Managing to save fuel

Fuel economy is a matter of concern to both the cost-burdened motorist and the nation trying to make its fuel supply last. Yet on a nation-wide scale the fuel economy of Australia's motor vehicles appears to be falling steadily.

If the amount of motor spirit consumed each year is divided by the distance travelled we arrive at the following figures: in 1963, 9·6 L per 100 km; in 1971, a deterioration to 12·1 L per 100 km; in 1976, a drop to 12·6 L per 100 km; and in 1979, a further drop to 12·7 L per 100 km. (The figures for distance travelled were obtained by the Australian Bureau of Statistics from surveys of vehicle owners.)

More than 70% of the fuel used for transport in Australia is consumed in urban travel. Traffic congestion in the cities works strongly in cutting short the number of kilometres that can be travelled on a litre of petrol. Three out of four urban kilometres are travelled on only 21% of the network, that is, on arterial roads. In Sydney and Melbourne, 30% of peak hour traffic is restricted to speeds of less than 25 km per hour.

Little is known about cars' and trucks' fuel consumption at any instant as they manoeuvre in stop–start traffic. Each manoeuvre takes different, but unknown, quantities of fuel (although we do know, of course, that city driving consumes more than cruising on the open road). The effect of urban traffic management options is also unclear — but figures would certainly improve if we could always get green lights and keep in the moving lane of traffic!

Scientists in the Transport Engineering Group of CSIRO's Division of Mechanical Engineering, led by Dr Ron Johnston, are studying the factors that together determine a vehicle's rate of fuel consumption. Traffic density, frequency of acceleration and braking, and other traffic-related factors are important, as well as the car's size, engine capacity, and so on. The Group is not only seeking the characteristics of individual vehicles, but needs those of a whole stream of traffic for gauging the impact, for example, of various traffic-light cycles.

Beginning with the first aspect, its members have continuously logged the fuel consumption of a Valiant station wagon over a number of routes in Melbourne. They have found that idling and stop–start driving can increase fuel consumption by almost 100% on congested roads.

The graph on page 17 shows how, for both urban conditions and steady travel, the car's fuel consumption varied with speed. It indicates that, if the average trip speed of the car could be increased from 25 k.p.h. to 30 k.p.h., fuel consumption could be reduced by 10%.

This is easier said than done. It would require the number of stops per kilometre to be reduced, and in an urban environment this may mean building expensive freeways, since there is a limit to how far traffic management (discussed later) can improve matters.

More than 70% of the fuel used for transport in Australia is consumed in urban travel.

Improved car design

Of course, the other way of saving fuel is to build more efficient cars. The engines of cars with radial tyres, less weight, and more aerodynamic lines don't have to work so hard against rolling resistance.

More efficient transmission systems, such as continuously variable gear boxes, could improve matters still further. Most petrol engines are only 25% efficient, and this can be bettered. Gas turbines reach about 30% efficiency, while diesel engines give out up to 35% of the energy fed in.

Unfortunately, many new-model cars show poorer fuel economy than their antecedents.

Members of the Transport Engineering Group analysed the road-test data on 234 cars collected by the NRMA and RACV over recent years. Making allowance for each of the many variables between tests, they found that cars with automatic transmissions scored 7% more petrol consumption than equivalent cars with manual transmissions.

Accessories, most notably air-conditioning, also contribute to lower fuel economy.

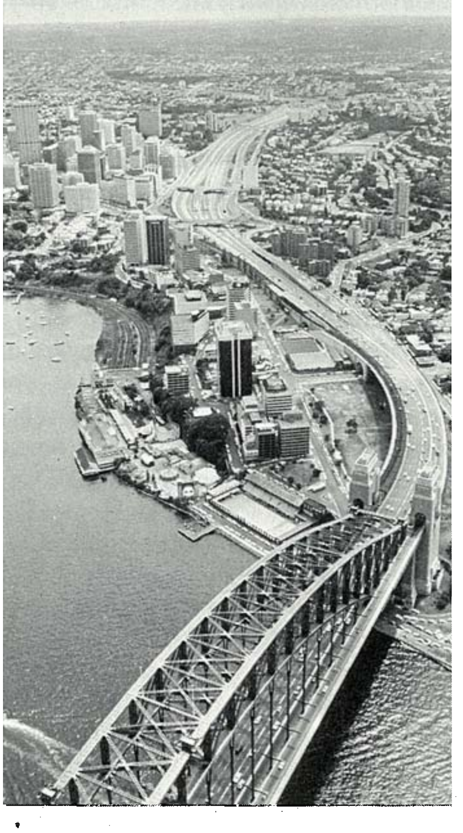
Traffic engineering

But whether or not we develop more efficient cars, a great amount of fuel will still be lost if those machines, designed to have a minimum fuel consumption at a steady 50 k.p.h., are left to idle in city traffic jams.

This brings us back to the low-cost traffic engineering approach to saving fuel. Clearways, changes in traffic-light co-ordination, and introduction of priority lanes for buses, taxis, and multiple-passenger cars obviously have an effect — but how much, and is the effect worth while?

American studies suggest that increasing the number of traffic signals on an urban arterial highway from zero to two per mile can increase fuel consumption by nearly 60%. In Atlanta, Georgia, fixed-cycle traffic lights were replaced by a system responding to traffic density as sensed by strips on the road. The engineers claimed significant improvement in trip speed, number of stops, time stopped, and number of accidents. They calculated a fuel saving of 22%.

Sydney. Freeways encourage the use of private transport.



Traffic engineers in Glasgow optimized the traffic lights for minimum number of stops rather than minimum delays. They claimed a 6% improvement in fuel consumption with a negligible penalty in journey time.

Measuring the effects of traffic lights is clearly important, but it is a difficult thing to do. Many unanswered questions surround what has been done so far. The commonest approach is to 'float' an instrumented test car in a traffic stream (like a leaf on a river) and measure its fuel consumption, speed, number of stops, and so on. In Victoria, traffic lights are being introduced at about 10 intersections a week. While improving traffic movement generally, on some roads they are likely to increase both the number of stops and fuel consumption.

The approach is to 'float' an instrumented test car in a traffic stream (like a leaf on a river).

Using the 'floating car' approach, Australian traffic engineers have recorded fuel savings of up to 30% when traffic lights have been co-ordinated, in comparison with isolated signal systems.

But Dr Johnston doubts that many of these results can be relied upon. Substantial fuel saving figures may be possible under conditions most favourable to through traffic, but what of the poor motorists waiting in the cross streets? Dr Johnston believes that, when the effect of cross-flow traffic is taken into consideration, net fuel savings would be unlikely to exceed 10%.

Any survey to verify this would require hundreds of vehicles to be monitored, because there are so many variables. Differences arise due to type of vehicle, weather, how vehicles are driven and in which lane, state of tune, manual or automatic transmission, hot or cold engine, day of the week, traffic volume, traffic-light settings, and so on. It's no wonder that no reliable method of estimating the fuel consumption of a stream of traffic along a stretch of urban roadway has to date been achieved.

Dr Johnston and his team decided to tackle the problem in a new way. They designed a statistical experiment in which a small number of representative test cars would be introduced into the traffic stream according to a planned schedule. The schedule would be designed to show the effects of chosen changes in traffic lights, type of car, lane used, and so on.

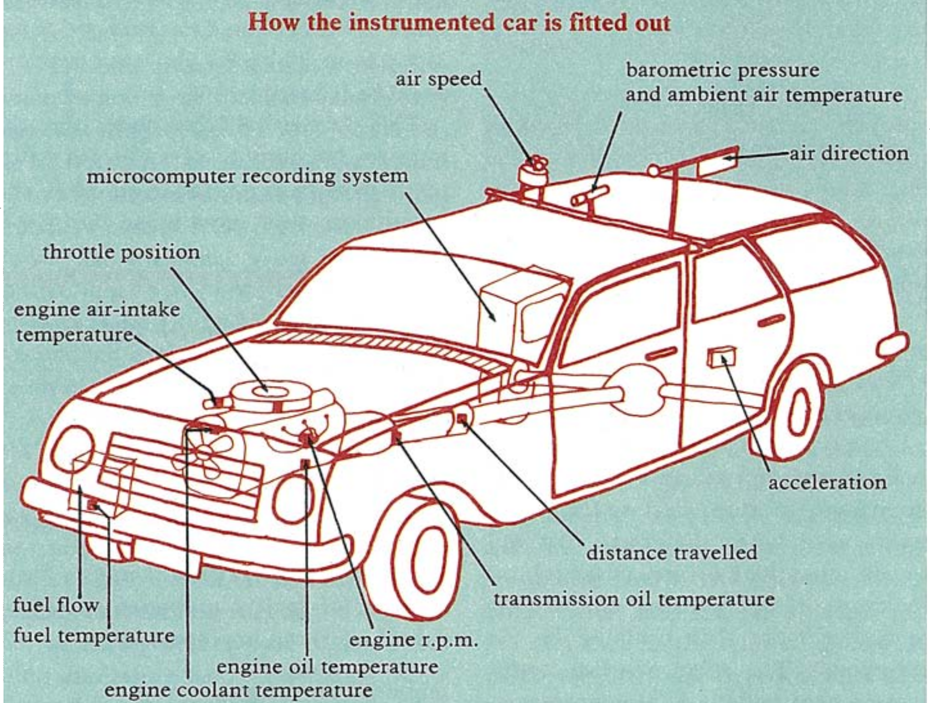
Tests in Sydney

Late in 1979 the CSIRO engineers put their statistical experiment into practice for 5 weeks on a 2·3-km length of Military Road in the Sydney suburb of Mosman.

The study — one of the most complex traffic experiments to be carried out in Australia — was undertaken in collaboration with the Traffic Authority of New South Wales and the State's Department of Main Roads. Federal Transport Research grants assisted the study. The aim was to measure the effect on fuel con-

The Division's instrumented car.

A microcomputer system continuously records 14 variables concerned with the car's operation.



An aerial view of Military Road at morning peak hour.

sumption of using two different traffic-light-control programs — with cycle lengths of 140 seconds and 90 seconds respectively. The two programs, each operating sets of co-ordinated lights, were used on alternate days.

Military Road was chosen because its traffic consists mainly of commuter vehicles — the road eventually carries traffic across the Harbour Bridge to the city. Flow of the traffic is not complicated by large diversions and cross flows, and the traffic-light system is computer-controlled and therefore easily altered.

Each day of a Monday-to-Thursday week, six cars were sent into the morning peak traffic. Four of them were test cars, used for a week at a time. Some travelled in the transit lane — a lane reserved for buses, taxis, or cars with multiple passengers — and some in the other two lanes. Each car was fitted with a fuel meter and carried a driver and an observer. The four drivers drove a different car every day. Over the 5 weeks of the experiment 20 different cars, ranging from 4-cylinder models to V8s, and from new to 10 years old, were tested.

In Sydney and Melbourne, 30% of peak hour traffic is restricted to speeds of less than 25 km per hour.

The dynamometer facility at the CSIRO Division of Mechanical Engineering. The engine drives through a tail-shaft to a brake drum. The braking resistance (torque) is computer-controlled.

Two fully instrumented cars were also run throughout the experiment to monitor variations in traffic conditions. They provided data on acceleration, speed, and distance travelled, as well as fuel consumption. Traffic flow was also measured, by sensing strips on the road and by observers counting cross-street traffic.

Further data were supplied by recording those number plates that ended in 'O' and '1' at the start and end of the study section and by aerial photography. In this way traffic congestion was measured in terms of travel time, number of vehicles in the section, and the number stationary at any instant. From this collection of data, and reference to registration records for figures on a vehicle's weight, number of cylinders, and engine capacity, it was possible to estimate the fuel consumption of the entire traffic stream — the 'aggregate' fuel consumption.

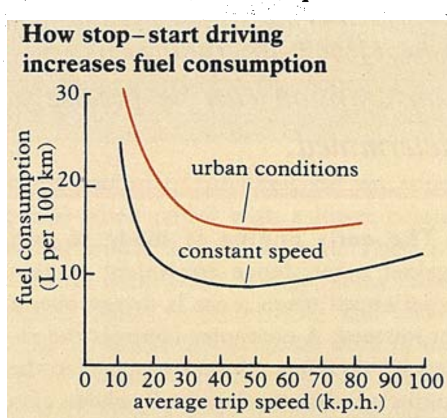
Idling and stop–start driving can increase fuel consumption by almost 100% on congested roads.

The experiment's results

Conclusions from the experiment were illuminating. On average, a car (not using the transit lane) took 65% longer, used 27% more fuel, and was stopped at least three times more often when the 90-second cycle was used than with the 140-second cycle.

The latter cycle was found to provide a net fuel saving of 10% (all traffic considered) during the morning peak. This control plan has been subsequently adopted by the Department of Main Roads. If this saving was repeated nationally on the 1000 km of arterial roads on which current speeds are below 25 k.p.h., drivers would save $15 million a year.

Differences in the style of driving of the four drivers showed up in fuel-consumption figures. Although their travelling times did not differ significantly, their rates of fuel consumption differed by more than 10% between the highest and lowest, regardless of the type of car they were driving.



The graph shows how stop–start driving on urban roads increases fuel consumption. Data were derived from the Division's instrumented car.

The four drivers were regular commuter drivers, three male and one female, on the staff of the New South Wales Department of Main Roads. Interestingly, all recorded the highest fuel consumption on Mondays.

Transit lanes

Transit lanes are something of a contentious issue, with the supporters of public transport praising them and the motor-car lobby criticizing them. They certainly speed up buses, but under some conditions they can slow down traffic in other lanes.

On Military Road at peak hour the study showed the transit lane carrying 400 vehicles an hour, whereas the other two lanes each carried 900. The smaller number in the transit lane is due in large part to buses stopping for passengers. Of course, in terms of the number of passengers carried per hour, the transit lane won handsomely, carrying 52% of people.

The study was not designed to evaluate the effectiveness of transit lanes; the section of roadway studied was too short and not representative of the total length of transit lane.

In the investigation, drivers of test vehicles using the transit lane were instructed not to move out of that lane, deliberately making them worse off than normal cars in the transit lane. Because of this experimental requirement, these test cars behaved more like a bus (because they got caught behind buses). They had a travel time 80% longer, stopped six times more frequently, and consumed 34% more fuel than cars in the other lanes.

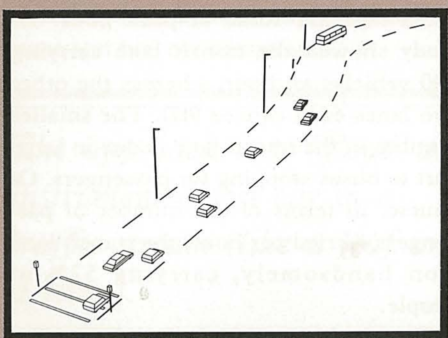
However, on a *per capita* basis, the experiment showed that people in the transit lane consumed far less fuel. Using figures for the average number of people in each car, the CSIRO engineers calculated that car travellers in the transit lane used half as much per traveller as those in the other lanes. Similarly, if bus occupancy figures are added into the calculation, transit lane travellers used one-fifth the fuel of the typical car commuter.

Dr Johnston and his group have not yet completed their analysis of the information gained. The results should help traffic authorities assess the fuel efficiency of alternative traffic management procedures.

Modelling traffic flow

If a traffic engineer wishes to know the effect of turning one lane of a particular roadway into a transit lane, Dr Peter Gipps can show him on a video screen.

Dr Gipps, of the CSIRO Division of Building Research, has developed a computer program, MULTSIM, that simulates the behaviour of traffic on a one-way multi-lane road. Up to 200 vehicles at a time can be handled. The model sets each vehicle — motorcycle, car, bus, tram, or truck — onto the road and controls its movement in the same way a driver would — basically responding to what the vehicle in front is doing.



A computer-drawn frame produced by Dr Gipps' traffic-flow simulation program.

The degree of success in simulating the real-life situation hinges on the model's ability to mimic the differing temperaments of drivers. The program gives each driver an individual desired speed, which can be greater or less than the average traffic speed (a distribution of desired speeds is specified). A maximum value for the acceleration, or strength of braking, that he will use is also specified. The reaction time of all drivers is assumed to be the same. Further, the program allows for each driver's propensity to change lanes — this depends on the size of the opening available and the distance to where the driver wishes to leave the road.

In summary, MULTSIM governs each car's movement by comparing the driver's goals with the location and speed of vehicles in front and in adjacent lanes — pretty well the way we do drive.

The model also simulates drivers looking ahead to see whether they need to change lanes to avoid obstructions or slow heavy vehicles. And if a driver's goal is to turn at some distance ahead, all possibilities for lane-changing are sought, even to the extent of changing speed to facilitate the manoeuvre. Slowing down of traffic due to grades is also taken care of.

The relevance of the model to the present discussion is that it can calculate the aggregate fuel consumption of the traffic, provided each vehicle's fuel-use figure at various speeds and accelerations is known. To fulfil this proviso, Dr Gipps is waiting for results from Dr Johnston's experiments with fully instrumented vehicles, so that he can plug in realistic values.

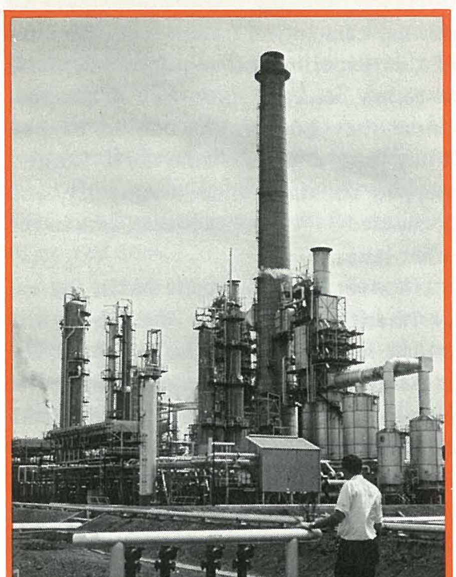
The effect of various traffic management options (like transit lanes) on aggregate fuel economy could then be predicted from data on existing traffic conditions. Air pollution figures could be produced in the same manner.

Readers may remember that *Ecos* 17 carried a story, 'Saving fuel in cities', which described the computer model TOPAZ, devised by Dr Ron Sharpe of the Division of Building Research. That model is more general, dealing in terms of 'zones' of interest to the town planner, and how to optimize their placement.

However, it is worth keeping in mind that, as TOPAZ showed, pollution, distance travelled, and energy consumed depend very much on the layout of a city and its road network.

MULTSIM: A computer package for simulating multi-lane traffic flows. P.G. Gipps and B.G. Wilson. *Proceedings, Fourth Biennial Conference, Simulation Society of Australia, Brisbane, 1980.*

Saving fuel in cities. *Ecos* No. 17, August 1978, 11–13.



A reduction of 1 in the octane rating of petrol sold in Australia would save 500 000 barrels of crude oil per year.

Laboratory experiments

Back at the Division, the Transport Engineering Group has begun work with a new test facility — unique in Australia — that will simulate and monitor, in the laboratory, the performance of a car on the road. It is a computer-controlled engine dynamometer.

The effects on fuel consumption can be precisely determined.

The car's engine is made to run against a resistance equivalent to that experienced when a car is driven over a set journey. A computer controls the resistance on a large drum connected to the engine's tail-shaft. A large flywheel, also mounted on the tail-shaft, simulates the effect of the vehicle's inertia.

A component vital to the accurate operation of the dynamometer is a precision torque-measuring device developed by the Group. Measurement of the tail-shaft torque by it allows the computer to precisely adjust resistance according to the test requirements.

The device can also be used to make the initial on-the-road torque recordings. In this respect it is matched by no other instrument in Australia, although expensive units, not so accurate, are in use overseas.

Trying to duplicate a vehicle's trip over a stretch of roadway by repeating the journey is always impossible. Weather and traffic conditions invariably differ, as do driver reactions. Test conditions with the new dynamometer set-up will be accurately repeatable, allowing close investigation of all the factors that influence car fuel economy.

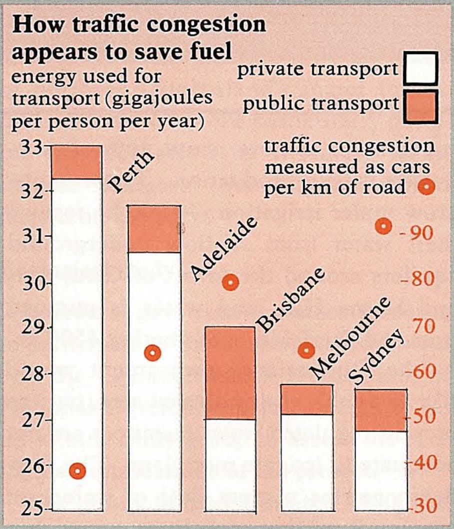
The effects on fuel consumption of anti-pollution devices, superchargers, air-conditioners, and so on can be precisely determined. The pin-pointing of areas where it's possible to make even small improvements in an individual vehicle's

Congestion planning — the other way to save fuel

Some experts say the best way to save petrol is to design more efficient cars: some consider we should build freeways and make traffic move more smoothly. A radical solution is to make roads more congested.

Some American studies have found that the cities with the most urban freeways are worst off in terms of fuel consumption. It seems that freeways encourage people to use their cars more. Lack of freeways promotes use of public transport, and, all other factors being equal, cities with the best public transport have the lowest fuel consumption.

Generally, the more traffic congestion a city has, the less fuel it consumes.



Dr Peter Newman and Mr Jeffrey Kenworthy, of the School of Environmental and Life Sciences at Murdoch University, have examined statistics to see whether, of Australian cities, the most congested registered the lowest fuel consumption. As their paper in a recent issue of *Search* shows, they do. Analysis of figures for the five Australian mainland capital cities shows that, generally, the more cars per kilometre the city has, the less is its petrol use per head (see the graph). This is true for other indicators of congestion too, such as length of road per person, and the proportion of the population taking more than 45 minutes to travel to work.

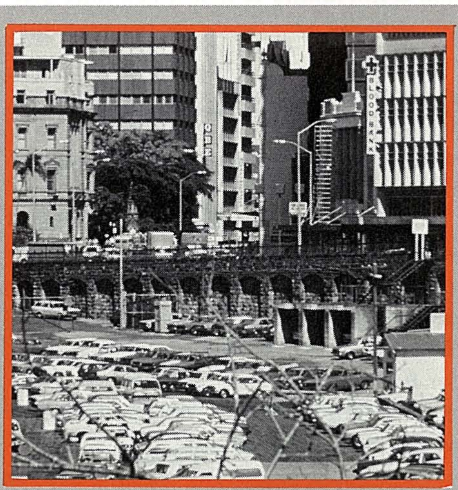
The authors also bring out other factors that go with decreased consumption of transport energy. The two most important are population density and 'degree of centralization' (how strong a central focus the city has).

Higher population densities encourage lower transport energy use because trips are shorter, public transport is used more, and walking and cycling become more favourable means of travel. Dr Newman and Mr Kenworthy point out that the outer areas of all our cities have much the same density. They speculate that these outer areas therefore have roughly the same transport characteristics and that the differences between the cities are due to their inner areas — which brings us to the 'centralization' factor.

In a centralized city some journeys may be longer, but there will be far fewer cross-city trips. Since more than 75% of urban travel is for non-work reasons, a decentralized city means the total distance travelled is longer.

A centralized city also favours public transport, as parking and congestion quickly reach a limit for private cars. One worker in the field has suggested that, when a central city work force grows beyond 50 000 to 100 000 people, only public transport access can enable it to continue growing. Figures for public transport usage in each of our main cities tend to back this up, with larger work forces relying more on public transport.

Inner-city residents live close to work, shops, and school, and depend less on cars. In 1971 only half the households — at all income levels — in inner-suburban Sydney owned cars, compared with three-quarters in other areas of the city.



Brisbane has few parking spaces available in the city, discouraging private transport.

Brisbane provides a prime example of how traffic-restraining factors such as short length of road per head, high traffic congestion, and few parking spaces can work. When the figures were gathered, this city showed these characteristics to a degree comparable with those in the larger cities, Melbourne and Sydney, even though Brisbane has a very low population density (11 people per ha). Significantly, Brisbane had a distinctly low use of private vehicles.

Brisbane has recently gained many new freeways, and it will be interesting to see the effect these have on its total fuel consumption (the data in the *Search* paper pertain to earlier in the 1970s). According to the authors' theories, fuel consumption should be higher.

They conclude that 'policies designed to encourage free-flowing road-based traffic work against the promotion of public transport, and hinder transport energy conservation overall'.

Land-use planning for transport energy conservation in Australian cities. P. Newman and J. Kenworthy. *Search*, 1980, **11**, 367–76.

fuel economy might result in substantial savings if the improvements were generally adopted. For example, reducing the consumption of each of the 450 000 new cars registered each year in Australia by only 0·1 litre per 100 km would save 6 million litres per year.

The octane rating of petrol affects both a car's fuel consumption and its performance. Only cars with high compression ratios need high-octane (super) petrol to prevent engine knocking, but many motorists run their car on super petrol when petrol with a lower octane rating would do just as well. They are wasting money and energy, since super petrol needs more refining and added lead. If Australia's vehicles were to use petrol rated one octane less than they do now, it would save 500 000 barrels of crude oil per year. With the dynamometer, it will be possible to determine the minimum octane requirements of engines with a variety of compression ratios. Tests on alternative fuels such as alcohol and vegetable oils are also planned.

The National Energy Research, Development and Demonstration Council (NERDDC) has granted the Division $332 000 towards projects involving questions such as these, and also to investigate the Australian Standard fuel-consumption test (AS 2077).

This test measures the fuel consumption of cars by running them on rollers (a chassis dynamometer). Although it allows a comparison between vehicles, one shortcoming is that it can only give an estimate of a car's on-the-road fuel consumption. Secondly, in the absence of accurate torque-measuring instruments, tests on chassis dynamometers vary somewhat from test to test and from one laboratory to another.

The new CSIRO torque-measuring device overcomes the second problem, enabling chassis dynamometers to be accurately calibrated and standardized. With regard to the first, it enables a test for fuel consumption on a chassis dynamometer to be devised that duplicates a standard on-the-road test.

At Sydney University and Melbourne University, research is under way to develop driving cycles more representative of Australian city and highway travel.

Andrew Bell

Public transport uses fuel more efficiently than private transport.

More about the topic

Fuel consumption in urban traffic — a 20-car design experiment. R.R.M. Johnston, R.S. Trayford, and J.W. van der Touw. *Transportation Research*, 1981,**15** (in press).

National fuel use efficiency — prospects for improvement. R.R.M. Johnston. *3rd Automotive Engineering Conference, 7–9 November 1977, of Japan and SAE-Australasia,* Paper 13.

Fuel economy in peak hour travel. R.R.M. Johnston, R.S. Trayford, and M.J. Wooldridge. *SAE-Australasia*, 1977, **37**, 53–9.

Passenger car fuel consumption from motor club road tests. R.R.M. Johnston, R.S. Trayford, and J.W. van der Touw. *SAE-Australasia*, 1979, **39**, 54–9.