THE CONSEQUENCES OF AN EXPERIMENTAL SOLUTION TO A TRANSPORT PROBLEM: PRIORITY VEHICLE LANES

R.G. Cox
Chief Traffic Engineer
N.R.M.A., Sydney

B. Searles
Traffic Engineer
N.R.M.A., Sydney

ABSTRACT:

Liquid petroleum fuels are expected to become increasingly expensive as supplies diminish. The effect of traffic management schemes on the overall amount of fuel consumed should therefore be considered.

This paper details a method of using available information on the effect of changing travel speeds to assess the effect of a particular traffic management scheme. The overall volume of fuel consumed by vehicles using the road system associated with the Victoria Road priority vehicle lane (transit lane) increased considerably after the introduction of the transit lane as a result of large increases in travel time.

A need for more exhaustive data on the effects of traffic congestion on vehicle fuel consumption is indicated.

PRIORITY VEHICLE LANES

INTRODUCTION

A high-occupancy vehicle lane (transit lane) was established for 2.9 km on the city-bound kerbside lane of Victoria Road from Seymour Street, Drummoyne to Robert Street, Rozelle in June, 1977. (Fig 1)

The kerbside lane is reserved for use by vehicles carrying three or more persons (including the driver), omnibuses, taxi cabs, motor cycles, bicycles and private hire cars. Vehicles turning left at or before the next intersection can also use the transit lane. The restrictions apply from 6.30 a.m. to 9.30 a.m. (the morning peak period).

The restrictions are designed to improve the person-carrying capacity of the route by encouraging the use of higher occupancy vehicles e.g. buses and car-pool cars. The success of such an experiment can be gauged by the effect it has had on the overall person-travel time and the variance of travel time.

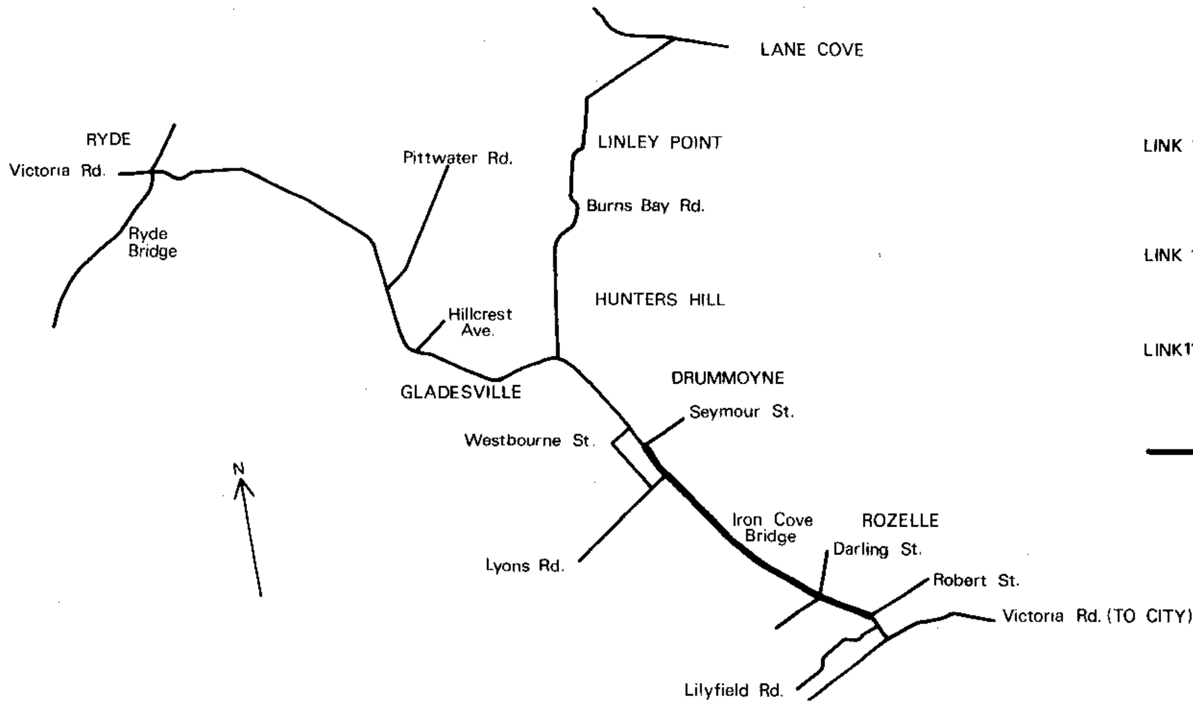
While attempting to encourage the use of higher occupancy vehicles the transit lane concept should not disbenefit those road users who, for various reasons, cannot travel with others.

Jackson Teece Chesterman Willis Pty. Ltd. and Sinclair Knight and Partners Pty. Ltd. (1976) noted that only about one third of the traffic travelling from the west and north-west of the metropolitan area is orientated towards the city, on which public transport services are focused.

Cox and Fleming (1976) indicated that 83% of car driver respondents to a survey appeared to have valid reasons for driving to the city.

With the present focus of attention on future energy requirements for transport, the transit lane concept should not increase the consumption of fuel resources.

This paper aims to assess the effect of a traffic management technique (transit lane) on the fuel consumption of vehicles using the routes to which the technique is applied. It is important to note that the data applies for September, 1976 and September, 1977. Conditions can alter seasonally and thus the data cannot be assumed to apply throughout the year. In addition, changes to the system have been made by the Authorities since September, 1977. A 'transit lane' has been installed for 2.2km through Gladesville on Link I in an attempt to allow users to by-pass queues on that link while bus seating capacity and enforcement has been increased.



LINK DETAILS

LINK 1 - HILLCREST AVE, GLADESVILLE TO WESTBOURNE ST, DRUMMOYNE (3·0 KM)

LINK 11 - BURNS BAY RD, LINLEY PT. TO WESTBOURNE ST, DRUMMOYNE (3·3 KM)

LINK111 - WESTBOURNE ST, DRUMMOYNE TO ROBERT ST, ROZELLE (2·9 KM)

TRANSIT LANE

FIGURE 1 ROAD SYSTEM IN STUDY AREA

PRIORITY VEHICLE LANES

The study relates to the effect on energy consumption of the traffic conditions created as at September, 1977.

METHOD

Person-time

To assess the change in time spent by commuters travelling in the system, travel time, volume and occupancy data for cars and buses was collected for the length of the transit lane and in the two main approaches. Data was collected in September, 1977 to compare with similar information collected in September, 1976 (before the introduction of the transit lane).

Searles (1977) analysed the data and provided details of methods of data collection and assumptions required in the analysis. The most pertinent results of the analysis will be presented in this report.

Fuel Consumption

Pelensky (1970) showed that travel time is a particularly useful predictor of fuel consumption in urban traffic and indicated a linear relationship between the two variables.

Everall (1968) and Srinivasan, Shetty and Sripathi Rao (1975) provided evidence to support Pelensky's observations.

Ker (1977) on reviewing literature in this field noted that "there does not appear to be any consensus on the levels of fuel consumption or the variation of fuel consumption with operating conditions".

An experimental procedure was therefore set up to measure the fuel consumption of a test vehicle travelling along the length of the Victoria Road transit lane and in its approaches under various levels of congestion i.e. at various travel times on fixed-length sections or links. The experimental relationships between fuel consumption and travel time for each survey link (Fig 1) are shown in figure 2.

By measuring changes in fuel consumption with travel time on the actual study routes the effects of features external to the traffic, such as roadway features, are eliminated provided the external features remain unaltered.

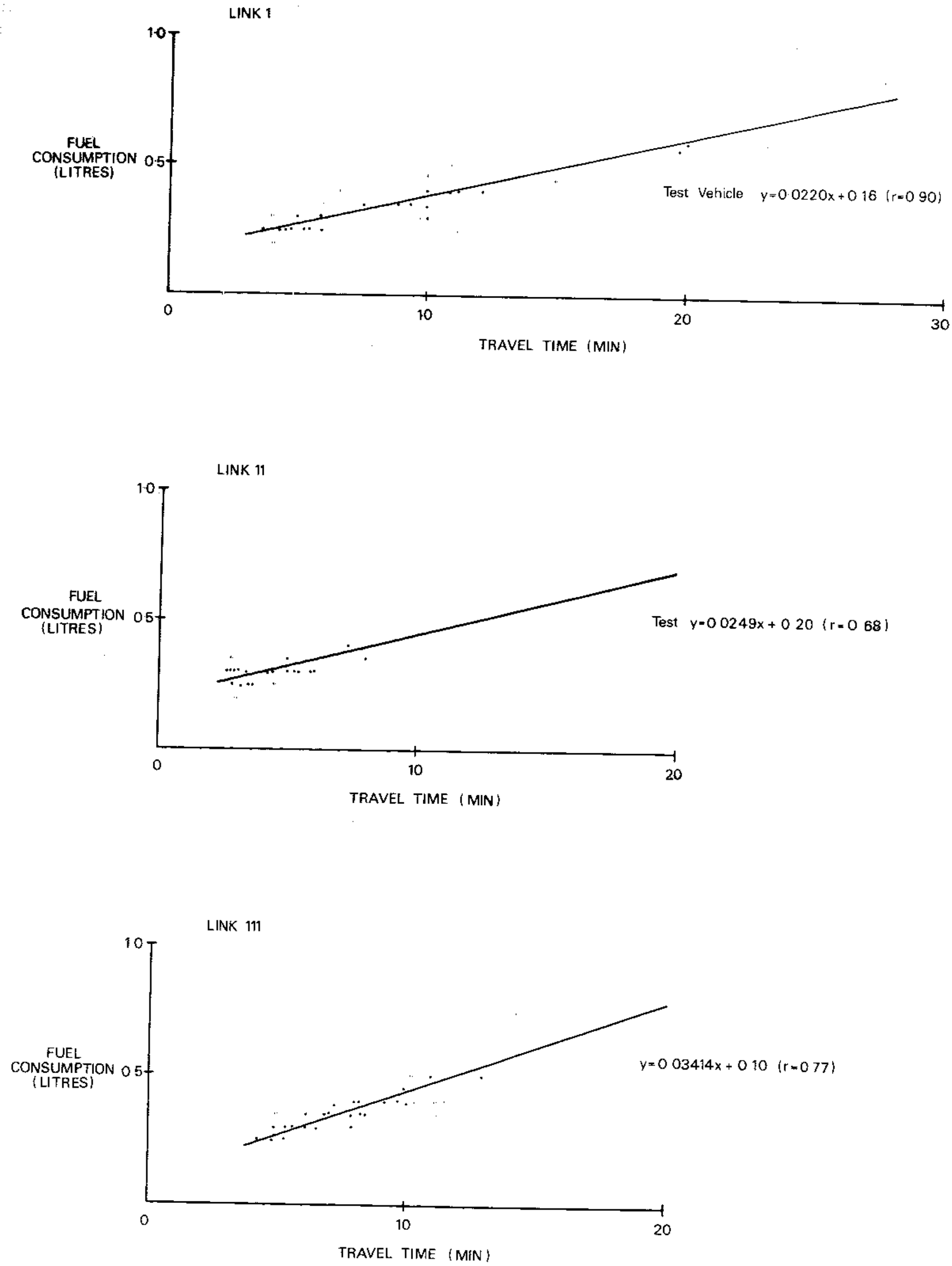


FIGURE 2 RELATIONSHIP BETWEEN FUEL CONSUMPTION AND TRAVEL TIME FOR TEST VEHICLE

The test vehicle was a 1976 model Toyota Corona SE with automatic transmission. The vehicle complies with the emission controls required under Australian Design Rule 27A. Fuel consumption was measured using a positive displacement type fuel meter. Travel time was measured using a mechanical tachograph, fitted with a remote button so that strategic points along the route could be located on the tachograph chart.

Pelensky (1970) derived relationships between fuel consumption and average speed for cars of various gross weights with manual transmission.

Pelensky's relationships have been used to expand the data obtained from the test vehicle to the population of city-bound cars using Victoria Road during the morning peak period.

A vehicle classification survey was carried out in which all city-bound cars at Westbourne Street were classified into five weight categories. The overall proportions measured in each category are shown in Table 4.

Proportional relationships between Pelensky's predictions of fuel consumption of the test vehicle and predictions for fuel consumptions of cars of median gross weight in each weight category were established over a range of average speeds. These relationships were then applied to the actual observed[1] fuel consumptions of the test vehicle to derive fuel consumptions over a range of average speeds for vehicles in each weight category on each survey link. The average speeds were converted to travel times on each fixed length of the Victoria Road transit lane survey routes.

Thus linear relationships between fuel consumption (in litres) and travel time were established for each gross car weight category on each survey link.

Actual average travel times for each half hour survey period 'before' and 'after' the introduction of the transit lane on each survey link were applied to the relationships to obtain average fuel consumptions for vehicles in each weight category for half hour periods 'before' and 'after'.

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1 Adjusted to compensate for automatic transmission and emission controls

The proportions of cars in each weight category as established from the vehicle classification survey at Westbourne Street were applied to actual volumes at Westbourne Street and in the approaches during the 'before' and 'after' studies to obtain average numbers of cars in each weight category for half-hourly periods. These half-hourly volumes are multiplied by the respective fuel consumptions and summed to obtain total fuel consumed by cars 'before' and 'after' for each survey link.

The derived total fuel consumed by cars 'before' and 'after' will not be actual as no adjustments have been made for the proportions of automatic vehicles etc.

However, if conditions other than travel times and traffic volumes can be assumed to be unchanged from 1976 to 1977, (e.g. the proportions of automatic vehicles are assumed unchanged, the proportions of cars in each weight category are assumed unchanged) the change in fuel consumption from 1976 to 1977 can be quite accurately predicted.

During the vehicle classification survey commercial vehicles were classified into four weight categories. Fifty-percent were assumed to be unladen. The travel times of commercial vehicles (assumed to be the same as that for cars) 'before' and 'after' were applied to relationships between fuel consumption and average speed derived by Everall (1968) to obtain fuel consumptions for each weight category. The proportions of commercial vehicles in each weight category as derived from the vehicle classification count were applied to the 1976 and 1977 volumes at Westbourne Street and in the approaches to obtain numbers of vehicles in each weight category for half-hour periods on each survey link. The numbers were then applied to the respective derived fuel consumptions to obtain total fuel consumed by trucks on each link.

A similar procedure was followed to obtain bus fuel consumptions 'before' and 'after' for buses travelling between Pittwater Road and Lilyfield Road using Everall's relationships for laden 12 tonne trucks.

Although the use of English data for Australian heavy vehicles may not prove strictly correct, its use should not greatly affect the overall results as trucks and buses only consume about 15% of the total fuel consumed on the study routes.

RESULTS

Vehicle Occupancy

One aim of the transit lane is to increase the occupancy of vehicles. Therefore, an assessment of the change in vehicle occupancy on the transit lane route and in its approaches is required to assess the performance of the lane in this regard.

TABLE 1.

CAR VOLUMES AND CAR OCCUPANCIES (6.30 a.m. to 9.30 a.m.)

Westbourne Street

THROUGH CITY-BOUND TRAFFIC

	'BEFORE'	'AFTER'	% CHANGE
Vehicle Volume	8461	7906	-6.6
Mean Occupancy	1.17	1.27	+8.6
Person Volume	9899	10058	+1.6

Westbourne Street

RIGHT TURNING TRAFFIC

	'BEFORE'	'AFTER'	% CHANGE
Vehicle Volume	2883	3249	+12.7
Mean Occupancy	1.09	1.15	+5.5
Person Volume	3137	3722	+18.7

Ryde Bridge

SOUTHBOUND TRAFFIC

	'BEFORE'	'AFTER'	% CHANGE
Vehicle Volume	6877	7707	+12.1
Mean Occupancy	1.16	1.18	+1.7
Person Volume	7977	9094	+14.0

BUS VOLUMES AND OCCUPANCIES (6.30 a.m. to 9.30 a.m.)

Pittwater Road to Lilyfield Road

	'BEFORE'	'AFTER'	% CHANGE
Bus Volume	47	45	
Mean Occupancy	43.3	37.6	-13.2

Table 1 shows that a reduction in car volumes has occurred on Victoria Road while volumes on major alternative routes have increased. Car occupancies have increased on Victoria Road and the alternative routes. It could therefore be concluded that the increase in occupancy for vehicles using Victoria Road may not be wholly attributed to the transit lane.

Combining the results from the three main alternative routes in Table 1 it can be seen that car person volumes on Victoria Road have increased by 159, during the three-hour morning peak period, while comparable person volumes on other routes have increased by 1702. Meanwhile bus occupancies on Victoria Road reduced by 13%, with almost equal bus volumes 'before' and 'after'.

Person-Time

Mean travel times and mean volumes are used to derive the total person-time spent travelling in the system in 1976 and 1977. Searles (1977) presents mean volume and travel time data in 1976 and 1977. Usable 1976 volume data was collected only on Tuesday and Thursday. However, travel time data was collected on each day of the survey week. Volume and travel time data was collected on each day of the survey week in 1977. Thus Searles presents volume and travel time tables comparing all consistent and available data in each year. However, he assessed the change in person-time by using only data collected on Tuesday and Thursday of the 1976 and 1977 survey weeks, thereby eliminating possible daily variations from the assessment.

TABLE 2.

ASSESSMENT OF EFFECT OF TRANSIT LANE ON PERSON-TIME

PERSON-TIME (PERSON-HOURS/3h)

	BEFORE	AFTER	%CHANGE
A) Cars			
Link I	312	600	+92
Link II	322	585	+82
Link III	1171	1482	+27
B) Buses	574	541	- 6
	2379	3208	+35

PERSON-DEMAND (PERSON-KM/3h)

	BEFORE	AFTER	%CHANGE
A) Cars			
Link I	19590	20631	+ 5
Link II	22489	23832	+ 6
Link III	29444	29317	0
B) Buses	13629	12333	-10
	85152	86113	+ 1

The results of the comparison of person-time in 1976 and 1977 using only data collected on the Tuesday and Thursday of the respective survey weeks are presented in Table 2.

Note that the assessment does not include changes in travel patterns or congestion on alternative routes.

It can be seen that despite a very small change in demand for travel along the transit lane route and in the approaches, the mean time spent by people travelling on the system has increased appreciably.

Only buses show a reduction in person time, but this is due to a reduction in travel demand by that mode.

Fuel Consumption

The method of determining the fuel consumed by the population of city-bound vehicles using the three links surveyed is described in the method.

Table 3 lists the linear relationships between fuel consumption (litres) and travel time (min) for each vehicle weight category on each survey link. The weights of cars on the market were obtained from the R.A.C.V. Vehicle Measurement Catalogue. One hundred and fifty kilograms was added to the vehicle weight to provide an estimate of gross vehicle weight, rounded to the next highest 50 kg.

Gross weight categories are as follows:-

1 - small 750 - 1050 kg e.g. Toyota Corolla
2 - small-medium 1050 - 1150 kg e.g. four cylinder Holden Torana
3 - medium 1150 - 1350 kg e.g. six cylinder Holden Torana
4 - large 1350 - 1650 kg e.g. Holden Kingswood
5 - luxury 1650+ kg e.g. Ford Fairlane
6 - test vehicle
7 - test vehicle (adjusted)

TABLE 3. RELATIONSHIP BETWEEN FUEL CONSUMPTION AND TRAVEL TIME

A) Cars

Basic Relationship

$c = mt + b$

c = fuel consumption (litres)
t = travel time (min)
m = constant
b = constant

VALUES OF CONSTANT TERMS

WEIGHT CATEGORY	1		2		3		4		5		6		7	
LINK	m	b	m	b	m	b	m	b	m	b	m	b	m	b
I	0.018	0.14	0.019	0.14	0.019	0.17	0.021	0.19	0.022	0.24	0.022	0.16	0.020	0.14
II	0.022	0.16	0.022	0.17	0.023	0.19	0.024	0.24	0.026	0.28	0.025	0.20	0.022	0.18
III	0.030	0.08	0.031	0.08	0.032	0.11	0.033	0.14	0.036	0.18	0.034	0.10	0.031	0.09

B) Trucks

Basic Relationship [a] (Everall)

$$c = \frac{l}{100} (d + e/v + fv^2)$$

c = fuel consumption (litres)
l = length of link (km)
v = speed (km/h)
d,e,f = constants

VALUES OF CONSTANT TERMS

WEIGHT CATEGORY	LIGHT VAN 0-10 tonnes			TWO AXLE RIGID 10-20 tonnes			3.4 AXLE RIGID ARTICULATED 20 + tonnes		
LINK	d	e	f	d	e	f	d	e	f
I II III	15.40	202.2	0.000817	19.76	326.3	-0.00137	35.06	274.9	-0.00255

(a) Adjusted to account for laden and unladen vehicles

TABLE 4. PROPORTIONS OF VEHICLES IN WEIGHT CATEGORIES [(a)]

CARS

Weight Category	1		2		3		4		5		TOTAL
Traffic Counted	No.	%	No.	%	No	%	No.	%	No.	%	No.
Through City-bound Traffic	1085	14 8	1696	23 1	1086	14 8	3256	44 3	221	3 0	7344
Through Traffic and Right Turning Traffic	1258	12 1	2124	20 3	2069	19 8	4725	45 2	266	2 6	10442

TRUCKS

Weight Category	LIGHT		TWO AXLE RIGID		3.4 AXLE RIGID 3 AXLE ART.[(b)]		4+ AXLE ARTICULATED		TOTAL
Traffic Counted	No.	%	No	%	No	%	No	%	No.
Through City-bound Traffic	62	17 8	204	58 4	38	10 9	45	12 9	349
Through Traffic and Right Turning Traffic	126	29 1	213	49 2	45	10 4	49	11 3	433

(a) From vehicle classification survey - 6 30 a m to 9 30 a m at Westbourne Street

(b) Articulated

Application of the relationships between fuel consumption and travel time as described in Table 3 to the average travel times experienced each half-hour 'before' and 'after' the introduction of the transit lane yields average fuel consumptions for vehicles in each weight category. These results are then applied to the numbers of vehicles in each weight category for each half-hour period 'before' and 'after' to derive the results described in Table 5.

TABLE 5. CHANGES IN FUEL CONSUMPTION

6·30 a.m. - 9·30 a.m.	PREDICTED FUEL CONSUMPTIONS (Litres)		CHANGE	
	'Before'	'After'	Litres	%
LINK I				
Cars	1288 6	1637 8	+349 2	+ 27
Trucks	309 8	328 8	+ 19 0	+ 6
TOTAL	1598 4	1966 6	+368 2	+ 23
LINK II				
Cars	1663 0	1908 4	+245 4	+ 15
Trucks	174 5	216 7	+ 42 2	+ 24
TOTAL	1837 5	2125 1	+287 6	+ 16
LINK III				
Cars	3010 4	3332 5	+322 1	+ 11
Trucks	518 7	473 4	- 45 3	- 9
TOTAL	3529·1	3805 9	+276 8	+ 8
BUSES - Pittwater Road to Lilyfield Road	130 4	130 9	+ 0 5	0
Overall	7095·4	8028 5	+933 1	+ 13
Change per annum			242 000 litres	

Table 6 relates the changes in fuel consumption to the number of vehicular trips, and the change in consumption for cars and buses to the demand for person travel.

TABLE 6.

RATES OF FUEL CONSUMPTION

6·30 a.m. to 9·30 a.m.

	Litres/Vehicle - km		%	Litres / Person - km [a]		%
	'Before'	'After'	Change	'Before'	'After'	Change
Link I	0 087	0 110	+26 3	0 066	0 079	+19 7
Link II	0 090	0 107	+18 6	0·074	0·080	+ 8 1
Link III	0 135	0 158	+17 0	0 102	0 114	+11 8
Buses	0 414	0 434	+ 4 9	0 010	0 011	+10 0
Overall	0 109	0 129	+18 3	0 072	0 081	+12 5

(a) Omitting commercial vehicles

DISCUSSION

An analysis of the traffic volumes, vehicle occupancies and travel times 'before' and 'after' the introduction of a high occupancy vehicle lane on Victoria Road has shown that the time spent in the system increased appreciably after the introduction of the lane (830 person-hours each 3 hour morning peak period or 35%). Meanwhile the travel demand in person-km did not change appreciably (+1%). Therefore, the increase in person-time was mainly the result of substantial increases in travel times.

On Link 1 (3.0 km) travel times during the peak half hour more than doubled (3.5 min to 8.3 min) while time on Link 11 (3.3 km) increased by up to 94% (3.1 min to 6.0 min). Although transit lanes users experienced a 24% reduction in travel time (12.1 min to 9.2 min) while in the lane (Link 111 - 2.9 km) times overall increased by up to 12% when approaching from Link 1 and by 20% from Link 11. Travel times on Link 111 (2.9 km) for non-users of the transit lane increased by up to 23% (7.0 min to 8.6 min).

Motor vehicle fuel consumption increases considerably as travel times over a fixed length of roadway increase. With a halving of average speed from 30 km/h to 15 km/h, fuel consumption of cars can increase by about 40% (Pelensky 1970).

With liquid petroleum fuels becoming increasingly expensive, a more efficient use of this commodity is to be expected as supplies diminish. There is therefore not only a need to assess the performance of a traffic management scheme in improving vehicle or person throughput during a fixed time interval, but also to assess the effect of such schemes on the fuel consumption of the vehicles using the particular section of roadway.

This paper has assessed the effect of the Victoria Road transit lane on the fuel consumption of vehicles travelling its length and in the approaches.

The results indicate that the introduction of the transit lane has caused an increase in fuel consumption of 930 litres each morning peak period (13%) or 240,000 litres per annum. The number of litres consumed per person-km of travel (cars and buses only) along the transit lane route and in the approaches has increased from 0.072 to 0.081 (12.5%)

Note that consideration has not been given to the probable increase in fuel consumption caused by traffic transferring to alternative routes and by additional delays in approaches to the system or on certain modes of travel, which could not be considered.

CONCLUSION

The introduction of a high occupancy vehicle lane on Victoria Road substantially increased the time spent by people travelling along its length and in the approaches (830 person-hours each morning peak period or 35%). The increase was mainly a result of extended travel times along the length of the transit lane for non-users, and in the approaches.

Traffic management schemes are often implemented to improve travel times. As liquid petroleum fuels are becoming increasingly expensive with the expected diminishing of supplies it is important to consider the effect of traffic management schemes on the overall consumption of vehicles using the road system to which the schemes are applied.

This paper has indicated one method of using available information on the fuel consumption of motor vehicles under varying traffic conditions. However, it is apparent that more up-to-date and more exhaustive data is required, particularly relating to heavy vehicle fuel consumptions under varying levels of congestion and for emission controlled and automatic cars.

The application of the methodology explored in this paper to the change in fuel consumption of vehicles using Victoria Road after the implementation of a high occupancy vehicle lane legally carrying only 5% of the traffic, with 95% in the remaining two lanes, has shown that overall fuel consumption has increases substantially. An additional 930 litres (13% increase) are being consumed each morning peak period (6.30 a.m. to 9.30 a.m.). This represents an additional 0.02 litres per vehicle - kilometre (+18%), or 0.01 litres per person - kilometre of travel in cars and buses (12.5%).

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