Edward P. Holland and Peter L. Watson

Traffic Restraint in Singapore

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1. Measuring the impacts of the Area Licence Scheme

Introduction. Research on transport policy suffers from the impracticality of setting up closely-controlled laboratory experiments with and without whatever policy measure is to be investigated. Comparisons between different countries or between urban transport systems within a country are usually hampered by lack of advance knowledge that would permit gathering an adequate data base before the policy change takes place.

One of the rare exceptions to the last statement was the case of the Area Licence Scheme instituted in Singapore in 1975. With more than a year's advance notice, members of the World Bank's Transport Research Division, in co-operation with the Government of Singapore and with support from the U.N. Environment Programme and the U.S. Department of Transportation, carried out an extensive programme of empirical data collection before the scheme went into effect and a follow-up programme afterward. This made before-and-after comparisons possible on many different impacts of the measures.

At the most general level of impact monitoring, one might say that the only requirement is to measure vehicle flows—distinguishing types, time of day, location and the occupancy of cars. This would be more than enough information to show whether the target, set in terms of reduced entries into the central part of the city, is being met. However, a more basic purpose underlying the target was a reduction in congestion. Hence it is desirable also to measure vehicle speeds as a measure of how freely the traffic moves or how much it is slowed by congestion. Beyond simply monitoring the effectiveness of the policy measures, the Bank's research programme was intended to learn the differential impacts on different groups of people, to do some elementary evaluation of these impacts, and to gather and analyse information on underlying relationships that would help in designing and assessing the merits of restraint schemes for other cities. For these broader purposes, travel behaviour interviews were conducted at several thousand households, interview surveys were made of business conditions and public opinion, and observations were made on pedestrian movements and air pollution.

Monitoring the direct impacts

Traffic flow measurements. The Singapore Public Works Department scheduled extensive measurements of traffic flows, composition and occupancy. Therefore, the Bank undertook no flow measurements except those that came as a by-product of the speed measurements described below. The Government's programme started about three months before introduction of the Area Licence Scheme and was continued for about six months afterward, and then on a quarterly basis. Some of the traffic counts were done by observers, who recorded the types of vehicles and their occupancy, the occurrence of cars. Other counts were made by automatic machines, which record only the total numbers of vehicles without distinguishing types. The primary types of the monitoring was traffic entering the Restricted Zone, but some data were also collected in the afternoon, mainly on outbound traffic.

These measurements showed that the number of cars entering the Restricted Zone between 0730h and 1015h fell by 73 per cent, from 42,790 in March to an average of 11,363 in September and October 1975. The volume of cars entering during the half-hour before 0730h rose by 23 per cent as people started their trips earlier to avoid paying the Area Licence Fee. The exemption from the licence requirement for cars with four or more occupants ('car pools') induced a large increase in occupancy during the restricted hours. The absolute number of car pools entering during the 0730-1015h period increased by about 60 per cent at the same time that the total number of cars, including car pools, was falling by 73 per cent. The proportion of car pools thus jumped from less than 7 to 37 per cent for these hours.

Before these changes, cars had constituted about 50 per cent of all motor vehicles entering the area during these hours, the other 50 per cent being taxis, goods vehicles, buses, motorcycles and scooters. Taxis were at first exempt from the licence requirement, and the number of them entering the Restricted Zone during restricted hours increased dramatically. Three weeks later their exemption was rescinded, and the number entering between 0730h and 1015h fell from 11,363 to 6,987, or 39 per cent of the level before the scheme began. By September and October, during the extended restricted hours, the number of taxis entering seemed to have stabilised at 35 per cent of its original level. Flows of other vehicle types either increased or decreased by much smaller proportions, and the net result was a 44 per cent reduction in traffic volumes during the 0730-1015h restricted period.

A surprising finding from the flow counts was that traffic flows in the evening peak (1600-1900h) changed very little. It had been expected that reductions in the mornings peak flows would be reflected by a sizeable reduction in the evening. It was assumed that much of the reduction in flow in the morning would be the result of commuters using other modes of travel and leaving their cars home. These cars, then, would be more likely to be used for a trip after work. When the flow data showed only a 6 per cent decline in the evening peak it could not be explained, until a detailed analysis of the home interview data gave enough clues to piece together the explanation.

The main factors were 'trans-Restricted Zone trips', trip scheduling and taxi trips. In order to measure mean speeds to trips with an origin on one side of the zone and destination on the other. It was found that many car drivers making work trips of type used to pass the zone in the morning, but returned home through the zone in the evening when the restrictions were not in effect. Another group of commutes, with work places in the Restricted Zone, took to driving in before 0730h, thus contributing to the reduction in traffic during the restricted hours, but still drove home during the evening peak. Taxis, as mentioned earlier, entered the zone in greatly-reduced numbers in the restricted period, but of course the logic that suggests a reflection in the evening of reduced morning commuting traffic does not apply to taxis. In fact, it seems that the number of taxis operating during the evening peak may have increased markedly. This is not known with certainty, since the data on evening flows before the Licence Scheme started do not distinguish vehicles by types, having been obtained from mechanical counters.

Vehicle speed measurements. An important indicator of performance of the traffic system is mean vehicle speed. The speed, of course, depends on the level of congestion, and one of the purposes of congestion-reducing measures is to allow traffic to move faster. It should be recognised that there are other purposes, including reduction in annoyance and frustration of persons using other modes of travel, improvements in pedestrian conditions, in air quality, and in the general ambience of the city. Nevertheless, the expected increase in traffic speed was one of the important effects to measure.

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licensure and occasional time signals into hand-held cassette tape recorders. Observations were made for 10 minutes out of each quarter-hour, continuing for an hour or sometimes longer.

Afterwards, the information on the tapes was used in a computer process which related the license observations to the time signals and calculated the average speed of each vehicle which lacked number was recorded at the successive stations. The computer program also screened out implausible values that sometimes resulted from errors in recording or coding, computed mean speeds, and standard deviations for each vehicle type in each 10-minute period on a particular road segment.

Obviously, results from this procedure depend on accurate recording of time, including the establishment of a common time-scale for observers at different locations. The procedure eventually developed made use of several digital electronic watches. The watches were synchronised within less than 0.5 s before each observation session, and one was issued to each group of two or three observers stationed on the same corner of any intersection. In this way, the problem of the common time-scale was solved. The use of digital watches also practically eliminates the time, which would have an occurrence rate in time recording and in determining the corrections necessary for synchronising time-scales. Thus, before-and-after comparisons were not possible. However, in the later period reliable data were obtained at different times of day, so that comparisons could be made between restrained and unrestrained conditions.

Because of these problems, we decided in the final survey to conduct moving-vehicle observations at the same time as the licence recording, so that results from the two methods could be compared.

Eight moving-car circuits (loops) were laid out so that they covered a sample of routes within the Restricted Zone, along radial roads and along part of the ring road. Each circuit included segments selected as suitable for licence observations in an attempt to provide a fair comparison. The operations were not scheduled so that whenever licences were being matched on a given segment, the moving car was surveying the long that included twelve.

In general, the speed from two methods was scattered over the same range for each segment, although the number of moving cars per hour during an hour of observations was usually only three or four. There was no systematic bias between the mean speeds from the two methods.

From comparisons between restrained and unrestrained conditions, inferences have been drawn about changes due to the Area Licence Scheme. Mean speeds within the Restricted Zone were 22 per cent higher during the restricted hours than during the evening peak (33 km h compared to 27). It seems plausible that the speed during the morning peak before the Area Licence

SINGAPORE—BACKGROUND INFORMATION

The main island of Singapore measures 42 km east-west and 22 km north-south, with an area of 548 km². The City of Singapore is located on the southern coast, and approx. 70 per cent of the island's 2.25m population and 70 per cent of jobs can be found within a radius of 8 km around the central area.

At the end of 1975, 280 376 motor vehicles were registered in Singapore: 143 155 were private cars (ratio of one car to 16 persons), 4 855 were buses, 42 008 goods vehicles, 5 252 motorcycles, and 83 taxis. From 1962 to 1973 the average annual growth rate of private cars had been 5.8 per cent p.a.

Two major transport studies carried out between 1967 and 1974 both independently reached the conclusion that restraints on both car ownership and car usage would be necessary before 1992 (in more recent year, government efforts to limit the growth of private cars through heavy taxation have actually succeeded in reducing their number to 136 574 at the end of 1976, and early in 1974 an inter-Ministry developed a Transport Action Committee concluded that it would be appropriate to restrain the inefficient use of private cars in the central area as soon as possible.

The Area Licence Scheme. The Government set the specific goal of designing a scheme to reduce peak-hour traffic by 25-50 per cent. It was estimated that this reduction was to be done by good traffic conditions equivalent to those found during off-peak hours. At the same time, several constraints were recognised. First, accessibility and mobility within the central area should be maintained to protect the economic vitality of the area. Thus, efficient and reliable alternative modes of transport should be available to those motorists who were discouraged from driving into the city's area. Second, the mobility of the private car should be recognised as a benefit, and restrictions should apply only when and where they are needed to combat local congestion. Third, the scheme should be easy to administer and enforce. Fourth, it should not require a subsidy. Several alternative policies were considered. General fiscal measures, such as import duties or petrol taxes, do not discourage the use of cars at specific times or in specific areas; vehicle metering requires the use of special equipment that was not readily available in city streets requires collection facilities that take up too much urban space and themselves contribute to congestion. The Government rejected these alternatives and based its restraint scheme primarily on area licensing supplemented by increased parking fees, combined with a park-and-ride scheme to promote motorists with attractive alternatives to the use of cars in the central area. The Government was confident that it could deal with the problems of administering and enforcing these measures.

In the Singapore context, the key concept underlying the Area Licence Scheme is that a special supplementary licence must be obtained and displayed if a motorist wishes to enter a designated area within which congestion is to be reduced.

The Restricted Zone. This includes the areas with congestion problems, leaves diversion routes for motorists who do not have destinations in the zone, and the number of entry points that have to be monitored and takes advantage of existing facilities for use as fringes car parks. The Zone (Fig. 1, p. 12) covers an area of 145 ha and is divided into two parts: the first (Fig. 1, p. 12) covers a day. They have since been raised to S$80 a month and S$9 a day.

Categories of vehicles. The requirement to display an area licence does not apply to buses or commercial vehicles, in order to favour public transport and maintain commercial activity. To encourage high velocity occupancy and more efficient use of road space, car pools (defined as cars carrying at least four persons) are also exempt from the licence requirements, as are motorcycles. These exemptions also counter objections that driving into the area is a luxury only the rich can afford; others can also do it if they form car-pools or rides. Taxis are not exempt.

Restricted times. The aim of the Scheme was to reduce the congestion arising during the peak hour, and it was thought that applying restrictions during the morning peak would significantly reduce traffic both then and in the evening peak. Therefore, the Scheme was designed to operate from 0730 h to 0930 h. After implementation, congestion developed after 0930 h and the time period was extended to 1015 h.

The Park-and-Ride Scheme. In order to provide an alternative mode of transport for motorists who had become accustomed to driving into the central area, a Park-and-Ride scheme was designed to complement the Area Licence Scheme. Ten thousand spaces in car parks around the periphery of the Restricted Zone were opened to commuters, and special shuttle buses were introduced to carry commuters from the fringe car parks to the central area. The shuttle-bus routes had limited stops, and only seated passengers were allowed in an attempt to provide a fast, comfortable alternative to the car. The combined monthly cost of parking and using the shuttle was set at S$30 (U.S.50). This service attracted very few passengers.

Parking policy. The third element of the Scheme was an increase of about 100 per cent in parking charges at public car parks within the Restricted Zone. Previously, there had been a flat rate of $50-40 (U.S.50-18) per hour. The new rates are higher and are designed to reflect the geographical and economic significance of congestion. These rates are short-term as opposed to all-day parking. In the most central part of the Restricted Zone, the rates are:

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Rate ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st hour</td>
<td>S$1.00</td>
</tr>
<tr>
<td>2nd hour</td>
<td>S$1.00</td>
</tr>
<tr>
<td>Each subsequent 1 hour</td>
<td>S$1.00</td>
</tr>
</tbody>
</table>

The range of monthly rates for all-day parking in the central area was also increased from S$50-60 to S$50-80.

January 1978
Scheme was about the same as that in the evening, and therefore that there has been a 22 per cent improvement within the zone during the restricted hours. On the ring road speeds were 20 per cent lower in the morning restricted period than in the evening peak, and this is taken to imply a 20 per cent traffic shift in the morning due to the Scheme. On inbound radial roads in the morning, the flow with the Scheme in effect is relatively uncontested and travels at almost the same speed as in the evening. It is possible that before the Scheme was instituted the speed bound in the morning was approximately the same as that observed on the outbound radials in the evening. On the basis of this assumption there was a 10 per cent increase in speed on inbound radials during the restricted hours, from 29 km h to 32 km h. Presumably the speeds on outbound radials were not affected by the scheme, inasmuch as outbound flow volumes diminished only slightly.

Travel behaviour impacts. The direct impacts of the traffic restraint scheme on travel behaviour falls on those car owners who formerly drove into the Restricted Zone. However, many other groups—bus riders and pedestrians as well as other non-vehicle-owning households and individuals also affected to some degree. Changes in the travel behaviour of these directly impacted by the scheme have widespread ramifications on other groups of travellers, e.g. traffic diverted away from the central area may cause congestion on peripheral streets.

Thus, to provide an overall picture of the impacts of this restraint scheme on travel behaviour, it was necessary to obtain information on the characteristics of trips by users of all modes travelling into, through or outside the Restricted Zone before and after implementation. It was also necessary to obtain data on the characteristics of the travellers in order to be able to classify impacts by socio-economic groups.

A household survey programme was carried out to obtain this information. A sample of 2035 households was selected, made up of 1544 vehicle-owning households and 491 non-vehicle-owning households. The former contained households selected at random from the data files of the Registrar of Vehicles and supplemented by a sample selected at random from household owning cars that were observed crossing the Restricted Zone border before the Scheme was introduced. The supplementary sample was added to ensure adequate representation for the primary impact group—households whose members drive cars into the Restricted Zone. The non-vehicle-owning households were selected at random from a local sample frame. Each household was interviewed once before the introduction of the Scheme and again four to six months later. A household informant provided information on the household and each person was then interviewed to obtain personal information and a detailed record of all trips made on the day preceding the interview.

The analysis is carried out at two levels: at the macro-level, convenient for examining the overall changes in the proportions of people making different decisions, e.g. the proportion of people travelling to work before and after the introduction of the Scheme; and at the micro-level, carried out on a sub-sample of 719 people who made home-to-work trips to the Restricted Zone both before and after the introduction of the Scheme. The latter analysis makes it possible to view the effects and sometimes opposing changes in individual behaviour that underlie the global results.

Impacts on people making work trips. The most important impacts in this category were expected to be on the choice of mode and on travel times of people who travelled to work in the Restricted Zone. For these people, the monthly cost of commuting by car rose from US$599 to US$2587 (U.S.597). In response, the proportion of trips that members of vehicle-owning households made by car fell from 56 per cent to 46 per cent, while the bus share rose from 33 per cent to 46 per cent. Within the declining car mode, the car-pool share rose by a factor of three, from 14 to 41 per cent of all car trips. In addition to the modal change, there was an important change towards earlier starting times. The proportion of work trips that were started before 0730 h rose from 27 to 40 per cent for car drivers and from 12 to 38 per cent for car passengers. The data indicate that about the same numbers of people from vehicle-owning households chose the options of changing to the bus, joining former car pools, and making a work trip at a different time. People from non-vehicle-owning households did not change their behaviour—90 per cent of them travelled by bus both before and after the introduction of the Scheme.

The changes in travel time for travellers who did not change mode were very small: one drivers, about ten minutes longer; bus riders from vehicle-owning households reported taking, on average, half a minute longer. However, bus riders from non-vehicle-owning households, who constitute the vast majority of bus riders in Singapore, reported taking, on average, about one minute less. Car drivers who changed to the bus took an average of nine minutes longer, but riders who changed to the car took an average of nine minutes less.

The second group to be significantly affected were travellers who travelled to work through the Restricted Zone and destinations on the other side of the city. For these people, the proportion of trips made by car fell from 53 to 51 per cent, but the proportion of car trips made in car pools rose from 9 to 28 per cent. The proportion of trips started before 0730 h rose from 50 to 60 per cent. Of course these travellers had the additional option of detouring around the Restricted Zone. Before the introduction of the scheme, 88 per cent of trips passed through the zone. Afterwards, only 66 per cent of them drove through the area, and only 13 per cent drove through during the restricted hours. The remainder changed time to avoid the fee.

Impacts on people making shopping trips. The number of shopping trips made to destinations in the Restricted Zone fell by 34 per cent, but not all of this can be attributed to the Area Licence Scheme, since the number of shopping trips outside the zone also fell by 14 per cent. The information gathered in the business survey indicated that the lower 10 per cent is due to recession, decentralisation of jobs and residences, and the increased parking charges associated with the Scheme. It seems unlikely that the contribution of the increased parking charges could account for more than about 5 per cent.

On the impacts of people driving outside the Restricted Zone. It is useful at this point to note that over 70 per cent of all trips and over 60 per cent of work trips are made outside the Restricted Zone. The majority of trips to work outside the Restricted Zone are by bus, and the majority of shopping trips are made on foot. The people making these trips have been unaffected by the Scheme. Many who use the ring road have been adversely affected by the increased congestion and reduced speeds.

Less direct effects. Flow counts, speed measurements and household interviews provided the data on the changes in traffic performance and the changes in people's travel behaviour underlying the traffic effects. For a general evaluation of the Scheme, research was also conducted on some other effects.

Some people have expressed concern that a scheme like Singapore's would hurt business in the central area of the city. After exploring the possibility of test cells, the availability of data on retail sales and other business transactions or on physical indicators of activity, we concluded that the available data in Singapore were not sufficiently comprehensive to yield a direct measure of business conditions, and that it would be too costly to design and carry out a reliable quantitative survey of transactions. Instead, in both interviews with selected leaders in the business community, including store managers, bankers, wholesale and property agents. Members of the group generally agreed that the Area Licence Scheme had not had an adverse impact on the business climate. It was believed that the increased parking charges had further depressed central area retail sales that were already suffering from recession, and decentralisation. It was also believed that the restrictions on car travel to the centre were accelerating the existing trend towards decentralisation. In both cases the Scheme and the increased in parking charges were viewed as adding to existing problems, not creating new ones.

Certain industries and businesses have been specifically affected. Some companies have been involved in additional expenses to buy licences for company cars. Taxi operators report that business is now very poor during the morning shift—people are unable to recover their losses later in the day. Wholesalers and retailers, on the other hand, report that they have benefited from easier movement of goods in the central area during the morning when many deliveries are made. The bus company also enjoys higher revenues and improved conditions in which to operate. It claims to be able to meet schedules better and avoid delays as a result.

Evaluation and conclusions. The various impacts of Singapore's Area Licence Scheme have been set forth in terms of a wide variety of variables measured on different scales or, in some instances, aggregated qualitatively. The most important aspect of crossing streets for pedestrians, cleaner air and people's perceptions that downtown Singapore has been improved are important.
benefits, but do not lend themselves to evaluation in economic terms without serious and difficult assumptions. The impact of the scheme on business was identified only qualitatively, not only because of a lack of statistics, but, perhaps even more importantly, because the impact of the scheme could not be quantitatively separated from the effects of the general recession or from the existing trend toward decentralization.

One of the areas of interest in having some portion of the evaluation done in economic terms, even if many important elements were omitted, a calculation was made of the value of net time savings to trip makers. It was found that the benefit over the value of small time savings is unresolved. It is the view of the authors that time savings such as those derived from the household survey are too small to be perceived by the travelers and to be considered of value in an economic evaluation. Nevertheless, for the purpose of applying a principle at a qualitative level to those resulting from analyses of other sorts of projects, all time savings and losses, no matter how small, were valued at the same rate. Like all value-of-time analyses, this one involves a value judgment about the social value to society of time saved by individuals. For the present analysis, this was assumed to be independent of individual income levels. Thus all time savings and losses were valued at one Singapore dollar per hour, which is between 25 and 40 per cent of the average wage rate. Based on these income levels, the average expenditure for fringe car park, shuttle bus facilities that not buses), signs and ticket booths, the minimum estimate of the rate of return in the first year was 15 per cent. This rate was the maximum rate of return, since the traffic restrictions, congestion would have continued to get worse. Thus, without putting a precise figure on it, we can conclude that the economic value of time savings in the first year could have been saved, thus multiplying the rate of return by a factor of four. In fact, some of the internal costs have already been incurred by converting car parks to other uses.

The economic rate of return based on the value of time savings may seem rather low. Public officials are more likely to be interested in costs and revenues. In these terms, the revenues from licence sales exceed operating costs (including special police for enforcement, and the printing and delivery of licences) by about $5,000,000 per month or $60,000,000 a year, which amounts to an annual cash return to the Government of more than 90 per cent of the total capital costs of $55,000,000.

Rather than either economic or cashflow considerations, it was the more general objective of changing people's attitudes toward freeways for commuting that motivated the planners of the Scheme. The aim was to prevent the existing moderate congestion from growing progressively worse. The penalties of congestion were described by Singapore's Road Transport Action Committee in these words:

'Daily traffic problems result in delay and frustration to motorists, bus commuters, goods and emergency vehicles, and poses danger to pedestrians and other road users. It also causes deterioration to the environment through noise, air pollution and visual blight.'

To solve the problem, the planners perceived that they had first to explain the rationale behind the more widespread use of public transport and other high-capacity vehicles, and second, to induce motorists to review and fundamentally change their attitudes towards the ownership and use of cars. This revision of motorists' attitudes and, hence, behavior was expected both to reduce the problems caused by congestion and at the same time create an environment in which public transport services could be improved.

In order to translate this objective into practical and measurable terms, a target was set at 25 to 30 per cent reduction in traffic entering the central area in the morning peak. This target was more than achieved. Therefore, it is clear that the Area Licence Scheme has forced motorists to modify their behavior, at least in the short run. It has reduced congestion in the central area, largely by inducing a shift towards public transport and car pools. Whether these are simply short-term behavior modifications or whether they represent fundamental changes in the attitudes of motorists cannot be determined at this point. It seems likely, however, that the continued use of such measures will result in a more widespread acceptance (rather than tolerance of) public transport and carpooling in the long run.

**REFERENCE**

Robertson, J. R., and W. F. McGee. The impact of traffic policies in Singapore: 1. Pedestrian accidents and air pollution. J. Urban Technol., 18 (187 November 1977), 3; 2. The impact of traffic policies in Singapore: 18 (187 July 1977). This is not yet a comprehensive catalogue of physical, legal, and fiscal methods of preventing vehicles from going where they would otherwise go or influencing people's travel choices. We are here primarily concerned with fiscal measures like Singapore's Area Licence Scheme. However, it is worth noting that they may be combined with different approaches in a policy package. For example, an addition to the Area Licence Scheme, also made use of parking charges, reserved bus lanes and prohibition of trucks with more than 40 axles from the area inside the ring road.

Physical and legal restrictions include barriers and sign-making, except by buses and emergency vehicles.
Table I

<table>
<thead>
<tr>
<th>BASIS OF CHARGES</th>
<th>METHODS</th>
<th></th>
<th>Automatic vehicle identification</th>
<th>Conventional parking charge methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone, entry or exit</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Zone, presence in</td>
<td>Yes*</td>
<td>Yes*</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Zone, parking in</td>
<td>Inconvenient</td>
<td>No</td>
<td>Yes</td>
<td>In principle</td>
</tr>
<tr>
<td>Crossing a line</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes**</td>
<td>Yes</td>
</tr>
<tr>
<td>(not at boundary)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Array of points</td>
<td>few</td>
<td>Possibly</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>many</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes:
- Windscreen stickers on cars, either moving or parked, spot-checked by roving wardens.
- By registering entry and exit meters or AVI could ascertain length of time spent in the zone, if desired.
- Possible, but other methods probably more convenient.
- For off-street parking places, entry and exit could be registered electronically; to do it for on-street parking would require equipment in every parking space.
- For a system with few control points, method could be the same as for zone entry or corner crossing.

These are suitable for setting off relatively small pedestrian shopping areas, but generally not for reducing congestion over a large area, especially making access too difficult. Area permits may be issued on the basis of occupation, e.g. to doctors or civil servants, or on the basis of officials' judgment about needs. It is generally considered almost impossible to administer such schemes fairly and to avoid corruption.

Another method that controls through traffic without restricting access to destinations within the city has been successfully used in Bremen, West Germany, and Göteborg, Sweden. It involves dividing the city into cells (four in Bremen, five in Göteborg) separated by barriers so that traffic can enter any cell from the ring road, but cannot move directly from cell to cell.

Other methods to reduce traffic congestion rely on giving priority to high-occupancy vehicles in bottleneck situations. For example, access to some freeways in the U.S. has been limited by reducing greenlight time on the access ramps as flow on the freeway approaches capacity, but buses, and in some cases high-occupancy cars, are enabled to bypass the queues thus created. A similar approach in the U.K. involves deliberate creation of delays to motorists trying to enter the central area of Nottingham, while buses were allowed to pass freely. Such confusion, frustration and induction was created that the scheme had to be abandoned. It may be that the failure of the Nottingham scheme was partly due to inadequate public education before the scheme took effect and partly to the unpredictability of the waiting times involved in entering the city at different points. There may have been other important differences between the two cases. However, it seems fair to conclude that the use of delays to ration low-occupancy-vehicle access to congested roads succeeded in one case and failed in the other. This should be a warning against casual generalisation and an indication of the importance of specifically tailoring each scheme to the local situation.

The other general approach to reducing traffic congestion is 'pricing', i.e. charging fees for some aspect of the use of the city streets. The selection of the most suitable form of pricing in any city warrants careful study of the effects of the different approaches in the context of local conditions. A final choice may require pursuing two or more approaches to the point of considering how each would be implemented, and comparing the practical problems they entail and their estimated costs.

As much as the subject of our research was Singapore, where pricing was the primary measure, the rest of the paper will focus on pricing approaches and methods of implementing them.

Basis of charging
Traffic in a designated zone may be reduced by assessing charges for entry into the zone, for operating within it, for parking in it or for exiting from it. There may be a single zone or multiple zones with different prices. Charges may also be assessed for passing control points which may correspond to concepts other than zone boundaries. On any of these bases, charges may be varied according to time of day and type of vehicle. All of them are location-specific. Thus they all conform to the idea of focusing the charges on the times and places where congestion needs to be reduced.

Differences among the charging basins will result in different effects on through traffic relative to traffic with deutilizations in the central area, on short versus long periods of staying in the area, and on residents of the restricted areas as compared to non-resident commuters.

Ideally, perhaps, the charging basins chosen would be such which came closest to having the desired impacts on different sorts of traffic, specifically in terms of requiring the user of each type of vehicle to pay the extra costs that his vehicle imposes on other road users in congested conditions. In practice, the method of implementation must be considered at the same time and may weigh heavily in the choice of the charging basin.

Method of implementation
Dated windscreen stickers were the method chosen in Singapore to show that payment had been made in advance (for the day or month). Some of the other possibilities are the use of stickers dated by clipping at the time of use, self-cancelling tickets, collection of tolls at toll-booths, the installation of meters in non-exempt vehicles, and the use of automatic vehicle identification (AVI).

Any of these methods can be used to charge for entry into or exit from a zone. Charges for being within a zone (without necessarily moving) can be administered by windscreen stickers or self-cancelling tickets, but by toll-booths, on-vehicle meters or AVI. However, the last two methods could, in principle, be used for the most sophisticated sort of scheme, one which would assess different charges for crossing different control points in various locations with the charges also varying by time of day. Various methods of charging for parking are well known. Table I indicates the applicability of different methods for implementing different approaches.

1. Dated windscreen stickers. One of the facts demonstrated in Singapore was that it is practical to administer and enforce a system of charging for entry to zone by using dated windscreen stickers. Success of such a scheme is not automatic, of course, but it has been shown that it can be done. The conditions for its success will be discussed later.

Toll stations. From observation of the traffic reduction in Singapore it can also be inferred that a scheme that reduced traffic so drastically could also have used on-street toll collection without seriously impeding the remaining traffic. That, of course, is true partly because traffic was reduced so much more than originally intended. However, even with considerably more drivers buying licences and entering the zone, it would probably be possible to collect tolls at the entry points for one-trip entries while continuing the windscreen-sticker method for monthly licences. The feasibility of this arrangement would have to be carefully studied in terms of the space available at entry points and the probable volume of one-day entries and all other traffic. However, after viewing the nearly empty streets in Singapore, one cannot dismiss the idea of toll collection, as many people have done, on grounds that huge toll plazas would be required.

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One inconvenience of the method used in Singapore is that one-day licences have to be renewed for the specific day and at locations that are not convenient for everyone. This is particularly irksome for the taxi passenger (especially the new arrival who does not know the system), who is sometimes forced to ride to the licence booth, spending time and taxi fare for the trip as well as paying for the licence before the driver will take him downtown. Collection at entry is one possible remedy for this problem.

Over-dated or self-cancelling tickets. Another proposed method that would solve the one-day licence problem uses a windscreen sticker or ticket from which portions are cut off by the user in such a way as to show the date on which it is to be used and rendering it invalid for any other date. The user can purchase these singly or in quantity without committing himself to using them on a specific day. Yet another means to the same end is the "self-cancelling ticket"—still to be perfected—which would undergo a chemical process and change colour on becoming invalid, at a convenient time (e.g. 12 hours) after having its cover removed to display it in the windscreen.

Electronic metering. Two basic electronic approaches have been under study and development for a number of years. One, which seems to have relatively few proponents at this time, requires that every vehicle carry a meter, whose action is triggered by infra-red beams from control points in the streets. An on-vehicle meter could run like a taxi meter, but charging at different rates depending upon the signal received from the most recently passed control point. The signal and, therefore, the charging rate would depend on the location and on the time of day. A simpler version could simply register a charge for entry of the vehicle into a zone and/or its exit therefrom, without accounting for the duration of stay in each zone, or it could register charges for passing through selected intersections between control points unrelated to a zone system. In practice, a difficulty with on-vehicle meters is the design of a simple payment system that cannot be tampered with by the user.

The same functions could be performed with automatic vehicle identification (AVI) equipment, which would identify each vehicle as it passed over sensing devices in the streets and transmit the information to a central register. This information would then be used to calculate the charges to be billed to the car owner. AVI also requires installation of an electronic unit in every car, but the unit is much simpler than the in-vehicle meter. One difference, which would be especially important if a complete parking charging system were used, is that the on-vehicle meter could be designed to show the driver the charges as they were incurred, while bills from the AVI system might come as a surprise to the motorist who does not give close attention to his crossings of critical points. Prototype AVI systems have been tested in toll-collection situations and shown to be reliable. The problem will come when the electronic equipment will be operational and will be used for zone-entry charging or for some more complex approach. Even then, however, there will probably have to be another parallel method such as toll-booths or windscreen stickers for non-local visitors or cars the motorist does not infrequently that is not worthwhile to install the electronic devices on the cars.

Impact of different bases of charging: Zone entry or exit. Singapore's zone-entry charge affects traffic from outside, whether it is bound for within-the-zone destinations or is crossing the zone to go out again. Traffic originating "within the zone is unaffected so long as it either stays inside or goes outside without returning during the hours of restriction. The fact that enforcement by visual observation makes it possible to grant exemption to high-occupancy cars, which would be difficult to do with an electronic system.

The absence of this control in the afternoon allows trans-zone travellers who by-passed the zone en route to wait in the morning to go freely through the zone in the evening—an unintentional effect. Various ideas have been considered to reduce the afternoon peak. Requiring the licence for entry, just as in the morning, would divert some of the trans-zone traffic; however, it would probably also deter people from going downtown for late shopping, eating at restaurants and going to places for entertainment, and these effects are not desired. Requiring the licence for leaving the zone in the afternoon (but not later in the evening) would avoid most of the undesired effects, while still differing some trans-zone traffic. To date, however, the problem has not been judged serious enough to justify introducing afternoon restraints.

Presence in the zone. Except for some difference in dealing with particular hours of restraint, a charge for presence within the zone would affect parking and transiting traffic in the same way as the entry charge, but would also apply to residents within the zone, unless they were issued free licences on the basis of their residence. The plan proposed for the central area would have charged presence rather than entry because that was believed more feasible to enforce under the prevailing local conditions. Whether that would be so varied one city to another, depending upon the area and number of entry points.

Parking. Since methods of charging for parking are well known and are already in effect in many cities, it is sometimes proposed that traffic could be reduced simply by charging high prices for parking in the central part of a city, perhaps with a supplementary charge or tax for entering car parks during the morning rush hour or with escalating hourly rates to penalise long-term parkers who are presumably commuters. Even in the absence of special charges or taxes, most cities could improve downtown transport conditions by levying parking charges that reflect the cost of providing the parking and by eliminating subsidised private parking.

This approach would be noted, would have no effect on through traffic. Unless complemented by other methods—such as a physical partition of the area, as in Göteborg, or a charge for crossovers—a central dividing line (see below)—the high parking charges might deter people from going downtown while they continued to be taken over by an increase in through traffic.

Another class of things that would be improved from parking charges as most cases from measures designed to impinge on through traffic is chauffeur-driven cars, which is of course an important component of the traffic in some cities of the world who might be missed; whether they should or should not be charged is a matter of some debate, and has been the subject of two policy changes in Singapore since inauguration of the Area Licence-Scheme. (The last decision is to charge them half-price.)

The increased parking charges in central Singapore were alleged to have had some adverse effect on the city's image, while the area licence, because of the timing of the restricted period, was not believed to have had such an effect. Perhaps varying the parking rates according to the time of day would have come closer to achieving the intended purpose of restraining commuters without restraining shoppers or people doing personal business.

Crossing a dividing line. Some approaches have more impact on trips that end in the city than on through trips. Others affect them more nearly equally. If it is desired to focus the impact more specifically on through traffic, perhaps the effects on trips to within-city destinations, a variant of the Bremen and Göteborg schemes could be used. Instead of physically separating the different kinds of the city, a charge could be assessed for crossing the dividing line between one cell and another. A single line would suffice in some cities; others might require two or more sections. The means that could be used for collection would be the same as for pricing entry to a zone.

Other pricing methods. Electronic devices, once they become operational, would not be limited to substituting for manual methods of implementing the pricing scheme proposed above. They would open up possibilities that would otherwise be infeasible. Instead of one or two pricing zones, there might be dozens of "pricing points" with different prices, all varying by time of day, to fit the price in each place more closely to the degree of potential congestion or the social marginal cost. Charges could reflect not only entry into a congested area, but also the length of time spent, or distance travelled, in it. There could be charges for passing through critical intersections or for turning in directions that delay other traffic. There has even been a proposal for measuring the frequency and sharpness of accelerations and decelerations in a vehicle as an indication of the degree of congestion in which it is operating and to which it is therefore contributing, and charging accordingly.

Even disregarding the last, extreme proposal, there is a danger in any of these relatively-complicated approaches that the motorist will not have a sufficiently clear and accurate understanding of the prices confronting him to behave as he is expected to. Moreover, a system that is hard to understand is likely to be unpopular.

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Delineation of a pricing zone
If charging for entry to a zone is chosen as the principal approach to be used, then, of course, delineation of the zone is a basic step in the system. This step will depend heavily on the size and shape of the city, its traffic flow patterns, the local geography and the pattern of roads. Nevertheless, some general principles can be suggested.

The size of the zone—aside from considerations of local geography and existing road systems—will depend on a judgment as to the extent of the area subject to congestion, not just at the present time but also for the future. It should also take into account the congestion that may be created outside the zone by diverting traffic that would otherwise go through. If the zone is too small, it may merely act as a local obstruction, causing more congestion around its periphery than it eliminates inside. However, the larger the zone, the more extra distance will be travelled in bypassing it to reach trans-zonal destinations.

The larger the zone, the more people there will be whose destinations lie within it and who (if they live outside) will be affected, having to choose whether to pay the tolls or take a different route or to a different time. The larger number of residents within a larger zone may or may not pose a problem, depending on details of the administrative design and on local boundary conditions. (A few in-zone residents in Singapore found that they could not drive to work without going out of the zone and re-entering it; thus they were faced with the choice of extra-zone residents, whereas most residents in the zone could travel freely.) Of course, if the zone were extremely large, it would include so much residential area and a large fraction of trips would be internal and charging for entry would be ineffective. This consideration would not apply to different zones, but if charging were to be based on presence in the zone, rather than entry.

Thus the zone should be big enough to embrace the important potential congestion area and be more than a local obstacle, yet small enough to be primarily a central business area, excluding as much residential or other 'congestion-free' territory as possible.

An important consideration in defining the zones is the presence of a reasonably convenient route for those who wish to bypass it. That may, in practice, be one of the most important determinants of the zone size and its boundaries, although the bypass route does not have to be the boundary. Figure 1 (p. 22) shows how far Singapore's zone boundary and ring zone were set from points, even while coinciding at a few.

If possible, the boundary should not divide neighbourhoods or shopping areas that also exist, and should not favour one retail store over its near competitor by making customers enter the zone to reach one while leaving the other outside. Where a natural or man-made physical division exists—e.g. a river or a railway—it may be desirable to use it as a boundary.

Other considerations in delineating the boundary are:
(a) is important to avert congestion in places where it would impede public transport.
(b) There must be opportunity for drivers to divert their routes if they find themselves approaching the zone boundary and do not wish to enter.
(c) If car parks or suitable locations for car parks exist near the proposed zone, the boundary should be drawn so as to leave the car on the outside.
(d) The number of entry points should be kept small to minimise the policing requirements.
(e) If minor roads are closed rather than policed, it should be done at points that will cause minimal disruption of local traffic.
(f) Where possible, major through routes should be left unaltered, to avoid impeding traffic that is not bound for the restricted zone. Thus, if a freeway passes through the area, its exits, rather than a point on the freeway, might be treated as entry points into the zone.

The hours of restriction
Given that the purpose of a pricing scheme is to reduce demand without reducing road space and thereby prevent excessive congestion, it is obviously necessary to keep the scheme in effect 24 hours a day. The question is whether it should be in effect only for the morning commuting hours, or for one period in the morning and another in the afternoon, or during the whole working day. This depends upon the intended impact of the scheme and on local conditions such as normal business hours, whether it is customary to drive home for lunch, and so on.

In Singapore the concern to avoid any negative effect on business dictated that restrictions should be focused on the morning commuting period. The beginning of the period was purposely set late enough (0730h) to enable a good many drivers to avoid the charge by going to work a half-hour or so earlier than before. Others avoided it by going after the end of the period. Thus, while the peak flow was suppressed, two new peaks were created. Although these peaks were lower and of shorter duration than the original one, the second one (0930h) was still higher than desired by the officials, and they eliminated it by extending the restricted hours to 1015h. It was believed that this extension would not affect retail business, since most stores did not open until 0900h or 1000h, but that any further extension would do so.

Opinions expressed by businessmen generally agreed with this judgment.

Restrictions on the afternoon were likewise also considered, but not instituted for fear of their possible effects on business. Had the zone included only non-consumer-oriented offices and industries, an afternoon scheme might have been acceptable, but stores that stayed open in the evening, restaurants and entertainment centres were valuable to diversion of their potential customers to places outside the zone. Thus the kinds of activity that exist in the zone are an important consideration.

In a city where going home for lunch is prevalent means that the morning and afternoon traffic might be equal, from an adequate approach. People might use car pools and buses for both of their morning trips, and then drive separate cars after lunch. Thus it would be necessary at least to consider a second period at the time of the after-lunch inbound traffic.

It should be noted that reducing peak flow levels is not the sole purpose of a pricing policy. Reducing inflows is also a method of reducing the vehicles moving around in the zone later in the day or reducing the number of vehicles occupying parking space that might otherwise be used by shoppers.

Setting the price
When the Singaporeans set the price for the area licence, there was no previous experience to guide them. Now there is one case. The Singapore experience could be used as a rough basis for choosing a price by relating it to the other costs of making trips, the mean income level, and the desired reduction in traffic. This basis should be better than none, however.

In other cases the demand relation may differ because of differences in the quality and availability of alternative transpor, the distances involved, and the less tangible factors. Thus, whatever price is set must be regarded as an experiment, and the authorities must be prepared either to change it after they observe its effect or to accept the resulting reduction in traffic congestion even if it is different from what they had intended.

If the effect is greater than intended it may be that the price, while too high for the immediate conditions, is right for a future situation when there will be higher incomes and more cars. In that case it may be best to keep it alone rather than reduce it and have to raise it again in a year or so.

If the effect is too little, the price should be raised before people get used to it. It is probably wise to start with a very low price and increase it gradually if it was announced at the beginning that charges would be increased by a certain amount at regular intervals until a specified reduction in congestion had been acheived.

Multiple zones and variable prices
The discussions above concerning zone boundaries, hours and prices assumed that there would be a single zone with a fixed price for entry (or for licence within the zone) during prescribed hours. In order to modify the sharp 'edge effects' of a single zone, or to intensify the effect in a critical area, it might be worthwhile in some cases to consider having two or even more zones with different prices or with different hours. While these more complex arrangements would be more difficult to administer with the same effectiveness, it would not be impossible to handle them with windscreen stickers.

The easiest of these variants to administer would be a two-zone system in which the same licence was valid for both zones, but was required for different time periods—e.g. during the morning commuting period.
for an outer zone and throughout the day for an inner zone. Slightly more difficult is the scheme, which requires stickers of different shapes or colours for the two zones.

"Edge effects" occur not only in terms of geographical boundaries, but also in terms of the beginning and end of the zone at different times. At zone entry points in Singapore there was a noticeable rush to get into the zone before the lights on the restricted zone were changed at 0830, and one could often see drivers, who had clearly intended to enter but arrived too late, turning onto the ring road instead. To avoid such effects, Columbia University's Professor William Vickrey - one of the earliest advocates of road pricing, and still its most ardent spokesman in the U.S. - has suggested that the tolls on bridges leading into New York City be varied continuously, minute by minute, charging a low price in very early morning, gradually increasing to a maximum at what is now the time of evening flow and lowering prices gradually after that time in such a way as to flatten the peak and spread demand uniformly over several hours. While this idea is clearly not feasible in its extreme form, it illustrates the desirability of trying to achieve a degree of smoothness at the 'edges' of a pricing scheme. The smoothness is important both at the geographical boundaries and at the end of a different time period.

In any case, windscreen-sticker methods could not be used for a variable price scheme unless perhaps for only two prices in different periods, using different colours or shapes to show what price was paid in advance for the sticker. Even this might add just enough complication to give serious consideration to administrative and enforcement. It is suggested that such refinements, as different prices for different entry times or even different prices for different zones be considered only after a simple one-price scheme has been successfully implemented.

Exemptions and different prices

Different types of vehicles is feasible, both in terms of exempting certain types from the licence requirement and charging different prices. This has been demonstrated in Singapore where commercial vehicles, emergency vehicles, motorcycles and scooters are exempt and where some different prices apply to business-owned passenger cars and taxis. There are, however, and there should be compelling reasons for any departure from charging the same price to all without exception.

The exemptions in Singapore were based on the desire to avoid imposing any new cost on bus operators, and on the difficulty of reading licence numbers of moving motorcycles or scooters for enforcement purposes (as well as the difficulty of putting windscreen stickers on motorbikes). So during April 1, 1977, the fare of $0.10 for one outside equipped with a licence fee was to go double to $0.20. The increased cost of the licence fee was cut in half for taxis and there was a marked increase in their availability.

COMPLEMENTARY MEASURES

Charging a price for the use of scarce road space is not a policy to be considered in isolation. It should be viewed in the context of an overall transportation policy for the city. If it is to be adopted, it will probably need to be complemented by other measures in the realms of traffic management and public transportation.

Procion for changes in traffic patterns

It was mentioned in connection with delineating the zone boundary that a convenient route should be available for drivers wishing to bypass the restricted zone. Unless a road ring with excess capacity already exists, it may be the easiest way to widen some roads along a circumferential route, modify intersections to handle increased traffic, and perhaps convert some parallel two-way roads into one-way pairs.

Improvements of this sort were done along the ring route before inauguration of the licence scheme in Singapore, but, even so, a few spots of local congestion appeared when the scheme took effect, and some further work had to be done to remove the bottle-necks.

One preparatory measure that was apparently entirely in line with the scheme was taken care of during the first few days of operation, was the re-timing of traffic lights around the periphery. At some intersections the increased circumferential traffic was backing up in long queues while the light remained green much longer than necessary for the diminished radial flow. At most such points the problem was quickly solved by giving a greater amount of "green time" to the circumferential flow.

If fringe car-parks are to be established, some changes in the adjacent roads may be needed to provide adequate approaches. Where circumferential car traffic may interfere with buses, travelling either circumferential or radially, there may be a need for reserved lanes, priority for buses at intersections or other means of avoiding delays to the buses.

Alternative transport facilities

If people are to be induced to give up driving cars into the city, they must have other means of getting there. Car-pooling will take care of some of them. Some may switch to motorcycles riding. In most cities, however, the main alternative to driving is public transport, usually in the form of buses or buses and jitneys. The demand is not sufficient but the transport capacity to absorb the increased load - the public reaction could force the pricing scheme to be abandoned.

The officials in Singapore not only recognised the need for adequate capacity on the standard bus services, but also felt that there should be higher grades of service (correspondingly higher prices) for those who were giving up the comfort and convenience of automobiles. Long before implementation of the Area Licence Scheme, they undertook several measures to expand the capacity of the standard bus service - using school and private buses to carry part of the peak load, improving maintenance to keep more buses operating and buying additional buses.

So it seems to have been dealt with a satisfactory manner. The officials in Singapore, however, have not been able to increase the number of buses operating during the commuting hours. Rather surprisingly, none of these services drew very much patronage. Whether this outcome could have been forecast by a market survey, or
whether it could have been altered by lowering the prices of the premium-grade services, cannot be known with certainty. However, it would probably be wrong to conclude from this experience that such services would not be used in another city, where different trip lengths and different public attitudes might yield different results. Contingency planning and experimentation are suggested.

**ESENIAL FACTORS IN IMPLEMENTING THE SCHEME**

Successful implementation of the Area Licence Scheme in Singapore has led some people to believe that if it can work anywhere, while others say that Singapore is a unique case and proves nothing. In a sense, both are partly right and totally wrong. It has been demonstrated that an area licence scheme can be successfully implemented under some conditions. The important thing is to try to identify what the conditions were, which ones were essential to success, and which ones could be different without making success impossible.

The following factors, all of which were present in Singapore, are in our judgment essential to the successful implementation of any area pricing scheme:

1. Competent management, with an organisational structure that fosters comprehensive policy-making and planning for all aspects of transport in the metropolitan area, including traffic management, traffic policy, bus services and motor vehicle registration.

2. Carefully worked-out, detailed provisions for issuance of licences, erecting signs on the approaches to the restricted zone, enforcing the rules and handling all administrative details.

3. Good design of the scheme, including upgrading of the circumferential zone, expanding public transport facilities, laying out of the boundary.

4. Advance education of the public as to the reasons for the scheme, its expected benefits, from short-run and long-run, exactly how it will work and what choices people can make. In Singapore, this process started a year before implementation of the scheme and involved publication of an explanatory booklet and expression in speeches and newspaper articles of opposing views as well as those of the government.

5. Pragmatism, as exemplified in Singapore by an effective programme of monitoring results and quickly making traffic management changes, or modifying the rules of the scheme to overcome observed problems.

**Other contributing factors**

Some other factors undoubtedly made successful implementation of the scheme in Singapore easier but, in our judgment, are not absolutely necessary for success elsewhere:

(i) The fact that cars were used by only a minority of downtown commuters, even before the Area Licence Scheme was instituted. This helped, not just because there were fewer potential opponents of the scheme, but also because it implied a greater capacity for public transport to absorb those who changed their travel mode.

(ii) Cultural-social attitudes favourable to compliance with regulations. Singaporeans are disposed to believe that the government acts in the general social interest, and to accept rules and costs imposed on them. This does not mean that no effort was necessary to enlist popular support. (See item (4) above.) However, in a society where protest is the typical response to government actions, an even greater effort to gain acceptance would be necessary.

(iii) The relative ease of planning and decision-making in a city-state, with one level of government dealing with one geographical area. In a multi-jurisdictional setting, it would be necessary to have a special agency with authority to establish and administer the necessary measures for the area as a whole.

(iv) Laws that made enforcement simple. While it was indeed convenient to be able to collect fines from car-owners by observing their licence-numbers and mailing citations to their homes, nevertheless other procedures would have been possible (and perhaps less open to possible errors). With the reduced flow on the streets just inside the Restricted Zone, there would have been plenty of space to stop all violators and cite them on the spot. This would have required a larger number of police at each entry, but would have been perfectly practical.

(v) The relative isolation of the region from outside traffic. Having significant numbers of vehicles from other jurisdictions entering the restricted zone would require more stringent provisions for issuance of one-day licences and on-the-spot citation of violators. These are not serious obstacles. Perhaps toll-booths for those without monthly stickers would prove convenient in both respects, since they would tend to eliminate the problem of violations by strangers who did not know about the system.

Considering both the essential factors and those that were helpful but not absolutely necessary, the possibility of successfully implementing area pricing schemes in other cities has to be judged on a case-by-case basis. Given a conviction that such a scheme would be worthwhile, appropriate organisational and administrative arrangements, and competent people in charge, it should be possible to design and implement a workable scheme within the constraint of local conditions of a wide variety of cities.

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**Fig. 7. The Restricted Zone, Ring Road and fringe car parks.**

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