NRMA rating scale)
5. Front leg room (cm)
6. Seating capacity
7. Household size
8. Rear internal volume (cubic metres)
9. Luggage capacity (cubic metres)
10. Gross vehicle weight (kg) (unladen but ready to run with full fuel tank)
11. Acceleration from 0 to 100km/hr in seconds
12. Vehicle age (years) (new =0)
13. Japanese manufacture (1,0)
14. Years available new (years)
15. Proportion of the vehicles on register of this model
16. Proportion of vehicles on register of this vintage

Note that items 3-9 are obtained from the household data base and included as class averages in the application phase.

Annual kilometres per vehicle is a function of:

1. Unit fuel cost (c/km)
2. Unit recurrent kilometre-dependent costs (c/km)
3. Proportion of model line which are registered as household-business
4. Proportion of model line which are registered as other-business
5. Household income ($/100)
6. Age of primary driver (years)
7. Gross vehicle weight (kg) (unladen but ready to run with full fuel tank)
8. Vehicle price ($)
9. Body type is station wagon (1,0).

Note that items 2-6 are derived from the household data base and included as class averages.in the application phase.

The list of variables set out above are the full set of influences in the calculation of fuel economy. In order to be able to map any change in the technology of vehicles (as suggested in discussions with manufacturers), it is necessary for the changes to occur via changes in the following variables:

1. Vehicle weight (kg)
2. Acceleration (0-100km/hr in seconds)
3. Country of manufacture
4. Body type
5. Carburation
6. Number of cylinders
7. Vehicle external length, width and height
8. Front legroom
9. Luggage capacity
10. Rear interior volume
11. Seating capacity
12. Years available new.

It is highly desirable that these 12 items be supplied for each model line by transmission for each year or selected years up to 2005.

Table 1a. The Auto Type Choice Model

Explanatory Variables	Acronym	Estimated Parameter	t-value
Cost Variables:			
Fuel cost (c/km)	PTCSKM	-0.3339	-5.60
Vehicle price ($)	PRICE	-0.000079	-3.84
Vehicle price* hhld income ($/10^6)	PRCHINC	0.00177	5.29
Insurance rating (0-26)	INSRAT	-0.04213	-4.34
Passenger Carrying Variables:			
Front leg room (cm)	LEGRMF	0.01863	3.36
No. of seats-hhld size	EXCESS	-0.07209	-1.29
Rear internal volume (m^3)	VOLR	2.7842	4.77
Weight (kg)	VMASS	0.00110	2.95
Luggage capacity if kids >1	LUGGCAP	1.0114	3.08
Performance Variables:			
Acceleration 0-100 km/hr (seconds)	ACC0100	0.02636	2.58
Other Variables:			
Age of vehicle (years)	AGEVH	-0.0163	-1.78
Japanese vehicle (1,0)	JAPAN	0.4795	5.41
West European veh (1,0)	WEUR	0.1528	1.40
Years available new	YRSAVL	-0.1704	-11.12
Log of proportion of vehs registered of this model (ln[x per 1000/100])	LNREGD	0.2457	9.84
Market availability of make (proportion of total fleet per 1000 vehs)	MKAVAL	0.00347	3.25
Log-likelihood at convergence		-2885.7	
Likelihood ratio index		0.24	

The auto type choice model is estimated on the 1985 data from a longitudinal panel of Sydney metropolitan households (Hensher et.al in press). A multinomial logit model was estimated for 2138 passenger vehicles in 1172 households. The model is estimated at the vehicle level taking into account household-level constraints. Each vehicle is evaluated in a choice set comprising the household's chosen vehicle and a random sample of 19 other vehicles from the universal set of all passenger vehicles. The choice sets are unranked, hence the parameter estimates are all generic with no alternative-specific constants.

The vehicle-related variables are divided into five categories: cost, passenger-carrying, load-carrying, performance, and other characteristics. Previous empirical studies have demonstrated that the significant cost influences on vehicle choice are the unit fuel cost and the annualised expected cost of capital. The latter has been shown to be similar to the annualised vehicle prices reported in Glasses dealer guides, and the unit fuel cost to be highly correlated with vehicle fuel efficiency.

The cost per kilometre of using a vehicle is a behavioural figure, derived from an equation embedded in the econometric model system which converts the Federal test procedure fuel efficiency into the on-road derived fuel efficiency and then multiplied by the unit retail price of fuel. The theoretical derivation of the underlying indirect utility expression for each alternative vehicle requires an interaction of vehicle price with household income. The vehicle price coefficient is negative and the price interacted with income effect is positive, suggesting that as household income increases, ceteris paribus, the price effect decreases.

We have included the insurance rating in the cost category because it adds another financial dimension as a proxy for the cost of repairs etc. deemed by insurance companies in the event of a crash. It is calculated on the basis of claims and associated expenses. The negative sign is consistent with the hypothesis of diminishing utility as the expected cost of repairs increases.

A long list of passenger-carrying characteristics were evaluated, with special emphasis given to internal dimensions and their interaction with household size and composition. Absolute variables such as total seating capacity or total interior volume were consistently non-significant. Front legroom and rear volume were significant influences on vehicle type choice. Excess capacity (the difference between seating capacity and household size) is a significant source of relative utility. Luggage carrying capacity conditioned on the presence of multiple children in a household has a positive influence on vehicle choice.

Vehicle acceleration from 0 to 100 kms per hour is a consistently positive and significant influence on auto type choice, its positive sign suggesting that less utility is attached to "zippy" vehicles. This finding is supported by previous evidence in Manski and Sherman (1980). The final set of variables are class-related and include the age/vintage characteristics, the country of manufacture and years available new. LNREGD and MAKAVAL are included to allow for the heterogeneity within car line type and the bandwagon effect. Within-type heterogeneity is assumed to increase logarithmically as the number of model variations increases within a car line. Each vehicle represented by the mean attribute levels for a car line has some variation in the set of unobserved attributes; this variability is assumed to increase as the number of such vehicle registrations increases. The years available new variable is negative, suggesting that the longer a model is available, the less desirable overall it becomes, ceteris paribus.

The set of models estimated on the population of new vehicle registrations are summarised in Table 2a.

Table 2 a The Aggregate Model System for New Vehicles (1988)
147 observations, 401944 vehicles

Explanatory Variables	Acronym	Estimated Parameter	t-value
ln(Fuel Efficiency: 70:30 cycle):			
ln(vehicle weight)	LVMASS	0.708999	11.25
Carburation (1,0)	CARBUR	0.105208	3.19
ln(no. of cylinders)	LNCYLIND	0.100290	1.98
Constant	CONSTANT	-2.83737	-6.88
Sum of squared residuals (OLS r-squared = 0.62)	1.93		
ln(Vehicle Price):			
ln(vehicle weight)	LVMASS	1.50957	10.88
ln(acceleration 0-100)	LACC0100	-0.776114	-5.79
Sedan (1,0)	SEDAN	0.165274	3.08
Japanese make (1,0)	JAPAN	0.135046	2.72
German make (1,0)	GERMANY	0.893200	12.53
UK make (1,0)	UK	0.724586	2.70
Sweden make (1,0)	SWEDEN	0.482391	5.54
Constant	CONSTANT	1.20683	1.07
Sum of squared residuals (OLS r-squared = 0.81)	10.37		

Note: Sedan represents sedans, hatchbacks, sports and coupe vehicles.

The system of equations in Table 2a have been obtained from the 1988 data set representing all new passenger vehicles registered as at December 1988 according to the PAXUS data sheets. Given the high degree of collinearity in vehicle attribute data, an extensive estimation process was undertaken to ensure that the empirical models to be used in the applications stage did not suffer from multicollinearity. Some of the vehicle attributes of interest in a study of vehicle fuel efficiency such as output (Kwh) and torque (Nm) are highly correlated with vehicle weight and engine capacity. Any one of these attributes would have been a suitable inclusion; however the decision to choose the vehicle weight was assisted by the lower correlation between vehicle weight and a number of other attributes such as carburation and number of cylinders. We found that fuel efficiency per se was not a direct source of influence on automobile type choice but was highly correlated with vehicle price. However given that vehicle weight and fuel efficiency are highly correlated and that weight is an important influence on vehicle price after allowing for acceleration and country of manufacture (the latter representing a myriad of country specific biases that are inherent in the Australian populations preferences), fuel efficiency was excluded as a right-hand side endogenous influence on both auto type choice and vehicle price. Changes to the weight of vehicles for whatever reason plays a very important role in impacting on both vehicle price and vehicle fuel efficiency.

Table 3a Annual Vehicle Use Model

Explanatory Variables	Acronym	Estimated Parameter	t-value
ln(Unit fuel cost) (c/km)	LPTCSKM	-0.264942	-7.7
ln(unit km dependent recurrent cost) (c/km)	LKMDEPKR	-0.321755	-17.2
Household-business registered vehicle (1,0)	REGHHS	0.210143	3.6
ln(Household income) ($/100)	LHINC	0.102085	3.6
ln(Vehicle weight)	LVMASS	0.459200	5.7
ln(Primary drivers age) (yrs)	LDRVAGE	-0.204091	-4.0
ln(Vehicle price)	LPRICE	0.162911	10.9
Station wagon (1,0)	STWAGON	0.207276	4.7
Constant	CONSTANT	5.26155	9.1

(OLS r-squared = 0.26)

It is recognised that changes in the prices of new vehicles will have an impact both within the new vehicle market (i.e. class share changes due to changes in the quantity of model lines demanded) and within the used car market. To accommodate this phenomenon we either have to establish an econometric model system to explain the relationship between the level of registrations for each new vehicle plus old vehicles or implement a series of price elasticities to represent the most likely switching between classes and out of new vehicles entirely. The former is adequately handled within the auto type choice model, however we need some mechanism for predicting the loss of new vehicle sales to the used vehicle market, as reflected in a reduced scrappage rate for used vehicles. Hensher et.al. (in press) has a scrappage model with price as a determinant. The implied mean elasticity of scrappage rate with respect to vehicle price is -0.66. Thus if we increase the price of a new vehicle by 10% this will reduce the mean scrappage rate of used vehicles by 6.6%. In 1988 this is equivalent to a reduction at the mean from 3% to 2.8%.

Evidence on the switch out of new vehicles in response to new price increases is limited because of the lack of econometric models for new vehicle which explicitly model the demand for used vehicles. For example, the BTCE model for new vehicle registrations reported in AIC (1988, 59) is a single equation with an implied vehicle price elasticity of -1.0921. This tells us that a 10% price increase for new vehicles will lead to a 10.921% reduction in the demand for new vehicle registrations, ceteris paribus. We have no way of knowing how much of this is substitution towards used vehicles or simply non-purchase of a vehicle.

A Canadian study in the later seventies (Blomqvist and Haessel 1978) provides evidence to suggest that an increase in the price of new large cars tends to cause fairly substantial shifts in demand towards new small cars and possibly old cars. The definition of small cars is the USA subcompact class; all other classes being aggregated into the large class An increase in the price of new small cars on the other hand shifts demand mainly towards old cars, but not towards new large cars. The implied elasticity of demand for used cars with respect to new prices of large and small cars are respectively 0.02 and 0.90. A recent time series study by Hensher and Ho (1991) using annual data over the period 1961 to 1988 and a suitable lagged structure to account for the long-term impact of vehicle price changes gave a mean new vehicle price elasticity of demand of -0.6.

Appendix B. Consumer Surplus

B.1 What are the Sources of Consumer Surplus?

Consumer surplus is the satisfaction or utility gained from the acquisition and use of cars.

Consumer satisfaction arises from a whole range of tangible services and intangible feelings associated with the car's attributes and how it performs in service, both now and as expected in the future.

It is obtained in several ways, including the improved level of service arising from vehicle attributes such as interior volume; the flexibility of the car for towing, carriage of garden rubbish, and so on; the feeling of elegance or status arising from colour, presentation and options; the comfort delivered by air conditioning, seating and gentle 'feel'; and the thrill of overtaking large trucks in 'tight' situations, which also allows the driver to 'save time'.

Interior volume is particularly important because it provides space for passengers or goods, and especially a contingency in case of infrequent uses such as holiday travel, occasional carriage of social or business groups, and carrying of unusual loads (like taking the TV to be repaired, or samples to a customer). This contingency appears to be highly valued.

Utility takes account of the price paid for the vehicle and the fuel savings it might deliver. But this goes well beyond money values. Rather, one must think in terms of a generalised "price"; in other words, the consumer subjectively weights product features and expectations along with money payments and chooses the vehicle with the lowest composite "price" (Cardell and Dunbar 1980, 424).

B.2 Changes in Surpluses

This note examines changes in consumers' surplus and government revenues arising from the combined effects of eliminating sales tax after first moving from the manufacturers' production plans to the maximum technology scenario. A complete account of this requires consideration of all of the substitution effects occurring between classes and involves extremely complex effects which cannot be explained using simple diagrams or intuitive argument. However, we can gain some insights up to a point by using conventional text-book reasoning.

Let us restrict the analysis by assuming that there is only one class of vehicle for which we have a demand curve DD. The manufacturer produces output Q1 according to the production plan and then proceeds to clear stocks. This requires that price be set at P1. The total amount of consumers' surplus at this (base) stage is the triangle DAP1. On the production side there is also a surplus which, in part, is the sales tax T1 and the other part is net revenue net of sales tax less cost*. So, we have a surplus transferred to government (T1) and a producers' surplus:
Producers' surplus = P1AQ1O - T1 - Costs1

Now the manufacturers move from the production plan to the maximum technology scenario. This has the effect of shifting the demand curve to the right to D*D* as the quality of vehicles improves. Assuming that the manufacturers do not at the same time attempt to change the level of production, their attempts to clear their stocks will result in a new price P2 and a new consumers' surplus equal to D*BP2. The tax is now T2 and producers' surplus is:

Producers' surplus = P2BQ1O - T2 - Costs2

The change in social surplus resulting from the change to the maximum technology scenario is equal to:

Change in surplus = change in consumers' surplus + change in tax + change in producers' surplus

= [D*BP2 - DAP1] + [T2 - T1] + [(P2BQ1O - T2 - Costs2) - (P1AQ1O - T1 - Costs1)]

= [D*DCB - P2P1AC] + [P2P1AB] - [Costs2 - Costs1]

= [D*DCB - P2P1AC] + [P2P1AC + CBA] - [Costs2 - Costs1]

= D*DAB - [Costs2 - Costs1]

That is, the change in total surplus is the parallelogram D*DAB less the change in costs of production.

Now let us eliminate the sales tax once this technology change has already occurred and further assume that this is fully passed on to consumers in the form of lower prices. That is,

P3 = P2 - T2

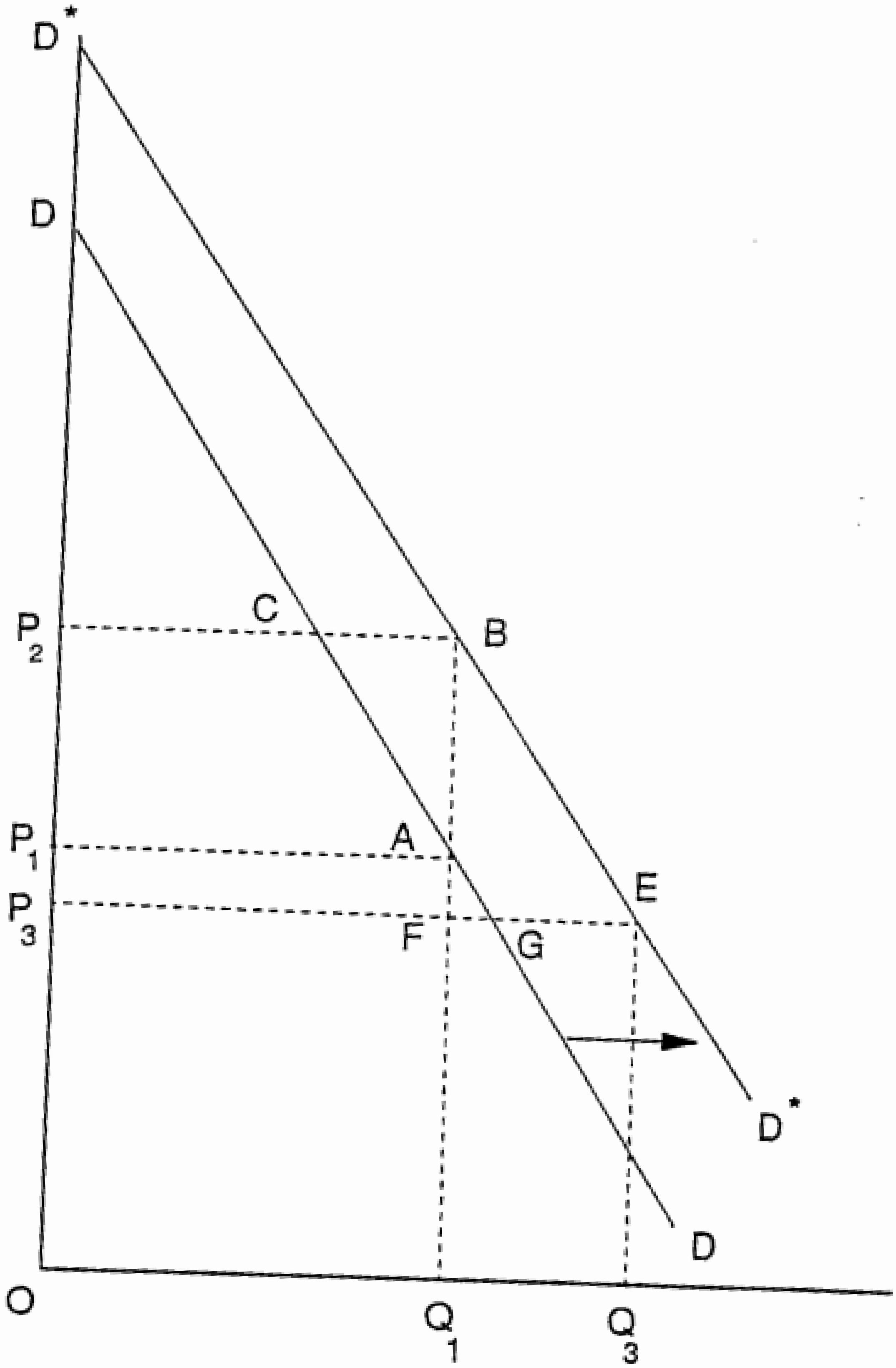
If production remains unchanged, consumers increase their surplus by the amount P2P3FB. This is achieved simply by transferring that portion of the surplus taken away in taxes back to consumers and there is no net change in total social surplus. If instead, output expands to Q3, there is an additional effect, the increased surplus to consumers arising from the extra demand (BFE) plus any increase in producers' surplus. The latter is equal to the change in revenue, FEQ3Q1, less the change in costs, (Costs3 - Costs2).

Taking the combined effect of a move to the maximum technology scenario and the elimination of sales tax (assuming output expands), the total change in social surplus is:

Change in surplus = D*DAB - [Costs2 - Costs1] + BFE + [FEQ3Q1 - (Costs3 - Costs2)

= D*DGE + AFG - [Costs3 - Costs1]

Note that this change in surplus has no necessary relationship with the amount of change in sales tax, the rectangle P2P3FB.



However, this analysis is far too simplistic. When we allow more than one class of vehicle and we begin to change the vehicle characteristics and their prices, the model allows substitution of one class for another. It would be impossible to demonstrate the complexity of the relationships involved in this situation in any simple way. In fact, the shifts in demand from one class to another are responsible for the largest part of the changes in consumers' surplus. No partial analysis (i.e. holding some factors constant whilst varying a smaller number of other effects) produces valid results and it must be said that any attempt to draw definitive conclusions from the type of graphical analysis presented above could lead to extremely misleading results.

The diagram and accompanying exposition clarifies the underlying theoretical interpretation of the results that flow from the application of the econometric model system developed by ITS. It is important to understand that the model system involves 9 classes of vehicles and hence a diagrammatic representation of the complete set of sources of consumer surplus change cannot be included in a single-good (class) diagram.

The changes in consumer surplus associated with the sale of vehicles in a given year reflect the effects of technology change (moving from the product plan to the maximum technology scenario), various taxes (sales, fuel) and any resultant impacts on the overall vehicle profile due to changes in class shares. This latter effect causes vehicle attributes such as weight and fuel efficiency to further change consumer surplus.

An issue of great importance in the calculation of changes in consumer surplus is the underlying behavioural rule implicit in a potential vehicles purchaser's choice process leading to the selection of a new vehicle. There are two extreme positions:

(i) An individual evaluates all attributes in a way that reflects the value of those attributes to the individual throughout the period in which the vehicle is likely to be held by that individual. Due account must be taken of the expected residual value after this period. In this situation one would assume that the future stream of consumers' surplus is capitalised in the year in which the car is purchased. That is, the individual has already undertaken subjective discounting in the process of arriving at a choice decision.

(ii) An individual evaluates all attributes in a way that reflects what is affordable at the time of purchase without giving any significant weighting to the manner in which the attributes provide benefit throughout the period the vehicle is planned to be held. In this situation some "lateral" discounting is required to accommodate the assumption that the individual has not undertaken any subjective discounting at the time of purchase.

An intermediate position might be one in which vehicle attributes are viewed in a manner which involves a mixture of discounted and undiscounted assessment. In particular, an assumption along these lines might be that an inability to undertake subjective discounting (lack of information etc) as reflected in the random utility maximisation assumption underlying the econometric model system results in the domination of "what is affordable" at time of purchase with limited appreciation of the profile of benefits over time.

The literature on how individuals evaluate vehicle attributes through time at the time of purchase is controversial. The issues are not well understood. If one prefers to adopt the conservative position this requires lateral discounting of the changes in consumer surplus reported in the main text.

The producers' surplus might be entirely retained as a rent on the capital inputs of the vehicle manufacturers or they might be earned by other suppliers of factor inputs.

B.3 Estimating Consumer Surplus

The estimates of consumer surplus calculated by the Study account for utility gains arising from changes to vehicle attributes, changes in the market share of each vehicle class due to overall changes in vehicle attributes, and flow through effects from vehicle choice into vehicle use.

There are great difficulties in measuring utility, but attempts must be made if Government decisions on policy matters (especially such important matters as fuel economy) are to take the national welfare into account.

A mathematical model was constructed which was based on actual vehicle attributes available on cars sold in Australia, the household, ownership and use characteristics obtained in consumer surveys, the unit costs of vehicle operation (including taxes) and vehicle retail prices (including taxes). This was presented in Appendix A.

Nominally, modelling information explicitly provided in a survey can be undertaken by a number of straightforward mathematical techniques, but these were not considered to be adequate for the purpose of estimating consumer surplus.

The difficulty with that type of estimation process is that the sources of consumer satisfaction are so dispersed; another is that consumers commonly cannot properly articulate their reasons for choice in a survey situation; a third is that researchers sometimes do not ask the right questions. Yet the advice must be prepared in the light of the data that can be gathered.

To circumvent these problems in survey technique, a mathematical construct was used. This assumed that respondents to the survey know explicitly or implicitly why a particular choice was made, but the data does not include a number of unobserved factors which must be taken into account.
The technique involved making some assumptions about the mathematical distribution of these unobserved (or random) factors. In econometric language, it was assumed that the unobserved component of

the utility expression was distributed extreme value Type I, and the choice model thus takes a multinomial logit form.

The survey data was used to obtain estimates of the probability that a representative consumer would choose the particular make/model which offers the highest utility, under a given set of product offerings and personal circumstances. These probabilities were extended to account for the model construct being oriented to vehicle classes.

The estimation data set is from Sydney households in 1985, and included both privately owned and company cars. The data contains information not only about the cars themselves, but also who owned them and why, and how they were used on a daily basis.

The estimate of consumer surplus accounts for the satisfaction obtained by all owners, year by year, throughout the life of the vehicle. It includes not only anticipated fuel savings, but also the anticipated pleasures of country tours, commuting, the admiration of friends, and so on. This year by year satisfaction was discounted according to the assumptions discussed in the main report.

To obtain the national benefit required that the taxation element of inputs be deducted; these appear as government revenue which is simply redistributed among Australians.

The model represents the current state of knowledge in this field. The main concern of the Study was not whether it estimated consumer surplus adequately, but that it was not asked to forecast beyond its calibration capability. This was thought to be about 30 percent variation from the conditions of the survey. Variations due to inflation were controlled by doing all modelling in constant prices.

Techniques are available to extend this range using stated preference techniques. However, the Study did not offer opportunity for such work but it may be needed in the future if Australia is to pursue a fuel economy policy which responds to the Government's interim target on Greenhouse.

It is to be noted that this methodology is quite different from the 'rule of a half' commonly used in cost benefit analysis (Williams:1978), or an alternative assumption that the capital value of future saving comes as an increase to the consumer surplus of a new car, which in turn is associated with tradeoffs between fuel economy and car price.

Consumer surplus is not derived from new cars only. Although the estimates are accounted in the year of purchase of the vehicle, they represent an accrual of satisfaction or utility from day one right up until the car is scrapped.

B.4 The Specifics of Calculating Consumer Surplus

The Study evaluated the benefits resulting from a change in the weight, price and fuel efficiency of new cars sold in Australia.

It is to be noted that other attributes change over time, e.g. household income, fuel price, rear volume of small/medium vehicles, unit operating costs, incidence of private/business-registered vehicles etc. Some attributes are highly correlated with weight, and implicitly bear on the calculation.

The motivation for measuring benefits is similar to the approach used in standard cost-benefit analysis. That is, the benefits derived from a policy change are a function of the differences between consumer utilities with and without the policy.

It is assumed that individual utility is derived from the chosen alternative, but not the rejected ones. The benefit measurement involves the differences in maximum utilities (over the alternatives available among classes of vehicles) with and without the policy. However, the maximums cannot be observed directly because of the random component in the utility function used to derive the mathematical (logit) choice model. Therefore, the expected values must be used. Specifically, the benefit measure is:

$$\text{Benefit} = \text{Expected Value } (\text{Max } U_1 - \text{Max } U_0) \quad \text{(B1)}$$

in which

Max U_1 = the maximum utility of the alternative with the policy change

Max U_0 = the maximum utility of the alternative without the policy change.

The literature shows that Equation (B1) has a very convenient form in the case of the logit version of a vehicle choice model. The form used to estimate the weights for each attribute influencing choice of vehicle are:

$$\text{Benefit} = \sum_{i=1}^{J_1} V_i - \text{Log} \sum_{i=1}^{J_0} V_i \quad \text{(B2)}$$

Where V_i defines the utility expression associated with vehicle type i, and is typically of a linear additive form:

$$V_i = a_1A_1 + a_2A_2 + \ldots\ldots + a_kA_k \quad \text{(B3)}$$

where A_k is the kth vehicle attribute and a_k is the utility weight indicating the relative importance of attribute A_k in explaining the level of (relative) indirect utility V_j, and J_i is no. of alternative vehicle types in the choice set associated with the policy change.

Formula (B2) was used to evaluate the benefits resulting from changes in classes and numbers of cars offered and purchased. It data were available, it could also be used to assess changes to socioeconomic attributes influencing vehicle choice, although the Study did not attempt this.

McFadden (1981) has shown that this measure of benefit is readily interpretable as the difference in the expected maximum (indirect) utility associated with comparing two situations under the assumptions stated above.

Mathematically speaking, the gradient of expected maximum (indirect) utility equals the vector of auto vehicle choice probabilities:

$$\partial Y^* / \partial (x_{iq}\, \beta) = P\,(i / x_q) \quad (i=1, ..., J)$$

Where: Y^* is the expected maximum (indirect) utility.
P is the choice probability
x_{iq} are attributes associated with vehicles type i and user type q
β are the unknown (estimatable) utility weights for each attribute.

In McFadden's view, the model can be interpreted as the demand function for fractional consumption of the alternative vehicle classes by a single 'representative' social consumer with the expected utility function.

Then Y^*q can be interpreted as an exact measure of social welfare or consumer's surplus. A full proof of this is available in McFadden (1981).

Thus Consumer Surplus is essentially a measure (or index) of the additional benefit which a consumer obtains from a change due to technology or some policy instrument. The units in which consumer surplus are measured are somewhat arbitrary. In Equation (B2) above the units are 'utility values'. It has become **common practice** however to translate measure into dollars. This is done by scaling the benefit equation by 1/ (coefficient of car price) = $1/\beta_p$. Thus we have:

Benefit (or change in CS in $s)

$$= \quad {}^1/_{\beta_p} \left(\text{Log} \sum_{i=1}^{J_1} V_i - \text{Log} \sum_{i=1}^{J_0} V_i \right) \qquad \text{(B5)}$$

The prices used in the calculation are inclusive of transfer payments (i.e. taxes, etc), which is valid for estimating changes to the consumer surplus of the consumer.

The taxation component associated with technology and fuel costs was netted out as it forms income to government from various sources. The netting out results in a measure of net social benefits.

B.5 What Comparisons Were Made?

The above econometric approach was used to estimate, for each target year, changes to consumer surplus arising from the Maximum Technology Scenario and the policy options listed by the Brief. These estimates apply to both new and used vehicles.

Estimates of fuel saving, technology cost and the tax effect were made separately.

Maximum Technology Scenario

For the comparison of the effectiveness of the MTS, the calculation involved comparing the attributes of new cars with Product Plan and MTS attributes. The utility of cars already on the road was assumed unchanged in respect of technology, except that reduced numbers of pre 1988 vehicles was taken into account as these were replaced.

In these comparisons, the change in consumer surplus is driven primarily by fuel efficiency (its impact on unit fuel costs), weight, and price increases due to technology improvements.

Policy Analysis

The basis of testing was that policy instruments designed to encourage manufacturers to deliver vehicles which conform to the Maximum Technology Scenario were evaluated for their economic implications.

Thus most policy analyses assumed that a MTS would be implemented, and benefits were estimated by comparison between the MTS and the Product Plan, **with the policy instrument applied to both**. In this way, the tests all isolate the change in consumer surplus obtained from technology, under the subject policy option. An exception to this was where policies were being examined to induce fuel economy improvements beyond that achievable via technology. For these cases, the MTS was tested with and without the policy.

Otherwise, changes to consumer surplus arising from policy options alone are not reported.

For these comparisons, changes to consumer surplus is driven by sales tax, fuel tax and vehicle retail price changes.

Impact on the Used Vehicle Fleet

Although primarily aimed at new vehicles, the effects of some policies applied to new vehicles flow through to cars already on the road (e.g. a policy which includes both sales tax and fuel tax).

The consumer surplus of used vehicles was assumed to be marginally affected by whether the MTS or the Product Plan was in place for the available new vehicles. It is only when policies affecting new vehicles are introduced do we see a change (impact) in the used vehicle market which has consequential implications on the change to consumer surplus.

In these cases, it was assumed that the relevant attributes of on-road vehicles were the same ones as influence the choice of new vehicles, except that the levels would differ. The flow-through effects were evaluated only for the Product Plan.

It was considered that this latter assumption would not lead the estimates of consumer surplus into significant error, because it takes so long for new vehicles to penetrate into the total car park. Scrappage rates are expected to remain in the range 3.5 to 4.5 percent during the planning period, depending on policy determinations. Thus it takes about 25 years to turn over the fleet, compared with a planning period of 14 years.

An attempt was made to dimension the order of magnitude of any discrepancy in consumer surplus estimates due to this assumption. Firstly, it was found that cars built according to the MTS would reduce total Australian fuel use in 2005 by about 700 megalitres, compared with an expected Product Plan fuel use of 15,000 megalitres.

This difference of 0.5 percent was considered to represent an upper limit on any discrepancy. Secondly, it is noted that the factors of most importance to consumer choice are not affected by the MTS. For each class, the MTS holds interior volume and performance constant with Product Plan levels; other consumer-directed attributes such as the cooling efficiency of air conditioners are not affected by the MTS. Thus it was considered that the use of Product Plan attributes in the estimation of flow through effects on consumer surplus is valid.

The major influence on change in consumer surplus associated with used vehicles is changes to fuel tax, although in 1995 only the "one-hit" impact of sales tax reduction on new vehicles spillover to the price of used vehicles, giving owners a once-off loss of surplus.

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