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ENVIRONMENTAL TRAFFIC CAPACITY OF ROADS

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ABSTRACT: *Recent attempts to develop measures of the Environmental Capacity of streets and street systems are described, particular reference being made to a study of part of the municipality of Fitzroy in Melbourne. As part of this project, noise generation and pedestrian delay characteristics of traffic streams were considered in order to produce Environmental Traffic Capacities.*

The paper illustrates how the Environmental Capacity approach may be used to identify both streets where environmental overload has occurred and streets in which additional traffic capacity exists within acceptable environmental levels. The use of the technique as part of a Traffic Management scheme is described, examples being given of the various options available for the upgrading of a street's Environmental Capacity.

Paper for Presentation in
Session 6

ENVIRONMENTAL TRAFFIC CAPACITY

INTRODUCTION

Traffic planning has traditionally used numbers of vehicles per 24 hours as the sole indicator of the impact of traffic on a street; more vehicles per day meant less residential amenity. A total of 2,000 vehicles per day has long been used as a yardstick to indicate an acceptable maximum number of vehicles travelling along a residential street in a 24 hour period; if the figure was below 2,000 v.p.d. there were no adverse effects; above 2,000 v.p.d. some local detriment might exist.

It is clear that 2,000 vehicles, travelling at an even speed, create much less impact than a similar number of cars, trucks and motorcycles, accelerating or braking coming in random fashion at all hours of day and night.

In effect, "vehicles per day" (or per peak hour) in no way reflects the impact of that traffic on the local environment. No indication is given of vehicle types, speeds, times or conditions of flow or the resultant impacts; noise, fumes, vibration, danger, intrusion or inconvenience.

The impact that moving vehicles have on the environment through which they pass is becoming more apparent as vehicle numbers and vehicle-kilometres increase, and as congestion, particularly in inner urban areas, forces traffic to seek quicker routes away from congested main roads. Many of the routes chosen by such traffic are local residential streets not designed to carry through traffic and whose environments were not planned to accommodate this additional intrusive element.

The ability of major roads to carry all non-local traffic is becoming saturated, not only at peak hours but during the day and evening as well.

Residential streets are capable of supporting a proportion of through traffic, provided the conditions of this traffic flow are not intrusive on the environment.

In an endeavour to find a solution to inner urban traffic management problems, planners are tending to overlay on the ill-suited 19th century street patterns the same hierarchy of roads they are applying in outer urban, greenfields situations.

In many cases this practice has resulted in streets that have good connectivity in the road network, but which are residential in character, being required to carry above the 2,000 v.p.d. figure.

The Fitzroy Experience

Typical of a number of inner urban situations in Australian cities is the one experienced by the Municipality of Fitzroy in Melbourne. After the opening of the Eastern

Freeway in December 1977, traffic leaving the freeway at its near-city end was forced onto a grid pattern of arterial roads which in peak periods was inadequate in coping with demand.

The network of internal, almost wholly residential streets was thus burdened with traffic volumes that were previously unknown, and Fitzroy City Council and residents sought means to reverse the situation.

Certain streets in North Fitzroy became attractive routes linking the Eastern Freeway with the Tullamarine Freeway and other parts of inner northern Melbourne. This is an area where major road constructions have been proposed, notably the Hume Freeway along the Merri Creek valley. Pressure from residents and municipal councils has so far prevented any broad plans being accepted by Government.

Seeing the problem of traffic infiltration into residential areas as one that will therefore not only exist for some years, but also continue to grow, Fitzroy City Council sought a means of finding a solution which respected the residential rights of its rate-payers and which did not accede to the proposal that increased traffic should be provided with whatever road space it wanted.

Fitzroy City Council, with the adjoining Councils of Collingwood and Melbourne, was represented on a committee set up by the State Government to monitor the effects of Eastern Freeway traffic on residential areas north of the C.B.D. This Monitoring Committee soon became little more than a forum for debate between these Councils and the Country Roads Board over the issue of traffic flows versus residential amenity. Fitzroy was seeking a solution which satisfied both demands and which it could use to at least contain further traffic growth in residential streets.

Within this setting, the Study described below was undertaken to investigate means whereby a satisfactory level of traffic flow for certain critical streets could be quantified having regard primarily to the rights of residents to be able to enjoy their neighbourhoods without undue imposition of excessive traffic.

The concept of identifying an environmentally-based capacity for streets appeared to offer a solution.

CONCEPT OF ENVIRONMENTAL CAPACITY OF A ROAD OR NETWORK OF ROADS

In identifying the Environmental Capacity of a road, the purpose is to determine the maximum number of vehicles that should be permitted to pass along that road during a certain period of time and under fixed conditions without causing environmental detriment.

These conditions relate to both the fixed environment and the vehicles and their conditions of movement and

include:
- pavement width
- building setbacks
- land use
- presence of pedestrian refuges (medians)
- vehicle speeds
- vehicle types
- intermittency (conditions) of traffic flow

It is assumed that by controlling vehicle speeds and types, noise and air pollution from such vehicles can also be controlled.

It can be seen therefore, that by altering one or more of the above, the impact of traffic on a street can be altered and hence the Environmental Capacity can be changed.

In commencing the study, it was quickly apparent that before the Environmental Capacity could be calculated for a network of streets or even for one street, it was first necessary to decide what were the significant adverse impacts of moving traffic, how to measure them, and how to use these measurements in identifying an acceptable upper limit.

A number of studies have been undertaken overseas in this area, and these are reviewed briefly below.

<u>Previous Relevant Research</u>

Buchanan (1963) developed the concept of Environmental Capacity as the capacity of a street or an area to accommodate moving and stationary vehicles, having regard to the need to maintain environmental standards. It is based on the delay suffered by pedestrians wishing to cross the road, and relates various proportions of "vulnerable" pedestrians (aged, infirm, very young, women with prams etc.) to different levels of protection offered by a street (driver visibility, footpath width, parked cars, etc.).

Reynolds (1968) pursued Buchanan's work to the stage where, for a road of particular width, an acceptable traffic volume (in vehicles/hour) could be calculated for various levels of pedestrian delay.

Burt (1971) showed that pedestrian delay, although only one method of indicating environmental capacity, correlated very closely to pedestrian accident statistics, and can therefore be regarded as a reliable indicator of the environmental impact of traffic.

Noise generated by road traffic is recognised as being one of the most damaging environmental impacts of uncontrolled road traffic and, whilst research is continuing into the maximum noise levels that may be produced at the facades of and inside various buildings and facilities, some basic standards have been set and have received wide acceptance.

Noise standards are specified in terms of that noise level over a specified period of time which is exceeded for a percentage of that time. British legislation used to assess compensation for noise increases associated with road works sets an L_{10} (18 hour) standard. (This is the noise level in decibels that is exceeded more than 10% of the specified time, in this case 6 am to midnight.) The figure set is 68 dB(A), recorded at a point 1 metre in front of building facades. The recent Inquiry into Town Planning Compensation in Victoria (Gobbo, 1978) recommended that this standard be adopted in Victoria for the treatment of compensation for noise effects.

Curry and Anderson (1972) developed a range of noise levels acceptable for various land uses; the commonly used figure of 68 dB(A) had been challenged as inappropriate in certain applications. To use noise levels as a measure of environmental capacity enables the traffic impacts within buildings and property boundaries to be considered, unlike the pedestrian delay method which is restricted to traffic impact in the roadway itself.

Acceptable noise levels for various situations are shown in Table 1.

TABLE 1: ACCEPTABLE NOISE LEVELS FOR VARIOUS LAND USES (Curry & Anderson)

LAND USE	RECOMMENDED MAX. SOUND PRESSURE LEVEL L_{10}-dB(A)		
	Time of Day	At Property Line	Inside Structure
Residential:	Day Night	70 65	65 55
Business, Commercial, Industrial:	All	75	65
Education Institutions:	All	70	60
Hospitals Rest Homes:	Day Night	60 50	55 45
Public Parks:	All	70	55

Sharpe and Maxman (1972) based environmental capacity on resident perception of a street. They attempted to find a relationship between the environmental aspects of an urban area and the demands placed on the street system by road traffic.

Their work acknowledged the shortcomings of using a single criterion (such as pedestrian delay or noise levels) to assess environmental capacity, and sought to produce a more representative technique.

To do this a large survey sample was questioned regarding the relative importance in people's minds of eleven different adverse effects of traffic. From these eleven, three clearly stood out; noise, air pollution and safety to pedestrians. An amalgamation of these three was used to develop a series of "street prototypes", each with its own land use, traffic flow and physical street characteristics. From this series of prototypes, an acceptable traffic volume for any street could be calculated, given its basic characteristics.

This technique, of assessing environmental capacity based on previously determined perception of the influences of traffic, is gaining greater acceptance in this area of traffic planning as it takes account of a number of variables. Unfortunately there has apparently been no comparable research undertaken for Australian conditions.

It is apparent from these studies that residents of heavily-trafficked streets are most concerned about three aspects of traffic, namely

1. noise
2. delay in crossing the road, and
3. safety to pedestrians

THE STUDY

The area selected for the Study is an area of North Fitzroy where recent increases in traffic volumes have occurred following the opening of the Eastern Freeway (Fig.1). No adequate arterial road system exists in this area to carry east-west traffic and as a consequence the residential streets are being increasingly utilised by through traffic.

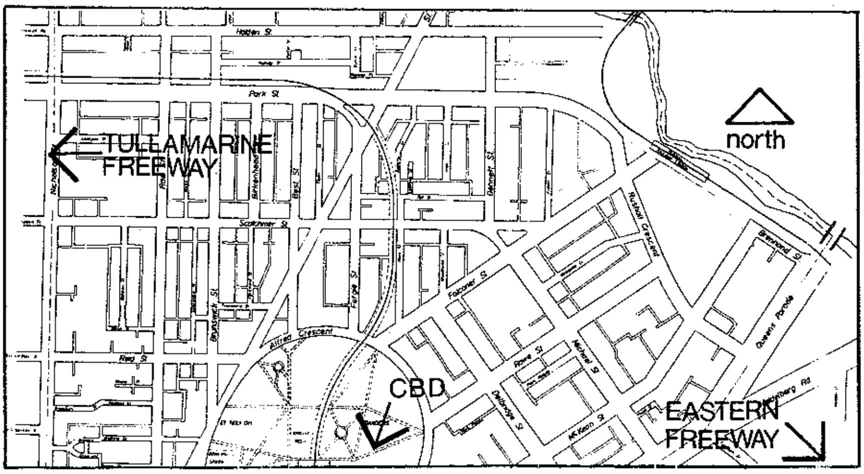

FIGURE 1: THE STUDY AREA

As discussed above three aspects of traffic movement are of greatest concern to residents. These are:

(a) noise generated by traffic
(b) delay to pedestrians in crossing the road
(c) pedestrian safety.

The first two of these are quantifiable, the third is not. However as has been shown (Burt 1971), as pedestrian delay is highly correlated with safety, pedestrian delay may be used as a reliable indicator of pedestrian safety as well as providing a meaningful measure of traffic impact in its own right. The two quantifiable measures of traffic movement, their theoretical basis and the manner in which they were employed in the Study are outlined below.

Both methods of analysis required knowledge of the major land-use groupings along the streets, set backs of buildings and physical dimensions of the various street cross-sections. A thorough inventory of the street system was therefore undertaken. Figure 2 illustrates the land use information for the Study Area, the street system having been subdivided into a series of typical links.

Environmental Capacity using Traffic Noise as a determinant

In accordance with previous studies, a 68 dB(A) L_{10} (18 hour) noise standard 1 metre from the building facade was adopted in the Study as a basis for the definition of environmental capacity. Whilst this level may be considered as marking the threshold of undesirable impact rather than defining a desirable design situation, it does provide a starting point of reasonably wide acceptance. Use was then made of noise prediction techniques (CORTN) developed by the Department of the Environment, United Kingdom (Department of the Environment, 1975) and validated by the Country Roads Board, Victoria for use in Australia (Saunders & Jameson, 1978). These techniques allow the noise level generated by a particular traffic volume to be calculated and then corrected for the following factors:

- speed of the traffic
- composition of the traffic flow (proportion of heavy vehicles)
- gradient of the road
- distance from the edge of the carriageway to the reception point
- intervening ground cover
- degree of screening etc.

From the cross-sectional characteristics of each link of the street system, hourly and 18-hour volumes of traffic that would generate a noise level of 68 dB(A) L_{10} (18 hour) 1 metre from the building facade were calculated and the 18-hour volumes (from 6 am to midnight) converted to 24-hour flows. These traffic flow figures were calculated assuming that traffic speed averaged 50 km/hr. and that 10%

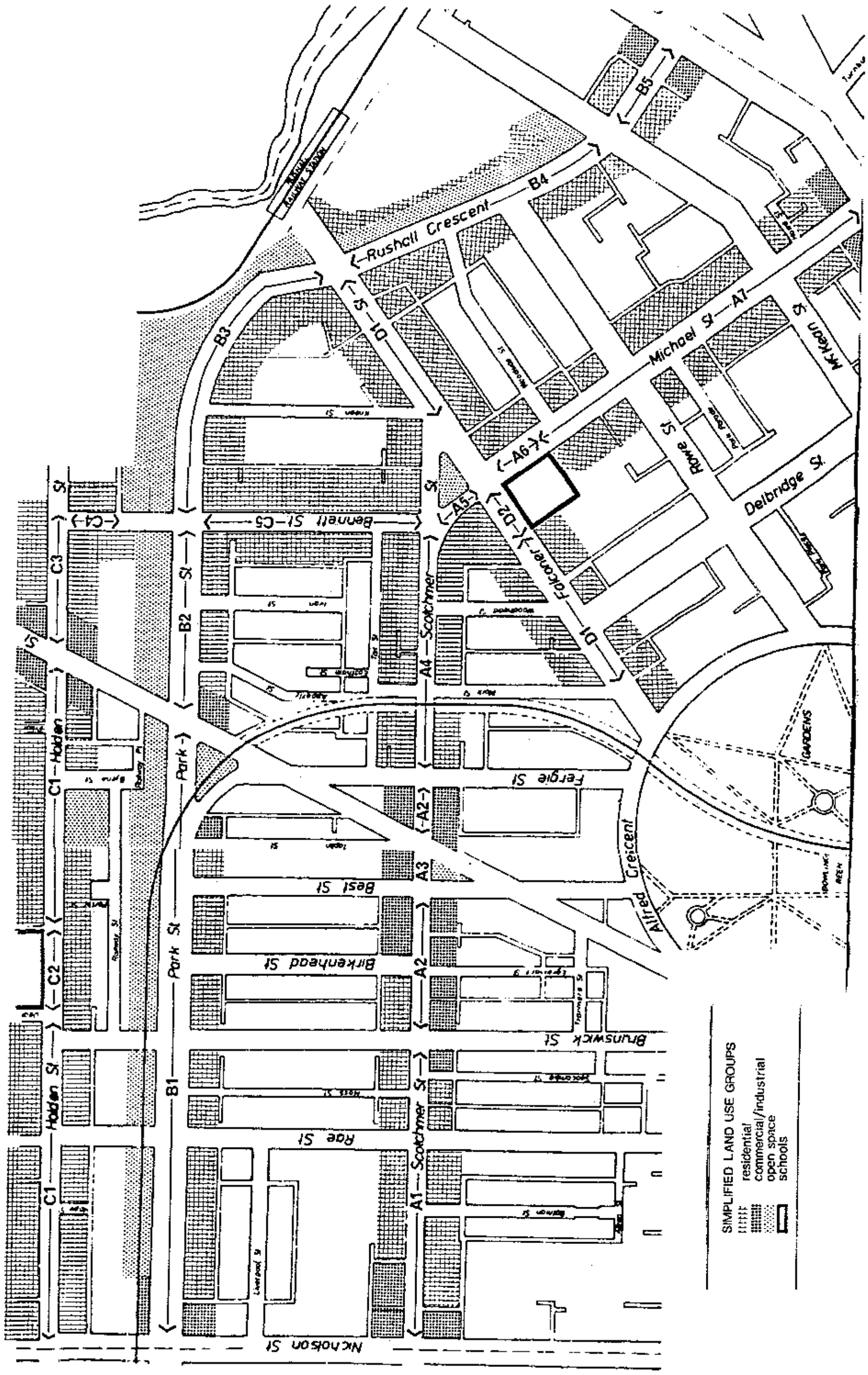

FIGURE 2: LAND USES IN THE STUDY AREA

of the flow were heavy commercial vehicles (defined in the CORIN procedure as any vehicle other than a motor car whose unladen weight exceeds 1525 kg.). This scenario was felt to represent a desirable current situation for a residential street in which proportions of heavy vehicles were restrained to levels commensurate with servicing of the area and where traffic speeds were at an acceptable average. Two alternative flow compositions were also considered for the purposes of comparison, namely:

(a) 50 km/hr. traffic speed and 0% heavy commercial vehicles
(b) 70 km/hr. traffic speed and 20% heavy commercial vehicles

These two alternatives were intended to represent two extremes of the flow situation with respect to the 50 km/hr. and 10% heavy vehicle desirable flow composition. Table 2 lists the Environmental Capacities calculated for each of the links for the three flow situations, from which it can be seen that the two "extremes" effectively double or halve each link's Environmental Capacity with respect to the desirable flow composition.

TABLE 2: ENVIRONMENTAL CAPACITIES USING TRAFFIC NOISE AS A DETERMINANT

LINK refer Fig.2	C.D.	24-hour capacity (2-way)			Peak hour flow (v.p.h. 2-way)		
Scotchmer Street/Michael Street							
A1	2.7	4600	9200	2300	210	420	100
A2	2.1	4600	9200	2300	210	420	100
A3	2.1	4600	9200	2300	210	420	100
A4	3.3	4600	9200	2300	210	420	100
A5*	6.4	6800	13600	3400	300	600	200
A6*	6.9	7400	14800	3700	330	670	200
A7*	4.9	6350	12700	3100	285	590	200
Park Street/Rushall Crescent							
B1	6.1	5750	11500	2850	260	510	130
B2	5.2	5750	11500	2850	260	510	130
B3	6.7	5750	11500	2850	260	510	130
B4	7.6	5150	10300	2600	230	470	110
B5	5.8	4600	9200	2300	210	420	100
Holden Street/Bennett Street							
C1	3.0	4600	9200	2300	210	420	100
C2	6.1	4600	9200	2300	210	420	100
C3	4.6	4600	9200	2300	210	420	100
C4	7.6	4600	9200	2300	210	420	100
C5	4.6	4600	9200	2300	210	420	100
Falconer Street							
D1	5.2	4600	9200	2300	210	420	100
D2	5.1	4600	9200	2300	210	420	100
Average Speeds:		50 km/hr.	50 km/hr.	70 km/hr.	50 km/hr.	50 km/hr.	70 km/hr.
% heavy Comm. Vehs.		10%	0%	20%	10%	0%	20%

C.D. = Critical distance - minimum distance between edge of carriageway & building facade

* - divided carriageway

Environmental Capacity using Pedestrian Delay as a determinant

The concept of environmental capacity employed in this method of quantitative assessment is based on the work by Buchanan discussed above.

Gap acceptance theory as applied to pedestrian crossing behaviour assumes that pedestrian and vehicle arrivals are random and that the pedestrian must wait for an interval between the successive arrivals of vehicles which equals a certain critical gap (related to the time taken to cross the road) before being able to cross safely (Iransportation Research Board, 1975; being a general reference which summarises the work of the many authors in this area). It can be shown that, for a particular road width, as the volume of traffic increases, the delay to pedestrians increases exponentially.

Buchanan's work involved the observation of pedestrian crossing behaviour at a number of sites and included the classification of the street crossed into one of three classes of "levels of protection"(1) and into one of three classes of "levels of vulnerability"(2). Observed delays were analysed to provide indications of acceptable levels for particular combinations of protection and vulnerability levels and this resulted in recommendations as to the maximum proportion of pedestrians for whom delay was acceptable at various types of crossing site (Table 3).

IABLE 3: MAXIMUM PROPORIION OF DELAYED PEDESIRIANS FOR VARIOUS LEVELS OF PROIECTION AND VULNERABILITY

Level of Vulnerability	Level of Protection		
	High	Medium	Low
Low	70%	60%	50%
Medium	60%	50%	40%
High	40%	30%	20%

Buchanan then produced graphs of acceptable traffic volumes (vehicles/hour) against street width for the various combinations of street vulnerability and protection levels i.e. acceptable proportions of pedestrians delayed. These graphs enable the environmental capacity of a particular street to be read off, once the level of protection offered and the level of vulnerability of the pedestrians at the site are known.

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1 "level of protection" - degree of protection offered by street, represented by degree of visibility, numbers of parked cars, width of footpaths etc.

2 "level of vulnerability" - measure of vulnerability of pedestrians using the site represented by proportion of old people, children, mothers with prams etc.

With the limited time available in which to carry out the Study, Buchanan's work, although based on observations of pedestrian activity in the United Kingdom, appeared to offer the necessary solutions and provided the graphs from which acceptable traffic volumes could be read directly. All of the streets within the Study area were assumed to afford HIGH levels of protection, except in the commercial areas where parked cars and distractions were assumed to lower the level to MEDIUM. Similiarly, given the basically residential nature of the Study area, all streets were assumed to have a MEDIUM vulnerability level (20% - 50% of pedestrians vulnerable); adjacent to schools, open-space and in commercial areas, the vulnerability level was assumed to be HIGH (over 50% of pedestrians vulnerable). For each link of the Study Area routes, maximum hourly vehicle flows were read off, particular attention being paid to areas of high pedestrian activity (Table 4).

TABLE 4: ENVIRONMENTAL CAPACITIES USING PEDESTRIAN DELAY AS A DETERMINANT

Link Refer Fig. 2	Road Width (m)	Proportion of Pedestrians Delayed	Current Environ-mental Capacity (2-way v.p.h.)	"Improved" Environmental Capacity (2-way v.p.h.)
Scotchmer Street/Michael Street				
A1	12.8	30%	85	2 x 135 = 270
A2	12.8	30%	85	2 x 135 = 270
A3	12.8	30%	85	2 x 135 = 270
A4	13.7	60%	200	2 x 340 = 680
A5	6.4)* 7.3)	40%	200+185 = 385	
A6	6.4)* 7.3)	40%	200+185 = 385	
A7	6.7)* 7.3)	60%	345+330 = 675	
A7 at Queen's Parade	6.7)* 7.3	30%	135+130 = 265	
Park Street/Rushall Crescent				
B1	8.2	40%	155	2 x 250 = 500
B2	10.4	40%	135	2 x 225 = 450
B3	10.0	40%	140	2 x 225 = 450
B4	11.6	40%	125	2 x 205 = 410
B5 at Queen's Parade	20.1	30%	60	2 x 105 = 210
Holden Street/Bennett Street				
C1	11.3	60%	230	2 x 370 = 740
C2	11.9	40%	125	2 x 205 = 410
C3	12.8	30%	85	2 x 140 = 280
C4	12.8	60%	215	
C5	12.8	60%	215	
Falconer Street				
D1	19.8	60%	155	
D2	20.1	40%	85	2 x 140 = 280

* Divided Carriageway

In using the graphs developed in Buchanan's work in the Fitzroy Study, several problems became apparent. As a result the theoretical background to these curves and the assumptions inherent in the theory were further investigated.

These problems were as follows:

(a) the graphs only covered roads up to a maximum width of 10.97 m (36 ft.) and several links within the Study Area were considerably wider than this,

(b) the figures for maximum acceptable delay to pedestrians appeared to be unreasonably low (e.g. 2 sec. to all pedestrians), leading to an under-estimation of maximum acceptable traffic volumes and hence Environmental Capacity,

(c) the critical gap assumed for a particular street width seemed to be low, being based simply on width ÷ crossing speed, with no account being taken of reaction and perception times or the safe interval between the passage of pedestrian and vehicle. As a result maximum, acceptable traffic volumes (and hence Environmental Capacity) were overestimated.

These observations led to a review of the technique and the development of revised guidelines based on the best information available. A brief description of the theoretical background to this review follows:

Assume that q = vehicle flow (vehicles/second)
t = critical gap (seconds)
P = proportion of pedestrians delayed

It may be shown that the probability that pedestrians will be delayed, $P = 1 - e^{-qt}$ (1)

and hence by manipulation

$$q = \frac{\log_e \left(\frac{1}{1-P}\right)}{t} \qquad (2)$$

Now Underwood (1957) has shown that the critical crossing gap, t, is made up of:

$$t = \left(\frac{\text{width}}{\text{crossing speed}}\right) + \left(\begin{matrix}\text{perception}\\ \text{time}\end{matrix}\right) + \left(\begin{matrix}\text{safe lag}\\ \text{time}\end{matrix}\right)$$

where crossing speed, V = 1.22 m/sec. (4 ft/sec.)

perception time, R = 2 sec. for 1-way flow
& 3 sec. for 2-way flow

safe lag time, L = 2 sec.

Hence for 2-way flow:

$$q = \frac{\log_e \left(\frac{1}{1-P}\right)}{\left(5 + \frac{W}{1.22}\right)} \qquad (3)$$

and for 1-way flow:

$$q = \frac{\log_e \left(\frac{1}{1-P}\right)}{\left(4 + \frac{W}{1.22}\right)} \qquad (4)$$

where W = street width (metres)

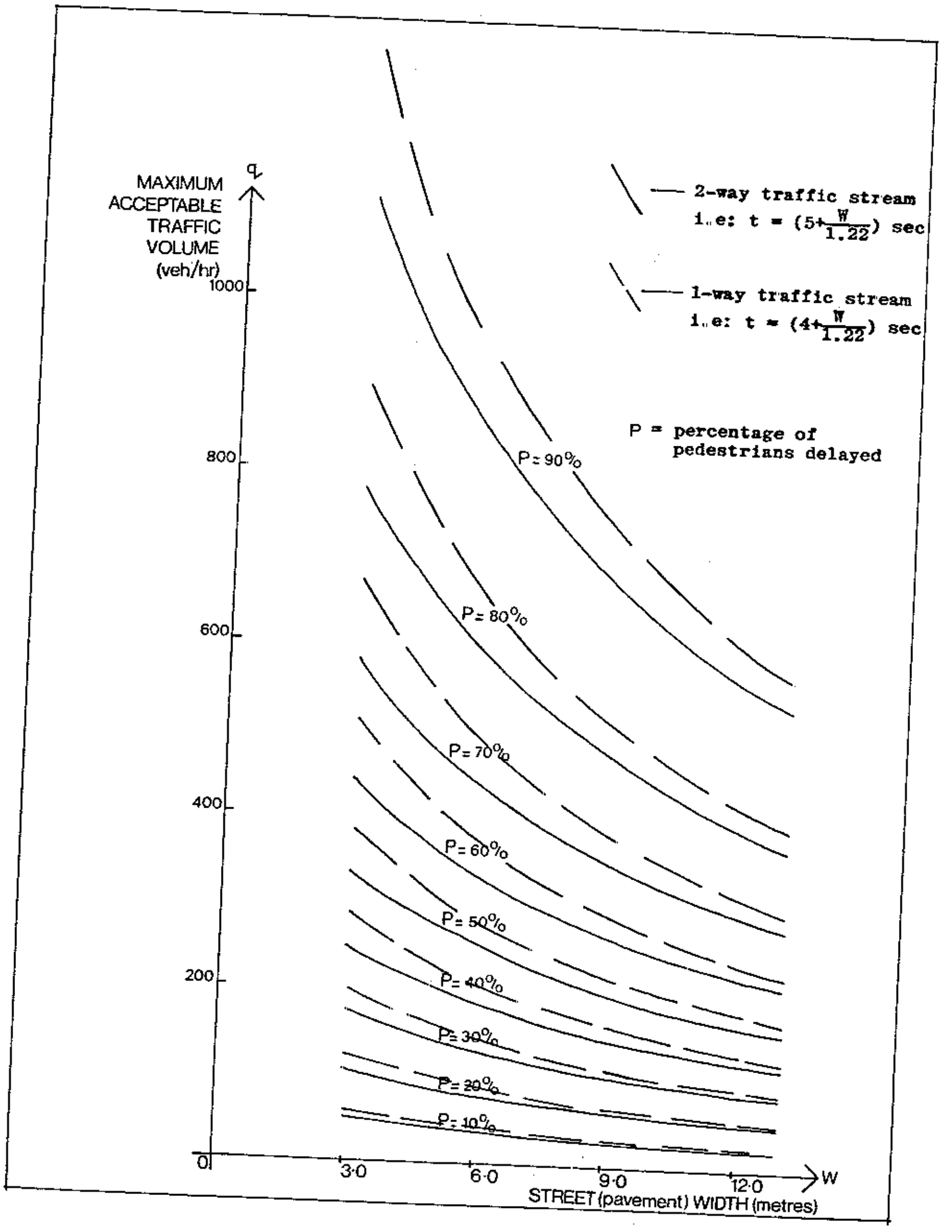

FIGURE 3: RELATIONSHIP BETWEEN MAXIMUM ACCEPTABLE TRAFFIC VOLUME AND STREET WIDTH

Figure 3 depicts a plot of maximum acceptable traffic volume, q, against street width, W, for various values of P, the acceptable proportion of delayed pedestrians and for both 1-way and 2-way flow situations. Table 4 lists the resultant environmental capacities for the various links in the study area, "improved" environmental capacity figures being included where street widths are such that pedestrian refuges may be provided in the middle of the road, thus converting the crossing manoeuvre to that of a street of approximately half the width with a reduced, 1-way traffic flow.

Environmental Capacity of Streets within the North Fitzroy Study Area

Table 5 (a combination of Tables 2 & 4) lists the environmental capacities calculated for the links of the street system within the Study area on the basis of traffic noise and pedestrian delay. In the case of capacities calculated on the noise criterion, the flow conditions assumed are those for the "desirable" situation i.e. 50 km/hr. average running speed and 10% heavy vehicles.

The implications of these results can perhaps be best assessed by consideration of one particular route e.g. Route A, Scotchmer Street/Michael Street. Various conclusions may be drawn from the Environmental Capacity values tabulated for links A1 to A7:

(a) the increased Environmental Capacity (calculated on a pedestrian delay basis) that results when a divided road is being considered, is illustrated by the values produced for links A5 to A7 inclusive. This effect can be reproduced by the installation of pedestrian refuges at locations with high pedestrian activity, as instanced by the "Improved" Environmental Capacity figures calculated for links A1 to A4 inclusive. In both cases, the crossing manoeuvre is converted to one in which a road of approximately half the width and carrying a one-way flow of approximately half the traffic volume must be traversed.

(b) the increased Environmental Capacity (calculated on a traffic noise basis) produced for a divided road is illustrated by the results for links A5 to A7 inclusive. Noise effects are less significant in this case because approximately half of the traffic stream is located at a considerable distance from the abutting building facades. This effect would be reproduced in part for the other links if a median break was introduced on the wider streets.

TABLE 5: ENVIRONMENTAL CAPACITIES OF EACH LINK OF STUDY AREA STREETS

LINK Refer Fig. 2	24-HOUR Noise Controls (50 km/hr. 10%)	PEAK HOUR Noise Controls (50 km/hr. 10%)	PEAK HOUR Pedestrian Delay Controls: Current E.C.	PEAK HOUR Pedestrian Delay Controls: "Improved" E.C.
Scotchmer Street/Michael Street				
A1	4600	210	85	270
A2	4600	210	85	270
A3	4600	210	85	270
A4	4600	210	200	680
A5	6800	300	385	
A6	7400	330	385	
A7	6350	285	265	
Park Street/Rushall Crescent				
B1	5750	260	155	500
B2	5750	260	135	450
B3	5750	260	140	450
B4	5150	230	125	410
B5	4600	210	60	210
Holden Street/Bennett Street				
C1)			230	740
C2)			125	410
C3)	4600	210	85	280
C4)			215	
C5)			215	
Falconer Street				
D1	4600	210	155	
D2	4600	210	85	280

(c) various Environmental Capacity values for the route as a whole may be selected given the introduction of a variety of traffic control measures and ameliorative devices:

- "no change situation" - links A1 to A3 control, pedestrian delay basis, Maximum Environmental Capacity (E.C. max) = 85 veh/hr.
- pedestrian refuges installed at critical points - links A1 to A3 control, traffic noise basis, E.C. max = 210 veh/hr.
- some noise barriers installed at critical points (links A1 to A4 inclusive) - links A3 and A7 control, pedestrian delay basis, E.C. max = 265 veh/hr.

Achievements of the Fitzroy Study

The Fitzroy Study has demonstrated that quantitative assessment techniques may be applied to the determination of acceptable traffic levels for residential streets. The variation in the results for the different links of the street system points to the opportunities available to improve Environmental Capacity levels, a concept that is discussed further below.

The apparent "insensitivity" of the analytical methods, as illustrated by the repetitious nature of the Environmental Capacity values of Table 5, is in fact a reflection of the repetitious nature of street environments. As a result, it can be seen that the time necessary to calculate Environmental Capacity values for all streets in a large area would not be excessive, as a number of "prototype" links may be identified and their Environmental Capacity values calculated. The task is then reduced to one of identifying the appropriate prototype link and noting the resultant Environmental Capacity value.

ENVIRONMENTAL CAPACITY TECHNIQUE IN PRACTICE

Under existing conditions (of traffic flow, vehicle types, land use and building type), the Environmental Capacity of a street can be calculated. This can be a 24-hour figure or a peak hour figure.

This figure may be compared with the actual volume of traffic using the street over 24 hours and during the peak hour. Even if actual traffic volumes are within the calculated Environmental Capacity, it may be that certain aspects of traffic flow are creating an unacceptable impact on the local environment (such as speeding traffic, noisy trucks etc.).

Steps to alleviate this particular impact, if successfully taken, have the effect of increasing the environmental tolerance of that street.

If traffic volumes are in excess of the calculated Environmental Capacity, steps must be taken to either:

(a) increase the ability of the environment to accept that traffic, or

(b) reduce the impact of that traffic on the environment. (This need not necessarily involve reducing actual vehicle volumes, and may in fact enable vehicle volumes to be increased).

For certain fixed conditions (road width, land use, building set-back etc.) there are a set of conditions of traffic flow which allow the number of vehicles travelling along that street to be maximised while keeping their impact on the environment to a minimum.

Such conditions of traffic flow include:

- smoothing out of vehicle speeds to minimise acceleration and braking (and hence noise and fumes) by linking traffic signals and placing signs advising that signals are set for unhindered progression at, say, 50 km/hr.,
- platooning traffic to provide opportunities for pedestrians to cross and other vehicles to enter the traffic stream (again by signal settings),
- banning heavy and/or noisy trucks from the street, possibly during certain hours only (e.g. midnight to 6 am).

Environmental Capacity can also be altered by changing the street cross-section or various elements of the built environment.

Changing the cross-section of the street offers a number of opportunities to increase Environmental Capacity:

- a median strip (or pedestrian refuge) located at points of high pedestrian flows means that pedestrians wishing to cross need only wait for a suitable gap in one traffic stream before they commence the crossing manoeuvre. Pedestrian delays are lessened and safety is increased.
- this median strip should be kept to a safe minimum width, so as not to move the noise source closer to abutting buildings. The Fitzroy Study showed the clear benefit to pedestrian safety and the reduction in pedestrian delays in crossing the road resulting from the installation of medians at appropriate locations,
- the traffic stream should be located as near to the centre of the road (or as far

from building frontages) as possible. Noise attenuation over distance means that the noise level at the property line and/or building frontages will be reduced. Wider nature strips offer the change to install sound deflecting mounds, dense tree and shrub planting, etc.

widening of footpaths in streets with wide pavement widths has the dual advantages of reducing the pavement width (and hence pedestrian delays) and increasing the distance between the traffic stream and building frontages (hence reducing noise levels at the building facade). In this manner, Environmental Capacity of the street is increased with respect to both determining effects.

Noise levels in front gardens of properties and in rooms facing the street or suffering from traffic noise can be reduced by the construction of sound reflecting front fences, installation of double glazing to windows, sealing of gaps under doors, etc. and by dense vegetation in front gardens.

These measures, and other low-cost traffic control techniques (half or full street closures, turn bans, roundabouts, etc.) are those which Municipalities can apply to in an endeavour to protect the amenity of their residential areas. In this context, the Environmental Capacity method of traffic management should not be seen as one which results in increased traffic flows, but rather as a means of determining the point at which environmental overload occurs.

CONCLUSION

It has been possible to assess the existing Environmental Capacity of a range of residential streets for a selected Study Area and to propose measures to increase this Capacity. (Because the results discussed in this Paper were based on the findings of overseas research, it was clear that they are affected to some extent by this research which is not totally applicable to Australian conditions, particularly because of the relatively wide residential streets and generally low traffic volumes which are a characteristic of the Australian residential environment).

Comparison of these results with the actual traffic volumes experienced, enabled identification of those aspects of traffic flow, the street and its environment which could be altered in order to raise the Environmental Capacity of critical sections of each street.

Although the Study concentrated on only a few streets within a residential area, it demonstrated that the Environmental Capacity approach to traffic management can be applied on an area basis. It can in fact be more effective in protecting residential amenity over a network of streets than for an individual street. This is so because, for an area scheme, the available traffic management devices available to Municipalities can be applied with greater effect when part of a co-ordinated programme.

It is also notable that this technique of traffic planning can be applied to arterial routes with high volumes of traffic, and in non-residential situations.

The theory, extended into this area, should then be influential on land use planning (or revision of land uses) where a change of land use can increase the Environmental Capacity of a route and hence its ability to carry traffic.

Maximisation of the Environmental Capacity of arterial routes should be the first step in area traffic management, with control of through traffic in lower-order streets being a subsequent process.

In this regard, the work done and described in this Paper can represent an alternative to the demand based hierarchical approach to inner urban traffic management generally accepted in Australia today.

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