



TOPIC 18
ENVIRONMENT AND
SUSTAINABLE MOBILITY

EFFECTS OF THE RECENT CHANGES IN THE SINGAPORE ROAD PRICING SCHEME

PIOTR OLSZEWSKI

Centre for Transportation Studies
Nanyang Technological University
Nanyang Avenue, SINGAPORE 639798

SOI-HOI LAM

Centre for Transportation Studies
Nanyang Technological University
Nanyang Avenue, SINGAPORE 639798

YIHK-DIEW WONG

Centre for Transportation Studies
Nanyang Technological University
Nanyang Avenue, SINGAPORE 639798

Abstract

The Singapore Area Licensing Scheme has recently been extended to cover the whole day, with a lower fee charged for entering the CBD during the mid-day hours. A panel survey was conducted to evaluate the impact of the change on motorists' behaviour. Changes in the mode, frequency, time of travel and the type of licence were analysed. A binary licence choice model was estimated.

INTRODUCTION

Since 1975 part of the central area of Singapore, known as the Restricted Zone (RZ), has been subject to road pricing under the Area Licensing Scheme (ALS). Motor vehicles entering the Zone during restricted hours are required to purchase and display a daily or monthly licence. The scheme is similar to a cordon toll, except that the licence is good for any number of entries to the Zone. So far, ALS is the only full-scale urban road pricing scheme in the world specifically aimed at reducing traffic flows during peak periods. The effectiveness of ALS was evident from the resulting traffic patterns: after its introduction the roads within the Zone were free from congestion during the restricted hours, with peaks occurring just before and after the ALS periods.

Since its introduction in 1975 the scheme has been modified several times. After the initial adjustment period, the restricted hours were fixed from 7:30 to 10:15 AM (Monday-Saturday) and only cars and taxis were required to purchase licences. In 1989, in response to increasing afternoon traffic congestion, an evening restricted period was introduced: from 4:30 to 6:30 PM (Monday-Friday). At the same time, the scheme was extended to include all types of motor vehicles (except scheduled buses). To offset the additional restraint imposed by these changes, the price of a licence for private cars was reduced from S\$5 to S\$3 (as of March 1995: S\$1 = US\$0.71).

The latest major revision of the ALS came in January 1994: to alleviate build up of mid-day congestion, a whole-day ALS was introduced extending the restricted hours to cover practically the whole day (7:30 AM-6:30 PM). A lower fee (S\$2) is being charged for a part-day licence which is only valid for entering the RZ during the mid-day period (10:15 AM-4:30 PM). On Saturdays the restricted period ends at 2:00 PM.

The effects of the ALS on travel behaviour of motorists are of great interest for planning of future road pricing schemes and were the subject of several studies. The initial effects, based on "before" and "after" household travel surveys, were investigated by Watson and Holland (1978), Pendakur et al. (1989) and Wilson (1988). The impacts of the 1989 modifications were reported by Menon and Seddon (1991) as well as Olszewski and Tan (1991). The long-term effects of the ALS on driver behaviour were analysed by Polak et al. (1994) using the 1991 household travel survey data and classified volume counts of traffic entering and leaving the Restricted Zone.

The objectives of the current paper are: to describe the impact of the whole-day Area Licensing Scheme on usage of private vehicles for trips to the Restricted Zone and to formulate an approach to travel choice modelling which could be used to estimate the impact of the various possible future charging schemes.

INTRODUCTION OF THE WHOLE-DAY ALS

Introduction of the whole-day ALS has to be viewed in the context of other transportation policies in Singapore. The basic goal of having an efficient land transportation system is achieved by a package of policies which, in addition to road network expansion (subject to the limited land availability) and public transport system improvements, includes restraint on private vehicle ownership and usage. Thus, in addition to the continued refinement of the ALS, fiscal disincentives to car ownership have been in use since the 1970s. As these measures were losing their effectiveness with rapidly rising incomes, in 1990 a Vehicle Quota System (VQS) was introduced, which effectively limits the number of new cars registered each month. Under this arrangement, anyone wishing to purchase a new vehicle (with the exception of public transport buses and emergency vehicles) must first obtain a Certificate of Entitlement (COE), a fixed number of which are auctioned to the highest bidders each month. The details of the bidding system and the initial experience with the VQS have been reported by Smith (1992), Olszewski and Turner (1993) and Phang (1993).

The government's intention was to keep the growth in vehicle population down to 3% per year. This meant that the vehicle quota had been kept more or less constant for the last 5 years, resulting in steadily increasing COE prices. In order to maintain the COE prices at reasonable levels, it was decided to put more emphasis on car usage restraint and possibly relax the car ownership restrictions by releasing more COE's in the future. There are plans to convert the present ALS scheme to a fully automated Electronic Road Pricing system by 1997 and evaluation of alternative technologies is currently being carried out (Menon et al. 1993). As an interim measure, it was decided to introduce "manual road pricing", that is a modification of the ALS coupon system in which entry charges would vary by time of day according to the level of congestion.

Before the change, the following traffic pattern was typical: roads within the RZ were free from congestion during the morning and evening ALS hours while peak inbound flows occurred during the mid-day "free entry" period. A travel time survey (Olszewski and Tan 1991) revealed that while during the restricted periods the average journey speeds were in the order of 25.4 km/h, they generally dropped to about 18.6 km/h during the mid-day period. Another problem was the "surge" of traffic into the RZ occurring just after the morning and evening restricted periods.

To alleviate mid-day congestion, in January 1994 the ALS was extended to cover the whole day while retaining higher charging during the peak periods. The types of licences and their prices for different types of vehicles are shown in Table 1. The part-day licence allows one to enter RZ only during the mid-day period from 10:15 AM to 4:30 PM. The whole-day licence is good for entering at any time. Both types of licences can be valid for a day or for a month, the latter costing 20 times more (ie \$60 for cars).

Majority of motorists who regularly drive to the Restricted Zone purchase monthly licences as there is some potential saving (5 working days) and added convenience. Daily licences are sold at many post offices, petrol stations and special booths located along the main travel corridors but buying them usually involves some detour and time delay.

Table 1 Types and prices of area licences (S\$)

Vehicle type	Daily		Monthly	
	Whole-Day	Part-Day	Whole-Day	Part-Day
Private cars, taxis, goods vehicles and private buses	3.00	2.00	60.00	40.00
Company cars	6.00	4.00	120.00	80.00
Motorcycles	1.00	0.70	20.00	14.00

CHANGES IN TRAFFIC FLOW PATTERNS

The Public Works Department of Singapore conducts regular cordon traffic counts to monitor the performance of the ALS. Results of the recent surveys conducted before (May 1993) and after the introduction of the whole-day ALS (May 1994) are presented in Figure 1. The counts, in 15-min. intervals, were converted to the equivalent hourly flow rates. The traffic flows shown include only private cars entering the RZ.

In 1993, the inbound car traffic was heavy throughout the mid-day free entry period. The maximum flow of around 16,000 veh/h occurred just after the evening ALS period ended at 6:30 PM. A significant drop in flows could be observed after the start of both the morning and evening restricted periods.

The situation looked quite different in 1994 after the whole-day scheme had been introduced. The morning peak became more distinct, with the highest flow of around 16,000 veh/h occurring at 8:30 AM. The flows throughout the mid-day period were reduced by around 17%. There was not much change in the traffic pattern during the PM ALS period. The traffic 'surge' which could have been observed previously at 10:15 AM, was practically eliminated. However, the 'surge' was still present after 6:30 PM.

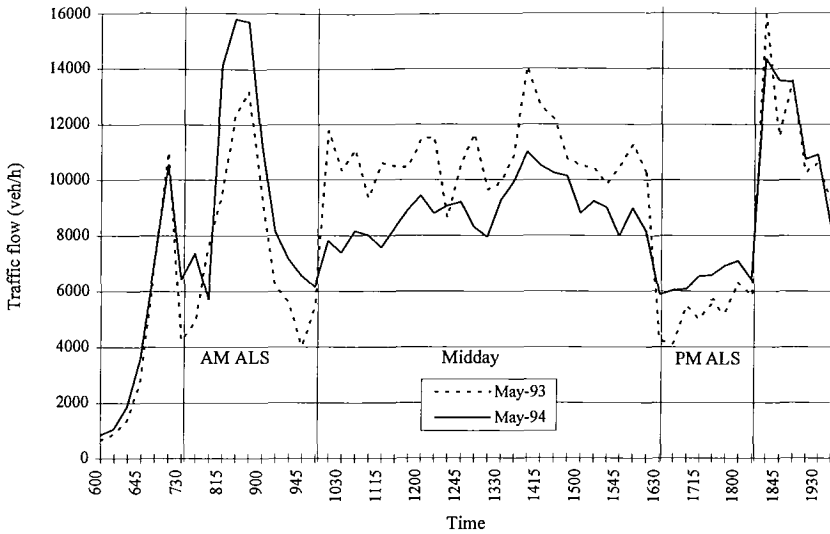


Figure 1 Variations of inbound volumes of private cars

The changes in numbers of vehicles entering the Restricted Zone during different time periods are shown in Figure 2. The five periods correspond to the different charging levels:

- Early before 7:30 AM free entry
- AM ALS 7:30 AM — 10:15 AM whole-day licence
- Mid-day 10:15 AM — 4:30 PM part-day licence
- PM ALS 4:30 PM — 6:30 PM whole-day licence
- Night after 6:30 PM free entry

Figure 2 shows that the introduction of mid-day charging had greater impact on cars than on other vehicles. There was a 17.5% drop in the volume of cars entering the RZ during the mid-day period, while the inbound volumes during the AM and PM ALS periods increased by 26.0% and 23.4%, respectively. There was also a 5.5% rise in the number entering early (before 7:30 AM) to avoid the charge. The changes in the volumes of other vehicles were smaller but followed a similar pattern (except for no increase in 'early' entries).

MOTORIST TRAVEL SURVEY

The introduction of the whole-day-ALS Scheme in January 1994 created an opportunity to study the effects of changes in road pricing on driver behaviour. The Public Works Department commissioned the Centre for Transportation Studies to conduct a small-scale panel survey with the aim to evaluate the impact of the whole-day ALS on usage of cars for trips to the Restricted Zone.

The first wave of the survey was carried out in December 1993. As the survey was designed specifically to capture motorists driving into RZ, the initial interviews were conducted at 14 large car parks located in different parts of the Zone. In order to get a representative sample of commuters as well as people coming on business and for shopping, interviewers were given

hourly target quotas which were proportional to the car park inflow traffic volumes (known from previous surveys).

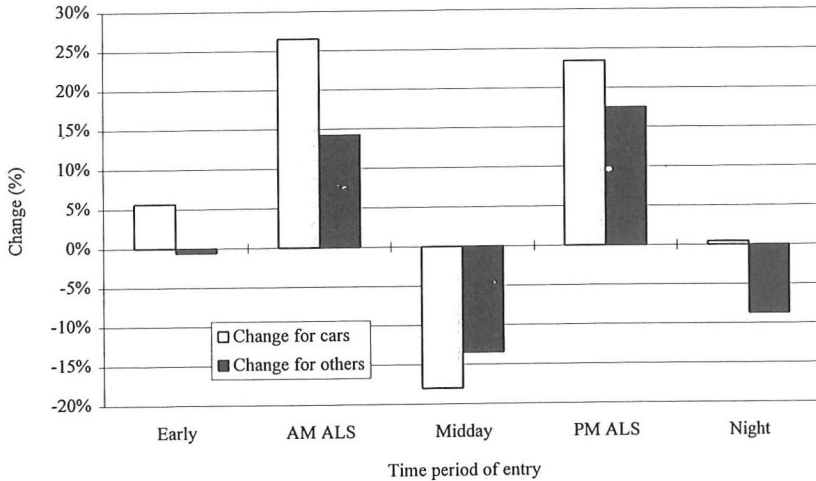


Figure 2 Percentage changes of inbound volumes after introduction of the Whole-Day ALS

Motorists were approached by surveyors after parking their cars and asked if they would like to participate. As an incentive, those who agreed were offered 10 parking coupons (worth S\$4.50) which would be mailed to them after the survey. They were also given two travel diary forms to be used as travel memos: one for the day of the first interview and the other one to be used in March 1994.

The interview process consisted of three parts:

- During the first contact in the car park, surveyors established the general characteristics of respondents (location of workplace, residence, working hours, gender), their travel pattern to RZ (frequency, purpose) as well as ownership, age and value of the car.
- The first telephone interview took place the following day. It was used to obtain details of all the motorised trips made by the respondent on the previous day (including mode, departure and arrival time, purpose, origin, destination and costs).
- Second follow-up telephone interview was conducted in late March 1994 (about 3 months after the introduction of the whole-day ALS) and captured details of all motorised trips made by the respondent on the previous day. In addition, the respondents were asked about the perceived impact of the whole-day ALS on their travel pattern (including changes in mode, time of travel, frequency and destination).

The target sample size for the survey was 1000 completed interviews covering all stages. However, due to various initial problems, lack of time and the inexperience of interviewers, the survey team succeeded in collecting only about 400 travel diaries in December 1993. During the second wave in March 1994, the interviewers managed to contact and obtain full response from only 239 respondents. Thus, the attrition rate was high: in the order of 40%.

The sample comprised 81% men and 19% women. 72% reported that they were the sole users of the car which they drove on the day of the first contact. Of the 239 respondents, 215 (90.0%) were

working, while 5.8% were students, 2.1% housewives and 2.1% others. Of those working, 64% reported that their main workplace was located inside the RZ and 88% had regular working hours.

ANALYSIS OF TRAVEL CHANGES

The March 1994 survey contained questions about motorists' perceived impact of the whole-day ALS. Respondents were asked to state whether the change had affected their travel pattern to work and for other purposes. Those who were affected, were further asked whether the change involved the mode, time, frequency of travel or the destination. Responses to these questions are summarised in Table 2.

Table 2 Declared effects of the whole-day ALS on motorists

	Trip purpose	
	Work	Other
Number of respondents	147	232
- Not affected	82.3%	77.2%
- Affected	17.7%	22.8%
Change involved:		
- Time	11.6%	14.7%
- Mode	4.1%	6.5%
- Destination	n.a.	12.1%
- Frequency	n.a.	18.1%

The percentages of those who reported being affected are not surprising although one would perhaps expect less impact on work trips and more on the others. Upon closer inspection it turned out that only two of 16 respondents who reported rescheduling of work trips have actually changed their time of entry to before 7:30 AM. For the rest, changes in time concerned 'employer business' and 'personal business' trips (respondents whose main work place was outside the RZ) or involved only small adjustments to the departure time. These could have been caused by the increased congestion during the 8:15-8:45 peak (see Figure 1).

Analysis of the actual changes in travel behaviour was based on comparison of travel diaries from the December and March surveys. The sample comprised 227 respondents who reported trips in both waves. The total numbers of trips reported were 900 and 897, in December and March, respectively. This gives an average trip rate of 3.96 motorised trips per person per day. There is no evidence of trip under-reporting in the second wave which has been observed in similar panel studies elsewhere (Polak 1995).

Trips were classified into several main categories according to the mode (car driver and others), purpose (work and non-work) as well as origin-destination (entering RZ and others). The comparison of numbers of trips reported in December 1993 and March 1994 surveys is shown in Table 3.

There is no evidence of any significant change in modal split in this sample; in fact the number of non-driver trips is lower in 1994. The number of driver trips entering RZ to work is about the same in both periods, while the number of trips for non-work purposes shows a big decrease (63%). However, this apparent drop cannot be attributed solely to the introduction of the whole-day ALS. This is because many respondents declared in December that they drove into the RZ only occasionally or a few times per week. Therefore, while they were captured inside the RZ in the first wave (due to the sampling method), chances of them making the trip to the city in March were smaller, regardless of the new mid-day ALS charges.

Table 3 Trips reported by 227 respondents in the two survey waves

Mode	Destination	Trip purpose			
		Work		Non-work	
		1993	1994	1993	1994
Driver	Entering RZ	156	154	95	35
	Other	146	198	439	461
Non-driver	Entering RZ	7	7	4	2
	Other	20	10	33	30
Total		329	369	571	528

Further analysis involved the time of entry to RZ (assumed to correspond to the reported arrival time). Five intervals were identified, corresponding to different ALS periods as defined before: 'Early', 'AM ALS', 'Mid-day', 'PM ALS' and 'Night'. The relative distributions of entries by the time period are shown in Figures 3a for work and 3b for non-work trips. Figure 3c presents changes in percentages of trips made in each period for the two trip categories. As expected, the impact on non-work trips has been greater than on work trips. There is only a small shift in work trips from mid-day to the earlier periods. For non-work trips, there is a considerable decrease in mid-day trips and a marked increase in trips made during the 'AM ALS' hours. These changes are generally consistent with the observed changes in traffic flows (Figure 2), except that there is no evidence of any increase in 'PM ALS' trips. However, one has to bear in mind that traffic flows shown in Figures 1 and 2 include through traffic.

MODELLING OF THE CHOICE OF LICENCE

Analysis of the types of area licences used by the survey respondents provides additional information on the process of making travel decisions. Statistics on changes in the types of licences held by respondents on the two survey days of travel are shown in Table 4.

Table 4 Changes in the type of licence held by respondents

December licence type	March licence type				Total	%	
	Daily		Monthly				
	Part-day	Whole-day	Part-day	Whole-day			
Daily	5	5	1	15	22	48	21.0%
Monthly	3	1	0	83	8	95	41.5%
None	13	4	2	13	54	86	37.5%
Total	21	10	3	111	84	229	100.0%
Percentage	9.2%	4.4%	1.3%	48.5%	36.6%	100%	

Table 4 presents a very diverse picture of changes which occurred between December and March. Some have stopped to be regular users (5.2% had a monthly licence in December but not in March) while others become monthly licence holders (13.5%). Despite the introduction of mid-day charging, the total number of licence holders has increased only marginally. However, there is a marked increase in the proportion of monthly licences. This trend is confirmed independently by licence sale statistics.

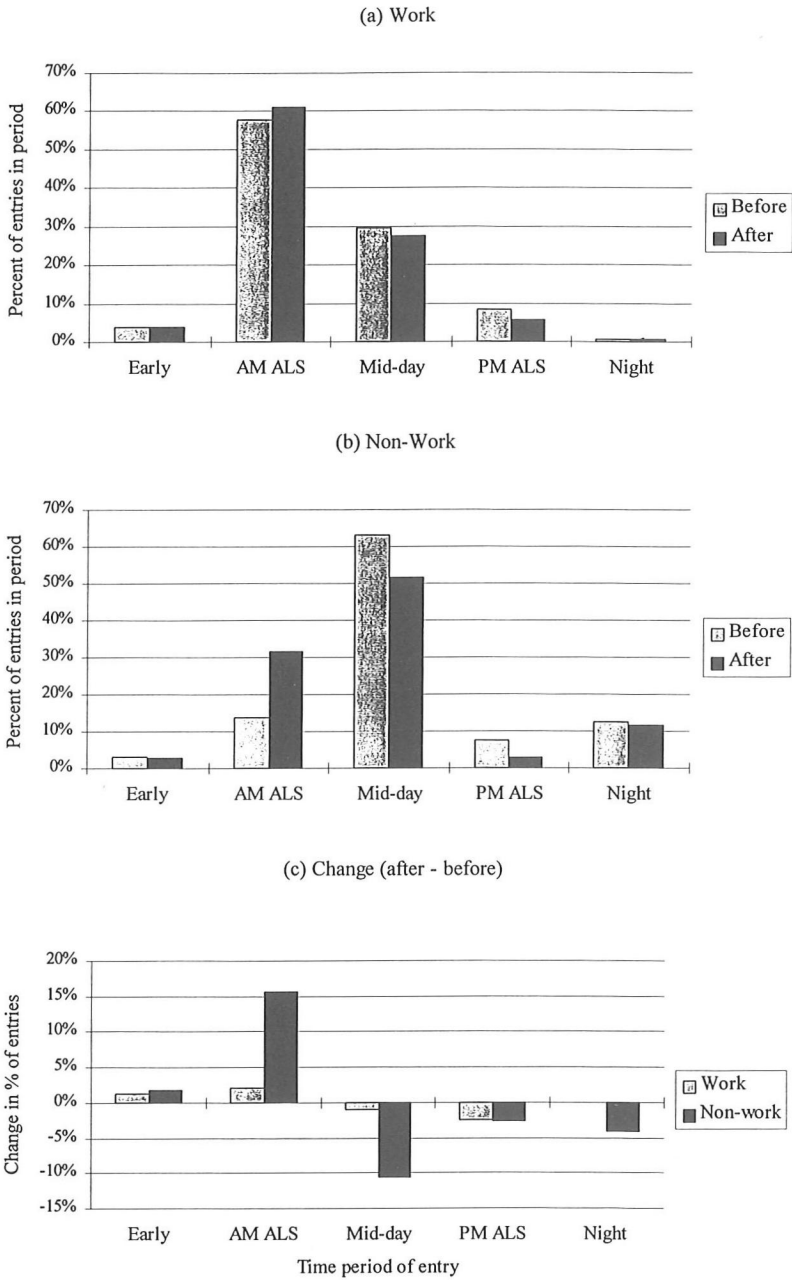


Figure 3 Changes in the time of entry to the Restricted Zone

To gain more insight into the decision process involving licence choice, two binary logit models were estimated. The first model (Model 1) represented the decision whether to have a licence for the March travel day, regardless of the type. The subset of those 145 respondents who had a licence, was then used to model the choice between a whole-day and a part-day licence (Model 2). The general formulation of both models is the same:

$$P_1 = \frac{\exp(\beta V)}{1 + \exp(\beta V)} \quad (1)$$

where P_1 is the probability of choosing alternative 1, V is the vector of explanatory variables and β is the vector of coefficients. Since both models represent binary choice, the probability of choosing alternative 2 is always equal to: $1 - P_1$.

The maximum likelihood estimates obtained using Limdep econometric modelling software are presented in Table 5. In case of both models, the results represent specifications which give the best statistical level of significance and only variables which are statistically significant are shown. The explanatory variables used in both models are all of generic type.

Results presented in Table 5 indicate that there is a strong inertia in licence holding: those who had licences in December were more likely to have them also in March, they were also more likely to buy whole-day rather than part-day licences. Working in the RZ was obviously the important factor influencing the decision to buy a licence and to choose a whole-day licence. Those working outside the RZ were more likely to buy a part-day licence.

It is interesting to note that personal income has a positive relationship with the decision to buy a licence. However, the relationship could be an indirect one—it is possible that the high-income earners are more likely to get the licence fee refunded as part of their transport allowance. The fact that the respondent is a sole user of the car also seems to be influencing the decision to buy a licence—perhaps in such cases the car use pattern is more regular.

Table 5 Results of licence choice modelling

Statistics	Model 1		Model 2	
	Alternative 1 (licence)	Alternative 2 (no licence)	Alternative 1 (Whole-day)	Alternative 2 (Part-day)
Sample size	229		145	
Log-Likelihood	-110.1		-44.1	
Log-Likelihood at 0	-150.5		-65.1	
Pseudo R ²	0.268		0.323	
Variable ¹	Coefficient	t-value	Coefficient	t-value
Constant	-1.929	-4.55	—	—
LICDEC	1.315	3.69	1.817	3.05
WORKRZ	1.719	4.94	1.270	2.25
WORKELSE	—	—	-1.225	-2.37
INCOME	0.121	2.18	—	—
ONLYUSER	0.664	1.79	—	—

¹The variable definitions are as follows:

- LICDEC = 1 if licence holder in December, 0 otherwise
- WORKRZ = 1 if main workplace inside Restricted Zone, 0 otherwise
- WORKELSE = 1 if main workplace outside Restricted Zone, 0 otherwise
- INCOME = personal income in thousand S\$ per month
- ONLYUSER = 1 if respondent was the sole user of the car, 0 otherwise

DISCUSSION

Under the new whole-day ALS system motorists who need to travel to the Restricted Zone face a complex system of choices. If they want to avoid paying the ALS charge, they can choose a different mode, different destination or drive into the Zone during the 'Early' or 'Night' free-entry periods. Those who need to enter during the restricted hours will decide to buy a whole-day or a part-day licence. The decision of what type of licence to buy determines to a large extent the subsequent travel pattern. This is because, unlike in the case of toll systems, motorists do not incur any extra entry cost for additional trips to the Zone and thus ALS does not affect their subsequent travel choices. This is especially true in the case of monthly licence holders—their daily behaviour and travel choices are not affected by the entry charge.

Attempts to model the choice of entry period using the March 1994 trip data were not successful. This can be partly explained by the small sample size and partly by the reasons given above. Many non-work entries during the mid-day and PM ALS periods were in fact second or third entries by motorists who worked in the RZ. The average number of entries per driver entering during the peak restricted periods (AM and PM ALS) was 1.07 in December and 1.06 in March. These numbers are very similar to that obtained from the 1991 household travel survey (Chandrasekar et al. 1994). However, if the mid-day period is included in the calculation, then the number of entries between 7:30 AM and 6:30 PM per driver entering was 1.26 in the March survey.

The specific nature of the Singapore area pricing system makes it difficult to model the effects of ALS price level on the number of car trips to the RZ. This is because the cost incurred is not proportional to the number of entries. Thus, the methods of estimating toll elasticities used in the evaluation of the Norwegian pricing schemes (Ramjerdi 1993; Polak and Meland 1994) are not applicable. In the future Singapore Electronic Road Pricing system the charges will be levied on per entry basis. Therefore, it seems that a model to predict the effects of the future scheme can only be estimated using a stated preference approach.

CONCLUSIONS

Since January 1994 motorists entering the Singapore Restricted Zone during the mid-day period (10:15 AM-4:30 PM) require a part-day licence which costs S\$2.00 for private cars. The introduction of mid-day pricing had caused substantial changes in traffic patterns. The mid-day traffic flows have decreased and the morning peak has become more distinct. Large increase in the inbound traffic volume which occurred at 10:15 AM and a corresponding drop at 4:30 PM are no longer present. However, there is still a surge of inbound traffic after the evening restricted period which ends at 6:30 PM.

The changes in travel behaviour were examined using panel survey data. As expected, the changes in time of travel affected mostly non-work trips which used to be scheduled during the free entry mid-day period (10:15 AM-4:30 PM). With the present S\$1 difference in the cost of a whole-day and a part-day licence, it is no longer worthwhile to delay the employer business and personal business trips until after 10:15.

The choice of whether to buy a licence and of what type seems to be the main decision which the motorists face. This is because the licence is valid for any number of trips (within the corresponding restricted period) and thus to a large extent determines the subsequent trip pattern. The situation will change with the future Electronic Pricing System under which the charges will be on a per entry basis.

ACKNOWLEDGMENT

The authors would like to thank the Singapore Public Works Department for the permission to use some of the data presented in this paper.

REFERENCES

- Chandrasekar, P., P. Olszewski, Y.D. Wong, J. Polak and P. Jones (1994) *Analysis of Travel Behaviour in Singapore*, Report No. NTU/CTS/94-2, Centre for Transportation Studies, Nanyang Technological University, Singapore.
- Menon, A.P.G. and P.A. Seddon (1991) Traffic in the Central Area—Part I: Volume Characteristics, *Journal of the Institution of Engineers, Singapore* 31 (2), 15-19.
- Menon, A.P.G., S.H. Lam and H.S.L. Fan (1993) Singapore's road pricing system: its past, present and future, *ITE Journal*, 63 (12), 44-48.
- Olszewski, P. and D.J. Turner (1993) New methods of controlling vehicle ownership and usage in Singapore, *Transportation* 20, 355-371.
- Olszewski, P. and Y.W. Tan (1991) Traffic in the Central Area—Part II: Speed Characteristics, *Journal of the Institution of Engineers, Singapore* 31 (2), 21-27.
- Pendakur, V.S., A.P.G. Menon and J. Yee (1989) TSM Innovations in Singapore—Lessons from Experience: 1974-88, *68th Annual Meeting of the Transportation Research Board*, Washington, DC.
- Phang, S-Y. (1993) Singapore's motor vehicle policy: review of recent changes and a suggested alternative, *Transportation Research* 27A, 329-336.
- Polak, J. (1995) Perils of panels: some cautionary notes on the pre-analysis of panel data, *UTSG Conference*, Cranfield.
- Polak, J. and S. Meland (1994) An assessment of the effects of the Trondheim toll ring on travel behaviour and the environment, *First World Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems*, Paris.
- Polak, J., P. Olszewski and Y.D. Wong (1994) Evidence on the long-term effects of the Singapore Area Licensing Scheme on travel behaviour, *Proceedings of 6th IATBR Conference*, Valle Nevado, Chile, Vol. 1, 319-330.
- Ramjerdi, F. (1993) *An evaluation of the impact of the Oslo toll scheme on travel behaviour*, Institute of Transport Economics, Oslo.
- Smith, P. (1992) Controlling traffic congestion by regulating car ownership, *Journal of Transport Economics and Policy* XXVI (1), 89-95.
- Watson, P.L. and E.P. Holland (1978) *Relieving traffic congestion: the Singapore Area Licence Scheme*, World Bank Staff Working Paper 281, The World Bank, Washington, D.C.
- Wilson, P.W. (1988) Welfare effects of congestion pricing in Singapore, *Transportation* 15, 191-210.

