Discussion Paper on Residential Streets

Occasional Paper

This Report summarises and draws together the results of a long and detailed series of investigations into aspects of residential streets, including residential street design, construction and operation, conducted by the former Commonwealth Bureau of Roads.

BUREAU OF TRANSPORT ECONOMICS

DISCUSSION PAPER ON RESIDENTIAL STREETS

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FOREWORD

Over recent years, residential streets have become a source of increasing concern to those interested in the economy, amenity and safety of urban development.

The former Commonwealth Bureau of Roads commenced a major review and analysis of residential street design, construction and operation in mid 1974. This Report brings together the major findings of the project.

The Report is not intended to be a handbook, although the practicing planner or engineer will find much in it that is directly or potentially useful. Rather, it is a discussion and review of the major issues associated with contemporary residential street design, construction and operation. In many instances existing practice is questioned, and new directions are recommended. In several cases, these would involve substantial change to current practice, or alteration to legislation. By publishing this Report, the Bureau of Transport Economics hopes that debate may be stimulated on these issues as a prelude to effecting desirable changes to practice and legislation in this area.

Several consultants were retained to assist the Commonwealth Bureau of Roads in undertaking the research reported herein. John Paterson Urban Systems Pty. Ltd. was engaged as primary consultant for the study. Sub-consultants to that firm were Scott and Furphy Pty. Ltd., for engineering aspects of the work, and Dr. John Helmer of Morris, Burden and Company Pty. Ltd. together with Keys Young and Associates for sociological aspects of the work. Mr. J. Holdsworth and Mr. T. Van Dugteron were retained to undertake case studies, in Middle Park and Hurstville respectively, as part of the overall study.

The Bureau of Transport Economics gratefully acknowledges the assistance provided by Dr. K.W. Ogden of the Department of Civil Engineering at Monash University in finalising this Report.

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GLOSSARY

- "access traffic": traffic, the origin or destination of which is the properties abutting the neighbourhood street.

- "amenity": an attribute of dwellings which accrues to them by virtue of their environmental quality and their location with respect to accessibility (desired trip destinations).

- "environmental areas": residential areas from which through traffic is excluded or discouraged and the size of which is such that access traffic generated within the area does not cause the environmental quality to fall below a predetermined level.

- "environmental capacity": the ability and capacity of the street to accommodate traffic volumes such that the environmental quality is not damaged.

- "environmental quality": the quality of a street, buildings and surroundings in terms of noise, safety, pollution, visual aspects, etc. which make an area pleasant or otherwise, particularly to the people who live there. The factors which make up environmental quality depend on the geometric design of the street, the traffic it carries, the design of houses and their allotments and the provision of public open space.

- "level of traffic service": the actual traffic flow on a street as a proportion of the traffic capacity of the street.

- "street hierarchy": a system of roads and streets in which each street provides almost exclusively for one function - arterial traffic, collector traffic or access traffic.

- "terrain": a general term to cover those geographical features which are not under the control of the planner, including topography, rainfall, vegetation and soil type.

- "through traffic": traffic which is using the streets in an area but is not seeking access to properties abutting the neighbourhood streets.

- "traffic capacity": a measure of the capacity of the street to absorb and carry traffic. It is usually a function of the design speed, number of traffic lanes and the treatment of intersections.

PREFACE

This Report summarises and draws together the results of a long and detailed series of investigations into aspects of residential streets conducted by the former Commonwealth Bureau of Roads.

These studies, and consequently this Report, were carried out within Terms of Reference prescribed by the then Minister for Urban and Regional Development in May 1974. These Terms of Reference covered consideration of:

(i) the layout and standards of residential streets which would be appropriate for alternative subdivisional patterns in new urban areas taking into account social, environmental and economic considerations;

(ii) changes which might be made to the standard of urban residential streets in existing urban areas so as to add to the social, environmental or economic advantages of these streets; and

(iii) pavement and drainage design of residential streets including cost.

The importance of residential streets is obvious when it is considered that some 70% of Australians live in urban areas. Almost all of them are interested to a greater or lesser extent in the street in which they live, since that street is an essential part of their day to day environment. That people are concerned about their residential street environment was demonstrated in a survey of community attitudes to roads and road expenditure conducted as part of the study. This survey showed that 87% of respondents in Sydney and 77% in Melbourne were in favour of "improved" residential streets.

When this concern within urban communities is examined more closely it becomes clear, perhaps not unexpectedly, that the concern is spread over a very large range of issues, for example:

(a) Excessive numbers of vehicles, many of which are large and heavy vehicles, use many of the local streets. This is particularly a problem in the older, well established parts of urban areas.

(b) Noise, vibration, air pollution or other degradation of the environment, whilst related to numbers of vehicles, are of themselves disturbing to many people.

(c) Traffic safety, in all its forms, is a matter of widespread concern. Safety in crossing the local street; safety to children playing on the road or walking to school; vehicular safety at intersections, etc.

(d) Severance of neighbourhoods due to the intrusion of traffic. This becomes obvious when it is just too difficult for pedestrians to cross the street.

(e) Costs in many instances are considered excessive, for example, the cost of providing services and the cost aspect of municipal rates for maintaining streets and open spaces.

(f) Many streets are thought to be unaesthetic. For example, in many areas residents are concerned with the sameness or drabness of their suburbs, or complain of urban sprawl or lack of trees and grass.

This is by no means an all inclusive list, but it is sufficient to illustrate the wide diversity of issues with which people are concerned. The Reports of the case studies conducted as part of the present study review these issues in more depth.

It is useful to note in passing that it is rare in urban areas for people to express dissatisfaction with the road surface, except in a few cases when the comment has been received that a road has been constructed to too high a standard. The issues are generally much broader and involve the road in its physical and social environment. It is quite clear that urban residential streets alone will not always be the solution to many of the aforementioned problems.

This Report distinguishes between residential streets where people live and roads which perform sub-arterial and arterial functions in urban areas, even though a considerable frontage onto this latter group of roads is occupied by dwellings. The residential streets represent about 80% of the total length of roads in urban areas, but only about 26% of the distances vehicles travel in those areas is on residential streets. In addition in 1976/77, Government expenditure on urban local streets (mostly Local Government expenditure - derived from the ratepayers, i.e., the residents in local streets) is estimated to have been $473 million compared with $292 million expended on sub-arterial and arterial roads in urban areas by all three levels of Government.

Circumstances differ from city to city and from suburb to suburb and quite often between areas within a suburb. However, throughout this Report, the existing urban areas have been treated as comprising three parts - the inner areas and the longer established portion of the middle suburbs; the balance of the middle suburbs and the well established parts of the outer suburbs; and the balance of the outer suburbs which have grown rapidly during the last two decades and are still growing. New urban areas include portions of the existing outer urban areas where development is current and also completely new urban developments.

It is considered that persons and groups in the community who are seeking improvements in the environment in which they live should not need to be concerned with the institutional framework which is in some way affected by any change. (As residential streets are both so local and so widespread the institutional framework is complex. It includes individual property owners, developers, builders, Local Governments and State Planning organisations who in turn are backed by by-laws, regulations, codes, standards and specifications). However, this Report, in order to be practical, must take this framework into account. Where necessary, changes to it are also suggested if such changes appear to be needed in order to facilitate desired innovations.

Finally this Report, while being concerned with desirable and possible standards, is concerned with all uses of the public open space provided in street reservations, and the impact of the street on people, for example:

1. social interactions,
2. network design of streets and, to a limited extent, land use,
3. geometric design of streets - road pavement width, nature strips, and footpaths, etc.,
4. informal recreational use of open space,
5. provisions for reticulated services and for service vehicles,
6. movement of motor vehicles, bicycles and pedestrians and hence safety, and
7. parking of vehicles.

These issues are addressed in the body of the Report. Chapter 1 comprises an overview of the functions of residential streets, and the objectives of planning guidelines relating thereto. Chapter 2 is a critical review of existing residential street standards and the reasons for them, in particular the institutional factors giving rise to those standards. In Chapter 3, the results of case studies are used to assess the sociological factors which are important from a planning sense in connection with residential streets.

Chapter 4 is concerned with residential streets in existing urban areas, and particularly how they can be changed to perform better in relation to certain prescribed criteria. Chapter 5 reviews network layout and related factors in relation to new urban areas, while Chapter 6 reviews various design aspects of streets in such areas, such as geometric design standards, relationships with abutting land use, traffic generation and cost of construction and maintenance.

Chapters 7 and 8 are concerned with engineering aspects of residential street and area design; Chapter 7 with drainage and Chapter 8 with pavement design.

Appendices are included on techniques for community participation in local street planning, on drainage, and on pavements.

CHAPTER 1 - FUNCTION OF RESIDENTIAL STREETS

Streets are a dominant feature of residential areas. The street itself, the vehicles and pedestrians using it, and the opportunity for access to other parts of the neighbourhood or to the wider urban complex provided by it, all emphasize the central role of the street in the day to day life of urban residents. When to this is added such considerations as public services and utilities below, above or beside the street reservation and the costs of building and maintaining the street, it can be seen that the social and economic importance of the street is considerable.

Basic to this Report's appraisal of residential streets is a discussion of their function; the uses to which they are put, and the opportunities which they provide. Having established these functions, it is possible to derive a set of performance criteria by which guidelines for residential street planning and design, developed in subsequent chapters, can be assessed. These criteria can also be related directly to particular features of residential streets and areas. These issues are explored in this Chapter.

FUNCTIONS OF RESIDENTIAL STREETS

Streets in existing residential areas serve a number of functions. Some of these are essential to the comfort and convenience of the people who live in the area, while other functions, necessary in a general sense, impinge on the physical and social amenity of a residential area and result in benefit or nuisance to residents in their day-to-day life activites. The various functions performed by these streets are discussed in the following paragraphs.

Vehicle Movement and Access

Virtually every residential lot abuts a street or road in order that access is available to it. Residential streets thus provide road space and facilities for people to use vehicles for private travel to and from their residences for such activities as employment, education, shopping, personal business, social occasions and recreation. Most vehicle travel of this type is undertaken in cars or light vehicles.

Streets also provide for the movement of other types of vehicles such as commercial vehicles transporting and delivering goods, service and repair vehicles such as garbage collection and builders' vehicles, as well as emergency vehicles such as fire engines and ambulances.

Apart from the vehicles which require access to properties along a particular street or in nearby streets, some existing streets also carry traffic which uses the street as a through route to other more distant areas.

Vehicle Parking

Street space has conventionally been considered as a space for which parking and storage is a legitimate right for residents, visitors and others. Although in many residential areas provision is made for vehicle parking and storage off the street in private properties, there are older areas of cities in Australia which do not have such facilities and in these areas the street is the only space available for vehicle parking and storage.

Movement and Access for Pedestrians and Cyclists

In addition to vehicular movements, in almost all of the existing areas in our cities, the residential street is also the only route for pedestrian and cycle traffic. Although most of these types of trips are shorter than the trips made by motor vehicle, they are extremely important to the welfare of residents. They include trips to schools, shops and other local community facilities, especially for children and non-working mothers and those who do not drive.

Service Utilities

Service utilities (especially water, gas, electricity, sewerage and telephone) are usually placed in the street reserve where there are advantages in locating services alongside the carriageway to enable easy access by heavy vehicles. It is usual for the various utilities to be allotted a specific location within the street reserve.

Residential Environment

Residential streets form an integral part of the residential environment in that they have a significant impact on the visual appearance of the area, and affect such environmental factors as noise, air pollution, safety and privacy.

Social Interaction and Recreation

In many existing residential areas, particularly in older inner-city areas, street space may be the only convenient open space in which people can meet to talk and in which children might play.

It is obvious that these functions can be in conflict. For example, traffic on streets can hinder the free access of pedestrians and cyclists. This may in time have an adverse effect on community associations and relationships. Moving traffic can also cause noise disturbance, air pollution, and can adversely affect the safety of residents. Parked vehicles can be unsightly, as can overhead utility cables. Attempts to resolve and reconcile conflicts such as these are at the heart of the urban design art, and strongly relate to the purpose of this Report.

OBJECTIVES RELATING TO STREET FUNCTIONS

The functions discussed above are most important considerations in defining objectives towards which any guidelines for the planning and design of changes to existing residential streets should be aimed. The guidelines derived later in this Report are based on the objectives related to those functions. The functional objectives are outlined below:-

1. Vehicle Movement and Access: Streets should cater for the safe and convenient movement of vehicles which need access to properties in an area but should exclude those vehicles which have no real purpose in a particular area and which adversely affect living conditions in the area.
2. Vehicle Parking: Where off-street facilities are unavailable streets should provide reasonable, convenient and safe parking for residents' and visitors' vehicles.
3. Movement and Access for Pedestrians and Cyclists: Streets should cater for the safe and convenient movement of pedestrians and cyclists.
4. Service Utilities: An important functional objective of a street is to provide for service utilities in a safe, aesthetic and economic manner.

5. Residential Environment: Streets should be an asset to the physical and social environment of the area.

6. Social Interaction and Recreation: Streets should provide safe and pleasant areas for social interaction and, where compatible with other uses, for recreation and play.

PERFORMANCE CRITERIA

The functional objectives outlined in the previous section follow directly from the functions which streets are called upon to perform. However, to assess the extent to which any street or street system satisfies these functional objectives, a set of performance criteria must be developed. For the purposes of formulating guidelines for the planning and design of changes to existing residential streets the following criteria are used.

1. Noise: Traffic noise should be reduced and kept to a level which does not interfere with the comfort and convenience of living and communicating in residential areas.

2. Safety: Streets should be safe for use by pedestrians, cyclists and motorists.

3. Severance: Streets and the traffic using them should not make crossing of the street difficult or dangerous for pedestrians.

4. Air-pollution: Air pollution caused by vehicles using the streets should not exceed recognised safe levels.

5. Accessibility: Streets should provide safe and convenient movement and access to and from desired destinations for pedestrians, cyclists, and motorists which have a purpose in, or reason for being in, the area.

6. Parking: Parking adequate for residents' and visitors' cars should be provided within reasonable distance of dwellings.

7. Public Open Space: All residential areas should have a reasonable provision of local open space including that provided within street reserves.

8. Visual Appearance: Streets should be attractive and complement the natural environment and other parts of the built environment to provide attractive living areas.

9. Social Impact: Four aspects are considered:-

(a) Social Mix: There should be a dispersion or diffusion of residents of different ethnic, cultural, occupational, age or other background characteristics in an area, although some homogeneity within the local street is not detrimental to social impact.

(b) Environmental Quality: While streets and areas will differ from each other in the degree to which they respond to the above mentioned criteria, and some trade-off between them is desirable, this should not be to the detriment of environmental and planning features of the street system and public space. For example the provision for parking should not be so extensive as to impact on visual appearance.

(c) Affiliation and Participation: Residents should have a high sense of belonging to the street and area in which they live, and should have the opportunity to participate to make the environment responsive to their felt needs.

(d) Social Distance: Resident groups may conflict with each other on planning and other issues but there should be no underlying hostility such as ethnic antagonism between groups. Effective social distance between groups should be minimised and be non-discriminatory.

It must be emphasised that these criteria relate to particular functional objectives, and since, as noted above, these objectives are inconsistent and conflicting, so these criteria must be assessed in comparison with each other. Moreover, the criteria listed above relate only to the function of the street or area; there are clearly other criteria related to other street planning and design objectives. Foremost among these is the objective of economy. These issues are addressed in later chapters.

APPLICATION OF PERFORMANCE CRITERIA TO RESIDENTIAL STREET FEATURES

In assessing residential streets and areas, there are a very large number of particular features about which planning and design decisions are to be made. The more significant of these are listed in Table 1.1 and many of these are reviewed in detail in later chapters.

TABLE 1.1 - RELATIONSHIPS BETWEEN PERFORMANCE CRITERIA AND FEATURES OF RESIDENTIAL AREAS AND STREETS

Performance Criteria / Features of Residential Areas and Streets									Social Impact			
	Noise	Safety	Severance	Air Pollution	Accessibility	Parking	Public Open Space	Visual Appearance	Social Mix	Environmental Quality	Social Distance	Affiliation and Participation
Service Utilities		*						*				
Vehicle Type and Traffic Mix	*	*								*		
Traffic Volume	*	*	*	*						*		
Road Surface	*	*						*				
Traffic Speeds	*	*	*	*						*		
Parking						*						
Flow Characteristics	*	*		*								
Street Width	*		*			*	*				*	
Noise Barriers	*									*		
Intersections		*										
Access Control		*									*	
Carriageway Geometrics	*	*	*	*		*		*				
Car Travel					*						*	
Pedestrians and Cyclists					*				*		*	
Public Transport	*				*						*	
Commercial and Service Vehicles					*					*	*	
Emergency Vehicles					*							
Length of Street		*						*	*		*	
Natural Environment							*	*		*		
Built Environment								*		*		*
Childrens Play Areas		*					*					

Since each of these design features is provided to contribute towards one or more of the aforementioned functional objectives, each must be capable of being assessed by reference to the performance criteria outlined earlier. Table 1.1 shows for each of the nine performance criteria those features of the planning and design of the street system which influence and affect performance.

SUMMARY

The functions of residential streets are vehicle movement and access; vehicle parking; movement and access for pedestrians and cyclists; service utilities; residential environment; and social interaction and recreation. These functions enable objectives to be defined towards which any guidelines for the planning and design of residential streets should be aimed. Nine performance criteria - noise, safety, severance, air pollution, accessibility, parking, public open space, visual appearance and social impact - are proposed for indicating achievement of the functional objectives. In addition the features of the design and use of the street system which influence and affect performance are tabulated and related to the performance criteria.

CHAPTER 2 - RESIDENTIAL STREETS: STANDARDS AND INSTITUTIONS

The planning of residential street layouts, and the standard to which these streets are designed, are controlled and influenced by the legal and institutional requirements of local government authorities and state government authorities and departments. Residential streets are criticised for being overdesigned by many people. Streets are said to be too wide, too straight, too long or too thickly paved. The alternative put forward is to design streets to be more in harmony with the residential environment.

In this Chapter, the influence of institutions on the planning and design of residential streets and areas is reviewed. The standards which have been developed for residential streets, and the institutional context of those standards are examined, and some alternatives to the present situation are proposed. In order to provide a context within which this discussion can take place, the first part of the Chapter briefly reviews the history of suburban subdivision practices in Australia, and in particular, the influence in recent years of the motor car.

THE HISTORICAL CONTEXT

The Influence of the Planning Climate

There are striking differences between streets planned and built at different times in Australian cities. This reflects the planning institutions, the technology (especially transport technology) and the public and professional opinions of the times. These factors are all related; changes cannot be made to streets without changing the institutions which control how they are built. However, the institutions alone do not cause streets to be as they are. Both depend partly on the current climate of opinion, and on technology.

Planning controls are not a new phenomenon. Many cities of pre-industrial Europe exercised controls, primarily directed to fire prevention, over the location, design, and construction of buildings. Even so, in 1800 the idea that authorities could and should exercise control over the design and layout of streets was still in its infancy. For example, a succession of early colonial governors tried, without success, to introduce regulations which would impose some restrictions on the ramshackle buildings and street layout in Sydney.

By the 1830's new regulations for streets and subdivisions had been prescribed for new towns in the colony of New South Wales. These rules encouraged wide streets and the gridiron style which are the legacy of the period in many Australian towns. The street patterns in Melbourne and Adelaide, which were laid out around that time, show how these regulations worked in practice. The same thing can be found on a smaller scale in many country towns.

In the 1830's the power of the authorities to influence street design was limited to surveying and drawing up cadastral plans for crown land. This power has influenced the present street pattern in direct ways. The pattern depends largely on whether the area was originally intended for sale to the rich or the poor. In suburbs originally intended for workers' cottages and the like, the streets remain today much as they were originally designed. The grid pattern was favoured at the time for both government and private subdivisions. It was simple and gave high block yield. Less regular street patterns are found when the land was originally sold in large lots, and re-subdivided later.

In the late 19th century legislation was introduced to control private subdivisions because private land was being sub-divided in a chaotic and unco-ordinated fashion. This was the first direct control of privately subdivided streets. Legislation was introduced by all States and it was similar in style. The regulations concerned two general aspects: the widths of streets and the dimensions of individual properties. The legislation was of a very rudimentary kind, and it showed no appreciation of the need for a street hierarchy and so did little to encourage a rational pattern of streets.

However, by the 1950's the demands of the motor car, and changes in public opinion, led to substantial changes in both the patterns of subdivision and the legislation relating to land subdivision.

By the late 1950's there was an almost general adoption of the 'informal' pattern for subdivisional streets (the map of any Australian city shows how sudden and consistent this change was). It became much more common for local Councils to require developers to sell only fully serviced blocks of land. The developer was required to construct streets and drainage, and in some cases to install sewerage and service utilities as well. Before this change local

Councils had to organise the construction of services for new subdivisions, a job they were not well equipped to do at that time. The requirement that the developer construct the services for his land to a high standard altered the 'rules of the game' dramatically. High profits could no longer be made simply by slicing up a parcel of land into the maximum number of blocks. The developer had to consider the economics of providing drainage and sewerage and of building roads. The effects of topography on the costs of providing services had to be considered and the result was usually an 'informal' plan sensitive to terrain features and designed to facilitate drainage.

Informal subdivision street patterns increased with the increasing role of the large builder-developer. Adventurous or different street layouts were constrained by the small scale of subdivision; small rectangular land parcels left little choice for the subdivider. The requirement that lots be serviced before sale tipped the economic balance in favour of the large firm which could achieve economies of scale by servicing large tracts of land. Furthermore, there was economic benefit in increasing the size of developments by assembling different contiguous land-holdings to permit a co-ordinated project. Neighbouring land-holders often combined to develop their properties as a single larger unit.

Thus today, local Councils, either through their by-laws or their power to seal subdivision plans, have considerable powers to ensure that detailed aspects of geometric design are followed. These design aspects include such matters as street width, kerb design, type and depth of pavement material, specifications for curves and radii, as well as a significant influence on the subdivision layout. In general, each Council sets its own standards although they are constrained by State law since all local government powers devolve from those of the States.

The Influence of the Motor Car

On a per capita basis, vehicle ownership has almost quadrupled since the second world war. This has had a revoluntionary effect on the structure of cities. This section examines the influence of increasing vehicle ownership and usage on residential streets.

In most Australian cities, although it was realised quite early that the network of arterial roads (streets intended mainly for through traffic), would become over-loaded in the future, traffic congestion did not become a real problem until motor car ownership increased dramatically in the 1950's and 1960's. Since that time, most new arterial roads in outer urban areas have been constructed to high standards and in many cases residential access to properties abutting arterial roads has been provided for by service roads. In most cases, arterial roads in such areas are generally adequate for the traffic they carry.

In the inner urban areas, congestion is a problem, and planning and transport authorities have sought solutions to it. Unfortunately, by seeing the problem only in terms of providing capacity for through vehicles, the effects of traffic on the residential environment has not been given due attention, at least until recent times. In these older areas, not only has the residential environment suffered from the effects of traffic (often because the grid pattern of streets allowed through vehicles a multitude of routes) but also these problems have been exacerbated by traffic management policies aimed at extracting the maximum capacity from the existing street system.

The need to design residential streets to take account of the motor car is becoming increasingly recognised in both new outer urban developments and in the 'redesign' of established inner areas.

In new developments, the most striking change has been the adoption of residential street networks based on a hierarchical concept. This concept recognises the tributory nature of streets within a residential area, and aims to restrict traffic volumes on residential streets to a level which is consistent with the residential nature of the street. It does this firstly by keeping through traffic out of the street, and secondly by ensuring that the catchment area of any street element is not so large that it will generate an excessive volume of traffic. This move to an 'informal' network of residential streets has been made possible by institutional changes, as described earlier, and also relates to the economics of large scale sub-division.

However, there has been no wide-spread adoption of really radical ideas to cope with the motor vehicle in residential streets. There are a few isolated

'Radburn' style suburbs, the largest of which is probably Charnwood in Canberra. This type of subdivision was initiated in the town of Radburn, New Jersey, U.S.A. in 1929. The essential feature is that all homes have access to a footpath system which caters for walking trips and separates vehicles and pedestrians except at loading and unloading points. The residential streets are in the form of culs-de-sac or loops, and footpaths are grade-separated from vehicle carriageways. The informal sub-division has some of these features, but as practiced, is not a total answer to the problems of motor vehicles in residential areas.

There has been one other innovation in the post-war period which is directly attributable to growth in motor vehicle ownership and use, and that is the use of T-intersections in new residential area design instead of cross or multileg intersections. In part this is associated with the adoption of informal street networks, as described above, but its adoption relates much more strongly to the realisation by planners and traffic engineers that in low volume situations, T-intersections are much safer than any other form of intersection. This too is discussed later in this Report.

In older areas, the problems created by through traffic and the widespread existence of grid street patterns have led to an increasing recognition of the need to 'redesign' the street networks. Although this has not been done on a large scale, there are numerous examples in all large Australian cities, and there is a growing interest in the opportunities available through the use of such schemes.

Summary

To summarise, Australian residential street patterns vary according to the influence of the institutional structure which existed at the time they were set out. At a very early stage the grid pattern was imposed without regard to topography or terrain. This was a reaction against the European experience which had been repeated in the first development in Sydney. Resubdivision of private land in the last half of the 19th century tended to be much less ordered than the Crown subdivisions of the time. Consequently, controls on private subdivisions became general by the end of the century. The next major change occurred in 1950's when institutional changes and a greater awareness of the need to keep through traffic out of residential areas led to the almost universal adoption of informal street patterns for new subdivisions.

Future change in residential street design is unpredictable, but since large scale development permits local authorities to give more attention to individual projects, this is likely to encourage more variety in street and subdivision patterns. Another change is the introduction of legislation permitting cluster housing where some land is held in common. This housing style has economic and other advantages. Cluster housing can lead to fewer streets and greater flexibility in street design. There are also signs that some people are beginning to demand more radical solutions to the problems posed by the motor vehicle.

STANDARDS

Technical Standards and Performance Standards

Many people in the community criticize residential streets as being overdesigned. Where it is valid this criticism implies that the controls and standards relating to residential streets as required by legislation and by the various institutions should be reviewed.

The controls and standards have been introduced or amended over a considerable time but in a general sense the use of standards is justified on one or more of the following grounds:

1. The benefits of consistency: Some standards make life simple. A standard is chosen to which everybody agrees or follows suit. A good example is the keep to the left rule of the road. Very few street standards are justified by this criterion.
2. Effects on other people: If one person's actions affect other people, authorities often have a right and the responsibility to control those actions or the results of those actions in some way. Many street standards purport to be of this type.
3. Provision of a merit good: A merit good is one which society says all people ought to have available to them whether they have expressed a preference for it or not. Some street and housing standards are typical examples. However, there is controversy about what is a merit good, and how much of it the community should invest in or can afford.

4. Consumer Protection and Ethical Considerations: Few purchasers of dwellings are sufficiently well informed to know exactly what they are buying. The value of each dwelling includes a proportion of the street but some things are hidden, such as street pavement construction and drainage pipes. Further, the ambient noise level and quality of sunlighting and ventilation can only be appreciated after living in the street for some time. Because information flows are imperfect, market forces are inadequate to safeguard the public when acquiring a building block or a dwelling. Standards are thus needed for consumer protection and for ethical considerations.

Considerations of an ethical kind underlie a good deal of public health, safety and planning regulations. Society takes a paternalistic stance towards safety and health issues. It is accepted that there is a moral justification for intervening on safety issues because the possible consequences of low safety standards are not usually appreciated by the public until it is too late.

In relation to home life and community value it is sometimes argued that there is a specific relationship between residential environments and values of people reared in them. This kind of thinking played an important part in shaping the regulations which created suburbs early this century. Street width, house setbacks, distances from boundaries and frontage widths are seen as measures to provide a form of housing, private space and character of neighbourhood which will produce a desired kind of person. This kind of underpinning to standards and regulations raises questions as to the validity of the goals which they are designed to support.

There are thus good reasons for the existence of standards and regulations in general. However, the desirability of particular elements of the structure of standards and regulations needs to be questioned. These elements are appraised in the following paragraphs.

<u>Appraisal of Street Standards</u>

Most standards which deal with street design are stated in physical or technical terms rather than in terms of performance. As a result, it is difficult to stipulate what a given standard is intended to achieve.

Standards which govern street design can be classified into two broad groupings. They are:

1. Standards relating to the street in cross-section: This category covers all those standards which govern how wide the street right-of-way between property lines must be; how wide the carriageway must be; the placement of service utilities; and the distance of setbacks of houses from the street boundary.

2. Standards relating to design speed: There are a large number of design parameters which are generally concerned with the curvature, superelevation and sight distance of the carriageway and which are collectively denoted by the maximum speed of travel for which they are appropriate.

There are two reasons why design standards are stated in technical rather than performance terms. Firstly, when they were formulated it was not possible to relate performance to physical and technical criteria. For example, the best way to ensure tolerable ambient levels of noise is to define a standard which states that internal or external noise levels should not exceed a particular level. To be workable, such a standard pre-supposes that there is an accurate measure for noise and that it is possible to predict in advance whether a particular house design or setback distance will comply with the standard. Where performance cannot be related to technical criteria a physical standard has to be used. In this case minimum setbacks would be specified. Secondly, standards need to be legally enforceable. This is usually much simpler with a technical standard than a performance standard.

Technical standards however, do become outdated. A technical standard is likely to be a more severe limitation on consumer choice than a performance standard. It not only stipulates what must be achieved but also how it must be done. In the case of noise abatement, a minimum setback requirement constrains the architect or planner since other methods of keeping down internal noise levels are possible, for instance, use of a single-aspect building design which faces away from the street. Moreover technical standards are unable to cope with changing circumstances. Technical standards by themselves will not determine performance. The performance of a physical design depends on external influences as well as the technical standards. For example, if vehicle noise is reduced in the future a technical standard on setback distance would not enable planners to take advantage of this unless the standard itself was amended.

There is thus a case for defining such standards more rationally and on a performance basis. Residential streets are often over-designed because the institutional structure does not encourage or allow more appropriate streets to be planned and constructued. (There is also a need to revise the methods of paying for these services to reduce the immediate financial impact on buyers and to relate payment more to the long-life nature of these facilities. This matter is discussed further, later in this Chapter.)

For example, instead of having a technical standard specifying the minimum width of a residential street, it is possible to have a performance standard to require that:

1. residential areas be designed so that ambulances, fire trucks and garbage trucks can get close to every property quickly and easily;
2. all properties have acceptable levels of ventilation, light, noise and drainage;
3. adequate provision is made for all underground services; and
4. the subdivided area provides for adequate open space.

However, a major problem with performance standards is that if they were used, more planners and designers, with much greater skills than are generally available for most housing projects, would be required.

In summary, standards are not normally formulated in the best possible way, that is, as performance standards designed to achieve desired levels of performance. There are two historical reasons for the adoption of technical standards. The first was a general ignorance of the relationship between built form and performance. This argument was only partially valid then, and is less so now. Second, it was a widespread belief that, with an improved physical environment, residents would develop pride in their locality with concomitant behavioural improvements. The evidence for this assertion is scanty and the cost of such improved physical environment may be great.

Standards and Consumer Choice

The imposition of minimum standards for street design, residential lots and services constrain the tradeoff that consumers can make between the quality of their residential situation and the amount of money needed to acquire and service it. That is, some standards may impose a cost to the consumer without improving quality in terms which consumers can perceive, or which they would purchase if they had the choice.

For example, standards which require that the carriageway be 7.4 metres wide provide no useful benefit in terms of on-street parking in places where the householders have no demand for it. For easy passing, only a minimum of 5 metres is needed. Of course, consumers may want a wide carriageway for its appearance alone, and this is a legitimate desire in a narrow economic sense, even if many people would not share it. However, at present consumers have very little option in this regard one way or the other.

House setbacks provide another example. Visually they may add prestige to an area, or security, but as noise abatement measures they add little in lightly-trafficked streets. If they are not valued for their appearance, standards of this kind increase the price to the consumer without significantly improving quality.

Standards thus restrict the minimum amount of housing which the consumer may purchase. As far as street standards are concerned, these include controls on minimum frontage; on setbacks and distances from other boundaries; on a minimum street width; on minimum carriageway width; and so on. When developers are required to meet such standards in new sub-divisions the law is in effect forcing land buyers to pay for them through the purchase price of their blocks. If restrictions applied to street and lot dimensions alone the effect may not be too serious, but all kinds of service standards, applying to road construction, kerbs and channels, footpaths, stormwater drainage and sewerage, act in concert. If the cost of a residential block was, say $12,000, one-third of this could be for services, including about $2,000 per block for the overall cost of the road. Actual costs vary between cities, but the cost of services is a high proportion of the purchase price in all locations.

These factors impinge on people in different ways. People with few assets and low incomes must pay for a large block and expensive streets which they may not want. Accordingly, in so far as standards reflect community values, they are misdirected. The increasing popularity and high price of property in inner suburbs such as Hawthorn and Prahran in Melbourne and Paddington in Sydney, shows that not all people want to live in wide-fronted blocks on wide streets, and that many people are prepared to trade-off these factors against the accessibility or other perceived advantages of living in these inner suburbs. Most homes in the inner and older suburbs have narrow frontages but these areas do not suffer from a public health or safety problem because of the narrow frontages.

In summary the imposition of minimum standards for street, carriageway, allotment and services constrain the trade-off which consumers can make between the quality of dwelling and the amount spent to acquire and service it. To a certain extent minimum service standards can be justified for consumer protection or as aids to public health and safety. However, beyond this they force people to spend more on servicing and less on the dwelling than they may want to. Areas of high amenity, with convenient location, pleasant terrain or generous provision of social services, tend also to have a high standard of servicing. There are people who would like to live in such areas if they could purchase a house with a lower quality of servicing, say a narrow street. The generally high quality of servicing in such areas may not actually produce tangible benefits but such people are forced out, or required to spend money on services that they do not really want, in order to obtain a location convenient to transport, schools and other services.

Standards and Social Segregation

The imposition of excessive standards is probably the greatest single contributor to the widespread phenomenon of urban residential segregation. In many municipalities, excessively high standards (such as large lot zoning, brick cladding requirements, dwelling size limitation, etc.) serve to exclude the less wealthy, since only the relatively affluent can afford to enter the market.

Controls on minimum standards are defended in terms of protection of the character of an area. However, there is clearly a trade-off between guaranteeing character (and thus often excluding the less wealthy) and the social goal of having a more integrated community in which equality of opportunity and access prevails.

It is fairly well established that neighbourly behaviour depends substantially on propinquity and social homogeneity. That is, people are much more prone to form social ties with people similar to themselves than with people in disparate circumstances. Thus there would also be social problems if a policy of "integrated communities" was followed too zealously.

A suitable compromise might therefore be to encourage homogeneity at the level of a residential block or street, while ensuring heterogeneity at a neighbourhood level. If such a policy were pursued, concomitant planning and building regulations would be required. For example, for every hectare in which standards in excess of the normal minimum was approved, another hectare nearby would be required to have standards less than the normal minimum - small lots, narrow frontages, smaller minimum house size, etc. The market would then be able to indicate the real extent of preferences for large scale social stratification, as well as for the standard of services provided.

Finally it should be noted that these comments apply mainly to new developments; the opportunity to vary standards, and indeed the relevance of standards as a social segregator, are less where older houses in older areas are concerned.

In summary, excessive standards contribute to urban residential segregation as they place a lower limit on entry costs. However, social segregation, while undesirable for reasons of equity at a neighbourhood level, is advantageous at a street or block level.

INSTITUTIONS

In this final section, some of the institutional factors which contribute to the rigidity and cost of standards are reviewed, and changes suggested. Similarly, some of the institutional factors resisting change and adaptation, particularly in middle and outer suburban areas, are discussed.

The Incentive to Overbuild

The present institutional structure tends to encourage excessively high standards. Typically the developer provides all or most of the services, and the costs are passed on to the initial purchaser of the land or dwelling, leaving the local government authority responsible for the upkeep of streets and drains. (Other authorities are responsible for their own utilities.) Since the local authority through its by-laws can set construction standards there is a clear incentive for it to require overdesign in order to minimise later maintenance costs which have to be met from rates paid by all ratepayers. Two examples serve to illustrate the point.

It is becoming common to demand full underground reticulated drainage for residential land. In areas of reasonably low density and loamy or sandy soil, shallow table drains may be quite adequate and environmentally preferable. However, they are generally frowned upon by local authorities because they require considerable maintenance and they are a source of complaint by some ratepayers. Similarly, it is common practice for municipalities to require road pavements designed for highway conditions, and to prescribe full kerb and channel cross sections in residential streets. These are virtually maintenance-free for many years. In both cases, the institutional situation whereby the responsibilities for construction and for maintenance are separated may well result in a sub-optimal design.

Any move to ensure that local councils were faced with the need to make decisions regarding trade-offs between construction and maintenance costs would therefore be desirable. Moreover, the present situation whereby almost all service costs are included in the price of the land is a powerful deterrent for less-affluent people to enter the housing market. Such people may prefer to pay for their services in the form of Council rates than to have to borrow funds for this purpose in order to be able to purchase the home in the first place. Clearly, Councils would need access to additional funds to enable them to provide services, rather than the developers, and for the residents to pay for the services through their rates rather than through mortgages.

In summary, this institutional change would produce the following advantages:

1. local authorities would have less incentive to over specify services - especially roads;
2. services, by their nature are virtually a risk-free asset and risk-free public sector funds could be used to finance them;

3. the initial cost of home purchase would be reduced thus allowing more people into the housing market;
4. services would be provided prior to occupancy and therefore in the least expensive way (this of course also occurs if the developer is required to provide the services);
5. residents would not be deprived of services they want simply because they could not afford them initially.

Institutions and the Scale of Development

There are clearly economies in large scale development; with piecemeal sub-division of small and separated blocks of land there is little scope for rationalising the layout and design of street or service networks, or for bringing modern construction techniques and equipment to bear. As a result, it has become common for a single developer or a consortium to assemble large blocks of land and to enter into an estate-type development.

It would appear however that there are other advantages in encouraging an even larger scale of development. These advantages relate to designing and locating not only services but also land uses in accordance with a wider sub-regional plan. For example, if whole suburbs are built to a comprehensive plan, such as in Canberra or in Elizabeth S.A., it is possible to build a proper hierarchy of streets and to site the major traffic generators (shops, schools, high density housing, etc.) in places where they are most suited, and cause the least environmental damage. In this way, the street network can be designed to ensure that environmental standards are preserved, a comprehensive system of pedestrian and bicycle paths can be provided at little extra cost, and drainage and other service networks can be optimally located.

Clearly, for this to happen, institutional adaptation would be necessary. The balance between the private and public sector would be altered, with more initiative and creativity required of the former, and more flexibility required of the latter. Similarly, the balance between local and "regional" government (e.g. the regional or metropolitan planning authority) would alter, with the former playing probably a lesser role.

Zoning and Resistance to Change

In the older areas of most Australian cities, land uses are mixed in a fine-grained way. Many local job opportunities are thus available. Similarly the mix and heterogeneity of land use permits relatively straightforward conversion of land use and redevelopment according to social needs and market forces.

However, this is not the case in newer suburbs created since, say, the 1930's. In these areas, planning practice has, to an overwhelming degree, segregated land uses, so that enormous tracts of dormitory suburbs, designed almost exclusively for people in the child-rearing stage of the family cycle, have been built.

As a result of this homogeneity, there are few areas which lend themself readily to early redevelopment with different land use zone boundaries. Broad bands of highly specialised residential areas have been created which are very much non-adaptable to the requirements of changing needs as demographic structures and tastes change over time.

Moreover, town planning practices make anything other than the preservation of the status quo very difficult; appeals are generally upheld on the grounds that residents do not want non-residential activities in their area. As a result, residential areas are able, often successfully, to protect themselves even from the 'intrusion' of activities which would be readily approved on social grounds by most people, such as creches, child-minding centres and clinics. Creation of industrial or commercial work opportunities within residential areas, something highly beneficial for people seeking work close to home, would normally be regarded as so difficult to get through the planning labyrinth as to be not worth trying.

Consequently, there are inbuilt physical and institutional restraints on adaptability, and the introduction of variety. The processes which have led to change in accordance with changing social and physical needs, and which have created the more vital and interesting areas of cities, have been arrested in Australian suburbia.

Summary

It is argued that some institutional changes are necessary to increase local government responsibilities in relation to the initial provision of services in new areas. This would provide councils with the opportunity to develop more rational standards of construction and maintenance of services. It would also assist the new resident if the provision of services was financed through public sector loan monies repaid by the resident through Council rates.

The comprehensive development of large areas provides an opportunity for flexible standards tailored to fit the particular circumstances to be applied.

Finally, institutional inertia is preventing healthy market and social forces from producing change in land use patterns in very large tracts of suburban Australia.

CHAPTER 3 - SOCIAL OBJECTIVES IN RESIDENTIAL STREET PLANNING

The development of the layouts and the standards of residential streets for new areas, and the planning of changes to existing streets, are influenced by a number of commonly held beliefs and theories (and, until recently, not much more than beliefs and theories) as to what people and communities prefer. Many of the beliefs and theories related to social issues, such as levels of social mix and interaction in newly planned areas, or the results of changes to the physical street environments in older residential areas.

Policies and programs relating to both new and existing residential streets can impinge significantly on the social, environmental and economic aspects of urban areas, and it is now a common requirement that major projects, both in the private and public sectors, be subjected to critical review before they are proceeded with. Such reviews are undertaken using economic, engineering, environmental and, more recently, social criteria.

For some time relatively sophisticated methods for assessment have been available to evaluate public expenditure programmes using engineering and economic criteria. Models are now being developed in applied sociology which will be useful to planners in the evaluation of proposals for new or alternative residential street plans, in the same way as such plans are evaluated by the application of engineering and economic criteria.

Sociological research has established that there are a number of factors relevant to the application of such social evaluation techniques. To assess the importance of these factors, and to enable recommendations to be made concerning the planning of residential streets from the viewpoint of the social objectives involved, two surveys were conducted as part of the present study. These case studies were conducted in Middle Park (Melbourne) and Hurstville (Sydney).[1] These two studies examined a wide range of issues related to residential streets, and this chapter includes a brief review of some of the conclusions related to social objectives in residential street planning, i.e. the way in which

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(1) The write-ups of these case studies have not been published by the Bureau as of this time. Those interested in further details of the work should contact the Director of the BTE.

residents of particular areas perceive the various components of public expenditure programs, and the way in which such programs affect social interaction and social amenity.

SOCIAL AMENITY

Many current physical programs, reflecting the conventional wisdom of urban planners, treat improved social amenity as a fundamental goal. The broad policies from which these programs derive may be desirable but often, in the absence of explicit social evaluation techniques, particular programs may not be the most efficient way of achieving the implied objectives.

Social amenity is an ambiguous concept in that it means different things to different people. It may be defined negatively as the absence or reduction in the community of such characteristics as deprivation, isolation, insecurity, anxiety, alienation, inter-group hostility and violence. The extent to which these characteristics are absent in a community depends on the extent to which people are committed to their area; are identified with their community; are satisfied with their living arrangements; interact with other people; and participate in the affairs and decisions of their community. It is reasonable to expect that the policies and programs directed towards urban residential streets, and the planning criteria of urban planners are, inter alia, directed towards the achievement of these objectives.

While violence and vandalism are obvious and physical indicators of the lack of social amenity there are other less conspicuous indicators. Inter-group hostility may be latent and subtle and only expressed as attitudinal reactions rather than in open conflict. Further, even if there is no manifest or even latent hostility, some groups may withdraw from social interaction with other residents following implementation of a planning action, with the consequences being just as damaging to their community amenity as would be the more visible results.

SOCIOLOGICAL RESEARCH

As mentioned previously, research based upon comprehensive sociological theory has established a number of principles which can be applied to a social evaluation of residential street plans. A study of the available literature related to sociological aspects of urban areas revealed the following factors to be central to residents' perceptions of their physical environment:-

1. social class - occupation, education, income and wealth (household goods, car);
2. stage in the life-cycle - age, marital status and children;
3. sex and the division of household labour by sex;
4. ethnic grouping;
5. mobility - residential and social;
6. spatial orientation - divided into internal (private household space) and external (public space);
7. area orientation - patterns of use of and time spent in local areas as against the whole metropolitan area;
8. class dispersion - concentration or diffusion of social similarities;
9. street environment quality - measured in such terms as traffic, safety, parking, congestion, trees and lawns;
10. interaction - neighbouring, friendships and visiting;
11. perceived relative deprivation, i.e., the perception that others are better off;
12. social conflict - measured by perceived social distance and inter-group hostility; and
13. pedestrianisation - perception of the utility of streets for walking, both by themself and by others.

Moreover, sociological research has shown the need to distinguish between people's behaviour (demonstrated by what they do and how they spend their money and time) and their attitudes or preferences (as for example, expressed in opinion surveys). Clearly, in a planning sense, the relevant parameter is the former. The difference between expressed attitudes or preferences and actual behaviour has been observed to vary with social position (class and ethnic background), age, sex, marital status and stage in the life-cycle.

THE CASE STUDIES

The case studies mentioned previously had a number of objectives, but one of them was concerned with determining the way in which people actually behaved in relation to the thirteen factors listed in the previous section. A representative sample of residents in the two case study areas (Middle Park in Melbourne and Hurstville in Sydney) were interviewed; according to the principle enunciated above, the interviews were concerned with people's actual use of time, and their use of private and public open spaces, including streets.

A separate assessment was made of the physical environment in which each respondent lived, including the public spaces nearby. An analysis could therefore be made of the inter-relationships between the factors outlined above, the physical environment, and the way in which residents actually behaved.

The case study areas were selected because they included a range of environmental design and quality, as well as a range of residential living patterns and types of residents. Accordingly, the results can reasonably be extrapolated to other areas, including the planning and design of new residential areas (see Chapters 5 and 6).

It should be noted that, although the studies produced statistically significant results, sociological research of this sort is still in its formative stages. Accordingly, the results are sufficiently conclusive to indicate that some of the implicit and explicit assumptions made in planning and design of residential areas are open to question. The results enable conclusions to be made concerning the appropriateness of public expenditure programs directed towards such plans, from the viewpoint of social amenity objectives.

IMPLICATIONS FOR RESIDENTIAL AREA PLANNING

As a result of the sociological research conducted during the case studies, a number of observations can be made which have clear implications for residential area planning.

Overall, the degree of social homogeneity or heterogeneity was a very strong factor in determining the extent of interaction in an area. Where social class was homogeneous in an area, or part of an area, in terms of socio-economic status and ethnic origin, there were also strong social interaction links within that area or part area. However, where people of similar socio-economic status and ethnic origin were randomly interspersed (social heterogeneity) there was considerably less frequent social interaction. The people in heterogeneous areas also tended to use only the local space within very narrow territorial limits from their homes.

When these interactions were examined in relation to residential environment and streets, it was found that the environmental factors had little independent influence on the degree of social interaction. However, although amongst homogeneous groups there was some tendency for more social interaction to be associated with the more improved physical residential environment and streets, this relationship was too weak to be considered significant.

The results of the study in relation to inter-group conflict were also interesting. For example, in the Middle Park area of South Melburne there is a relatively high proportion of people of Greek origin or descent (the proportion of Greek people in the area rose from practically nil to 17% in the 10 years between 1961 and 1971, a period when both the overall population of the area and the proportion of Australians was falling overall). There tended to be some antagonism and hostility between Australians and non-Australians, the degree of which rose as the ratio of non-Australians to Australians rose. However, at the highest level of concentration of non-Australians an unexpected phenomenon occurred; it was observed that Australian households in areas where non-Australians were relatively concentrated (more than 15% of the population) and those households without non-Australian neighbours at all, exhibited less hostility to non-Australians than did those Australian households in areas where less than 15% of the people were non-Australian scattered throughout residential blocks. Conflict and hostility in all areas was accentuated where Australian householders were older (50 years or more) and were long-term residents of the area. Where Australian and non-Australian households were in similar stages of their life-cycle, as for example where both had young children, there tended to be considerably less conflict than where there were marked differences in the stages of their life-cycles.

These relationships were found to exist whatever the physical environment situation, and they cut across different social classes as well. In areas where conflict and hostility were high, the streets and other public open spaces were often perceived as defining territorial boundaries, and the implications are that changes to these areas might serve merely to exacerbate existing conflicts by removing the buffer zones set up by people to manage or stabilise these conflicts.

A further important consideration was found to be the orientation of people in terms of whether they were oriented internally to their own house space; whether they were oriented to their immediate local public open space; or to the whole metropolitan area for their activities and interests. People's orientations were very much related to their socio-economic and ethnic characteristics and reflected the economic resources they were able to command.

The implications for environmental planning are that where people are highly interally oriented they can be expected to react against efforts to change their external street environments or alternatively to treat those efforts as essentially irrelevant to their concerns. Their priorities for assistance programs would be for home or site improvements or for child-care and home-help rather than for street changes.

Those who are highly oriented to the use of local public open space and streets can be expected to react favourably to street changes, and those who are metropolitan oriented, while reacting favourably to street changes, would be little affected in their life-style and in their use of local space by changes to their local street environments. These people can be expected to enjoy the benefits of increases in their property values which may be expected to occur from public expenditure on residential street improvements.

The behaviour of those people who expressed attitudes favouring improvements to local areas and streets was generally found to be oriented to the wider metropolitan area for their life-style, activities and interests. From their behaviour these people were considered most unlikely to change their life-style and behaviour to one more locally oriented if changes were made to their residential environment - as might have been assumed from their expressed attitudes.

Conversely, those people who responded least in attitude to their local environment were found to be those who were most likely to be in a position to use and to benefit from local residential street areas if they were redesigned. They tended to live in housing and street environments most in need of upgrading in the area and had narrow localised territorial limits for their activities and interests. An exception to this conclusion may be noted in relation to safety of pedestrians; aged residents, and relatively poor immigrant families were found to be concentrated in zones of high traffic volumes with greatest incidence of traffic accidents. Environmental changes to ameliorate the traffic hazards could substantially reduce the experience of anxiety and insecurity of residents in these zones. However, such measures in these cases cannot be expected to increase appreciably the use of street space or to expand the territorial base for social interaction.

CONCLUSIONS

The conclusions of these investigations into the social objectives of residential street and area planning fall conveniently into areas; conclusions regarding the sociological information needed for such planning, and conclusions related to sociological factors in planning changes to existing residential streets and implementing such changes.

The conclusions with respect to information for planning are as follows:-

1. Planning proposals for allocation and distribution of public funds on residential streets should include sociological data to support claims of likely change and distribution of benefits and patterns of use.
2. Surveys of availability and use of people's time and space are the most effective means of predicting preference priorities and the likely pattern of use of residential environments, including streets.
3. Planning procedures which rely on the expressed preferences and attitudes of residents can be misleading in relation to planning and implementation of changes to residential streets.
4. There is considerable evidence that programs of work, derived directly from expression of residents' attitudes to what should be done, might run contrary to underlying priorities, exacerbate social differences and thereby result in aggravation of social disamenity of the particular area. However, attitudinal studies can be valuable and useful particularly for assessing preferences among relatively homogeneous groups of residents; between clearly identifiable alternatives; and also occasionally for identifying new concepts for future research and investigation.

The conclusions with respect to programs for existing residential areas are as follows:-

1. The optimum areas for promoting improved social interaction by physical changes to the environment, including residential streets, are areas where the population is relatively stable and also homogeneous in terms of social class and ethnic origin.

2. At present, certain areas in our cities have relatively high levels of conflict over planning priorities; over rights of access to particular areas; and over the desirability of efforts to improve social contact and social mixing. The people in these areas would react negatively towards physical programs for changing residential streets. These areas are typically those where levels of migration, in and out, are relatively high; where many and wide differences exist in social class and ethnic origin; and where people of similar social position are diffusely spread throughout the areas rather than concentrated. For such areas it must be accepted that changes to residential streets may increase any conflict in the short term but might eventually, over a period of years, stabilise and overcome any initial problems.

3. People in certain parts of our cities are highly oriented to the internal space of their homes and little interested in their streets. Such people tend to be lower working class, relatively poor and live in the more heavily trafficked streets or areas of our cities. However, notwithstanding the prima facie case for improving the streets in these areas, the residents' highest priorities are for improved internal private household space. Any attempt to spend funds on streets in these areas could be expected to be met with antagonism or with indifference, and in the resident's view, funds would be better allocated as a first priority to home or site improvement rather than to street changes in these areas. Only then, perhaps, would changes to street environments be seen as worthwhile in these areas. However, these people value improvements which increase pedestrian safety.

4. Programs for residential street changes and improvements should be integrated with other programs such as area improvements, school support and child care, which residents perceive as inter-related in the planning of their immediate local environments.

CHAPTER 4 - PLANNING OF RESIDENTIAL STREETS IN EXISTING URBAN AREAS

The previous two chapters have reviewed, respectively, the design standards for residential streets, and the social objectives of residential street planning. In this chapter, these two aspects are brought together in the context of planning for existing residential streets in already built-up areas of our cities.

Built up areas have particular problems and constraints which simply do not apply to newly-developing areas. Thus in this chapter, those design features within existing residential areas which can be used by the planner to influence residential amenity are examined. The distributional effects of such changes are also discussed with a view to determining ways in which adverse impacts on particular groups within the community can be minimised. From these considerations, a set of planning principles is developed which can be used by those responsible for planning of residential areas in existing parts of the city. The chapter concludes with a discussion of the need to involve the public in residential area planning and the ways in which such participation can be developed.

DESIGN FEATURES

As discussed in Chapter 2 the street patterns which were established many decades ago in the older parts of Australian cities are, in many cases, not consistent with comtemporary needs. In particular, problems to do with vehicles, pedestrian and cycle access, with through traffic and with safety abound. Moreover, the previous chapter has shown that many of these problems can be overcome without detracting from social objectives of residential area planning, and indeed, many of the social problems which were identified are capable of being tackled systematically and successfully.

These considerations lead directly to the conclusion that there is, in many areas in the inner and middle suburbs, scope for improving the residential and social amenity of streets and residential areas through changes in or improvements to traffic performance.

It is thus necessary to identify the features associated with residential areas which may be influenced through the planning process, and which can be used as a means of improving the residential amenity of those areas. Seven such features are identified:

- street hierarchy and environmental (residential) areas
- bikeways and walkways
- intersections
- public transport
- emergency and service vehicles
- commercial and industrial vehicles
- geometric design

These features are discussed below. In a later section of this chapter, these design features are summarised as a set of principles for use in residential area planning.

Street Hierarchy and Environmental (Residential) Areas

The concept of a street hierarchy is intuitively obvious; streets can be classified according to their function within the total road network, and from this, such parameters as the acceptable level of traffic, the design standard and the necessary traffic control measures can be established. The concept is discussed in detail in the following chapter in the context of the design of road and street networks in new areas, but for the purposes of the present discussion, it is only necessary to note that the hierarchical concept has equal application (though more difficult to implement) to the re-design of existing areas. For the moment it is only necessary to classify streets into two categories - streets carrying through traffic (arterials), and streets carrying only or mainly local traffic (residential streets).

The designation of arterial roads and the designation of environmental, or residential, areas are closely related, since the implementation of a proper street hierarchy would produce environmental areas from which through traffic is excluded or severely restricted. In an area where the present road and street network is not working as a true hierarchy, changes directed towards implementing a hierarchy would reduce traffic volumes on some streets, and increase traffic on those streets which would be acting as the arterials. This raises two main issues - the roads or streets which should be designated as arterials; and the adverse impacts on specific categories of land use activities along the designated arterials.

The question of which streets should be designated as arterial needs to be resolved in the context of two generally conflicting objectives. For obvious reasons, it would be desirable for arterials to be designated so that they cause the least overall harm to residents and road users. However, this must also take account of the equity issues as to which residents and which road users are harmed. For example, changes directed towards reducing overall impacts may result in those impacts being transferred to residents less able to cope with them. Furthermore, impacts on road users need to be considered and balanced in relation to the conflicting requirements of local versus through traffic, i.e. some improvements to the arterial roads may be required when traffic on residential streets is reduced by diversion.

Neglecting all other considerations, through traffic would have its least impact if it were to be directed through areas with insensitive land-uses (for example industrial areas) and along routes which cause least severance to existing residential communities. In most cases, these two principles will indicate the same route because those areas which have the least sensitive land-uses normally act as barriers to, or sever, community interaction links. Examples of such areas are railway lines, industrial areas, special land-uses of non-residential nature (such as airports and sewerage treatment works, but excluding hospitals and schools) and large office blocks (but excluding administrative centres serving the local area such as post offices and social welfare organisations). The considerations pertinent to particular land uses are elaborated below.

Retail areas present special problems because they attract comparatively large numbers of pedestrians and motor vehicles. Historically, many retail areas developed along arterial roads, and these now cause hazardous traffic characteristics. Although evidence indicates that retail areas should not abut arterial roads, they do need to be close to arterials because of the large volumes of traffic they generate.

Traffic noise, although at times appreciable, does not present a significant problem to retail areas. However, changes which result in existing retail areas being on the boundaries of environmental areas, and preferably near, but not hindering, the main entrance to the area should be explored. Desirably they should not be located on both sides of an arterial road even though many shop owners indicate a preference for such a pattern.

Schools present a particular problem in that they attract large numbers of pedestrians and cyclists, as well as an appreciable number of cars which drop off and pick up children. Changes to traffic patterns would normally assist school areas best if they result in schools being near the centre of environmental areas. This would result in reduced walking distances, reduced crossing of arterials by children, and the school would be less affected by traffic noise. However, in most cases, a single environmental area is not large enough to support a school. Thus, a 'gateway' location may be preferable (see Chapter 5).

Arterial roads which skirt public open space and recreation areas normally impinge on few residential properties because development, if any, is normally on only one side of the road. However, such roads may present a barrier to pedestrian access to these areas although solutions in the form of pedestrian crossings and overpasses or underpasses are available.

Where areas are being planned for redevelopment, the street hierarchy should be replanned in concert with the land redevelopment in much the same way as discussed in the next chapter.

Hospitals, like some other institutions, are sensitive to noise. While it is possible to insultate them from noise, capital and operating costs to achieve this are high. Further, hospitals are high generators of traffic and need to be readily accessible for ambulances and emergency cases. Often they may, with advantage, be located near arterial roads.

These comments are general guidelines as to the considerations which might be taken into account in designating an arterial or 'through traffic' street network. Clearly in any particular situation local considerations will be paramount, especially as in most practical cases it will be impossible to satisfy all of the above guidelines simultaneously. In changing the street network so as to designate some streets as arterial, and others as non-arterial (and thus primarily intended for local traffic) some areas are going to have increased amenity and others are going to be disadvantaged.

Any network re-design should thus be based upon the existing arterial road system. These streets will normally form the basis of the 'new' arterial system since the impact of diverted traffic will, in most cases, be least if the existing lines of severence are reinforced, rather than having new ones created. If it is necessary to introduce new arterial roads by diverting traffic onto presently lightly-trafficked streets, these should be selected with care having regard to the guidelines enunciated above. Environmentally sensitive streets or areas should be protected as much as possible, both by diverting any existing through traffic away from them, and by ensuring that extra traffic is not diverted into them.

Once the principle that through traffic should be diverted from residential areas is accepted, the solutions to arterial road problems become focussed on increasing the capacity of the arterial roads, providing additional road space (including, in some cases, new freeways), providing alternative modes of transport, or suppressing the demand for travel by traffic restraint or land use control. These considerations are beyond the scope of this Report.

Bikeways and Walkways

In existing urban residential areas, it will not always be possible to create entirely separate bikeways and walkways. However, it may be possible to make certain provisions which would merit and even encourage the use of bicycles or walk-trips for certain activities, especially those within the local area. Several approaches to this issue are available for application when existing residential streets are being reviewed and replanned.

One approach would be to construct or impute a desire-line of walk-trips and bicycle trips to find where facilities for crossing major streets would be required. A second approach would be to designate a system of bicycle routes at a metropolitan-wide or regional scale by using residential streets. This could not be done by individual local authorities as it requires a metropolitan or regional plan. By using specially designated residential streets, routes through parks and other open space where feasible, and by providing crossing facilities on arterial roads, such systems may cost very little. Such systems would not necessarily create a demand for long trips, say to the Central Business District but would facilitate intermediate range intra-suburban and even some inter-suburban trips. Bikeways can also be provided for purely recreation purpose trips by building them along creek reserves and in parkland areas. However, these types of routes will not always be suitable for non-recreational trips, such as those to school or to work.

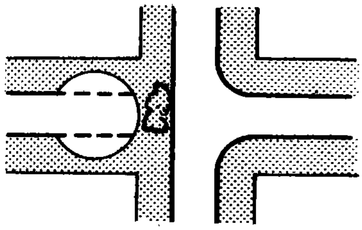
Three additional factors could assist the use and convenience of bicycle travel. Bikeways should, where possible, pass near to public transport routes, schools, and shops. They should be as direct as possible e.g. they could pass through street closures. Finally, secure and convenient bicycle storage facilities at shops and at public transport interchange points should be provided.

Intersections

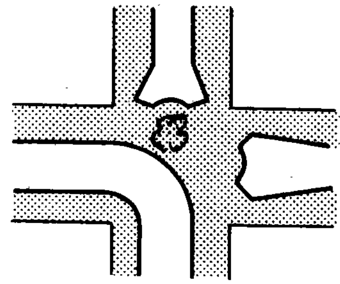
Intersection design and location are of critical importance in the re-design of street networks in existing urban areas, for reasons of both safety and residential amenity.

From a safety viewpoint, it has been shown that, in low-volume streets, two T - intersections are many times safer than a single cross-intersection. Since most residential areas developed before the second world war were laid out on a grid pattern, with numerous cross-intersections, the desirability for re-design of these networks, from a safety view point alone, is obvious. However, in high-volume streets, the accident potential of the two types of intersection is comparable, and since traffic control is more readily provided (e.g. with traffic control signals) at cross-intersections, this type of intersection is preferred at the crossing of two high-volume streets. To a first approximation, high volume streets are synonomous with arterials, and low volume streets are synonomous with residential streets. Thus intersection re-design follows, and is dependent upon, the designation of a street hierarchy, as described above.

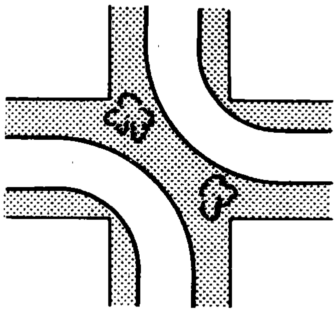
From the viewpoint of residential amenity, intersections are important since intersection modifications are one of the principal tools available to protect residential areas from through traffic.



(a) Close one arm of intersection

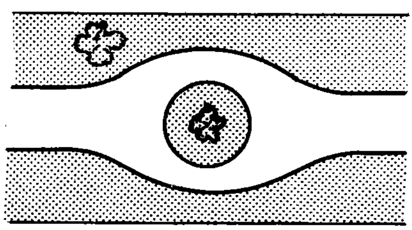


(b) Close two arms of intersection

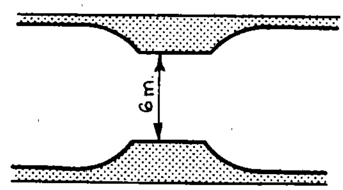


(c) Diagonal closure

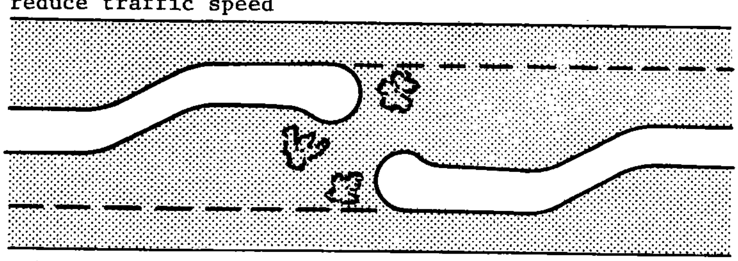
FIGURE 4.1 - STREET CLOSURES



(a) Mid-block roundabout to reduce traffic speed



(b) Mid-block restriction



(c) Mid-block closure

FIGURE 4.2 - MID BLOCK MODIFICATIONS

There are, broadly speaking, three approaches to the re-design of street networks. Firstly is is possible to use street closures (Fig. 4.1). These may be used to exclude or discourage through traffic, to create small open spaces, to reduce traffic speed, to improve the appearance of the locality, or to improve traffic flow on the arterial network.

Secondly, where full closures are not practicable, geometric restrictions at intersections can be introduced (Fig. 4.3). These tend to reduce vehicle speed, deter through traffic and improve conditions for pedestrians and cyclists.

Thirdly, and fourthly, although strictly speaking not intersection re-design, it is possible to use mid-block modifications (Fig. 4.2) or alterations to the street geometry (Fig. 4.4). These also reduce traffic speed, deter or eliminate through traffic, and tend to facilitate pedestrian and cycle movements.

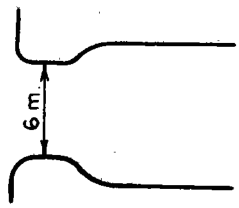
While these measures are available, and are physically easy to implement, careful planning must precede their use. If not sensibly planned, their introduction can have serious effects on access by emergency vehicles (fire, ambulance, police) and can increase costs of servicing properties with garbage collection, bread and milk deliveries, etc. (see below). Moreover, the modifications may have a deleterious effect on the residents themselves, since access by car between dwellings and local facilities or arterial roads may be reduced.

Experiments with some of these network modification procedures were conducted as part of the Middle Park (Melbourne) and Hurstville (Sydney) case studies and the reports on the case studies include more detailed guidelines related to the use of these procedures.

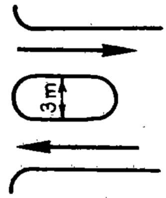
Public Transport

Road based public transport (especially buses) will normally operate along arterials; indeed, one of the considerations which might be taken into account in so designating a street is its suitability for public transport.

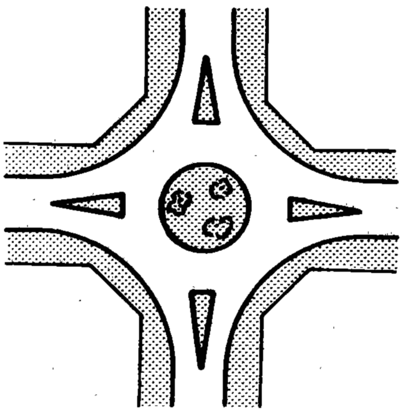
However, public transport should also be considered in network design within the residential areas. Taxis are an important form of public transport, and these together with such local area public transport services as community



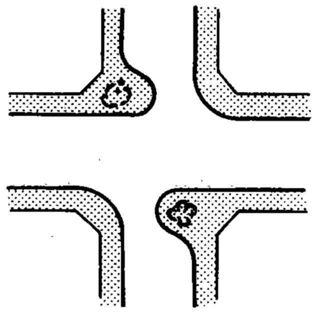
(a) Narrowed entrance



(b) Central island at intersection entrance (or mid-block)

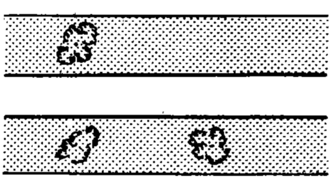


(c) Small rotary intersection

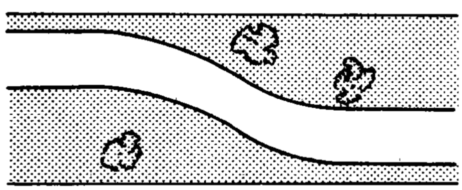


(d) Right turn prohibition left turn only no entry into side street

FIGURE 4.3 - INTERSECTION RESTRICTIONS

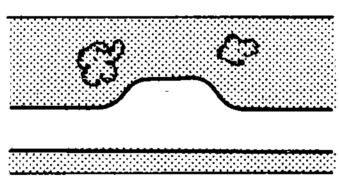


(a) Narrowed carriageway



(b) Curves to reduce traffic speed

(c) Narrowed carriageway moved to one side



(d) One-lane carriageway with passing bay

FIGURE 4.4 - CHANGES TO STREETS

buses, elderly citizens' buses, handicapped persons' buses and, occasionally, school buses, should be provided for in residential areas. If the internal circulation pattern is too circuitous or if adequate standing or turning areas are not provided these vehicles will have difficulty in providing a satisfactory local public transport service.

Emergency and Service Vehicles

Similar comments to those made for public transport vehicles apply in respect to emergency and service vehicles. In re-design of street networks, the needs of these vehicles should be borne in mind, and the authorities which provide emergency and other services should be involved in the planning. These vehicles should not be unduly hampered in their access to properties, and their ability to circulate within the residential area should be preserved; this may be achieved by such means as designing street closures to permit trucks (especially garbage trucks) to drive over or through them.

The cost of providing services may be increased by network modifications. For example, gargage collection costs could increase, and where this is provided on a contract basis, there will be explicit cost increases which can be attributed to the modification. Consideration could be given to charging the residents of the area concerned for those extra costs, as part of the price they must pay for a secluded and quiet neighbourhood.

Commercial and Industrial Vehicles

Because of their noise and physical size, commercial vehicles are one of the principal targets of traffic diversion schemes. Every attempt should be made to ensure that unnecessary commercial vehicle traffic does not penetrate residential areas, but is encouraged to use the arterials.

Two main issues are involved here. Firstly, the layout of the arterial network and the geometric design standards of the streets comprising the network must take careful account of the needs of trucks. Extra travel distances or times forced upon trucks are a direct economic cost, and these should be minimised. Routes which it is intended that trucks use should be as direct as possible for this reason. Similarly, the routes should not be circuitous, because of the physical difficulty of negotiating numerous bends and turns. Arterials should, where possible, avoid geometrically sub-standard streets, where such items as pavement strength, lane width or vertical clearance are inadequate for trucks.

Secondly, although it is desirable to exclude 'unnecessary' through commercial vehicles, many commercial vehicles have a legitimate need to use residential streets, and thus these vehicles cannot be excluded entirely. As well as the emergency and service vehicles discussed above, other trucks with legitimate needs include trucks driven by residents of the area and garaged at home, trucks making deliveries to properties within the residential area, and trucks generated by non-residential (e.g. industrial, retail, warehousing) land uses within or near the residential area concerned. Thus, in re-designing an existing street network, the desirability of keeping through trucks out must be considered alongside the need to provide for the movement of trucks that have a legitimate reason for being in the area.

Apart from the network re-design principles outlined above, which apply to trucks as well as to other vehicles, it is possible to have selective restrictions of truck access to an area. These restrictions can be physical (i.e., a barrier of given height or width to physically prevent the passage of large trucks) or regulatory. The latter, which might take the form of size, mass, or 'no entry except for access', can be effective, but are difficult and costly to enforce.

A final point to be noted is that in planning the re-design of an existing street network, commercial, industrial and trucking interests should be represented and consulted, along with residents and emergency and service authorities.

Geometric Design

Many streets in existing urban areas have been designed and built to an inappropriate standard. Ideally, the design standard should bear some relation to the function of the street in the street hierarchy. If the street network is re-designed in a more hierarchical fashion, it may be necessary or possible to alter the design standard of certain streets; arterials may need to be upgraded, while residential streets can be downgraded.

Upgrading of arterials is beyond the scope of this report, but re-design of residential streets can take several forms. For example, the width of the carriageway might be wider than is appropriate for the new function of a street; surplus width can be used for landscaping or conversion to public open space. Street closures can be used to enhance the aesthetics of an area, and also provide small areas of open space, as discussed above.

The desired vehicle speed will also in many cases be less in a street which is protected from through traffic, and which, after re-design, serves only a local function. Curves in a street itself, introducing discontinuities into the network (i.e. avoidance of long straight streets) and introduction of narrow pavement are all effective in reducing vehicle speeds. Humps and dips in the pavement should be avoided because of the potential safety hazard, and because vehicles often create noise in passing over them.

Summary

In many of the older parts of our cities, there is scope for improving the residential and social amenity of streets and residential areas through changes in, or improvements to, the street network.

A primary aim in any such re-design is to create a hierarchy of streets. Streets should be designated initially as residential (those intended for access only) or arterial (those used principally for through traffic). A considerable array of traffic management techniques is available to the planner for this purpose, although considerable care is needed in the planning of such networks, taking particular account of the needs of public transport, service, emergency, and commercial vehicles.

Within residential areas, and along residential streets, intersections of the cross-type and Y-type should be converted wherever possible to T-intersections. Where this is not practical, signs should be installed. Cross intersections are appropriate on arterials, especially where they are signalised.

The street reserve can sometimes be an almost costless source of conveniently located public open space, i.e., streets can be closed to create small parks, or the carriageways of wide streets narrowed. This is especially valuable for some inner city areas which have wide streets and little public open space.

DISBENEFITS OF STREET SCHEMES

In places where there is no significant problem with through traffic in the residential streets and where in all likelihood the arterial system is not overloaded, measures to create residential areas free of through traffic will not increase traffic flow problems on the existing through routes. However, in other places, and this includes most places where the pressure to implement a street improvement scheme is strongest, the residential street system may be taking significant flows of through traffic, especially during the morning and evening traffic peaks. In such places, any measure to concentrate through traffic flows must cause some residents to be worse off in terms of the amount of traffic they experience and also must increase congestion on arterial roads. It is thus necessary to consider the disbenefits of street schemes as they are experienced by certain groups within the local community, and also by people from other areas who use the streets in the vicinity of a particular street scheme.

Equity and Residential Amenity

In the previous section of this chapter, the concept of a street hierarchy was introduced, and it was suggested that in the re-design of existing street networks, a division between local streets (i.e., those within residential neighbourhoods) and arterials should form the basis of the revised street network.

Although conditions will vary from one street scheme to another, a reasonable goal in such a re-design exercise is to ensure that traffic on residential streets does not exceed 3000 vehicles per day and desirably should be much less, and that through traffic be diverted into arterials carrying in excess of 10,000 vehicles per day. (It might be noted that a typical trip generation rate in Australian cities is 10 vehicle trip ends per household per day - i.e. 5 arrivals and 5 departures, including service and delivery vehicles - so a maximum flow of 3000 vehicles per day implies a catchment area of only 300 residences, and no through traffic whatsoever.) If a multi-level local street hierarchy is adopted, the desirable traffic limit on some streets would be as low as 250-500 vehicles per day.

The theoretical support for these flow values is based on research into traffic noise and severance (as measured by pedestrian delay).

If noise is considered the only criteria, 3000 vehicles per day is regarded as an upper limit for residential streets having 'normal' house setbacks, no special sound insulation for dwellings, and no special street crossing facilities for pedestrians. To achieve reasonable noise amenity in residential streets with traffic higher than 3000 vehicles per day will, in most cases, be very costly and may not even be possible in many existing areas. On the other hand it has been shown that above a traffic flow of about 10,000 vehicles per day the incremental effect on noise of a few thousand extra vehicles is barely detectable. The U.K. Department of the Environment showed in 1972 that the noise level increases by about 2.5 dB(A) - an increase barely detectable by ear - for each doubling in traffic flow above 10,000 vehicles per day.

Pedestrian delay, unlike noise, shows a progressively severe deterioration for unit increases in traffic flow. For example, it has been found that above a traffic flow of around 2,000 to 3,000 vehicles per day, pedestrian delay increases rapidly until a stage is reached when it is almost impossible to cross the road at all. Roads which carry 10,000 vehicles per day or more should be controlled by traffic signals at intersections. This both breaks up the flow to allow pedestrians to cross, and may provide a pedestrian crossing phase at the signals themselves. Further increases in traffic at locations where signals are installed will have little effect on pedestrian delay.

It should thus be possible to make most people in a given local area better off without significantly harming people who already live along existing arterial roads. Where a substantial increase in traffic noise is unavoidable however, some form of compensation may be justified. Cases of this kind will occur typically when an existing arterial route is actually diverted. To justify such a move the benefits would have to be great, though it may be necessary in some cases, e.g., for the creation of a shopping mall in a street which has a high accident record, or to redirect the arterial traffic to a route where the residents affected are only a small fraction of the number affected on the original route. Such cases will be rare, but it is worth considering who should be eligible for compensation, and what form it should take.

Only where such changes result in traffic flows in excess of 3,000 vehicles per day would it generally be worthwhile doing something to offset the effect of increased noise. Ideally, it would be desirable to protect all dwellings which exceed tolerable levels of traffic noise for whatever reason. A satisfactory form of compensating for increased noise levels would be insulating dwellings from noise as, in general, other methods such as noise barriers, will not be workable for dwellings already in place along a street. Double-glazing of front windows can in most cases reduce internal noise to acceptable levels but can be detrimental to ventilation. (There are no known specifically set tolerable standards for traffic noise but 60 to 65dB(A) is suggested as a guide.) If double-glazing is not practical, consideration should be given to whether the traffic should be diverted at all, or, if so, whether it would not be better to acquire the dwellings affected and to redevelop the land.

Equity and the Motorist

Where the arterial road system is congested for all or part of the day, any attempt to divert traffic from residential streets to the existing arterial system is bound to cause a deterioration in the level of traffic service overall. Of course there is a basic conflict of interests here between road users and the residents of the area concerned. The major problem here is probably with motorists travelling to work in central city or inner suburban locations. However, other road user groups, including trucking firms, service and emergency vehicle authorities, cyclists and persons engaged in recreational, social or shopping activities may also be disadvantaged by street schemes. (The effects of such schemes on some of these groups has been discussed earlier in this chapter.)

So far as car-commuting trips are concerned, it is probably true to say that in the larger metropolitan areas at least, the demand for peak hour road space will always exceed the supply. Allowing commuters to use residential streets thus does little to assist the overall road situation for commuters. On the other hand, if commuter traffic is actually forced out of residential areas, attempts should be made to improve the capacity and level of service of arterials. This not only compensates the commuter traffic for any disbenefit, but also helps ensure that people living in the local area can still gain access to the arterials.

While there are obviously limits to the extent to which the capacity of arterials can be increased, most arterial networks in Australian cities can be improved using appropriate traffic engineering techniques such as improved traffic signals, turn bans, clearways, lane markings, etc. The detailed consideration of these aspects is beyond the scope of this report, as are related issues such as public transport use, traffic restraint and the provision of new roads and freeways.

<u>Summary</u>

The planning of street schemes must take into account those groups within the community which stand to lose as a result of the scheme. So far as the local community is concerned, if traffic on residential streets does not exceed 3,000 vehicles per day, little environmental degradation will result. On arterials, once traffic exceeds 10,000 vehicles per day, it is capable of carrying much greater volumes without significant further degradation. Where existing low-volume streets have to be used as arterials, considerations should be given to compensating abutting residents.

Where through traffic is forced out of an existing street network onto a defined system of arterials, those arterials should be improved to cater for the extra traffic both from through vehicles and from locally-generated traffic.

GUIDELINES FOR RESIDENTIAL STREETS

The preceding sections of this chapter have reviewed the design features involved in local streets, the factors which are susceptible to change in modifying existing street networks and the equity implications of such changes.

In Table 4.1, these factors are brought together as a series of principles for planning and implementing street improvement schemes in existing urban areas. For each of the nine performance objectives developed in Chapter 1 (noise, safety, severance, air pollution, accessibility, parking, public open space, visual appearance and social impact), the various planning measures are enumerated, together with the mechanism by which these measures affect the performance objectives, and the actions which may be considered for implementing the planning measures.

TABLE 4.1 - PRINCIPLES FOR PLANNING AND IMPLEMENTING STREET IMPROVEMENT SCHEMES IN EXISTING RESIDENTIAL AREAS

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
1. NOISE Traffic noise should be reduced and kept to a level which does not interfere with the comfort and convenience of living and communicating within residential areas.	1.1 Adoption of a street hierarchy	Control of traffic mix.	1.1.1 Adopt a street hierarchy which designates certain routes as arterials for the use of through traffic (which will include most heavy vehicles).
			1.1.2 Designate arterials, where possible, in places where the prevailing land-use is insensitive to noise (eg. commercial, industrial and 'open' areas).
		Control of traffic volume and speed.	1.1.3 Impose the hierarchy in such a way that the streets which carry the most and the fastest traffic - that is, streets highest in the hierarchy - are those which are best able to tolerate a high level of traffic noise.
		Use of street width (including setbacks).	1.1.4 Designate, where feasible, the widest streets as those which are to serve the highest function in the hierarchy.
		Use of noise barriers and insulation.	1.1.5 Channel high traffic volumes along streets in which the buildings are of solid construction, for instance brick, not weatherboard.
			1.1.6 Channel high traffic volumes along streets in which the traffic noise is shielded by barriers. (These may be non-residential buildings or a railway embankment.)
		Control of traffic volume.	1.1.7 Minimise the total amount of vehicle usage (ie. the number of vehicle-kms) in residential areas.
			1.1.8 Locate arterials and streets which are high in the hierarchy near to land-uses which generate large numbers of vehicle trips (eg. high density housing, large factories, offices, shops, etc.).
			1.1.9 Select arterials and other streets which cater for high volumes of through traffic, as direct as possible consistent with other requirements.
	1.2 Street closures	Control of vehicle type and traffic vol.	1.2.1 Use street closures to exclude through traffic when the street is not required in the network to cater for through traffic.
		Control of flow characteristics.	1.2.2 Employ street closures to smooth traffic flow when traffic is heavy (for instance, by preventing right turns off, and prohibiting right turns on to, arterials).
	1.3 Carriageway geometry	Control of traffic volume and speed.	1.3.1 Adopt a narrow carriageway, a curved alignment or introduce discontinuities in the street network.
		The use of wide street reserves.	1.3.2 Offset the carriageway in a wide street to the side of the street which has the least noise-sensitive land-use.
	1.4 Street operation	Control of traffic mix and volume.	1.4.1 Use signs to exclude heavy vehicles and/or through traffic from residential streets.
		Control of traffic speed.	1.4.2 Impose speed limits where appropriate.
			1.4.3 Use traffic management techniques to smooth traffic flow (without spilling traffic onto once quiet streets).
		Control of traffic flow characteristics.	1.4.4 Prohibit street parking in heavily trafficked streets as far as practicable.
			1.4.5 Confine angle-parking to streets with a very low traffic volume (say 500 vehicles per day or less).
			1.4.6 Provide parking in areas of high demand in separate parking bays linked to the street by (desirably) an intersection designed to full intersection standards.
	1.5 Landscaping	Denoting level of street in hierarchy.	1.5.1 Use hard and soft landscaping and street furniture to denote the function of a street in the hierarchy.
		Noise barriers.	1.5.2 Use hard and soft landscaping to reduce noise where feasible and necessary.

2. SAFETY Residential streets should be safe for pedestrians, cyclists and vehicles.	2.1 Adoption of a street hierarchy	Control of traffic mix.	2.1.1 As for 1.1.1. 2.1.2 Designate arterials where possible in streets where there is little pedestrian activity (eg. in industrial areas, along railway lines, and at the rear of commercial buildings).
		Control of traffic volume and speed. Use of wide street reserves.	2.1.3 Channel large traffic flows through streets in which it is easiest to take measures to protect pedestrians from traffic (eg. wide streets) whenever it is not possible to channel large traffic flows through streets which have little pedestrian activity.
	2.2 Street closures	Control of vehicle type.	2.2.1 As for 1.2.1.
		Control of traffic volume. Control of traffic flow characteristics.	2.2.2 As for 1.2.2.
		Using street closures to alter intersections.	2.2.3 Convert low-volume cross and multileg intersections to T-intersections wherever feasible. 2.2.4 Consider eliminating the intersection by means of street closures where sight lines at an intersection are inadequate. 2.2.5 Employ street closures where possible to provide a safe path for pedestrians and possibly cyclists. 2.2.6 Co-ordinate street-closures in an area-wide plan to permit large scale separation of vehicles and pedestrians, at least along the major pedestrian desire lines.
		Use of street closures as pedestrian and cycle routes.	2.2.7 Close streets at one end to provide 'play streets' where feasible to provide more playing space for children in areas where indicated. These should have traffic signs warning the motorist and a driveway-type crossover at the entrance.
		Use of street closures as children's play spaces.	2.2.8 Provide children's play areas, where feasible, at the point of closure itself.
	2.3 Carriageway geometry	Control of traffic volume and speed.	2.3.1 As for 1.3.1.
		Intersection design and sight lines.	2.3.2 Re-model acute-angled intersections.
		Access control.	2.3.4 Avoid permitting arterials to serve access functions where alternative access can be conveniently provided to abutting properties.
		Children's play areas.	2.3.5 Reduce width of carriageways in very wide streets to provide play space for children in the form of a 'strip park'. However, care must be taken to prevent children in such a park inadvertently running into the street, for instance chasing a ball. Barriers may be required.
	2.4 Street operation	Traffic management, including signs.	2.4.1 As for 1.4.1. 2.4.2 As for 1.4.2. 2.4.3 As for 1.4.3. 2.4.4 As for 1.4.4. 2.4.5 As for 1.4.5.
	2.5 Landscaping	Denoting level of street in hierarchy.	2.5.1 As for 1.5.1.
		Sight lines.	2.5.2 Landscaping objects near the carriageway should not be capable of concealing pedestrians.

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
3. SEVERANCE Streets and the traffic using them should not make difficult or dangerous, the crossing of the street by pedestrians.	3.1 Adoption of a street hierarchy	Control of traffic volume.	3.1.1 Locate arterials, so that, wherever possible, they run between neighbourhoods and not through them. (Typical locations are along railway lines, airfields, creeks if not used as parkland, etc.)
	3.2 Street closures	Control of traffic volume.	3.2.1 Use street closures within neighbourhoods to exclude through traffic.
	3.3 Carriageway geometry	The effect of a narrow carriageway.	3.3.1 Use as narrow a carriageway as is consistent with the demands for traffic and parking.
			3.3.2 Use pedestrian refuges in centres of wide streets (where tram-lines permit).
			3.3.3 Use constrictions in the carriageway width at pedestrian crossing points.
	3.4 Landscaping	Severance as a visual illusion.	3.4.1 Use landscaping to reduce the apparent width of streets where it is thought that they emphasise severance where it is not wanted - that is, within neighbourhoods.
	3.5 Street operation	Crossing facilities.	3.5.1 Provide crossing facilities (grade-separated or at-grade) when traffic volume and pedestrian trips warrant it.
4. AIR POLLUTION Air pollution caused by vehicles using the streets should not exceed recognised safe levels.	4.1 Adoption of a street hierarchy	Control of traffic volume.	4.1.1 As for 1.1.1.
			4.1.2 As for 2.1.2.
			4.1.3 Route heavy traffic flows along streets which are well ventilated whenever possible.
			4.1.4 Keep heavy traffic flows away from residential areas.
5. ACCESSIBILITY Streets should provide convenient and unhindered access to desired destinations for vehicles, pedestrians and cyclists.	5.1 Adoption of a street hierarchy	Division of traffic.	5.1.1 Weigh the environmental advantages to residents of any given route against the advantages to through travellers of locating arterials along the shortest and most direct route.
		Traffic capacity.	5.1.2 Locate arterials in wide streets.
		Trip distance.	5.1.3 As for 1.1.8.
	5.2 Street closures	Division of traffic.	5.2.1 Locate street closures so that they do not cause an intolerable loss in accessibility to residents. (Participative planning must determine what is tolerable in any particular case.)
		Traffic capacity.	5.2.2 Consider the deterioration in level of traffic service which may occur elsewhere, when employing street closures to exclude through traffic from streets.
		Public vehicles and pedestrians.	5.2.3 Design street closures to permit the passage of public vehicles, pedestrians and cyclists.
	5.3 Carriageway geometry	Vehicle movement.	5.3.1 Use the guideline standards in Table 5.1 as desirable minima.
	Vehicle access: (a) emergency vehicles (b) garbage collection (c) private car (d) delivery (e) removals		5.3.2 Provide refuse collection points desirably within 100m of every dwelling.
			5.3.3 Include, at refuse collection points, an additional area of at least $20m^2$ for temporary storage of building materials or garden refuse where direct vehicular access is not available to any allotment or its private area.
			5.3.4 Provide an area suitable for temporary parking of service or delivery or emergency vehicles within 50m of every dwelling and connected thereto by approved footpaths.
		Pedestrian access and movement.	5.3.5 Provide pedestrian access to every property.
			5.3.6 Make all footpaths at least 1.5 metres wide and such as to permit the movement of a wheelchair or pram (eg. no steps). (Refer to recognised code of practice of demensions of paths.)

5. <u>ACCESSIBILITY</u> (Contd.)	5.3 Carriageway geometry (Contd.)	Pedestrian access and movement.	5.3.7 <u>Footpaths need not follow the street</u>; however, when it is likely that pedestrians will use the street reserve (because it is shorter) an approved footpath must be provided. 5.3.8 <u>Separate footpaths need not be provided</u> in some streets with low traffic volumes and speeds.
		Bicycle access and movement.	5.3.9 <u>Provide</u> (as a general guide) a separated bicycle facility where bicycle volumes will be 200 or more per day in conjunction with motor vehicule speeds of 70 km/h or higher.
	5.4 Street operation	Bicycle arterials.	5.4.1 <u>Give consideration</u> in any street scheme to the formulation of a system of bicycle arterials on a metropolitan-wide scale. Such arterials would be designated by special signs.
6. <u>PARKING</u> Parking adequate for residents' and visitors' cars should be provided within reasonable distance of dwellings.	6.1 Street closures	Street closures to create garage courts.	6.1.1 <u>Use</u> street closures to create garage courts where parking is needed.
	6.2 Carriageway geometry	Revision of parking spaces.	6.2.1 <u>Provide</u> every dwelling with a given number of parking spaces whether on or off-street. (The number is to be decided according to local circumstances. It will normally be between 2 and 3 spaces per dwelling.) 6.2.2 <u>Provide</u> parking spaces for each dwelling desirably within 50m of each dwelling. 6.2.3 <u>Provide</u> parking spaces arranged in any way the planner thinks fit provided the above principles are generally observed; however angle-parking is generally to be avoided, especially where traffic volume is high.
	6.3 Street operation	Parking controls.	6.1.1 <u>Consider</u> introducing parking controls to prevent outsiders usurping residents' car parking where this is necessary.
7. <u>PUBLIC OPEN SPACE</u> All residential areas should have a reasonable provision of open space including that provided within street reserves.	7.1 Street closures	Use of street closures to provide public open space.	7.1.1 As for 2.2.7. 7.1.2 As for 2.2.8. 7.1.3 <u>Aim</u> to provide a play space for children within 100m of every dwelling (for a detailed discussion see 'Children in Residential Areas: Guidelines for Designers' (Marcus in <u>Landscape Architecture</u> 1974)).
	7.2 Street geometry	Children's play areas.	7.2.1 As for 2.3.5.
	7.3 Street operation	Play streets.	7.3.1 <u>Use</u> the concept of the 'play street' to provide public open space in the street and yet still permit vehicular access to abutting properties.
8. <u>VISUAL APPEARANCE</u> Streets should be attractive and complement the natural environment and other parts of the built environment to provide attractive living areas.	8.1 Street closures	Tree-planting.	8.1.1 <u>Relieve</u> the visual monotony of long streets by tree planting on verges and street closures.
	8.2 Carriageway geometry	Changes in carriageway geometry may be used to provide visual variety and opportunities for landscaping.	8.2.1 <u>Provide</u> variations in carriageway alignment to relieve otherwise monotonous streets. 8.2.2 <u>Provide</u> space for both hard and soft landscaping by narrowing or offsetting the carriageway.
	8.3 Landscaping and street furniture	Landscaping and street furniture are one of the main ways of making a street attractive to look at.	8.3.1 <u>Use</u> hard and soft landscaping to create an attractive street. (For a further discussion see 'The Design of Streets and Other Spaces' - Area Improvement Note 6, UK Dept. of the Environment 1973).

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
9. SOCIAL IMPACT			
9a. Social Mix There should be a dispersion or diffusion of different ethnic, cultural, occupational, age and other background characteristics.	9a.1 Street design and street hierarchy should avoid reinforcement of social or ethnic backgrounds.	Territorial Boundaries: (between socio-economic and ethnic groups). Chain Settlement: (of immigrant groups). Market Factors: (availability and location of differently priced housing).	9a.1.1 Adopt a street hierarchy to separate heavy traffic volumes from living areas so that traffic, noise, danger, etc. do not in themselves constitute boundaries to pedestrian crossing, children's play and other forms of social mixing. 9a.1.2 Locate public space and recreational facilities on boundary lines dividing social concentrations. 9a.1.3 Locate walkways, public transport stops, etc. in such a way as to maximise the visibility of all types of residents to each other. 9a.1.4 Avoid flat topography and long straight streets as far as practicable so as to create social conclaves for visibility of and contact between residents. Note that environmental planning as such is unlikely to alter the ecology of social differences and that manipulation of boundaries (as in 9a.1.2 above) is limited in its effects on social mixing.
9b. Environmental Quality (Equality of Access Costs) Areas which differ from each other in terms of socio-economic, ethnic or other bakcground characteristics of residents should not also be marked by significant inqualities in the environmental and planning features of the street system and public space, such as traffic volume, safety, parking concentration, availability of services, recreational facilities, etc.	9b.1 Street design to compensate for existing inequalities. 9b.2 Adoption of a street hierarchy. 9b.3 Street closures 9b.4 Carriageway geometry 9b.5 Street operation 9b.6 Landscaping	Class Dispersions: (Residents of lowest income and socio-economic resources tend to live in areas of poorest environmental quality). Effect of Age and Life Cycle.	9b.1.1 Spread and diffuse community services and facilities to take account of social and socio-economic distribution of residents. 9b.2.1 Adopt a street hierarchy which has the effect of setting apart streets carrying the most and fastest traffic, from residential areas. 9b.3.1 Install barriers, cross-overs and other devices to protect from traffic hazards existing lower-class residential areas and areas having high proportions of aged or incapacitated people.
9c. Social Distance Resident groups may conflict with each other on planning and other issues but there should be no underlying hostility between groups such as ethnic antagonism; effective social distance between groups should be minimised and non-discriminatory.	9c.1 Provision of common or spatial access and facilities for use by pedestrians (walkways, promenades, cycle lanes, parks, play-grounds, open air cafes).	Spatial Orientation: Reserach shows that Australians have unusually high levels of confinement to internal household space. Lack of facilities in the immediately adjacent external or public space is one factor causing this.	9c.1.1 Permit the reticulation of commercial facilities, such as laundry, food preparation, entertainment, etc. throughout residential areas and within large apartment complexes. 9c.1.2 Provide special spatial access for old people who cannot walk far and who are the most isolated within private household boundaries. 9c.1.3 Integrate the provision of child-care, play supervision, schooling, public health facilities, etc. with street design to facilitate contact and reduce isolation of people within private household space.

9. SOCIAL IMPACT (Contd.)	9c.2 Re-zoning to reduce isolation effects of existing private property boundaries by up-grading rear lanes, ensuring mix of services.	Familism: Research also shows that spatial isolation within private house-hold space is reinforced by the limitation of social contacts in leisure or free time to members of the immediate household family or to kin.	9c.2.1 Encourage the provision of functions and services currently carried on by the family within its private household space - such as cleaning, cooking and childcare - by commercial public agencies serving the local area.
		Mobility: In areas with large proportions of renters, relatively low property values, and low socio-economic profile, there is both higher social and residential mobility.	9c.2.2 Encourage the development of co-operative residential services carried out on a non-commercial basis such as co-op. food purchasing, commuter car pools, etc; by making available notice boards and marquees, small meeting shelters, accessible distribution points, local area communications, eg. closed circuit television.
		Life Cycle: One factor which cuts across the influence of the above factors is the stage in the life cycle of householders.	9c.2.3 Encourage the design of housing to reduce high fencing and to facilitate greater visibility and contact through house walls and yards to external (public areas).
9d. Affiliation and Participation Residents should have a high sense of belonging to the area in which they live, associated with a satisfactory sense of local autonomy and the power through local participation to make the environ-ment responsive to felt needs.	9d.1 Street design (see 2.1 - 2.6) to integrate local area	Relative Deprivation: Perceived deprivation is associated with both social class differentiation within an area and with a relatively rapid rate of social and residential mobility among householders.	9d.1.1 Encourage formation of local associations and provide suitable facilities. This can be achieved naturally through environmental design which maximises contact and the accessibility of services (see preceeding guidelines under 9a, 9b and 9c).
	9d.2 Decentralisation of decision-making and expenditure powers.	Powerlessness: Lack of effective say in decision-making for local plans and lack of control over how money may be spent in the local area reduce both participation and affiliation.	9d.2.1 Allow local associations to have decisive role in initiation and review of environmental policy. The availability of expenditure powers ensures that participation will not be limited to an advisory or liaison role which, according to research, never achieves strong local support. 9d.2.2 Train local people to conduct their own planning research.

In this context, five broad planning measures are identified as follows:

1. The imposition of a street hierarchy. The planner, by imposing a street hierarchy where none existed before, can keep through traffic out of streets where it is not wanted. When a street hierarchy is imposed on an existing street pattern with existing land-uses, the most crucial issue is the choice of streets to serve as through routes (that is, arterial roads).

2. The use of street closures. This measure may be used as a means of enforcing a street hierarchy. However, it has other uses such as providing open space and better routes for pedestrians.

3. Altering carriageway geometry. Generally the planner is relatively free to alter the carriageway geometry within the street reserve. For example, the carriageway may be narrowed or curves may be introduced into the alignment.

4. Modifying street operation. This covers traffic signs and signals to regulate traffic movement - devices such as pedestrian crossing facilities and physical measures such as channelisation or one-way streets.

5. Use of landscaping. This covers both hard landscaping (that is, the use of hard materials including street furniture), and soft landscaping (that is, trees and other vegetation).

PUBLIC PARTICIPATION

In the earlier parts of this chapter, the need to consult with particular groups within the community, and to involve them in the planning process, was mentioned. Apart from residents, other groups vitally concerned with any re-design of an existing street network include the operators of service and emergency vehicles, and commercial, industrial and trucking interests. It is thus necessary to consider ways in which this consultation and involvement can be included in the planning process.

It is important to note that active public participation is perhaps more easily arranged, and gives a greater immediate benefit to all, in the case of schemes to change existing streets than in any other kind of 'physical' planning. This is so because first, the people involved constitute a fairly small and, above all, geographically cohesive group. They are nearly always concentrated in a definite area and are usually under a single local authority. There is one exception - the commuters who may pass daily through the area in question - but even so, the problem is a lot simpler than the more normal freeway location types of issues which have metropolitan-wide ramifications. Second, everybody in a residential area is affected in one way or another and so it is more likely that general community interest will build up. Third, the issues are not particularly complicated and lie within everyone's range of experience. Generally, people find it much easier to imagine the consequences of a street scheme than, for instance, the ramifications of a major freeway proposal.

Public participation is a useful planning tool since a plan for a street scheme which is presented to people without their involvement is almost bound to meet opposition. In almost all schemes there are inevitably some people who do not benefit, or even those who may be worse off as a result of changes. These groups cannot be expected simply to acquiesce to their fate. In short, public participation in street schemes should be relatively easy, is likely to be effective, and is essential for the schemes to be successful.

In most cases, the local authority (usually the local government authority) is the appropriate body to conduct, control and co-ordinate all aspects of a street network modification scheme, including the planning and public participation aspects. This is because, firstly, local councils are closer to the problems and opportunities which are involved, and secondly, local government has, in most States, wide powers to close residential streets, and to change their design (Table 4.2).

Although the local authority has the main concern for residential streets, several other authorities, including emergency and service authorities, need to be involved. The State Road Authority, in particular, becomes involved when anything is contemplated which might affect arterial roads. The State Road Authority with its wider metropolitan responsibility may, for example, impose quite severe limitations on what can be done.

It might also be noted that, although the local government authority must be in charge of any residential street scheme, the initial impetus may come from any concerned resident groups.

TABLE 4.2 - CURRENT STATUTORY RESPONSIBILITY AND AUTHORITY OF PUBLIC ORGANISATION

Activity	Responsible Body(1)						
	N.S.W.	VIC.	QLD.(2)	S.A.	W.A.	TAS.	A.C.T.
ABILITY TO DETERMINE PAVEMENT WIDTHS WITHOUT REFERRAL (3)	LGA	LGA	LGA(4)	LGA		LGA	CGPA
ABILITY TO PASS BY-LAWS ABOUT TRAFFIC MANAGEMENT	LGA	LGA	LGA(4)	LGA	LGA	LGA	CGAA
ABILITY TO PROHIBIT CERTAIN TYPES OF VEHICLES WITHOUT REFERRAL (3)	LGA SRA	LGA	LGA	LGA		LGA	CGAA
ABILITY TO REGULATE TRAFFIC MOVEMENTS THROUGH AN AREA	LGA			LGA			CGAA
RESPONSIBLE IF ROAD DECLARED PUBLIC, GOVERNMENT, MAIN ETC.	LGA SRA RA	LGA SRA RA	LGA SRA RA	LGA SRA RA	LGA SRA RA	LGA SPA RA	
STAGE AT WHICH SUBDIVISION PLANS ARE PRESENTED FOR APPROVAL	LGA(5) SPA(6)	LGA(5) SPA(6)	LGA(5)	SPA(5)	LGA(5)	LGA(7)	CGPA
RESPONSIBILITY FOR APPROVING SUBDIVISION PLANS	LGA	LGA	LGA	LGA	LGA	LGA	CGPA
RESPONSIBILITY FOR SETTING DESIGN STANDARDS	LGA	LGA SPA(8)	LGA(4)	LGA	LGA SPA(4)	LGA SPA	CGPA
RESPONSIBILITY FOR SETTING CONSTRUCTION STANDARDS	LGA	LGA SPA(8)	LGA(4)	LGA	LGA SPA(4)	LGA	CGPA
RESPONSIBILITY FOR ROAD MANAGEMENT AND CONTROL WITHOUT REFERRAL (3)	LGA	LGA SPA(8)	LGA	LGA	LGA(5) SPA(4)	LGA	CGAA
RESPONSIBILITY FOR ROAD MAINTENANCE WITHOUT REFERRAL (3)	LGA	LGA SPA(8)	LGA	LGA	LGA(9) SPA(4)	LGA	CGAA
ABILITY TO OBTAIN FUNDS FOR CONSTRUCTION OR MAINTENANCE	LGA	LGA	LGA	LGA	LGA(9)	LGA	CGAA
ABILITY TO CLOSE ROADS TEMPORARILY WITHOUT REFERRAL (3)	LGA	LGA SPA(8)	LGA	LGA	LGA	LGA	CGAA
ABILITY TO CLOSE ROADS PERMANENTLY WITHOUT REFERRAL (3)	LGA SPA			LGA	LGA(9)		CGAA

(1) Where no responsibe body is shown authority has not been delegated by the Minister responsible
(2) There is no SPA in Qld.; planning is supervised by the Minister
(3) It is not necessary for the local government authority to refer the proposed project to the relevant State Minister for authority for preliminary approval
(4) Ministerial involvement is possible
(5) Final approval
(6) Initial approval only
(7) Intermediate approval only
(8) With Ministerial approval
(9) If street is private only

CGPA Commonwealth Government Planning Authority
CGAA Commonwealth Government Administrative Authority
LGA Local Government Authority
SPA State Planning Authority
SRA State Road Authority
RA Regional Authority

Having reached a decision to investigate the possibility of re-designing parts of its residential street network, the local government authority must establish an effective means of planning the scheme, including its public participation aspects.

There are a variety of useful techniques for carrying out public participation programs including community forums, advisory panels, co-option, consultation, community development officers, search conferences, and information centres. Brief descriptions of these techniques and the way in which they can be applied are given in Appendix 1.

Given that improvements or changes to residential streets appear to be required a typical program for planning schemes is outlined in Table 4.3. An important aspect of the planning process is that affected parties should not be held in a state of uncertainty for an unduly long period. The entire public participation program outlined in the table should not exceed four months duration, including the time needed to collect and analyse data.

The first stage of the planning process as outlined in Table 4.3 is to set up an advisory committee. This will normally be followed by a search conference. The conduct of conventional surveys before this stage is reached may be a cumbersome and wasteful process since the surveyors will have few guides beyond their own intuitions as to what might be the salient issues and facts. At this stage, although public meetings and exhibitions may be useful, they are also problematical as it is likely they would attract only a few people with firm ideas on the matter and would provide little opportunity for interchange of information and opinion in any depth.

A structured panel exercise, along the lines of a search conference, is well suited to provide some indication as to what are the real local issues and community lore against which solutions might be pursued. In order to perform these functions effectively, this exercise should draw on as diverse and representative a group of local residents and business people as it is possible to assemble. It can help provide a safeguard against the danger of a minority or an a-typical group pushing ahead with plans which are full of unintended or unforeseen implications for others. Drawing on the experience and opinion of a diverse group of locals will also help to establish useful lines of communication within the community and thus make follow up work easier.

TABLE 4.3 - A TYPICAL PROGRAM FOR PLANNING STREET IMPROVEMENT SCHEMES

Stage	
1	Set up Advisory Panel.
2	Conduct Search Conference.
3(a)	Initiate information flow (to and from community as well as appropriate Authorities) and set up information control if Search Conference supports desirability and feasibility of improvements or changes.
3(b)	Set up Information Centre and mount exhibitions to inform the public of the reasons why improvements are considered necessary and of possible solutions (in broad terms) and to obtain public reaction or suggestions.
4(a)	Conduct studies and collect and analyse data.
4(b)	On the basis of guidelines set out in this Report, formulate schemes for improvements or changes.
5(a)	Set up second exhibition (in Information Centre) to inform the public of the scheme(s) likely to be submitted to the local authority for decision and implementation, and to obtain public reactions.
5(b)	Conduct public meeting(s) to supplement exhibition but, more formally, to record objections or to hear proposals for amendments to scheme(s).
6	Report to local authority.
7	Implement the approved scheme(s) on a trial basis to ensure, among other things, the highest possible level of public acceptance consistent with the levels of performance being sought and the most efficient use of public funds.

Stage 4 consists of collecting data about the area and the local people; studying and analysing it; and evolving one or more plans for street improvement schemes against the background of the search conference findings. It will be valuable to organise a second public exhibition (stage 5) and a more formal public meeting after a number of schemes have been formulated to elicit public reaction. The local authority, once satisfied with a particular scheme, implements it, preferably on a trial basis (stage 7). Many street and traffic improvement schemes lend themselves to implementation on an experimental basis, say for a trial period of three to six months. The advantages are obvious - public acceptance or rejection; the avoidance of over-commitment to a scheme which may pose unforeseen difficulties; and a final opportunity for further meetings or surveys to provide guidance for those responsible for deciding on continuation, modification or abandonment of a scheme.

This brief outline of the need for public participation, and the type of program needed to ensure its success, has served to highlight the central role of public participation in planning residential street schemes. The reports of the case studies carried out in Middle Park and Hurstville discuss public participation, as carried out in those areas, in more depth.

Summary

There are a number of street or network design features which can be utilised by the planner to improve the residential amenity of local areas. Care must be taken in such residential areas to minimise adverse impacts, and consideration should be given to compensating groups who are adversely affected. Public participation in local area planning is essential.

CHAPTER 5 - NETWORK DESIGN AND LAND USE IN NEW URBAN AREAS

The previous chapter was concerned with the re-design of existing street networks to improve residential amenity. This chapter and the next focus upon new areas. Network design and land-use planning have significant impacts on traffic flows in residential areas and are hence powerful tools for ensuring the livability and amenity of a residential area. These are discussed in this chapter. The physical dimensions and shape of individual roads to cater for, and control, traffic are discussed in the following chapter.

THE HIERARCHY OF STREETS

The concept of a hierarchy of streets was introduced in Chapter 4 in the context of the re-design of existing street networks. In that chapter streets were considered as either residential or arterial; no further categorization was warranted given the objectives of such re-design. In the design of new areas however, there is greater scope for designing the overall street network to ensure that residential amenity, at least from a traffic intrusion viewpoint, is maximized. An extension of the hierarchical street system discussed earlier can achieve this end.

The value of the street hierarchy principle is best illustrated by examining the properties of two different types of street layout. The first type is the hierarchical or 'tree' type, while the second is a non-hierarchical or 'grid' type in which there is no difference between streets either in their function or in the traffic which they carry (Fig. 5.1).

Dwelling sites in the hierarchical system can experience a wide range of traffic impacts depending on where they are located within the street network. In contrast, under the non-hierarchical system the probability is that all dwelling sites experience similar traffic impact. The total traffic impact (impacts totalled for all sites) is the same for both systems; thus there would seem to be little advantage of one system over the other if all possible sites are used for dwellings.

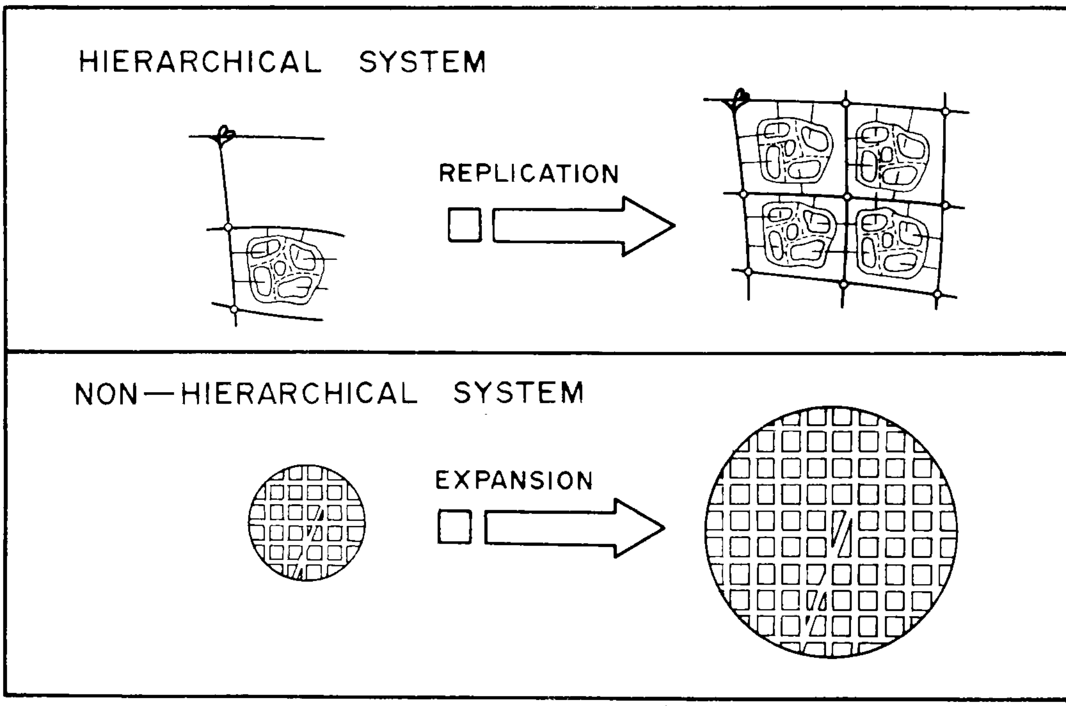


FIGURE 5.1 - THE HIERARCHICAL AND NON-HIERARCHICAL SYSTEMS CONTRASTED

The hierarchical system does however, offer a wider range of consumer choice including the choice that some sites are not selected for dwellings, and hence a more efficient and equitable allocation of resources can be expected. The further advantage of the hierarchical system is that it has the potential to limit the impact of traffic on dwellings as the number of dwellings is increased. Analysis shows that as the number of dwellings is increased, the average traffic impact per dwelling increases in both the simple hierarchical system and the non-hierarchical system. That is, the relationship between the two systems stays the same, in relative terms, and neither gains a relative advantage. However, under the hierarchical system the planner can retain the option of replicating 'trees' rather than merely allowing the single tree to grow, as shown in Fig. 5.1 (i.e., a tree is used at the local level, and a grid at the metropoltian level). With this system, a much lower level of impact can be obtained than with either of the other systems.

In practical terms, advantages can be obtained from the hierarchical system if the following principles are followed.

1. Residential development should be built in units of a limited size. To cope with urban growth the units should be replicated and not expanded. These units are known as 'environmental areas' throughout this Report, and are a key concept for planning residential streets. More is said about their optimum size and design later.

2. Environmental areas should be inviolate to through traffic. This is plainly the case if they have - or can be regarded for all practical purposes as having - a single entrance.

3. Environmental area entrances should be from streets which have no residential frontage and which serve only limited access function for residential purposes. Such streets are referred to in this report as 'arterial roads'.

The superior performance of the policy of replicating environmental areas is largely a result of not using arterial roads for residential frontage and by locating arterials in areas which are insensitive to the impact of traffic, for example, abutting land uses such as factories, offices and shops or capitalising on terrain features.

APPLICATION OF THE HIERARCHICAL CONCEPT TO RESIDENTIAL STREETS

The concept of the hierarchy of streets has implications for both network design and for the geometric design of streets.

Network Design

It is impractical to design residential streets - which occupy the lowest rungs of the hierarchy - without first deciding where the arterials are to be placed. This in turn requires the development of regional traffic and land-use plan before detailed residential planning takes place.

Apart from the advantages of designing different streets for different functions, the co-ordination of land-use planning and street network design can also reduce total travel demands. This can be achieved by placing travel generators (dwellings) as close as possible to trip attractors (community facilities) and to the start of the line-haul portion of the journey to work, thus providing an appropriate hierarchy of streets to cater for the resultant trips. In addition the total overall road cost, including environmental impact cost, is reduced by channelling a given volume of through traffic into concentrated large flows as against keeping the through traffic in dispersed smaller flows.

There are many more accidents at intersections of arterial roads with local streets than at intersections between local streets eventhough there are fewer intersections between the former than between the latter. This results from the failure in the past to plan for a true hierarchy of streets to segregate local traffic from through traffic on arterial roads. It leads to the principle that intersections should only occur between classes of streets which are adjacent in the network hierarchy.

Moreover, all intersections within an environmental area should be T-intersections; these are many times safer than cross intersections where only small traffic flows are present. Cross intersections are acceptable on high-volume streets where traffic can be controlled.

Adoption of the principle that through traffic should be kept out of environmental areas poses the difficult task of designing a street network for a fast, efficient and convenient public transport system. The factors which assist in reducing car travel result in street patterns which do not permit through or fast traffic. Unless the public transport service to a residential area terminates outside the area, the service must enter the area and then double back on its route to continue its journey. The only alternative is for the route to be along the arterials which fringe the area. Although this latter arrangement could still provide adequate service to people who live within walking distance of the arterial road, the level of service, depending on the size and shape of the area, would tend to drop for those who live farthest from the arterial road.

An alternative would be to provide some through route connections for public transport vehicles. However, there would be difficulties in providing such routes in residential areas and prohibiting other through traffic at the same time.

Provided the area was of suitable size and residential density, it could be that developments in para-transit services such as jitneys[1], dial-a-bus, etc. might act appropriately as feeder services to community facilities and to express public transport on the arterial roads.

Geometric Design

Geometric design is discussed in some detail in Chapter 6. However, it is helpful to explain here how the street hierarchy concept should influence the geometric design of streets.

The hierarchical nature of the road and street network facilitates the application of different standards of construction, operation and maintenance on network links with different purposes. A hierarchical functional classification gives an indication of how much traffic and of what type the road or street is carrying. For instance, in urban areas the function of a residential street is to provide access to a number of dwellings (or persons) which it serves. This definition automatically determines the traffic carried, provided the street really does serve its intended function.

(1) Jitney - small bus carrying passengers at very low fare rates.

The classification also tells the planner something about the purpose of the trips of the traffic carried by the street. For instance, an arterial road carries traffic between environmental areas and hence the planner has a rough idea of the length of the trip. A hierarchical functional classification thus gives a good guide to the design speed and level of traffic service which are appropriate to a road or street.

GUIDELINE STANDARDS FOR RESIDENTIAL STREETS AND NETWORKS

Three classes of public street and two classes of semi-private street may be defined to comprise a hierarchical street system within environmental areas. The definition of a classification system for arterial roads, e.g. sub-arterial, major arterial, etc. is outside the scope of this report.

The three classes of public street within environmental areas can be described as follows:

1. The collector street is the highest category of street within the environmental area, and serves to connect arterials outside the area with lower order streets within the area. Residential as well as non-residential development is appropriate (see below).
2. A major local street is an intermediate category of street, and is used to define a street which serves abutting properties, or which serves properties in minor local streets connecting with it.
3. Minor local streets are the lowest category of public street and they serve only properties which abut them. They may be designed as a loop or a cul-de-sac.

TABLE 5.1 - STANDARDS FOR RESIDENTIAL STREETS AND NETWORKS[1]

Residential Street and Category[16]	Maximum Traffic Volume at Entrance to Street (2), (7)	Maximum Length (3),(7)	Design Speed (15)	Carriageway width(5) (6): No Kerb Parking	No Kerb Parking - width on bend	Kerb Parking One Side	Kerb Parking Both Sides	Turning Bays	Verges (14)	Footpaths: Conventional Development (12)	Radburn Type Development (12)	Tributary Streets
1. Collector This is the highest category of residential access street.	3,000 veh./day (or 300 dwellings)	Undefined	60km/h	7.3m	7.3m	9.0m	10.0m	Not applicable	Two (2m wide) (13)	Two (2m wide) (13)	One (1m wide for emergency use only low quality)	Type 1, 2, 3a, 3b, 5
2. Major Local This is an intermediate category of street between collector and minor local streets. Many new developments will not use this category at all.	1,000 veh./day (or 100 dwellings)	500m	40km/h	6.0m	6.5m	8.0m	Not Recommended; Use Group Parking	Not applicable	Not necessary except for services and tree planting	Two (2m wide)	Nil (separate)	Type 2, 3a, 3b, 4, 5
3. Minor Locals[4] Minor locals are the lowest class of public street and the lowest class designed to accomodate service vehicles. 3a Loops	500 veh./day (or 50 dwellings)	300m	20km/h	5.0m (8)	5.5m (8)	7.0m (8)	Not Recommended; Use Group Parking	Not applicable	Not necessary except for services and tree planting	Two (2m wide)	Nil (separate)	Type 3a, 4, 5
3b Cul-de-sac	250veh./day (or 25 dwellings)	150m	15km/h	5.0m	5.5m	7.0m	Not Recommended; Use Group Parking	Provide for service vehicle to turn without reversing - eg. bowl-end with 15m diameter (10)	Not necessary except for services and tree planting	One (2m wide)	Nil (separate)	Type 3b, 4, 5
4. Mews Mews are small courts serving a maximum of 10 dwellings and which are jointly owned by the residents. They are suitable for 'cluster' developments. Fire hydrants are not needed. Access must be over an actual or simulated driveway-type crossover.	100 veh./day (or 10 dwellings)	50m	10km/h	5.0m (or 5.5m between walls)	5.0m (or 5.5m between walls)	Not applicable	Not applicable	Provide for private car to turn with not more than two reverse movements	Not necessary however, combined vehicle/pedestrian area must be 5.5m between walls	Paved width is sufficient for pedestrians to share the carriageway with vehicles		Type 5

5. Driveway These serve a maximum of three dwellings and are privately or jointly owned by residents. Access must be over an actual or simulated driveway-type crossover.	30 veh./day (or 3 dwellings)	Undefined	10km/h	3.0m (9)	3.0m	Not applicable	Not applicable	Driveway need only permit a car to turn where (a) driveway adjoins street Type 1 or 2, (b) where driveway is more than 20m long, (c) where ends are not intervisible.	Not necessary	Not applicable	Type 5

NOTES:

(1) These standards are presented as guidelines for the development of streets and networks in both new and existing residential areas. There may be a need to vary the categorisation and the standards according to local conditions and requirements.

(2) As a planning 'rule-of-thumb' it can be assumed that each dwelling generate a maximum of 10 vehicle trip ends per day (unless there are indications to the contrary).

(3) Length if measured from the intersection of the street in question with the next highest category of street to either (a) the head of furthest minor local cul-de-sac or (b) the centre point of the furthest minor local loop street.

(4) These streets must never be capable of being used as short cuts for through traffic.

(5) Vertical clearnace of 6m (16ft. 4in.) is required over the full width of carriageway plus 0.50m (1ft. 8in) either side. In the event of a crossfall on the carriageway being greater than 2½% the 0.5m (1ft. 8in) dimension will need to be increased to 0.61m (2ft.) on the low side of the carriageway.

(6) Streets on which significant volumes of cyclists are expected (eg. bike routes) can have width increased by 1m for each direction with cyclists.

(7) The category of street is defined by both its length and its traffic volume. If either the length or the number of dwellings or the traffic volume of a particular street are greater than those presented in a particular category, the standards applicable to the next higher category should be used (ie. the lowest maximum figure is controlling).

(8) Streets of this class may be operated as one-way loop roads (but this is not recommended). If so, the carriageway width may be reduced as follows: - no kerb parking - 3m (3.5m on bends; parallel kerb parking on one side - 5m (5.5m on bends).

(9) For a shared driveway, provide 4.5m for the first 6m from street boundary.

(10) Cul-de-sac designs which require reversing movements, though undesirable, may be permitted in areas where land costs are high.

(11) Carraigeway may be reduced to 3.7m for short stretches of not more than 20m where both ends are intervisible.

(12) In 'conventional' layouts, all pedestrian access is wholly or partly from the street. In Radburn type layouts, no pedestrian use of the street is intended and pedestrian access is provided by a separate footpath.

(13) Special pedestrian crossing facilities are warranted on this category of street.

(14) Verges are not necessary for most streets but may be needed as a service easement and for tree planting.

(15) Other than for sight distance.

(16) Categories 4 and 5 cannot be used for bus routes.

In addition to these public streets, the semi-private streets can be defined as follows:

1. Mews are small culs-de-sac serving a maximum of ten dwellings and which are jointly owned by the owners of those dwellings. They are suitable for cluster developments. Access is via a simulated or real driveway type crossover.

2. Driveways are similar to mews, except that the maximum number of dwellings served is three.

Table 5.1 shows, for each of these categories, guideline standards which can be used for residential street or network design. Although primarily applicable to new developments, similar standards may be adopted for use in the re-design of existing street networks (see Chapter 4).

CONNECTIVITY

The foregoing discussion, and Table 5.1, has outlined the elements of a street hierarchy for use in designing environmental areas, but it has not shown how these elements should be combined to make a network.

To do that, it is necessary to introduce the concept of 'connectivity'. The connectivity of a street is a measure of the directness of movement that street and others provide between two points on the street system. If the street, the connectivity of which is being measured, provides part of the shortest route between two points, then its connectivity is one. A similar, perhaps parallel, route with a slightly greater travel distance would have a connectivity just less than one. At the other extreme, a cul-de-sac, because it has no traffic in it apart from traffic with one end in the street, has a connectivity of zero.

To illustrate, the extreme examples referred to earlier - a tree and a grid - may be used. Fig. 5.2 shows that with a tree, there is little or no choice of routes between two points A and B. This system thus has low connectivity, and the street distance between A and B can be very large. However, with a grid system (Fig. 5.3) there are many routes with a travel distance little different from the shortest route, (i.e., many routes with a connectivity approaching the value of 1.0), so traffic would be expected to use a variety of routes between A and B.

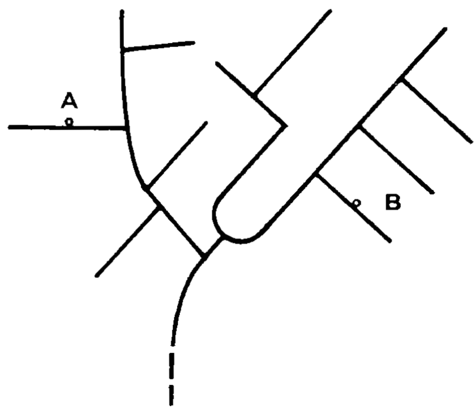


FIGURE 5.2 - THE PROPERTIES OF THE TREE

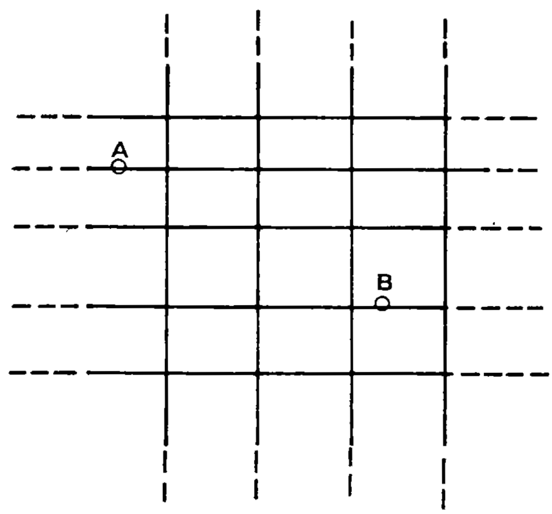


FIGURE 5.3 - THE PROPERTIES OF THE GRID

The use of this concept in design will be obvious. If it is desired to keep through traffic out of an environmental area (or out of a residential street within an area), the connectivity should be significantly less than one. That is, it should be more desirable for through traffic to stay on the preferred route than to use the route or street which is to be protected. Connectivity does not have to be zero however, as even a value as high as 0.67 would imply that 50% extra distance is required to use the protected street rather than the proposed street. This means that the street hierarchy does not have to be of a pure 'tree' form; some connections are acceptable. This will not only permit alternative paths for vehicles, but will also allow the use of loop roads rather than culs-de-sac. Loop roads lead to economies, particularly in delivery and collection services such as garbage collection.

Moreoever, the relaxation of the need to have a pure 'tree' network within the environmental area means that it is possible to have more than one exit or gateway for the area. In this way, larger environmental areas can be provided, so long as all gateways carry a share of the traffic, and the accessibility of the area to activities outside it is increased. Layouts of this kind must be carefully designed to ensure that connectivity is kept at a reasonably low level, particularly at peak hour, where travel times on the arterials are lower, and the desirability of alternative routes increases.

ENVIRONMENTAL AREAS

Environmental areas, a term introduced by Buchanan (1963), describe residential development from which through traffic is excluded. It has been adopted in preference to such terms as neighbourhood, which seems to imply a sociological context, or precinct, which connotes a place that is vehicle-free.

The concept of an environmental area is closely related to that of a street hierarchy, and just as it is possible to develop guidelines for street network design, so guidelines for the design of environmental areas can be introduced. The critical issues relate to size of environmental areas, provision and sitting of community facilities, schools and public open space.

The Size of Environmental Areas

The maximum flow which an access street can carry determines how large environmental areas should be since, if traffic flows interfere unduly with residential amenity, these areas cease to be environmentally desirable. In Chapter 4, it was concluded that traffic flows on residential streets (serving a residential access function) should not exceed 3,000 vehicles per day (v.p.d.). Clearly there is a large subjective element in this figure and in some circumstances much lower flows are desirable and occasionally higher flows can be tolerable. (This is typically the case if living areas are protected from noise, and if pedestrians are either segregated from traffic or provided with road crossing facilities.)

Australian studies have shown that the average number of vehicle trips per household per day is around ten. This figure, together with an upper limit of 3,000 vpd for residential streets, points to a maximum size of environmental area of 300 dwellings. However, that figure is too low for residential area design purposes for three reasons.

Firstly, many of these trips do not leave the environmental area. Residents trips to school, to shops, and for social purposes are often entirely within the environmental area. Moreover, the above trip generation rate of 10 vehicle trip ends per household per day includes delivery and service vehicles, many of which make multiple stops within the area (e.g. garbage collection trucks).

Secondly, in the design of a new area, it is possible to design for a greater than normal incidence of walking and cycle trips. To the extent that this is successful, the vehicle trip generation rate will fall.

Thirdly, as noted in the previous section, it is possible for an environmental area to have more than one gateway without compromising residential amenity. If the traffic entering or leaving an area can be distributed over several gateways, clearly the size of the area can be increased.

The number of dwellings that should comprise an environmental area thus varies with the planner's judgement in relation to the three factors just mentioned (particularly the distribution of traffic among the various gateways) and could vary up to 1000 - 1200 households.

Provision of Community Facilities in Environmental Areas

In a totally car-borne society there might be little to be gained from placing community facilities such as shops, schools, doctors, libraries, churches, etc. within environmental areas. Some fringe areas of Australian cities approach this sort of urban style with most shopping, for instance, being done by car at large regional shopping complexes. However, a totally car-borne existence is not possible for the substantial part of the population who, for one reason or another, cannot or do not choose to drive a car (for example people in one-car families, children, poor families, and some aged people). For all these people it is essential to have at least some community services close at hand.

Clearly it is not possible to provide all community facilities within an environmental area. Either the environmental area is too small to constitute a viable market, or it is so large that it generates more traffic than it can handle. Planners usually strike a compromise in which only those facilities which really are necessary at a local level, and which attract a good many walk trips, are placed within the environmental area. Typically, these include schools - especially primary schools - and some shops and recreation facilities. Other facilities are provided to groupings larger than the environmental area.

It is helpful to view the provision of community facilities as constituting a hierarchy. Various kinds of community facilities are provided at different levels in a hierarchy, the level depending upon the size and scale of economies of the facility in question. For instance a primary school may be planned for every 1,000 households, a corner shop for 300, and a major shopping centre for 5,000. Linked to such a hierarchy of facilities is a hierarchy of roads such that each type of road has the capacity to cater for the traffic generated by the type of centre it serves. A system of this sort is simple and is difficult to fault on logical grounds. There appears to be no clear consensus among planners on what facilities whould be provided at any given hierarchical level.

The Provision of Schools

It used to be accepted that an environmental area (often called a neighbourhood) should be large enough to support one primary school. For a school of about 500 pupils, a range between 1,000 and 2,000 households provides an adequate catchment area. This compares with the maximum size of an environmental area of 1,200 households derived earlier using an acceptable traffic volume criterion. Whether or not traffic issues have influenced the choice of size of primary schools, rather than the other way around, it is certainly true that schools, and primary schools more than any other type of community facility, should be located so that walk trips are easy and safe. Unless each environmental area is provided with its own primary school, some children will have to cross arterial roads on the way to school. Even if crossing facilities are provided, the severance caused by the arterial is likely to lead to a long and circuitous trip.

The experience of Canberra, however has shown that, strong as the above arguments are, environmental areas should not always be designed around the primary school. In recent years it has been found necessary in Canberra to enlarge the size of primary schools so that each school, in some parts, caters for two or three environmental areas.

The conclusion is that, primarily the planner should allow traffic considerations to dictate the size of environmental areas, but should design them in such a way that community facilities can draw people from more than one area, even if many of the trips are on foot or bicycle. Furthermore, design should be sufficiently flexible to cope with unforeseen demands.

Provision of Public Open Space

Public open space can for some purposes be treated as a community facility. Depending upon its size and accessibility it may have only a local catchment area in the vicinity of several streets, or its attributes and convenience may appeal to the whole neighbourhood or even the whole metropolis. Local public open space differs from most other neighbourhood facilities in the following ways:

1. It is often needed for only short periods of time and therefore must be close to people if it is to be useful at all (for instance, if it takes even as long as ten minutes to get to a park, it is unlikely any period less than about one hour would be used effectively for park activity as distances are particularly important for children);
2. Public open space probably induces many trips by people who are neither able nor willing to use cars (for instance, children and those who enjoy exercise);

3. Car access if often harmful to the quietness that parks can offer;

4. Public open space, unlike many other land-uses, can take on any convenient shape the planner wants; and

5. Public open space, unlike shops and most other community facilities, generates little if any noise (unless used for organised sport) and is therefore suitable to be imtimately associated with dwellings (in fact surveillance of public open space from neighbouring dwellings can be very effective in keeping the area safe).

For all the above reasons public open space is best sited at the rear of housing blocks and not adjacent to street frontages. In fact, at the local level, much public open space is best planned as long fingers of land narrow enough to facilitate surveillance and sited, in general, behind housing blocks. A long, relatively narrow shape would increase the boundary length for a given area and would allow a large number of blocks to touch on to the open space directly. A variation of this would be to surround the public open space with hammerhead housing blocks. Such a plan would make it possible to integrate the park system with pedestrian walkways and bikeways (both local and metropolitan-wide), drainage and other service utilities.

Siting of Community Facilities

Community facilities, like streets, form a hierarchy and in this Report the principal interest is in those facilities which may be expected to be found within environmental areas - that is, facilities which require a market size of around 1,000 dwellings. The siting of facilities of a higher order, although important, does not have any immediate impact on the design of residential streets. Experience tends to show that major shopping centres are only viable when they have a market area of about 4,000 dwellings, or about 3 to 5 environmental areas. At the level of the environmental area then, the facilities required are basically schools, some recreational areas and a few local shops.

In choosing how to site these local community facilities, the planner should aim to:

1. minimise walking distances;

2. minimise vehicle travel;

3. place those facilities which, by and large, are insensitive to noise, next to heavily trafficked streets;

4. allow facilities to be used by residents of neighbouring environmental areas; and

5. allow for changes in the types of facility demanded and the catchment area they require - in short, to allow for some flexibility.

Basically there are only two real alternatives in locating community facilities - either they are placed in a generally central location in the environmental area, or they are put at an entrance or 'gateway'. Both have strong and weak points and neither is completely satisfactory but they may be appraised against the five objectives mentioned above.

A central location obviously minimises the length of walk trips for residents of the environmental area.

In Canberra, a policy was originally followed of placing community facilities roughly at the centre of each environmental area thus theoretically minimising vehicle travel required. However, in recent years opinion has favoured location at the gateway to the area. This change in approach is demonstrated well by Figures 5.4 and 5.5. The experience in Canberra with the centrally located shopping centres was that many trips to these centres were made by car on the way to or from work. This resulted in an increase in the amount of vehicle traffic over what is possible with a gateway location, with resultant extra vehicle operating costs and environmental problems.

The hierarchical street network model characterises environmental areas as 'trees', with traffic concentrating towards the exit or, continuing the analogy, towards the 'trunk' of the tree. As the density and volume of traffic increases towards the exit so the environmental quality of the land diminishes. The land around the exit to gateway from the environmental area would have the lowest environmental quality and hence is suited to noise-insensitive (i.e., non-residential) uses and in this way the 'gateway' policy gives a higher overall average environmental quality to residents.

FIGURE 5.4 - COMMUNITY FACILITIES AT GATEWAY TO AREA (CHARNWOOD, CANBERRA)

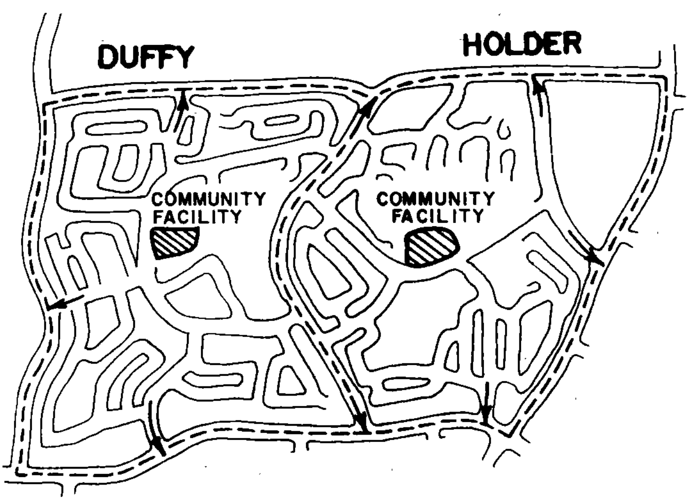


FIGURE 5.5 - COMMUNITY FACILITIES AT CENTRE OF AREA (DUFFY AND HOLDER, CANBERRA)

It is inevitable that some facilities should have a catchment area greater than a single environmental area. This suggests a policy of siting at least some facilities at the edge of the environmental area they are in. Residents from a neighbouring area still have to cross the arterial which separates them, but, provided road crossing facilities exist, the facilities are more or less equally accessible from both sides.

There are two aspects to flexible planning in the provision of facilities. Firstly, community facilities should be built in places which allow a variety of catchment sizes. Figure 5.6 shows how this might be done so that a certain facility may serve either a single area or four areas. It is essential of course that convenient and direct crossing facilites be provided for pedestrians and cyclists. Basically this means that areas for community facilities should be set aside which are at the edge of environmental area.

The second aspect of flexibility demands that there should be space available for more facilities if they are needed. One possibility is to leave space around community facilities for future expansion - but the cost is high. Such land, while open to more noise, has a premium value because of its good location. Also - and this has been found in Canberra - unused land tends to be regarded as public open space and any attempt to build on it meets with opposition. Perhaps a better solution is to build at least some structures of a fairly universal nature which could be demolished, dismantled, or converted to a new use, if and when a need arises.

It is clear from the foregoing discussion that, with the exception of the objective of minimising walking distances, all objectives are better achieved by gateway locations of community facilities. The exception is not to be overlooked however, particularly when it is realised that walking distances are important in the case of primary school locations. Thus a useful compromise, which was in fact adopted in the case of the Canberra suburb of Charnwood (Fig. 5.5), is to place the primary school in a central location, but to locate shops and other community buildings at the gateway. The logic behind this is that primary school trips tend to be by bicycle or on foot, more so than shopping trips, and so a central location for the school is important. Furthermore, the separation of the school from the heavy traffic around the shopping areas has obvious advantages and schools could be expected to have

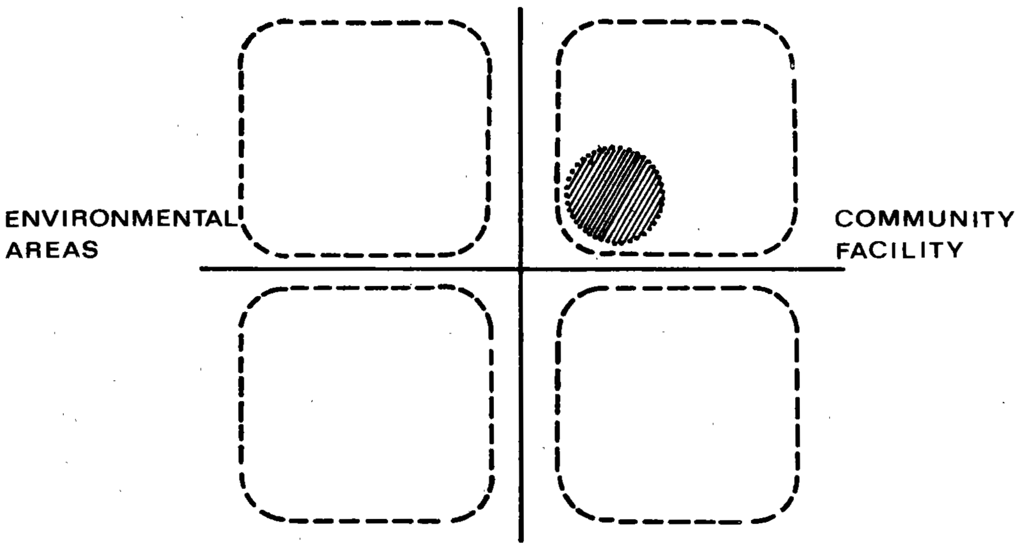


FIGURE 5.6 - COMMUNITY FACILITY SERVING ONE OR MORE AREAS

sporting and meeting facilities which could be used by all residents in the environmental area. Shopping, on the other hand, if often combined with car trips outside the area, and thus is best placed at a gateway location.

SUMMARY

The preceding discussion on the design of street networks and land use in new urban areas can be summarised by the following points:-

1. Residential development in new areas should be on the basis of environmental areas in which the number of dwellings is strictly limited;
2. Increases in dwelling numbers should be provided by replication of environmental areas not by their growth;
3. A hierarchy of streets is essential to environmental areas which should contain no arterial roads;
4. Traffic in residential streets should be less than 3,000 vehicles per day;
5. Connectivity of residential streets should be sufficiently low to discourage through traffic but not so low as to significantly increase travel distances within the areas;
6. Community facilities, as well as streets, form a hierarchy and should be located to make walk trips safe and to minimise walking distance and vehicle travel;
7. Where community facilities are insensitive to noise and where their market size is larger than one environmental area they may best be located at gateways to environmental areas; and
8. Special attention should be given to the location of primary schools within an environmental area.

CHAPTER 6 - DESIGN OF RESIDENTIAL STREETS IN NEW URBAN AREAS

In the previous chapter, various aspects of residential area planning at the network level were discussed. These included considerations related to the design of the network itself and to the land uses within residential areas. In this chapter, attention is given to the design of particular streets within the network.

Five planning measures are relevant to the design of a residential street within a network. These include the street cross-section, design speed, residential density, traffic architecture, and allotment design. Each of these measures are to some extent, under the planner's control, and each has a direct bearing on the geometric design of streets. The way in which each of these factors affect residential street design is discussed. A series of guidelines are presented showing how these five factors plus network design and land use planning factors can be used to achieve the performance objectives outlined in Chapter 1.

THE STREET CROSS-SECTION

For legal purposes, a street is defined as the width of right of way between property lines. However, from a visual point of view, the street may be considered as extending to the building lines on either side of the street (Fig. 6.1).

Figure 6.1 shows that the street is composed of a number of separate elements. The design of each of these elements is affected by both the function which the street will be expected to perform, and by consideration of amenity.

In function, the street is expected to provide for vehicular traffic, vehicle parking, vehicle turning and property access, pedestrian and bicycle traffic, and carriage of services utilities both above and below ground. Amenity may be considered in terms of privacy and freedom from excessive noise and good visual appearance.

The influence of each of these factors on the geometric design of street cross-sectional elements is outlined below.

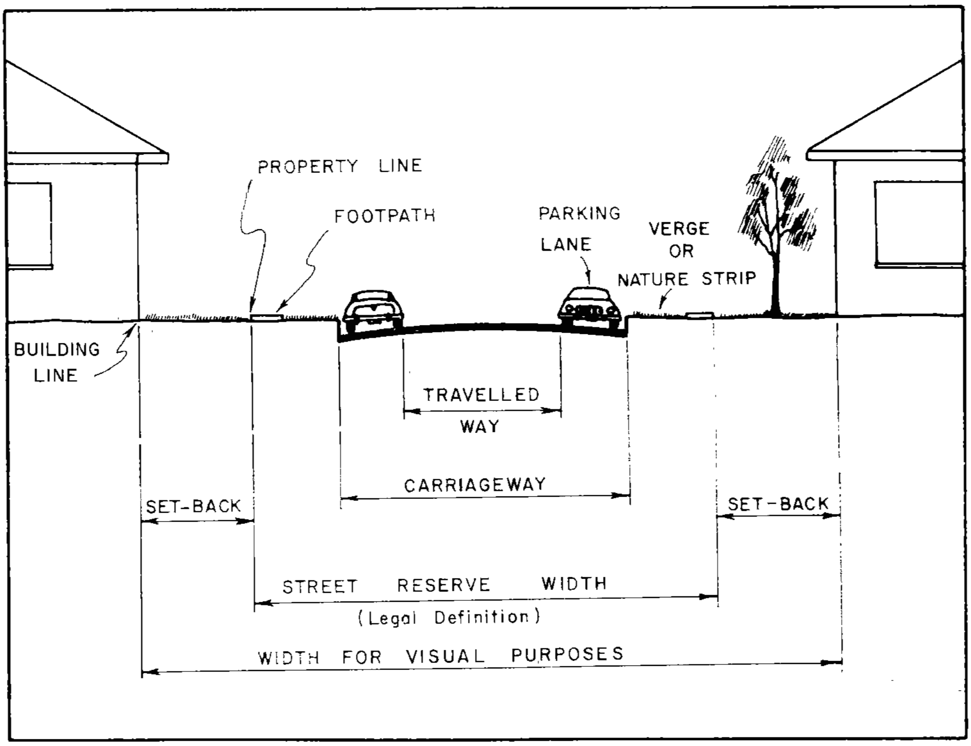


FIGURE 6.1 - THE STREET IN CROSS-SECTION

Vehicular Traffic

Vehicular traffic is very much bound up with carriageway width; clearly a street and the carriageway within it must be wide enough to cater for the traffic it is intended it should carry. However, a distinction can be drawn between the part of the carriageway which is used for parking and the part which is available to moving vehicles - called the 'travelled way' in this Report.

In general, three factors related to vehicular traffic affect the width of travelled way: traffic volume, vehicle width and speed, and whether one lane or two lane operation is required.

Traffic volume is not an issue in the design of residential streets. The physical capacity of even a one-lane street is very much in excess of the flow that would be judged acceptable from an environmental viewpoint. For example, a typical Australian residential street with 7.3m between kerbs and allowing for two vehicles travelling in opposite directions to meet and pass with a third car parked at the kerb, has a traffic capacity of the order of 10,000 - 15,000 vpd, depending on intersection treatment. This contrasts with an acceptable environmental traffic volume of no more than 3,000 vpd.

Vehicle width and speed are thus the critical factors affecting the width of travelled way. Few cars are much wider than 1.75m, and the maximum legal width for road vehicles and trailers in most States is around 2.5 metres. This means the minimum width of a lane might be as little as 2.5m provided that vehicles travel very slowly (at about 10-15 km/h) and that the travelled way is unobstructed by trucks or parked vehicles. In effect a carriageway of only 5.0m wide would, in some circumstances, be quite sufficient to cater for two-way traffic; this is in fact the recommended value for minor local streets shown in Table 5.1 where kerb parking is not permitted. Where parking is permitted, an extra width is of course required (see below). Additional width may also be necessary on bends in such narrow streets to accomodate the extra width of the swept path of a moving vehicle. A width of 5.5m on bends would be suitable.

The number of lanes is important because clearly if one-lane operation is tolerated even narrower street widths are possible. The critical parameter in deciding whether such a situation is acceptable is the probability of vehicles travelling in opposite directions wishing to pass each other in any given stretch of street. Table 6.1 shows the average frequency with which two vehicles will meet each other on a length of carriageway 200 metres long, as related to the overall traffic flow on that street. (For the purpose of the Table it is assumed that the traffic is divided evenly between both directions and is travelling at 30 km/h.)

TABLE 6.1 - AVERAGE FREQUENCY OF MEETINGS OF OPPOSING TRAFFIC IN A RESIDENTIAL STREET

Approximate Number of Houses Served	Peak Traffic Flow (veh/h)	Equivalent Daily Flow (veh./day)	Average Frequency of Meetings (per hour)
10	10	100	0.34
20	20	200	1.34
50	50	500	8.2
100	100	1,000	33
200	500	5,000	834

It can be seen that a one-lane carriageway will produce surprisingly few confrontations if traffic volumes are low, but that the situation will rapidly become intolerable if traffic volumes increase. For example, a typical minor local street 200m long with 20 houses, carrying 200 vehicles per day would result in the meeting of two vehicles travelling in opposite directions at about 40 minute intervals on average. Whether such a frequency is acceptable, and whether the extra cost of road pavement to eliminate the resultant - very minor - delay is justified, must be subject to the judgement of the local community.

Leaving aside the demands for parking (which is dealt with in the next section) it seems that the carriageway width of residential streets need not be more than about 5.0m on the straight, and up to 5.5m on bends. For streets in which the traffic volume is very low, a single 3m lane may be sufficient - the minimum width being limited only by the need to allow garbage trucks, fire trucks, removal vans and the like, access (refer Table 5.1).

Parking

The amount of street parking which should be provided depends on three principal factors:

1. the amount of off-street parking provided,
2. residential density,
3. household size,

and to a limited extent on:

4. age structure of resident population,
5. income,
6. closeness to public transport, community facilities and the city centre,
7. car ownership (to the extent that this is not determined by the above factors).

The 1971 Australian Population Census provides an indication for the demand for vehicle parking, whether on or off-street, in residential areas. Table 6.2 has been extracted and adapted from the Census and classifies households by the number of vehicles parked at or near the households. (Similar results from the 1976 census are not yet available from the Australian Bureau of Statistics.)

TABLE 6.2 - DISTRIBUTION OF VEHICLES PER HOUSEHOLD

Number of Vehicles per Household	Percentage of Households %
0	23
1	51
2	21
3	4
4 or more	1
	100%

Source: Australian Bureau of Statistics: Census 1971.

The table shows that in 1971 about half of Australian households had one vehicle each, approximately one quarter had no vehicle at all, and the remainder had two or more. Very few households had more than two vehicles. There was very little difference in vehicle ownership between houses and flats and the average number of vehicles per household was a little higher than one. This figure can be expected to rise slowly over time.

In addition to the parking needs of residents there must also be some parking provision for visitors and, occasionally, for large social gatherings. Such statistics are not readily available but several things can be said about parking provision for visitors: not every household has visitors at the same time so the parking load can be spread around the immediate neighbourhood, say 50m up and down the street; visitors may tolerate walking a little further than residents; it may be tolerable, occasionally, to have cars parked on the grass verges of the street as it is doubtful that these occasions would be frequent enough to result in damage, mud and dust.

The ownership of boats, trailers, and caravans is increasing and these may take up prodigious amounts of space if left on the carriageway (either legally or illegally). It is considered carriageway space should not be provided for these; hard-standing parking areas are unnecessary and they could be parked within the residential block.

For Australian residential areas it is considered the provision of two parking spaces per household would be adequate, and three per household quite generous. There could be quite wide local variations in the requirements, and the parking provision for any particular area should be selected to suit local conditions. Having decided how much is needed in total and the demand for parking which is not satisfied by private off-street provision, the planner is able to determine the need for on-street parking.

Implicit in the normal carriageway width of 7.3m is the assumption that cars can be parked all along one side (or randomly on both sides) without blocking two-way traffic. However, parking areas do not have to form an integral part of the carriageway. As long as cars are expected to park on the carriageway, as they are now, the carriageway must be wide. The planner, by creating parking bays, can reduce the visual intrusion of the street substantially, even though the total paved area is the same. A narrow carriageway, too, has an important function in slowing down the traffic; more is said on this in the section on design speed. Whether the visual intrusion of the street is regarded as important depends on community values; it is to be expected that many people may still prefer the sight of a wide carriageway on principle.

Broadly, there are five different ways of providing on-street parking although, within these broad categories, there are numerous variations. Each method, illustrated in Figure 6.2, is discussed briefly, and summarised in Table 6.3.

Parallel parking on the carriageway: This most used method has convenience and simplicity in its favour. Cars can be parked close to every dwelling and extra parking area is not called for. The parking lane, being integral with the travelled way, has to be built to a higher construction standard than would perhaps be necessary for a free-standing parking surface. However, the ease and simplicity of the conventional practice may cancel out any gains from the saving of material and construction.

Angle-parking bays: The example shown is for parking bays in a quiet residential street. Research and practice has shown that angle-parking is more hazardous than parallel parking and it has rightly been generally shunned on these grounds. However, in very lightly trafficked residential streets (say, 200 vpd and below) where speeds are very low, the chance of an accident is small. Apart from its visual advantages it is arguable that angle-parking in specially provided parking bays is actually safer in quiet streets than parallel parking because there are less concealed spaces close to the travelled way. Also, if parking bays are unsealed or some other cheap material is used, there may be some saving in cost. In summary, angle-parking bays seem to be appropriate for culs-de-sac and very low density areas.

Parallel parking separate from the carriageway: This method has all the convenience of conventional kerb-parking combined with the visual advantages of a narrow carriageway. The cost would depend in part on the type of surface adopted for parking strips, but is unlikely to be much more expensive than the conventional approach and in some cases will be cheaper. The use of commercially available hard standing surfaces which allow grass to grow through it could be considered for parking areas such as this.

Separate parking bays: The use of separate parking bays is safer than parking on the carriageway (provided children do not play in the car-park) and, if

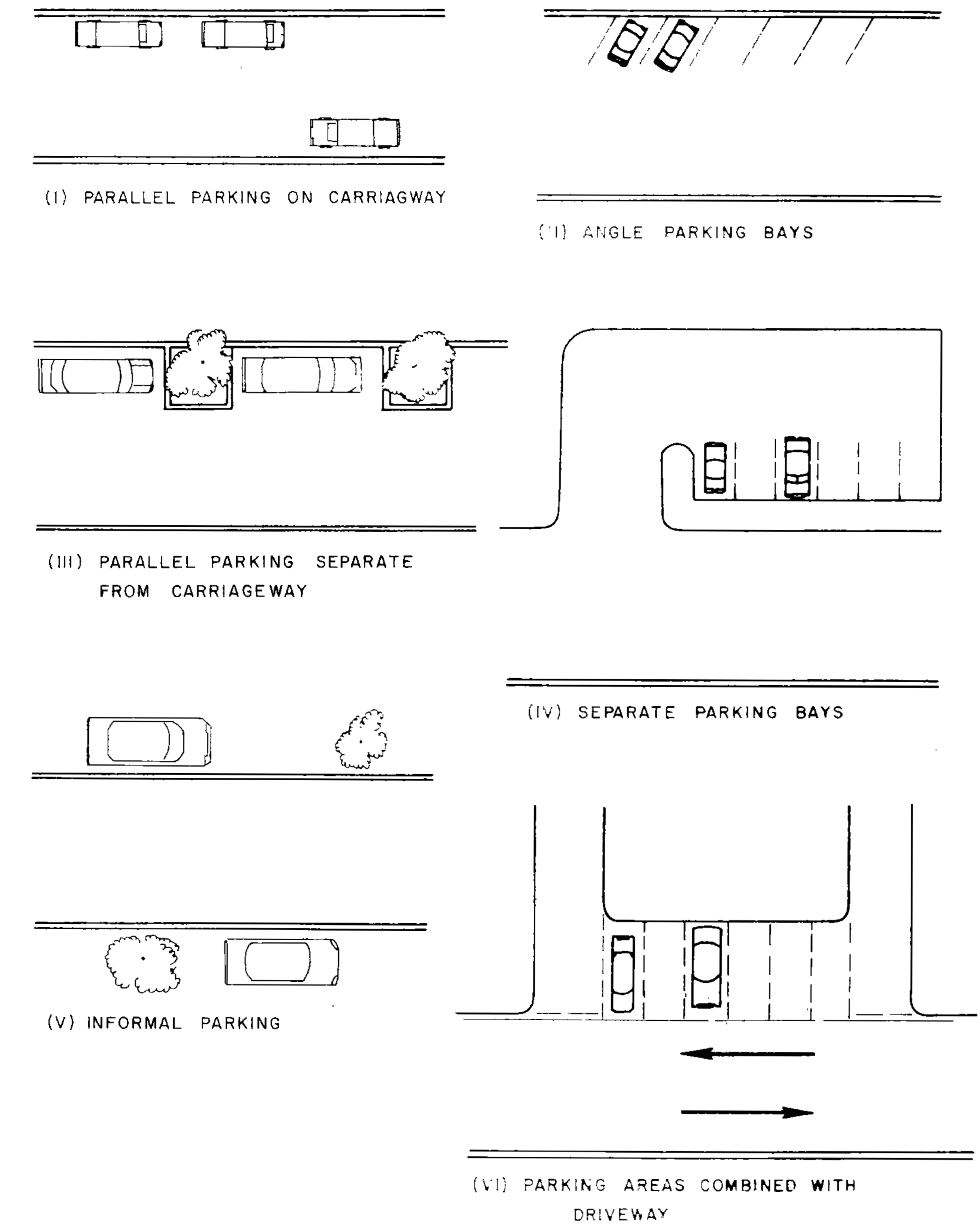


FIGURE 6.2 - METHODS OF PROVIDING FOR ON-STREET PARKING

TABLE 6.3 - COMPARISION OF PARKING METHODS FOR RESIDENTIAL STREETS

	Residential Density for which suitable	Traffic Flow for which suitable	Cost Comparison	Visual Effect	Pedestrian Safety	Vehicle Collision Potential
1. Parallel Parking on Carriageway (conventional)	all	all non-arterial	normal	normal	normal	normal
2. Angle Parking Bays	all (in culs-de-sac)	low	as for 1	all reduce visual intrusion of the carriageway	possibly safer	high, except in culs-de-sac
3. Parallel Parking Separate from Carriageway	all	all non-arterial	as for 1		as for 1	as for 1
4. Separate Parking Bays	high only	all	may be cheaper		safer	low
5. Informal Parking	low only	low	cheaper		as for 1	as for 1

designed as an integral part of a residential development, may allow substantial savings on the cost of road construction. It is only practicable where densities are high and, therefore, walking distances short.

Informal parking: Parking on the verges allows a narrow pavement which has the tendency of slowing down traffic. However, if the verge is other than a gravelly material it can become very unsightly in wet weather. It should only be used in low density residential areas and where traffic flow is light.

Parking areas combined with driveways: This is a variation of angle parking bays.

In summary, the amount of parking to be provided and the design of parking facilities depends on the particular location. Australian experience indicates that between two and three spaces per dwelling (including off-street parking) are required, desirably within 50m of the dwelling. All spaces should be accessible by footpath, or located within a street. Angle parking should be avoided except where very low traffic flows are involved.

Vehicle Turning and Property Access

Any street clearly must have geometrics such that vehicles can turn and have access to properties. A two-axle truck (e.g. a garbage collection vehicle) has a turning circle of 12-13m, while most cars can turn in a circle of about 10m diameter. Because reversing manoeuvres, especially by trucks, are dangerous to pedestrians and unpopular with service and delivery truck drivers, all culs-de-sac should have a turning area of at least 13m diameter. In long narrow streets there will be a demand for turning manoeuvres, but these can usually be accommodated using a 3-point turn into property driveways. If for some reason this is not possible, turning bays, again of 13m diameter, should be provided at intervals along the street.

A car turning from a street into a driveway needs a turning radius of about five metres, but if the carriageway width is less than about six metres, the normal turning movement in residential streets (swinging out to the opposite side of the street) is impracticable without a 'flare' having been built into the driveway or forcing the driver to drop a wheel on to the verge. The first possible solution is expensive and the second would be unacceptable in many circumstances, and in any case, lay-back kerbs would be necessary. An alternative solution would be to locate parking areas so that driveway entrances can be combined with them to give the required turning radii, as shown in Figure 6.2(vi).

<u>Pedestrian and Bicycle Traffic</u>

At very low vehicular traffic volumes, both pedestrians and cyclists can safely use the roadway. Although the choice of traffic which constitutes an upper limit to such joint use is somewhat arbitrary, it is considered that traffic volumes which result in one vehicle every three or four minutes in peak traffic periods would be appropriate. This is equivalent to about 150-200 vpd. That is, if vehicular traffic volumes are of that order or less, footpaths may not be necessary. Again there is a trade-off between the convenience (and possibly safety) of footpaths and their cost and visual appearance.

At higher traffic volumes separate footpaths should be provided. Conventional practice is to place such paths within the road reserve, parallel to the roadway, as shown in Figure 6.1. However, more innovative residential area design can provide a pedestrian-cycle path network which is separate from the vehicle networks. This concept is carried to its logical conclusion in the so-called Radburn layout, where the two networks are completely independent.

In the design of a pedestrian/cycle path network, whether completely or only partially segregated from the road network, there are a number of criteria governing the location of such paths:

1. the pedestrian/bikeway network should be connective to enable the pedestrian or cyclist to travel to most places by quick and direct routes,
2. the network should be focused on school and community facilities and should not follow collector roads,
3. the network should not only provide access to open space but should be combined with it where feasible,
4. it is desirable to provide linked bikeways to form continuous metropolitan-wide routes to encourage diversion of trips from cars for intermediate range trips of say six to ten kilometres.

Carriage of Service Utilities

Service utilities, both above and below ground, are very often located within the road reserve. While there may be advantages in terms of cost and aesthetics in locating services in easements at the rear or side (or even, where the road reserve is narrow, in the front) of properties, it is nevertheless likely that the road reserve will continue to be the most common locale for such utilities.

The gravity systems - sewers and stormwater drains - provide a constraint on residential network layout because they must be closely related to the terrain. Although it may often be possible to slope the street network layout so that most sewer and drainage connections are at the front of the property (see chatper 7), rear property connections to a main running along an easement will still be common.

Telephone and electric power overhead lines are generally regarded as unsightly and undergrounding of these services is becoming more common. Unfortunately, the cost of underground cables as compared with overhead wires for both these services - particularly for electricity supply - is high in low density housing areas. It would be difficult to justify the additional cost if people are prepared to put up with the unsightly overhead lines. In high density areas with multi-storey dwellings undergrounding may be justified from a safety viewpoint. In some localities, overhead wires are located at the rear of blocks to preserve the environmental quality of the front street although there is little saving, if any, in the initial capital and in ongoing maintenance costs.

The practice of clustering housing together in small groups can reduce the length and cost of service lines. A cluster housing scheme could save up to 50% of the length of service lines between the trunk lines and houses compared with a conventional sub-division.

There are advantages in setting out a sub-division with 'hammer-head' blocks by locating two rows of housing blocks along each side of a street and providing access to the rear blocks by easements through or alongside the front blocks. This practice can be very attractive and efficient as regards the locating and cost of service utilities. With service mains in the street the cost of connecting the rear houses would be high because of the longer connection; however, this would be offset by the savings in the cost of the mains in shorter streets. There is no reason why the service mains to hammerhead blocks should be located in the street provided every block is adjacent to some non-private open space, where the utilities can be located and provision made for maintenance vehicles to have access on the few occasions they are needed.

Fire hydrants should be within a hose length - approximately 60 metres - of every dwelling. Significant savings are possible by designing culs-de-sac short enough so that they do not need individual hydrants, and water supply pipes need only be large enough for domestic water supply within the cul-de-sac, provided a hydrant is located at the mouth of the cul-de-sac.

The precise location of service utilities is a technical matter which must depend on local conditions. In most cities codes exist for the location of each service - stormwater, sewer, gas, oil and water pipes, telephone and electricity cables - whether under the footpaths, nature strips or carriageways or overhead wires. These codes are arrived at by co-ordinating committees comprising representatives of the various responsible organisations and of State and Local Authorities, and are valuable to planners for designing streets and their networks. The space required for such service utilities has a bearing on street width. Sometimes it is justifiable to locate services under the carriageway when land is scarce but this practice causes repair and reinstatement of trenches in the road pavement to be difficult and costly, with an unsightly and sometimes unsafe result. Where front fences are not allowed, such as in Canberra, some services could be located in front gardens when the street reserve is not sufficiently wide to take them, but this would restrict the location and growth of trees in front gardens.

Visual Appearance

The street network affects the natural environment insofar as the street occupies land which may have attractive natural features such as creeks and trees. Streets themselves should be attractive and compliment the natural and the built environment in providing attractive living areas.
The network should permit the street space to be 'closed' or 'open' according to desired architectural principles. The visual sense of enclosure or

openness may be assisted by the choice of cross-sectional design. A narrow street cross-section and carriageway may allow more scope for conserving attractive natural terrain features and vegetation. The choice of road surfaces should be influenced to some extent by visual criteria - gravel may be preferred in some areas to, say, concrete or bitumen.

Privacy and Noise

It was earlier suggested that the visual width of the street extends from building line to building line. However, the standards or regulations for minimum set-backs are more related to privacy, light, ventilation, and perhaps noise, than to aesthetics. Whether minimum set-backs are effective in achieving these objectives is open to debate.

In areas of medium to high density development, set-backs can be counter-productive to privacy; open space may be better provided at the rear or side of the buildings. In low density areas, the set-back may be viewed as wasted space. So far as noise is concerned, in properly designed street networks traffic flow on most residential streets is so low that traffic noise is not a problem and, in any case, the difference in noise level between the normal set-back and one somewhat smaller is not significant. Finally, it can be argued that light and ventilation requirements can be met through careful architecture and therefore a performance standard rather than a technical standard would be more appropriate (see chapter 2).

There is thus no clear-cut relationship between street cross-section (including building set-backs) and privacy and noise. These requirements are more closely related to network layout - ensuring that traffic volumes and vehicle speeds in residential streets are kept low -- and to architecture.

DESIGN SPEED

The design speed of a road is a measure of the minimum standard to which the road is designed and built. It is the way of ensuring that a vehicle travelling at that speed can do so in safety when the geometric design features of the road are the only factors governing its speed. The concept has proved its worth in rural road design where it is used to determine such design elements as vertical and horizontal curves, grades, stopping distances, etc. In the design of residential streets it is clear that factors other than the geometric design features of the road affect vehicle speed. Thus the concept of design speed needs to be modified and interpreted in a way very different from that used in rural road design.

In particular, there is a need, irrespective of such geometric design related parameters as sight distance, to keep traffic speeds low. The following sections discuss this need, review the ways in which the speed of vehicles in residential streets can be controlled, and present suggested values for use with various types of residential street.

The Need for Low Traffic Speeds

Low traffic speeds on residential streets are advantageous for five reasons - cost, safety, social amenity, visual appearance and vision.

Cost: Many of the current practices in residential street design are justified on the grounds that the street would be unsafe without them. For example, it is often said that full-barrier kerbs are needed to protect pedestrians from vehicles mounting the footpath and that generous nature strips give protection from stones and mud thrown up by passing vehicles. Nature strips are said to give drivers a greater warning time if a pedestrian decides to step on to the carraigeway and wide street reserves are sometimes justified because of the existence of curves or intersections.

These arguments are reasonable if the vehicles using the street are travelling at 50-60 km/hr and the geometric design standard and the street layout of most residential street networks in Australia permit these vehicle speeds. However, if the traffic speed was lower, many of these costly design features would not be necessary and significant economies in the cost of providing residential streets could be obtained. A hierarchical street structure as discussed earlier would be conducive to this.

Safety: There is no information which relates the frequency of accidents to both the speed of the vehicle and the design speed of the street. However, it seems reasonable to assume that a street with a low design speed would be no more dangerous than one with a high design speed provided that traffic moved at the speed for which the street was designed.

Social amenity: The social amenity of a street is composed of many factors, among them being the ability to use the street for social interaction (such as children's games) and the perception that residents have of the street (whether correct or not). Various studies have shown that people value quiet streets but no research is known to distinguish between the speed of traffic on the one hand and volume on the other. It can be hypothesised that speed plays a substantial part in these perceptions and that the ability to use the street carriageway as a social space has some importance. It is known for instance that children are attracted to hard surfaces for playing, especially for ball games. Many streets with traffic flows of 200 vpd and less may be quite satisfactory for use by pedestrians. In the peak hour, for instance, a daily flow of 200 vehicles is equivalent to one vehicle every three minutes on average at peak times, and every 7 to 8 minutes at other times. Use of the street in this way is only possible if cars are travelling relatively slowly, say around 30km/h and in some areas, and for some purposes, streets may be designed for this speed.

Visual appearance: A high design speed is a substantial constraint on the visual design of the street since the planner or architect has less flexibility in designing imaginative or innovative streets and street networks.

Noise: Vehicles travelling at slow speeds produce much less noise than vehicles at higher speeds. For instance a car travelling at 30km/h produces about half as much noise as one travelling at 60 km/h. (A reducation of 10 dB(A) is considered to be equivalent to halving the traffic volume.)

It can be seen that lower traffic speeds can lead to economic benefits, social benefits, and possibly have safety advantages as well.

The Achievement of Low Traffic Speeds

If the advantages of low traffic speeds outlined above are to be achieved, the network and street designers must ensure that traffic does not have the opportunity to travel at high speed. It is not enough simply to use a low design speed and expect that the reduced geometric standards would alone keep traffic speed to an acceptable level.

There are basically two ways of achieving low traffic speeds: the use of physical restraints and the use of visual cues.

Physical Restraints: The most effective physical restraint is simply to avoid long stretches of street, either straight or gently curved, where the driver is able to build up speed. Frequent discontinuities in the street network, which are usually easy to achieve with a hierarchical layout, are thus necessary. Similarly, the introduction of curves, as well as having aesthetic advantages, serves to limit vehicle speed.

Physical restraints in the pavement itself may occasionaly be justified. Humps in the roadway should in general be avoided, since research has shown that it is impossible to design a hump which is effective and safe for all categories of vehicle, ranging from motor cycles to trucks. Moreover the noise of vehicles passing over the hump would be intolerable to many residents. A device such as a shallow table drain across the entrance to a very short cul-de-sac is acceptable, though in most cases, if provided, it would be because of drainage cost, rather than speed control, since traffic cannot attain a high speed in a very short cul-de-sac.

Visual Cues: A very effective way of controlling the speed of vehicles is to use purely visual devices. Techniques of this sort rely on the psychology of the driver and are not based on physical criteria. Although research in this field is in its infancy, it appears that three main factors are of importance - width of carriageway, closeness of objects to the edge of the carriageway, and type of road surface.

Evidence suggests that drivers tend to slow down when the carriageway is narrow and there are objects within two metres of its edge. While these findings are for highway conditions where travel speeds are fairly high, it seems likely that they would be true also for lower speeds. If so, the desire to keep traffic speeds low is yet another argument in favour of narrower carriageways. Objects near to the carriageway should not, of course, be of a kind capable of concealing pedestrians.

Very little of a quantitative nature is known about the effect of road surface on driving speed. Naturally a very rough surface must affect driving speeds but residents are unlikely to put up with the discomfort. In some situations gravel and unsealed surfaces may work well - more is said about this in chapter 8 on pavements - but even if they reduce driving speeds they can be expected to increase the braking distance. Patterned and tiled pavements have been found to be very effective in slowing down traffic in shopping malls but this is likely to be much too expensive for residential streets.

Pending further research, it seems that vehicle speeds in residential streets are best controlled by avoiding long straight or gently curved street segments in which vehicles can build up speed (i.e. using a discontinuous street pattern) and/or providing narrow pavements, with objects close to the edge of the pavement.

Suggested Speed Standards

The speed which is acceptable and desirable for a particular street varies with the place of that street in the hierarchy. The higher the category of street, the longer, in general, is the length of trip and hence the greater the absolute time savings due to a higher speed of travel. Driver expectation is, quite reasonably, that higher speed is acceptable on a higher-category street. Moreover, the relationships between level of service and traffic volume demands a higher speed of travel for high volume streets.

This principle is not questioned. What is questioned is the use of conventional design speed criteria as the key design parameter for residential streets low in the hierarchy, and the use of values for that parameter of 50 - 60km/h.

It is argued that in low volume streets, low in the hierarchy (especially culs-de-sac and loops), much lower speed standards are desirable and attainable. In assigning values to the speed standard, the following points are relevant:-

1. the likelihood of the safe speed limit being exceeded (this effectively limits low design speeds to short loops and culs-de-sac);
2. the decrease in accessibility which results (this, again, limits low design speeds to short streets);
3. the traffic flow (except at very low flows a low design speed can limit capacity); and

4. if drivers are required to travel slowly for long distances, the temptation to drive too fast may result in 'slow' streets becoming dangerous.

Based on these considerations, the values shown in Table 6.4 are proposed.(1) It should be emphasised that analytical techniques are not sufficiently refined to allow formal derivation of the values shown in Table 6.4, and that these values are open to interpretation and revision in the light of experience.

TABLE 6.4 - SUGGESTED RESIDENTIAL STREET SPEED STANDARDS

Street Category(1)	Speed Standard (km/hr)	Max. Length of Street (m)	Traffic Volume (vpd)	Approximate Number of Dwellings
Collector	60	undefined	3,000	300
Major Local	40	500	1,000	100
Miner Local - loop	20	300	500	50
- cul-de-sac	15	150	250	25
Mews	10	50	100	10
Driveway	10	undefined	30	3

1. Refer Table 5.1.

This table is interpreted in two ways. Firstly, for all but the collector street, restricting the maximum length of street to the values shown should ensure that vehicle speeds do not exceed those indicated. Secondly, for all classes of street including the collector, the speed value shown is appropriate for use as the design speed in the usual sense, i.e. the geometric design of the road should be in accord with the design speed shown.

Summary

It is considered that design speeds required by most authorities for residential streets are too high. There seems to be a vicious circle involving design speed, traffic speed and safety. The result is a carriageway width which is expensive, which lacks human scale, and which is potentially dangerous. What is required is a street which encourages slow driving without at the same time exposing drivers and pedestrians to danger. Certain visual techniques and

(1) Street width is not included in Table 6.4 because this depends on other factors - especially parking - refer Table 5.1 for recommended street widths.

physical restraints to speed have been suggested to bring this about. But, if safe speeds are not to be exceeded, it is most important to employ low design speeds only in streets where there is little traffic and where the trips are short. This means that low design speeds must be limited to short streets generating a daily traffic flow of not more than a few hundred cars.

RESIDENTIAL DENSITY

Residential density affects the design of residential streets in two main ways: the length of streets and parking requirements.

Length of Street

The effect of increasing the residential density - having more dwellings per unit length of street - is simply to reduce the length of street since desirable traffic levels previously developed apply, in general, irrespective of the residential density of the area. Table 5.1 shows the maximum number of dwellings suggested as being appropriate for the various classes of street.

However, the relationship between density and street length is not a simple linear one, because at higher densities, it is reasonable to expect that the influence of traffic on residential amenity will be different. There are two main influences which alter this relationship: changes in vehicle trip generation and altered architecture.

All else being equal, it would be reasonable to expect (and research bears this out) that somewhat fewer vehicle trips per household are generated in high density areas. Because distances are shorter, some car trips are replaced by walk or cycle trips. Public transport services tend to be better in high density areas, thus attracting more trips than would be the case at lower densities. It may be that there are more opportunities for trip satisfaction within higher density areas thus reducing the need for trips to leave the area.

At higher densities, there is probably more scope to explicitly design dwellings to reduce noise. A block of flats for example, may be designed with a blank wall to the street. To the extent that this is successful, higher noise, and thus higher traffic flows, can be tolerated.

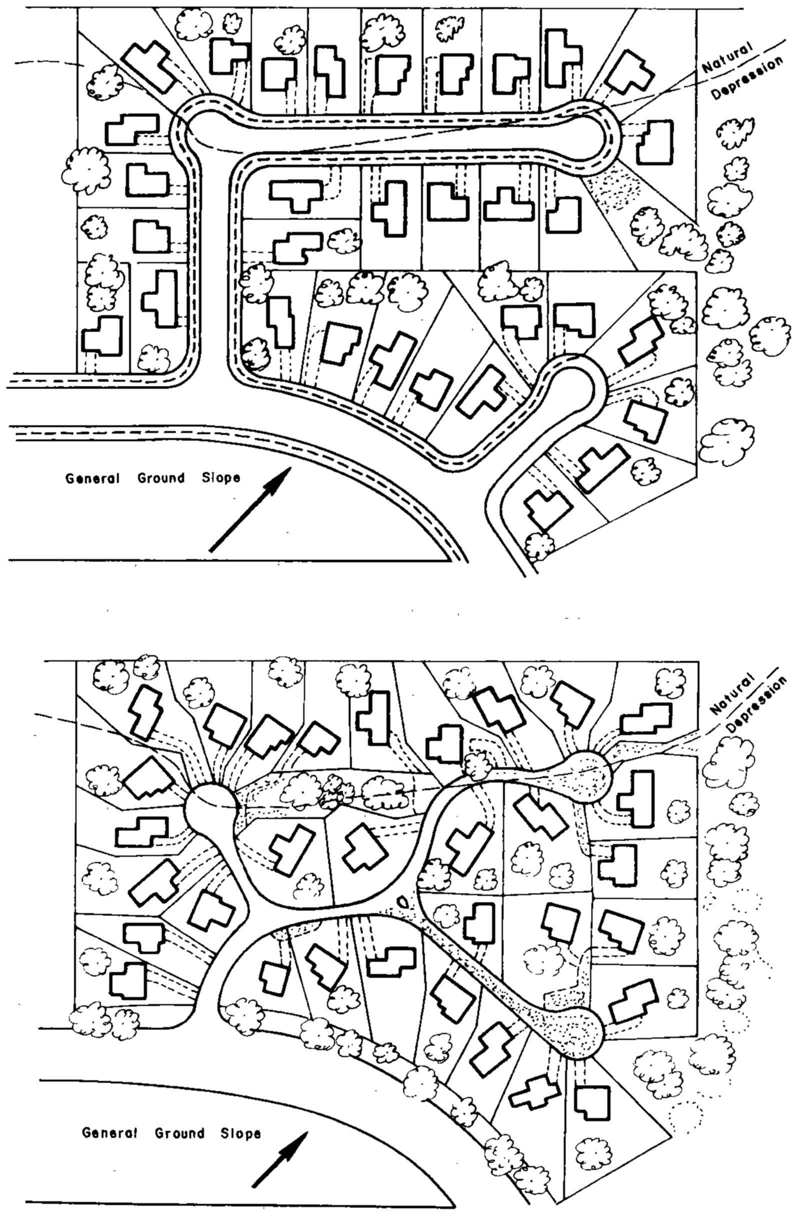


FIGURE 6.3 - RELATIONSHIP BETWEEN STREET DESIGN AND ALLOTMENT DESIGN

The effect of residential density on the length of street overall is to reduce the length, although not in direct proportion to increasing density.

Parking

Unless there are reasons why car ownership rates would be different for a development of a higher density, the demand for car parking can be assumed to be directly proportional to residential density. Thus the amount of parking needed per household does not, in general, vary with density.

There is probably more scope in high density areas to provide for parking in a different to normal fashion. Because walking distances are, in general, shorter, street parking can be provided in grouped parking bays (see discussion in an earlier part of this chapter). Off-street parking in group parking garages or in off-street lots may also be viable. These alternatives to mixed off-street and on-street parking typical in low density areas can be economic, aesthetic and safe.

TRAFFIC ARCHITECTURE

Traffic architecture is a general term used to describe architectural techniques to mitigate the effects of traffic. It includes such aspects as the provision of noise barriers to shield residential allotments from traffic noise, the design of buildings to take account of traffic noise (e.g. a blank wall facing the traffic, or the provision of double glazing), and the use of one building to shield other buildings.

The effect of these various measures on residential street street design is to remove constraints on the street designer, e.g. by allowing extra traffic to use a particular street (see the above discussion on residential density).

ALLOTMENT DESIGN

There is clearly a close relationship between street design and the policies or regulations governing the design and shape of the allotments served by the street. This is illustrated in Figure 6.3, in which two alternative means of dividing a parcel of land into a given number of allotments are shown.

The first typifies current Australian practice. Blocks tend to be rectangular and of similar (minimum) size unless they are at the head of a cul-de-sac or at a corner, in which case they are usually fan shaped.

An alternative, which would be possible if minimum frontage, block size and street width constraints were removed is shown in the lower diagram. The reasons why few, if any, designs of this type are seen are largely institutional, as discussed in Chapter 2. Technical standards rather than performance standards dictate minimum lot sizes and frontages, and a developer who wishes to minimize the cost of blocks and maximize the number of blocks has little alternative to designing all blocks to the same minimum standard

Reference to Figure 6.3 shows that the street design associated with different allotment designs can be quite different. More flexible allotment design will usually allow a greater variety of street types - driveways serving 2 or 3 'battleaxe' blocks, mews serving a cluster development, and so on.

In summary, street design must obviously be related to allotment design, but if greater flexibility is allowed in the latter, there must be an even closer relationship between the size, location, and access to allotments and the sensible, safe and functional layout of the street network.

GUIDELINES FOR RESIDENTIAL STREET DESIGN IN NEW URBAN AREAS

The design of residential streets and residential street networks should be based upon clearly defined environmental areas and should aim to meet safety, economic, amenity and functional objectives. The provision of a clearly defined hierarchy of streets is the key to the achievement of these objectives. The suggested traffic volumes, vehicle speeds and design parameters for the various categories of street outlined in the residential street hierarchy outlined in chapter 5 are set out in Table 5.1.

Table 6.5 reviews many of the points set out in this chapter and the previous one, and outlines the planning measures, the mechanisms by which the planning measures affect the objective, and the principles for implementing the planning measures in respect of each of the performance measures developed in Chapter 1 (noise, safety, severance, air pollution, accessibility, parking, public open space, visual appearance, and social impact).

The planning measures are those developed in this Chapter and Chapter 5 - network design, land use planning, street cross-sections, design speed, residential density, traffic architecture, and allotment design.

Summary

The major conclusions that have been reached in regard to residential streets in new urban areas are summarised in point form below.

1. Present minimum standards applying to street widths, block frontages and lot size in new residential areas should be reviewed and expressed in terms of performance requirements wherever feasible. It would be preferable for standards to be in the form of guidelines rather than as fixed arbitrary minima to encourage innovation and variety.

2. Street networks in new residential areas should be planned and designed to provide high levels of environmental quality and to eliminate through traffic. This could be accomplished by the adoption of the environmental area concept.

3. Residential street networks should be planned as a true hierarchy to limit traffic flows adjacent to residential properties and to segregate pedestrian and bicycle travel from vehicle travel.

4. Community facilities should be located to be highly accessible to residents by walk and bicycle travel as well as by car, and to reduce travel to such facilities to a minimum. Provision should be made for walkways and bikeways (separate from vehicle traffic ways wherever possible) to provide convenient access to community facilities.

5. Location of housing for residential densities should be planned to place medium and high density areas adjacent to the more heavily trafficked roads and nearest to community and commercial facilities.

6. Street layouts and designs should provide convenient access to public transport routes. Where feasible and appropriate, the opportunity to provide public transport routes through the areas should be considered, with adequate safeguards against traffic passing through the area.

7. Public open space should be sited close to residents and whenever possible designed as inter-connected long narrow fingers of land abutting the rear of house blocks. Bikeways and walkways should be built along such areas.

TABLE 6.5 PRINCIPLES FOR PLANNING AND DESIGN OF STREETS AND NETWORKS IN NEW RESIDENTIAL AREAS

Performance Objective	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
1. NOISE Traffic noise should be reduced and kept to a level which does not interefere with the comfort and convenience of living and communicating within areas.	1.1 Network design	Vehicle type and traffic mix: Street networks can be designed to provide attractive routes for through traffic which do not go through residential areas. In general this could be used to ensure that only private cars and occasional delivery vehicles use residential streets.	1.1.1 Adopt a proper street hierarchy and develop environmental areas of limited size from which through traffic is excluded. 1.1.2 Confine heavy vehicles to arterial roads. 1.1.3 Locate arterials so that they pass around and not through environmental areas.
		Traffic Volume: Network design can affect traffic flow in several ways: . Traffic on residential streets is reduced by providing a system of direct arterial routes to take through traffic. . Through traffic can be excluded from environmental areas by making residential streets discontinuous. . The wider the spacing of arterials, the greater will be the amount of purely access traffic on residential streets. . Vehicle travel in environmental areas (and hence traffic volume) depends on directness of streets from dwelling to arterial. . Vehicle travel depends on the efficiency of other travel modes.	1.1.4 Design residential streets with low connectivity and arterials with high connectivity. 1.1.5 Make residential streets as direct as possible without permitting them to form direct connections between arterials. 1.1.6 Arterials should be spaced closely enough to produce tolerable flows in residential streets. 1.1.7 Street networks should facilitate walk, cycle, and public transport trips.
		Traffic Speed: Network design influences the speed of traffic by means of straightness of the network, by their lengths and by the number and type of intersections.	1.1.8 Residential streets should not contain long straight sections. 1.1.9 T-intersections can be used and spaced so as to encourage slow driving.
		Flow characteristics: Network design affects the flow characteristics of vehicular traffic to the extent that the number of intersections and their configurations cause vehicles to slow down and stop, accelerate and decelerate.	1.1.10 Reduce the number of intersections. 1.1.11 Locate and design intersections to cause minimum disruption to traffic flow. 1.1.12 Use one-way operation when practicable.
	1.2 Land-use planning	Vehicle type and traffic mix: Different land-uses generate different kinds of traffic. Land-use planning influences the proportion of different types of vehicles (eg. cars, trucks, buses, etc.) in the traffic streams using individual streets.	1.2.1 Land-uses which generate heavy traffic should not be sited in residential streets, or in places which would require heavy vehicles to pass through residential streets. 1.2.2 Generators of heavy vehicle traffic (eg, commerce and industry) can with advantage be located on or near arterials.
		Traffic volume: Different land-uses generate different amounts of travel. The planner can influence traffic volumes on a given street through the choice of abutting land-uses and the location and types of all land-uses served	1.2.3 Cluster dwellings closely around local facilities which attract trips in order to minimise total travel. 1.2.4 Place housing which generates highest number of trips (that is, high residential density housing) closest to local facilities and arterials in order to minimise travel in residential streets.

1. NOISE (Contd.)	1.2 Land-use planning (Contd.)	by that street. In addition, total travel (and hence, traffic volume) can be influenced by placing land-uses such that multi-purpose trips occur and/or trip origins are close to destinations.	1.2.5 Place local facilities (eg, shops) along routes used for work trips, for instance near arterials, in order to promote multi-purpose trips.
		Location of noise-sensitive land-uses: Land-use planning can control the location of noise-sensitive land-uses with respect to streets.	1.2.6 Use land near arterials for uses which are relatively insensitive to noise (eg, commercial and industrial). 1.2.7 Place residential buildings sufficiently far from arterials to mitigate noise.
	1.3 The street cross section	Road surface: For the purpose of this study road surface is regarded as an aspect of cross sectional design.	
		Traffic speed: The street cross-section as well as design speed (which is dealt with later), can influence traffic speed. In general, the speed of traffic is slowed down where a narrow cross section is employed. That is, a narrow carriageway and a street geometry which permits objects, trees and buildings to be close to the road.	1.3.1 In general employ as narrow a carriageway as is consistent with traffic volume and the demand for parking. 1.3.2 Buildings and hard and soft landscaping features can be used to foster a sense of enclosure and hence encourage slow driving speeds. 1.3.3 Kerbs, by defining the limits of the carriageway, can on narrow carriagways be used to encourage slow driving.
		Flow characteristics: The design of the street cross section affects traffic flow characteristics in the following three ways: . By the provision of parking facilities on, and adjacent to, the carriageway which may give rise to disruptive parking and unparking manoeuvres. . By the design and location of property access points (crossovers). . By provision for weaving, merging and turning manoeuvres.	1.3.4 When feasible, provide parking areas (for instance garage courts and hard-standing areas) off the carriageway. 1.3.5 When the separate parking area is large enough, its access point should be designed to intersection standards. 1.3.6 Avoid angle-parking except where necessary and traffic speed and volume are low. 1.3.7 Street design should avoid conflicts due to weaving, merging and turning manoeuvres.
		Street width: (including setbacks ie, from building to building).	1.3.8 Employ wide street reserve widths and setbacks in noisy streets. 1.3.9 Use soft ground surfaces (eg, grass and soft landscaping) to absorb noise between source and receiver; (trees and shrubs have little barrier effect on reducing noise, (all that is required is a soft ground surface), but may have substantial visual and physiological value).
	1.4 Design speed	Traffic speed: The speed of traffic is affected by the horizontal and vertical alignment of the carriageway as well as by any visual cues as to the appropriate speed of travel.	1.4.1 Use a low design speed and a discontinuous alignment (ie, frequent bends and curves) where the resulting loss in accessibility is tolerable - that is, in short streets, loops and culs-de-sac). 1.4.2 Use buildings, landscaping and street furniture to enclose and break up the visual space. 1.4.3 Use visual cues consistently to denote low-speed areas (eg, road surface types, street lighting, street furniture, street signs).

Performance Objective	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
1. NOISE (Contd.)	1.5 Residential density	Traffic volume: Within any given area, the higher the residential density the higher will be the total amount of travel undertaken. For a given street network, an increase in total travel will increase traffic volumes on the streets. For any given overall residential street density, total travel can be reduced by the clustering of the highest densities nearest to local community facilities and to access points to arterial roads. This may result in an increase in traffic volumes on some streets. In addition, the higher the residential density along any particular street, the higher will be the traffic volume.	1.5.1 Relate the length of street to the residential density adopted - use short streets for areas of high residential density. 1.5.2 Place areas of high residential density closest to local community facilities and areas of low residential density furthest from local facilities.
	1.6 Traffic architecture	Noise barriers:	1.6.1 Use tall buildings to screen residential areas from noisy streets. 1.6.2 Design and locate buildings to screen their interior space and rear gardens from noise (eg, eliminate windows or use double glazing on the noisy side and place all 'living' rooms on the quiet side). 1.6.3 Use earth mounds and other special barriers to shield buildings, facilities and open spaces from noise. 1.6.4 Trees and shrubs are not effective noise barriers but they may have phychological and visual value.
	1.7 Allotment design	Street width: The size and shape of allotments within a residential area will influence the size, shape and location of buildings which can be erected on them and hence the effective separation between buildings on opposite side of the street and their distance from the carriageway.	1.7.1 Use long narrow blocks which provide opportunity for some rooms in the house and all of the rear garden to be well removed from the carriageway. 1.7.2 The use of hammerhead blocks would allow many dwellings to be far removed from the carriageway.
2. SAFETY Residential streets should be safe for pedestrians, cyclists and motor vehicle occupants.	2.1 Network design	Vehicle type and traffic mix. Traffic volume. Traffic speed. Flow characteristics. Intersections: Network design determines the number and type of intersections in the system (eg, cross, multileg, acute-angled and T-intersections). Access control: Network design governs, for any given street, the number, type and location of access points from abutting properties and adjoining streets. Network design can also	2.1.1-3 as for Noise guidelines 1.1.1-3 2.1.4-7 as for Noise guidelines 1.1.4-7 2.1.8-9 as for Noise guidelines 1.1.8-9 2.1.10-12 as for Noise guidelines 1.1.10-12 2.1.13 It is desirable on safety grounds to have as few intersections as possible. 2.1.14 Eliminate cross, multileg and acute-angled intersections. 2.1.15 Adopt the 'T' configuration for all intersections not controlled by traffic signals. 2.1.16 Provide the greatest level of access control along streets which carry the highest traffic volume. 2.1.17 In streets with the lowest level of access control, such as residential streets, ensure the lowest traffic volume of all streets in the network.

2. SAFETY (Contd.)	2.1 Network design (Contd.)	be used to regulate the amount of traffic which will use individual streets in accordance with the level of access control on each street. Pedestrians and cyclists: The design of the street network influences the ability of the planner to provide convenient path systems for pedestrians and cyclists, including those path systems which are located outside the street reserve.	2.1.18 Provide a footpath and bikeway system which is as far as possible physically separated from the street system. 2.1.19 Pedestrians and cyclists should only be allowed to mix with vehicles in streets where the traffic volume is very low (eg, short culs-de-sac). 2.1.20 Minimise the number of points where footpaths and bikeways cross streets. 2.1.21 Where footpaths and bikeways need to cross streets, special crossing facilities should be provided where traffic volume warrants it. 2.1.22 Footpaths and bikeways should always provide a shorter route to desired destinations than the carriageways.
		Emergency and repair vehicles: The street network can affect the performance of emergency and utility repair services.	2.1.23 Networks may contain shortcuts for emergency vehicles. 2.1.24 All buildings and areas of public use (such as parks) should be generally accessible to emergency and repair vehicles.
	2.2 Land-use planning	Vehicle type and traffic mix. Traffic volumes. Childrens' play areas.	2.2.1-3 as for Noise guidelines 1.2.1-3 2.2.4-6 as for Noise guidelines 1.1.4-6 2.2.7 Childrens' play areas should be set aside in places away from moving and parked vehicles. 2.2.8 They should be close to all dwellings. 2.2.9 They should be visible for supervision by residents and casual passers-by. 2.2.10 Cul-de-sac heads may be safe enough for older children
	2.3 The street cross section	Road surface.	2.3.1 Unsealed surfaces (if the inconvenience of dust and regular maintenance are acceptable) should only be used in streets where traffic speeds and volumes are low 2.3.2 Surface textures on sealed roads should be rough to resist aquaplaning and skidding, especially in areas of concentrated rainfall.
		Traffic speed. Flow characteristics. Intersections.	2.3.3-5 as for Noise guidelines 1.3.1-3 2.3.6-9 as for Noise guidelines 1.3.4-7 2.3.10 Use recognised intersection design practice. 2.3.11 Channelisation and control should be adopted appropriate to the volume and speed of traffic using the intersection.
		Carriageway geometrics: Features such as carriageway width, crossfall and super-elevation form an important part of geometric design.	2.3.12 Follow recognised codes of practice for crossfall superelevation and related features. 2.3.13 Carriageways should be wide enough to allow two vehicles to pass safely at the safe overall travel speed. 2.3.14 Avoid carriageway widths of between 7 and 8 metres.
		Pedestrians and cyclists: Cross-section design must cater for foot and cycle traffic.	2.3.15 Use, in general, recognised codes of practice. 2.3.16 Where footpaths and bikeways are combined the resulting path should be wide enough to obviate the risk of accident (especially to elderly pedestrians). 2.3.17 Paths should be well lit, and, where possible, visible from dwellings.
	2.4 Design speed	Traffic speed. Carriageway geometrics: Design speed encompasses sight-lines, horizontal and vertical curve radii, which affect visibility and vehicle handling.	2.4.1-3 as for Noise guidelines 1.4.1-3 2.4.5 Ensure that sight lines and curve radii are adequate for the expected speed of travel.
	2.5 Residential density	Traffic volume	2.5.1-2 as for Noise guidelines 1.5.1-2.

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
3. SEVERANCE Streets and the traffic using them should not make difficult, or dangerous, the crossing of streets by pedestrians.	3.1 Network design	Traffic volume.	3.1.1-4 as for Noise guidelines 1.1.4-7
	3.2 Land-use planning	Traffic volume.	3.2.1-3 as for Noise guidelines 1.2.3-5
	3.3 The street cross-section	Street width.	3.3.1 Use the minimum street width compatible with acceptable noise standards in abutting buildings. 3.3.2 Use the minimum width of street reserve compatible with the demands for traffic, utilities and footpaths (if any). 3.3.3 Utilities may sometimes with advantage be placed in easements outside the street reserve, or beneath the carriageway, in order to reduce reserve width.
	3.5 Residential density	Traffic volume.	3.5.1-2 as for Noise guidelines 1.5.1-2
	3.6 Allotment design	Street width.	3.6.1 Use block shapes and sizes which permit houses to be built close to their street frontages consistent with other requirements on account of noise, etc.
4. AIR POLLUTION Air pollution caused by vehicles using the streets should not exceed recognised safe levels.	4.1 Network design	Traffic volume. Traffic speed. Flow characteristics.	4.1.1-4 as for Noise guidelines 1.1.4-7. 4.1.5-7 as for Noise guidelines 1.1.10-12.
	4.2 Land-use planning	Traffic volume.	4.2.1-3 as for Noise guidelines 1.2.3-5.
	4.3 The street cross-section	Flow characteristics.	4.3.1-3 as for Noise guidelines 1.3.1-3. 4.3.4-8 as for Noise guidelines 1.3.4-8.
	4.4 Design speed	Traffic speed.	4.4.1-3 as for Noise guidelines 1.4.1-3.
	4.5 Residential street density	Traffic volume.	4.5.1-2 as for Noise guidelines 1.5.1-2.
5. ACCESSIBILITY Streets should provide convenient and unhindered access to desired destinations for vehicles, pedestrians and cyclists.	5.1 Network design	Pedestrians and cyclists.	5.1.1 Provide footpath and bikeway systems. 5.1.2 Footpaths and bikeways should lead directly towards a definite desired destination (eg., towards the activity centre or public transport). 5.1.3 Dwellings should desirably be located within a reasonable walking distance of public transport and local facilities. 5.1.4 Bikeways should be linked through the metropolitan area to form a system of long-distance bikeway arterials.
		Car travel: The design of the street network governs the ease of car travel.	5.1.5 Provide a road system for vehicles which serves all dwellings. 5.1.6 Provide a road system with high connectivity subject to other constraints (such as the desire to exclude through traffic and to produce a visually attractive street).
		Public Transport: The design of the street network governs in part the performance of any road-based public transport service; namely (a) the access walking distance and (b) the directness and length of bus routes using the streets.	5.1.7 The street network should contain some routes suitable for bus operation. 5.1.8 Bus routes should pass conveniently close to all dwellings. 5.1.9 Bus routes should be direct and allow for fast trip times. 5.1.10 Provide access for commercial and service vehicles to within a tolerable 'carry' distance from dwellings. (This distance need not be as short as is required for private cars and emergency vehicles.)

5. ACCESSIBILITY (Contd.)	5.1 Network design (Contd.)		5.1.11 Back-tracking and reversing should be unnecessary. 5.1.12 The network should provide convenient routes for sequential access to dwellings (eg., garbage collection, post and milk deliveries).
		Emergency and repair vehicles.	5.1.13-14 as for Safety guidelines 2.1.23-24.
	5.2 Land-use planning	Car travel: Land-use planning governs the location of trip generators and trip attractors.	5.2.1 Dwellings should be clustered around local facilities. 5.2.2 Dwellings should be close to arterial road access points, consistent with tolerable noise levels.
		Pedestrians and cyclists: Land-use planning affects the location on the one hand, of land-uses which attract walk and cycle trips (such as shops, and especially schools) and, on the other hand, the location of the dwellings which generate walk and cycle trips. Moreover land-use planning sets aside public open space and other areas which may with advantage incorporate footpaths and bikeways.	5.2.3 Dwellings should be clustered around local facilities. 5.2.4 Footpaths and bikeways may with advantage follow 'spines' of public open space, utility easements or drainage easements.
		Public transport: Public transport and land-use planning are related in the following ways: . Some land-uses (for instance, high density housing and employment centres) generate more public transport trips per unit area than others. . There may be a demand for land for parking near bus-stops and stations. . Land may need to be set aside now for future public transport services or technologies.	5.2.5 Locate areas of high residential density close to public transport routes. 5.2.6 Locate local facilities and employment centres convenient to public transport routes. 5.2.7 Provide parking areas near bus-stops and stations. 5.2.8 The possible future location of public transport routes (for instance Personal Rapid Transit) may be considered in locating public open space and other land-uses in residential areas.
	5.3 The street cross-section	Car travel: The cross-sectional design of the street controls the ease and extent of car travel.	5.3.1 The carriageway must be wide enough to accomodate the demands of traffic and parking (if any). 5.3.2 The carriageway design must permit access to abutting properties when this is planned (eg., the crossover and adjacent carriageway must give adequate space for vehicles to turn). 5.3.3 Parking should be provided for visitors and residents where this is not catered for by offstreet (ie. private) parking. 5.3.4 Streets and culs-de-sac should permit vehicles to turn at convenient intervals.
		Pedestrians and cyclists.	5.3.5 Use surface materials which are convenient and easy for walking and cycling. 5.3.6 Grades, widths and clearances should permit easy passage. 5.3.7 Steps and steep ramps should be avoided. (This is especially important for the aged, infirm and prams).
		Public transport: Street cross-sections must cater for public transport where provided.	5.3.8 Construct carriageways wide enough for buses along bus-routes. 5.3.9 Provide stopping bays, seats and shelters.
		Commercial, service and emergency vehicles: Street cross-sections must cater for commercial, service and emergency vehicles.	5.3.10 Construct carriageways wide enough for a low volume of trucks. 5.3.11 Turning bays and culs-de-sac should preferably permit trucks such as garbage vehicles to turn around without reversing.

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
5. ACCESSIBILITY (Contd.)	5.4 Design speed	Car travel: Design speed affects the speed and time of car travel.	5.4.1 Adopt a high design speed consistent with safety and environmental criteria.
	5.5 Residential density	Car travel: The higher the residential density the more car trips will be generated within a given area.	5.5.1 Locate medium and high density residential areas near to local facilities. 5.5.2 Avoid congestion on streets serving such areas as this would tend to increase travel time and reduce accessibility.
		Pedestrians and cyclists: The higher the residential density the more walk and bicycle trips will be generated for a given area.	5.5.3 Locate medium and high density areas, if used, close to local community activity areas.
		Public transport: The higher the residential density of an area the more public transport trips are generated and the better the public transport service which could be supported.	5.5.4 Adopt higher residential densities (around 25 dwellings per gross residential hectacre or greater) if an economic, high standard bus service is required.
	5.6 Allotment design	Car travel: The design of individual allotments affects the degree to which access to the allotment may be provided for cars.	5.7.1 Allotments should be to permit car entry and allow parking unless separate convenient facilities such as grouped garage courts are provided.
		Commercial, service and emergency vehicles: The design of individual allotments will affect the ease of access to the allotment by commercial, service and emergency vehicles.	5.7.2 Allotments should permit access to dwellings by emergency vehicles and commercial and service vehicles should be able to get conveniently close to buildings.
6. PARKING Parking adequate for residents' and visitors' cars should be provided within reasonable distance of dwellings.	6.1 Land-use planning and street cross-section	Parking spaces.	6.1.1 Provide every dwelling with a given number of parking spaces whether on or offstreet; the number is to be decided according to local circumstances. (It will normally be between 2 and 3 spaces per dwelling). 6.1.2 Provide parking space for each dwelling desirably within 50m of each dwelling (treat as a guide only). 6.1.3 Ensure all parking spaces are either (a) accessible by a footpath, or (b) located within a street. 6.1.4 Provide parking spaces arranged in any way the planner thinks fit provided the above principles are generally observed; however, angle-parking is generally to be avoided, especially where traffic volume is high.
7. PUBLIC OPEN SPACE All environmental areas should have a reasonable provision of public open space.	7.1 Network design	Emergency Vehicles.	7.1.1 Public open space, particularly if large enough for organised sport, should be generally accessible to emergency vehicles. 7.1.2 Design public open space as an integral part of the pedestrian walkways and bikeways (both local and metropolitan wide) and other service networks. 7.1.3 Large open space areas should be adjacent to but not abutting on to arterial or collector roads.

7. PUBLIC OPEN SPACE (Contd.)	7.2 Land-use Planning	Public open space, unlike many other land-uses, can take on any convenient shape the planner desires.	7.2.1 Plan some open space as long narrow 'fingers' of land sited in general behind housing blocks to facilitate surveillance from dwellings. 7.2.2 The siting of cluster housing may be considered around and backing on to public open space. 7.2.3 Provision should be made for children's play areas within reasonable distance from all dwellings - say within 100m. 7.2.4 Children's play areas should be located away from moving and parked vehicles.
		Natural environment.	7.2.5 Creeks and other attractive natural features can be incorporated into public open space. Landscaping increases accessibility and attractiveness for recreational purposes.
8. VISUAL APPEARANCE Streets should be attractive and complement the natural environment and other parts of the built environment to provide attractive living areas.	8.1 Network design	Natural environment:	8.1.1 Street networks should visually complement the terrain and natural features.
		The street network affects the natural environment insofar as the street occupies land which may have attractice natural features (eg., creeks, trees, etc.).	8.1.2 Networks may be drawn for maximum advantage of, and to cause least destruction to, existing attractive vegetarian and terrain features (eg., creeks, dunes, etc.). 8.1.3 Scope should be left in suitable areas for tree retention and planting possibly with an eventual commercial payoff (urban forestry).
		Built environment: The street network forms a major part of the built environment.	8.1.4 The design of the street network cannot be isolated from the intensity and type of residential development which it is designed to serve. 8.1.5 The network should permit the planner, through the placement of buildings and hard and soft landscaping, to produce a visually pleasing combination of form and space. 8.1.6 The network should permit the street space to be 'closed' or 'open' according to desired architectural principles.
	8.2 Land-use planning	Natural environment: In defining the uses to which land will be put, land-use planning governs the extent to which the natural environment is conserved, altered or replaced.	8.2.1 If desired, the natural environment may be partially preserved by means of zoning injunctions (eg., tree-preservation orders) and low density zoning. 8.2.2 Creeks and other attractive natural features can be incorporated into public open space. 8.2.3 Geomorphologists and landscape architects may with advantage be used to assist in defining the land-use plan of an area.
	8.3 The street cross-section	Natural environment: Street cross-section affects the extent of clearing natural vegetation and the need for cut and fill.	8.3.1 Narrow street cross-section and carriageways may allow more scope for conserving attractive natural terrain features and vegetation.

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
8. VISUAL APPEARANCE (Contd.)	8.3 The street cross-section (Contd.)	Built environment: The built envornment (both carriageway, buildings and street furniture) is governed to a large extent by street cross-section.	8.3.2 The visual sense of enclosure or openness desired by the architect may be assisted by choice of cross-sectional design. 8.3.3 Trees and soft-landscaping may be used to complement the built form where desired. 8.3.4 Choice of road surfaces should be influenced by visual criteria (eg., gravel may be preferred in some areas and concrete ruled out in others).
	8.4 Design speed	Natural environment: The cut and fill, and the clearance for sight lines required to achieve a high design speed causes more damage to the natural environment than if a low design speed is adopted.	8.4.1 Adopt a low design speed consistent with a tolerable level of accessibility.
		Built environment: The short sight lines of a low design speed permit street space to be enclosed by buildings or hard and soft landscaping features.	8.4.2 Adopt a low design speed consistent with a tolerable level of accessibility.
	8.5 Traffic architecture	Built environment: Any special traffic architectural treatments used will form part of the built environment.	8.5.1 Use sensitive design for traffic architecture treatments to reduce the visual impact on the area.
	8.6 Allotment design	Natural environment: The size and shape of allotments will affect size, shape and placement of buildings and hence the extent to which the natural environment will need to be changed by clearing, excavation and levelling of allotments.	8.6.1 Flexibility in allotment sizes and shapes may enable more of the attractive features of the natural environment to be preserved.
9. SOCIAL IMPACT 9a. Social Mix There should be a dispersion or diffusion of different ethnic, cultural, occupational, age and other background characteristics.	9a.1 Street design and street hierarchy should avoid reinforcement of possible social or ethnic boundaries.	Territorial boundaries: (between socio-economic and ethnic groups)	9a.1.1 Adopt a street hierarchy to separate heavy traffic volumes from living areas so that traffic, noise, danger, etc. do not in themselves constitute boundaries to pedestrian crossing, children's play and other forms of social mixing.
		Chain settlement: (of immigrant groups)	9a.1.2 Locate public space and recreational facilities on boundary lines dividing likely social concentrations. 9a.1.3 Locate walkways, public transportation stops etc. in such a way as to maximise the visibility of all types of residents to each other.
		Market Factors: (availability and location of differently priced housing)	9a.1.4 Avoid flat topography and long straight streets as far as practicable to create spacial concaves for visibility and close contact of residents passing through.
9b. Environmental Quality (equality of access costs) Inequalities in the environmental and planning features of the street system and public space, such as	9b.1 Adoption of a street hierarchy 9b.2 Street design	Class Dispersions: (Residents of lowest income and socio-economic resources tend to live in areas of poorest environmental quality).	9b.1.1 Spread and diffuse community services and facilities to take account of possible social and socio-economic distribution of residents. 9b.1.2 Adopt a street hierarchy which has the effect of setting apart streets carrying the most and fastest traffic from residential areas.
	9b.3 Carriageway geometry 9b.4 Street operation 9b.5 Landscaping	Effect of Age and Life Cycle.	9b.1.3 Provide barriers, cross-overs and other devices to protect from traffic hazards residential areas and areas likely to have high proportions of aged or incapacitated people.

9b. Environmental Quality (Contd.) traffic volume, safety, parking concentration, availability of services, recreational facilities, etc. should be avoided.			
9c. Social Distance New resident groups may conflict with each other on various issues. Attempts should be made to avoid hostility arising between groups by minimising possible social distances.	9c.1 Provision of common or spatial access and facilities for use by pedestrians (walkways, promenades, cycle lanes, parks, playgrounds, open air cafes).	Spatial Orientation: Research shows that Australians have unusually high levels of confinement to internal household space. Lack of facilities in the immediately adjacent external or public space is one factor causing this.	9c.1.1 Permit the reticulation of commercial facilities, such as laundry, food preparation, entertainment, etc. throughout residential areas and within large apartment complexes. 9c.1.2 Integrate the provision of child-care, play supervision, schooling, public health facilities, etc., with street design to facilitate contact and reduce isolation of mothers within private household space.
	9c.2 Re-zone to reduce isolation effects.	Familism: Research also shows that spatial isolation within private household space is reinforced by the limiation of social contacts in leisure or free time to members of the immediate household family or to kin. Mobility: In areas with large proportions of renters, relatively low property values, and low socio-economic profile, there is both higher social and residential mobility. Life Cycle: One factor which cuts across the influence of the above factors is the stage in the life cycle of householders.	9c.2.1 Encourage the provision of functions and services - such as cleaning, cooking and child-care - by commercial and public agencies. 9c.2.2 Encourage the development of co-operative residential services carried out on a non-commercial basis such as co-op food purchasing, commuter car pools etc. 9c.2.3 Encourage the design of housing to reduce high fencing and to facilitate greater visibility and contact through house walls and yards to external (public) areas.
10. COSTS Actions taken in relation to the other performance criteria will affect the cost of developing and servicing an environmental area. Although standards cannot be set to establish an environmental area and its streets, an objective should be set to establish an environmental area which achieves desirable pre-determined standards in other performance measures, at the lowest cost.	10.1 Network design	Allotment yield: Network design determines in part the amount of land used up for streets, and hence the allotment yield. In addition, under traditional controls on allotment size, shape and frontage, rectangular street networks generally give a higher allotment yield than curvilinear networks and in some cases, culs-de-sac. Length of street and utilities per allotment: Network design determines in part the length of street and utilities per allotment. In general curvilinear street layout and culs-de-sac require a shorter length of street and utility lines per allotment than rectangular layouts, especially in hilly terrain. Footpaths, bikeways and property easements may be used to reduce the length of utilities per allotment.	10.1.1 Reduce the land occupied by streets. 10.1.2 Where curvilinear networks and culs-de-sac are used, traditional controls on allotment size, shape and frontage may with advantage be relaxed. 10.1.3 Reduce the length of street and utility lines per dwelling. 10.1.4 Adopt curvilinear layouts and culs-de-sac, especially in hilly terrain. 10.1.5 Use footpaths, bikeways and private property easements where practicable to reduce line lengths.

Performance Objectives	Planning Measures	Mechanism by Which Planning Measures Affect Objectives	Principles Proposed for Implementing Planning Measures
10. COSTS (Contd.)	10.2 Land-use planning	Length of street and utilities per allotment: Land-use planning may allocate street frontage land as public open space and hence increase the overall length of street and other facilities per allotment.	10.2.1 Street frontage should not be used for land-uses which do not require it. 10.2.2 Public open space may be placed away from streets, perhaps behind dwellings.
	10.3 The street cross-section	Allotment yield: A wider street cross-section reduces allotment yield especially when cut and fill is required in hilly terrain. (When cut and fill is needed, an increase in levelled width requires a more than proportional increase in the total batter to batter width.) Unit cost of street: The unit cost of street (per unit length) largely depends on cross-sectional design.	10.3.1 Street width should be the minimum compatible with other requirements. 10.3.2 Carriageway should be as narrow as possible, consistent with demand for traffic and parking. 10.3.3 Eliminate kerbing unless required for pedestrian protection or drainage. 10.3.4 Footpaths should not be provided along the street where the dwellings have well-designed pedestrian access elsewhere (eg., at rear). 10.3.5 Parking areas, when physically separate from the carriageway (eg., parking bays, courts, etc) may be constructed to lower and cheaper standards than the carriageway. 10.3.6 Pavement type should be appropriate to the frequency and mix of traffic. 10.3.7 Surface type should minimise the sum of construction and maintenance cost subject to requirements for safety, comfort and convenience.
	10.4 Design speed	Unit cost of street: In undulating terrain the earthworks and other engineering associated with a high design speed generally increases unit construction costs relative to a low design speed.	10.4.1 Adopt a low design speed especially in hilly or undulating country, but consistent with safety and accessibility.
	10.5 Residential density	Length of street per dwelling: The higher the overall residential density of an area the less the length of street and services per dwelling.	10.5.1 Adopt high residential density consistent with other requirements. 10.5.2 Cluster houses together to reduce lengths of service runs between houses. 10.5.3 Locate high and medium density areas closest to trunk roads and service mains.
	10.6 Allotment design	Allotment yield: The sizes and shapes of the allotments will to a large extent determine the number of allotments obtained from a given area, especially when curved streets are used. Length of street and services per allotment: The length of street and services per allotment is affected quite significantly by the size and shape of allotments, especially the frontage length.	10.6.1 Flexibility in the design of allotment size and shape can assist in increasing allotment yield especially in areas where curved streets are used. 10.6.2 Permit flexibility in allotment frontage length consistent with accessibility and other requirements such as standards for light, privacy, etc. 10.6.3 Use narrow blocks and hammerhead blocks.

8. Cross-intersections should not be used within environmental areas, but all intersections inside environmental areas should be T-junctions. Intersections at the 'gateway' to a residential area may be designed as cross intersections if traffic volumes are such as to warrant signals.

9. Design and construction of street carriageways should be such as to minimise total transport costs rather than to reduce costs for a particular sector such as the local authority. Residents should be allowed some say in the type of construction to be used.

10. Carriageway widths should be only wide enough to carry the anticipated traffic flows. There is considerable scope for using much narrower pavements than current practice allows.

11. Parking provision should be planned according to the particular requirements of the area. Approximately 2 to 3 spaces should be provided per household with some being off street. Parking areas on streets with narrow pavements could be built adjacent to property entrances and verges built to serve as peak parking areas.

12. Design speeds for residential streets should be consistent along the full length of a street. Discontinuous streets and curved alignments could be used for this purpose. The appearance of a street should give visual cues on safe driving speeds.

CHAPTER 7 - DRAINAGE OF RESIDENTIAL STREETS AND AREAS

An important part of the design of a residential street or area is the consideration of stormwater removal. The costs of drainage are significant, the consequences of inadequate drainage can be costly and hazardous, and, because stormwater drainage within a residential area is inevitably a gravity system, the location of drains imposes a constraint on the layout of streets and properties within a resdiential area.

In this chapter, the objectives of urban drainage systems design are first established. Current practice is then reviewed and an alternative approach to the design of urban drainage systems is developed; this approach is briefly discussed and recommendations are made concerning the way in which this alternative approach might be more widely introduced into practice.

Appendix 2 presents a review of the hydrologic factors involved in urban drainage and details recommendations concerning design parameters for use in urban drainage system design.

OBJECTIVES OF URBAN DRAINAGE SYSTEMS

The drainage and flooding characteristics of an area are primarily determined by six general characteristics of the area:-

1. climatic conditions,
2. rainfall patterns and intensities,
3. soil types,
4. ground slopes,
5. vegetation, and
6. proportion of impervious areas.

With urbanisation, direct changes usually occur to the last four of these in that excavations and filling of areas affect ground slopes; areas are cleared of natural vegetation for buildings and roads; new types of vegetation are planted in gardens; natural soils are removed or new types of soil are imported for gardens, etc; and the sealing of roads, construction of driveways and paths and the introduction of houses and other buildings increase the proportion of impervious areas. However, since there are rarely major changes to the ground slopes and soil types to the extent that drainage would be affected significantly, the major changes to drainage occur as a result of changes to impervious areas and vegetation. There is some evidence that urbanisation also causes some change to the meteorological aspects of an area which could affect the rainfall patterns and intensities. However, the effects of these changes on drainage of an area are not yet fully known but are believed to be slight.

Each of these changes has some effect on the drainage pattern of the area and, in general, the changes affect drainage and run-off characteristics both locally and to areas down stream.

The objectives of urban drainage may be defined in terms of safety, efficiency, and environment (see Appendix 2).

Safety: Run-off, flooding and drainage facilities should not present hazards to the safety of people and their properties and drainage facilities should have a fail-safe operation with inbuilt overload capacity.

Efficiency: The capital and maintenance costs of draining an area should not present an undue economic burden on the community. The objectives should be to minimise drainage, construction and maintenance costs and to maximise the potential of the catchment for a residential development by planning for multi-uses of drainage facilities.

Environment: The drainage system should aim to minimise impacts on the hydrological cycle of the catchment area and drainage systems should complement the natural environment. Pollution of streams should be controlled and minimised and erosion of land and siltation of streams should be controlled. Planning of drainage should be comprehensive and include all schemes within a catchment and receiving area. Moreover, the area on which drainage facilities are located should be available for alternative community uses and their characteristics should relieve and not introduce anxieties and insecurities in the community.

The one over-riding factor in most, if not all, of these objectives is that the greater the amount of concentration and velocity of stormwater run-off from an area, the greater its adverse effects tend to be. Thus, in general, the less the interference with the natural drainage characteristics of an area, the easier it is to achieve the above objectives, provided that areas where natural drainage causes flooding are avoided or are bypassed in the daily life-cycle of the area.

APPROACHES TO THE DESIGN OF DRAINAGE SCHEMES

The present drainage practice in respect of roads and houses involves directing water into drainage pipes and removing it from the area. This practice results in the overloading of natural water courses into which the drains discharge, leading to progressively increased flooding as urbanisation proceeds. The combination of building houses and roads and increasing the run-off velocities and flows by piping the stormwater causes an increase in the flow rates which have to be carried by creeks. The increase can be as much as 10 to 15 times the original flows from a given storm.

The 'concrete creek' approach tries to cope with this overload by 'improving' the creek - an expensive process and one which merely transfers the problem further downstream. This practice is criticised on environmental and aesthetic grounds.

An alternative philosophy would be to retard the water flows and to encourage absorption of water, for example, by directing surface flows over permeable areas, rather than allow run-off. The results of such a practice would vary according to the shape of storms experienced because once permeable areas become saturated the run-off rate rises rapidly. The velocities of run-off would still be considerably lower than with the conventional practice.

Although it is not widely practised, this alternative philosophy is not new. For example, the Dandenong Valley Authority, in the eastern suburbs of Melbourne, has established a series of retarding basins on Dandenong Creek. Similarly, in Canberra the National Capital Development Commission is designing stormwater systems for a 3-year storm flow and allowing higher flows to spill in a planned manner onto open spaces.

In comparing these alternative approaches to the design of urban stormwater drainage systems, and assessing the extent to which they meet the above objectives, the following considerations are important:-

1. hazards to human life and property;
2. fail safe operation;
3. capital and maintenance costs;
4. effect on hydrological cycle;
5. effect on the natural environment;
6. pollution of streams;
7. erosion and siltation;
8. system effects;
9. alternative community uses; and
10. community anxieties.

Hazards to Human Life and Property

Present planning and urbanisation philosophies tend to increase the volume, and generally the velocity, of stormwater run-off. Even though people can be prohobited from living in areas where high flows concentrate, it is not always possible to ensure that children will not stray to these areas. In any case, maintenance and service staff will require access to these areas on occasions, including times of high flows. Drainage schemes should therefore be designed such that if people and properties are likely to be endangered by flood waters, adequate warning of approaching danger can be given to allow people, especially children, caught in threatened areas to escape. These aims require that changes in flow volume and velocity be gradual rather than sudden and for flow velocities to be kept to a level which would allow people to stop themselves from being swept along. This is practically impossible to achieve in some areas with tropical conditions.

Present systems, using kerbs and channels at edges of paved carriageways, underground pipes and lined channels, increase the volume and velocity of run-off and introduce significant risks when pipes are large enough for children or maintenance staff to enter them. Only where flat grades are used can velocities in smooth pipes or channels be kept low.

Flows over land on the other hand would tend to reduce both the amount of run-off and its velocity, so systems designed with large proportions of the flow going overland would tend to be safer than piped or channel flows. In most urban situations this is rare and velocities can only be reduced by energy dissipators which in themselves are hazardous to anyone caught in the flow.

Low flow volumes and velocities would lessen the chances of downstream areas being flooded. If flooding did occur, the damage to property would also be significantly lower than with high concentrated flows.

Fail-Safe Operation

Present drainage systems are designed to carry run-offs from storms of an intensity expected to occur within a statistically determined recurrence interval. In residential areas it is usual to design for storms of recurrence intervals of five and occasionally ten years. Consequently when storms of greater than the design intensity occur, the extra run-off causes flooding and damage to gardens, houses and streets.

The alternative drainage policy would be to provide by various means, some overload capacity to control or carry without serious damage the extra run-off from such heavier storms. This can be achieved through the retention of natural drainage features such as depressions, permeable areas and vegetation or by the incorporation of integrated floodways and retarding basins. Open space areas can also be effectively used as safety valves for peak flows from severe storms. The depth of water flow which should occur in these open areas must be small and the water velocities kept low if dangerous conditions are to be avoided.

Capital and Maintenance Costs

The capital costs of conventionally designed drainage systems increase roughly directly with the volume of design run-off. On the other hand, maintenance requirements of these schemes are usually infrequent but when they occur repair costs can be high due to the heavy structural units used.

The alternative system would reduce the size and capacity of the constructed drainage system and hence reduce the capital costs. The resultant higher use of over-land flows may result in more frequent maintenance requirements but, because of the lower flows and velocities, the type of maintenance work required would be relatively simple and inexpensive.

Effect on Hydrological Cycle

The hydrological cycle is the process of evaporation of water into the atmosphere from whence it precipitates as rain. Part of this precipitation runs overland into storage areas, lakes or the sea, part soaks into the ground as groundwater, some of which also finds its way into lakes or the sea, and the balance is either used or evaporates. The principal ways in which this cycle is disturbed by urbanisation are by increasing surface run-off and by lowering groundwater levels.

Run-off is increased by increasing the proportion of impervious areas, and by conventional drainage systems being designed and constructed to remove run-off much faster than the natural situation.

The impervious areas of a development can be reduced by the use of porous pavements and by reducing paved and roofed areas on private properties. The time of concentration of water can be increased by sheet flows across flat or grass areas or by the use of rainwater tanks to store rainwater for household purposes.

Groundwater recharge is reduced when the area of impervious surface is increased or when storm water is removed more quickly than normal. Conventional pipe and channel drainage schemes contribute little to recharge. Alternative schemes which retain natural features and provide for slow removal of run-off would increase groundwater recharge. Retarding run-off in ponding areas would allow water to infiltrate if the soils are porous. If not it may be feasible to discharge the ponded water through a well or bore into porous underground strata.

Effect on the Natural Environment

Native flora and fauna and scenic amenity are all affected by urbanisation. Conventional drainage systems, particularly stream works, do not generally blend with the natural landscape. Alternative schemes would more readily be designed to harmonize with the landscape. They would also take account of natural ponds and would not reduce ground-water, both of which are vital to vegetation and wildlife.

Pollution of Streams

Drainage systems can cause pollution to natural water courses in several ways - stormwater run-off carries pollutants from roofs, pavements and properties. Overloaded stormwater drains can overflow into sewerage systems and either overload treatment works so that effluents are not completely treated, or sewage may overflow into stormwater drainage channels and be carried into streams. Stormwater run-off carries discharge from septic tanks in areas not having water-borne sewerage systems.

With conventional drainage systems, pollutants entering the system are carried quickly to natural water courses with little chance for their removal or treatment. With the alternative system, since both the volume and velocity of run-off is reduced there would be less chance of pollutants being washed into streams. The effect on pollutants is fourfold:-

1. suspended solids settle out of the flow into grassed depressions and retarding basins;
2. dissolved oxygen helps decompose organic matter before the watercourse is teached;
3. pollutants in groundwater infiltration are decomposed and removed; and
4. petroleum pollutants are either removed by vegetation and broken down by bacteria or can be collected in interceptors which would be feasible because of low velocities.

However, since slower over-land drainage would tend to increase the risk of stagnant water, drainage sysems should be carefully designed so that water which might accumulate at any point is not permitted to become stagnant.

Erosion and Siltation

Siltation of streams, reservoirs and dams is a natural consequence of erosion further upstream. Natural erosion of soil occurs in most areas. Urbanisation, by increasing run-off volumes and velocities, and by the removal of natural vegetation and by excavation, tends to aggravate the problem. Conventional drainage systems, by increasing the volume and velocity of run-off, tend to aggravate erosion and concomitant siltation downstream from the point where pipes or lined channels discharge water into natural watercourses. Systems which reduce both the volume and velocity of discharge, while interferring as little as possible with natural ground surface and vegetation, will tend to reduce the problems of erosion and siltation.

System Effects

Drainage schemes designed and constructed such that they increase the volume and velocity of run-off from an area increase the likelihood of flooding downstream areas in direct proportion to the increased flows over the natural flows. To nullify the problems of this increased flooding and the inherent hazards to people and property, two courses of action are generally used in conventional drainage practice:-

1. protect the downstream areas with levees, etc.; and
2. increase the capacity of the stream to make it more efficient at removing the extra run-off, for example, by connecting watercourses.

The first of these is rather a belated approach and in any case can be expensive. The second can have the effect of further increasing peak run-off and merely transferring the flooding problem further downstream.

The alternative approach, if designed such that all drainage scheme designs in the catchment comply with the planning for the total catchment and upset the hydrologic balance to a minimum extent, can ensure that the damage and hazard due to flooding is minimised. This implies that developers of individual sub-areas in a particular catchment would be permitted a stated volume of peak run-off and that their design of the drainage system should ensure that this would not be exceeded. Some concessions may be required to such a policy in areas where the density of housing is high and in areas of high cyclonic precipitation.

Alternative Community Uses

Few, if any, of the components of conventional drainage systems are useful for alternative uses. The enormous investment involved, which is used only when it rains, and the surplus capacity provided makes attractive any proposal which would provide alternative uses for such public facilities when they are not being used for their primary functions.

There would appear to be significant advantages if, in areas where the rise of water is slow, some drainage system components could be used as recreational areas and facilities during fine weather and at times of no run-off. The location and design of open space areas to be used as drainage areas during storms and as recreational areas at other times would improve the use of resources involved.

Community Anxieties

Wherever large drainage pipes exist, open channels run adjacent to houses or fast flowing streams are within the range of children's play areas, parents, and the community generally tend to be anxious and insecure. These types of components are usual features of conventional drainage systems. Alternative systems which result in low volume and slow flows, particularly over-land flows, could help reduce such anxieties.

DESIGN OF A DRAINAGE SYSTEM

In designing an urban drainage system, the area characteristics defined earlier are the design inputs, namely climatic conditions, rainfall intensity, soil type, extent of impervious area in the catchment, ground slope, and vegetation. The design of urban drainage systems, and the influence of the above characteristics on design, are reviewed in Appendix 2. Table 7.1 shows the design features which are appropriate for the various components of the drainage system (the house, the street, trunk flow and stream flow), if a drainage system is designed according to the design philosophy advocated in this chapter.

SUMMARY

In summary, the overall aim of the drainage system should be to protect the area from flooding and ponding of stagnant water while causing no increase in run-off as compared with the natural state. Most existing drainage systems aim solely to remove stormwater as quickly as possible; this is usually expensive and can be environmentally harmful. An alternative approach to the design of urban drainage systems is advocated. It should possess the following characteristics:-

1. The time of concentration for the catchment area - that is the time for water from any part of the catchment to reach the exit point - should as far as practicable remain as it was before residential development.

2. Drainage schemes should operate in a fail-safe manner. For instance, routes for surface flow should be provided (preferably in areas of public open space) for those times when drains are blocked or overloaded.

TABLE 7.1 - DRAINAGE DESIGN FEATURES

Component		Rainfall Intensity			
		Low to Moderate		Moderate to High	
Impermeable Area	Works	Deep Sandy Soil	Clayey Soil	Deep Sandy Soil	Clayey Soil
Low 0-30%	house	discharge onto ground	retarding tanks	discharge onto ground	1. retarding tanks 2. pipes
	street	table drains	combination	table drains	combination
	trunk	overland flow	1. overland flow 2. pipe, low flow	overland flow	1. overland flow 2. pipe, low flow
	stream	natural	natural	natural	1. natural 2. landscape/ protected
Medium 25-70%	house	1. discharge onto ground 2. soak pits	retarding tanks	1. discharge onto ground 2. soak pits	1. retarding tanks 2. pipes
	street	1. table drains 2. combination	combination	1. table drains 2. combination	1. combination 2. kerb and channel
	trunk	overland flow	1. overland flow 2. pipe, low flow	overland flow	1. pipe, low flows 2. pipe where necessary to retarding basins
	stream	natural	natural	natural	1. natural 2. landscape/ protected
High 60-100%	house	1. soak pits 2. retarding tanks	1. retarding tanks 2. pipes	1. soak pits 2. retarding tanks	1. retarding tanks 2. pipes
	street	combination	1. combin-ation 2. kerb and channel	combination	1. combination 2. kerb and channel
	trunk	pipe, low flow	pipe, low flow	pipe, low flow	pipe to retarding areas
	stream	landscape/ protected	landscape/ protected	landscape/ protected	1. landscape/ protected 2. improved creek with retarding areas

NOTES: Numbers 1 and 2 refer to first and second preference options.

3. Drainage schemes should retain the level of water table and the amount of groundwater except where this is required for agricultural purposes or for increasing pondage.

4. Drainage schemes should not pollute natural waterways by sweeping rubbish and road debris into the system or by admitting sewerage overflows.

5. The drainage scheme should complement the natural environment by allowing creeks and ponds to remain in their natural state.

6. Land reserved for floodways and retaining basins (part of the drainage system) can with advantage be combined with public open space and recreation uses.

7. New residential areas and streets should be designed around an area drainage plan. All construction, whether of streets, services or dwellings, should follow and be subordinated to the established drainage pattern.

To facilitate the incorporation into practice of the alternative drainage philosophy advocated herein, demonstration projects could usefully be carried out and research conducted to develop more detailed design guidelines for use by developers and local authorities. The following are suggested for consideration:-

1. Demonstration projects should be undertaken on combined table and subsoil drains, ponding systems, multi-use retarding basis, household retarding tanks, land-scaped floodways and water-courses.

2. Results of demonstration projects should be widely distributed to provide data and induce initiative for designing alternative types of drainage systems.

3. Demonstration projects should be monitored to enable the relative merits of alternative types of schemes to be quantified.

4. The results of current research into estimating rainfall run-off more accurately should be distributed widely as they become available.

5. Studies should be initiated into some particular aspects of drainage systems such as:-

   (a) the effects of urbanisation on the hydrological cycle and changes in the local water balance caused by city growth;

(b) the effect of household retarding/storage tanks on water supply requirements;

(c) the drainage effects of large developmental projects and methods (both administrative and practical) of minimising those that are undesirable;

(d) identification of situations where (household) ponding areas would be more beneficial than larger (area) retarding basins; and

(e) administrative and financial problems of the management of drainage on the catchment-wide basins.

CHAPTER 8 - RESIDENTIAL STREET PAVEMENTS

Pavements used in residential streets have generally been designed and constructed in accordance with principles and standards developed for heavily trafficked highways and rural roads. However, the objectives of residential streets are somewhat different to highways and rural roads. In this chapter, a set of objectives are developed for pavements in these streets. Where appropriate, alternative approaches are advocated and areas where further research into residential street pavement design appears to be needed are highlighted. Appendix 3 treats the subject in more detail.

The design and construction of road pavements in residential streets affect a number of factors. Objectives for street pavements are defined in terms of traffic, safety, efficiency, environment and lifestyle. The influence of each of these factors on pavement design is reviewed below.

TRAFFIC

Traffic loadings are likely to be predetermined by street network design and land use decisions (see Chapters 4 and 5). The pavement designer, in designing the pavement for that level of traffic, must consider the traffic loading, soil types and drainage, the life of the pavement, the type of pavement, and the level of traffic service.

Traffic Loading

There are two issues concerning traffic which affect the design of the pavement - the short-term heavy traffic whilst roads and houses are being constructed and residential areas are being developed; and the design traffic after the area is fully developed. The traffic after development will consist primarily of light vehicles, both private and service, and occasional heavy service vehicles. Not only will the traffic be generally light in weight, but the daily traffic volumes will be low. Accordingly, the heaviest traffic, both in number and weight, which such a street carries will probably occur during the period of construction and area development.

A street designed to carry construction traffic would be more than adequate for the continuing requirements of traffic during the remainder of its service life.

Provided satisfactory arrangements can be made for the short period when heavy construction traffic is in the area, the pavement of a residential street could be designed for the expected longer term light traffic and, accordingly, cost savings may be significant.

Three alternatives are available in relation to the problem of heavy construction traffic:-

1 House and building construction traffic could use temporary tracks and street pavements could be constructed only after most heavy work has been completed. This could cause problems during the winter periods and it would only be a viable alternative in an estate-type development where all (or almost all) houses were constructed before residents moved in.

2. Streets could be formed, but not paved and sealed. Subgrades would be compacted by construction traffic where practicable and the pavement constructed after heavy work has been completed. A temporary thin pavement over the subgrade may be required, but if of suitable material, this would form part of the eventual street pavement as a sub-base. Here again the winter period could be a problem.

3. Street pavements could be constructed for light traffic and separate temporary access tracks provided for construction traffic.

Apart from the different nature of the short-term and long-term traffic which will actually use the residential streets, there is a problem in the way in which design traffic is determined. As mentioned earlier, available pavement design techniques have been developed for highways where the numbers of heavy commercial vehicles in the traffic mix has a significant effect on pavement and pavement life. The formulae and charts for highway pavement design were originally prepared in the U.S.A. and the lowest traffic volumes allowed for was 150 commercial vehicles per day. As Australian rural roads generally have lighter traffic volumes than U.S. roads, the design techniques have been modified in Australia to include roads with commercial traffic volumes down to 45 vpd and in some cases to 15 vpd. In applying these design techniques to the design of residential streets the normal procedure is to use the factors related to traffic volumes of 45 commercial vpd.

It will be obvious that the majority of residential streets would not carry commercial volumes of this order. If the approaches outlined in chapters 4 and 5 of this Report are adopted, the incidence of heavy commercial vehicles on residential streets in environmental areas will average less than 10 vehicles per day. Accordingly the traffic on such streets will be predominantly light private and commercial vehicles, mainly cars, utilities and vans and the traffic volumes would frequently be of the order of 200 light vehicles per day and less. Short roads, culs-de-sac and loop roads may never carry more than 100 light vehicles per day. Accordingly, if heavy construction traffic can be allowed for in one of the ways described above, much lighter pavements than those which are customarily provided can be used in residential streets.

Soil Types and Drainage

Soil types vary in strength and drainage characteristics and the strength of any given subgrade soil will vary according to the moisture present. Drainage of the soil and the pavement material is therefore an important consideration in pavement design.

Usual pavement design practice assumes saturated conditions even though this assumption may not be tenable in all cases. More detailed study of the moisture content which might actually occur in both soils and pavements could lead to substantial savings in costs by reducing pavement thicknesses. Alternatively, the use of sub-soil drainage or moisture waterproofing techniques could be used to lower subgrade moisture content, and thus increase strength, thereby possibly reducing the depth of pavement and, hence, cost.

The alternative drainage philosophy outlined in Chapter 7 would result in an increase in subgrade moisture content and may negate any benefits derived from the above.

Pavement Life

Design criteria currently employed for planning residential streets are not based upon the requirements of those streets. For example, existing design methods imply a much greater than actual incidence of heavy vehicles using these streets. Accordingly, it is necessary to refer to empirical and performance evidence for pavement design paramaters for residential streets. This is discussed in some detail in Appendix 3.

Indications are that reductions in pavement thickness, of the order of 30% below those determined using present practices and criteria, could be achievable without reducing pavement life for lightly trafficked streets.

The element of the street pavement most susceptible to failure is the bituminous surfacing. Bitumen tends to retain its flexibility and ductility longer on roads with high traffic volumes than on roads with very low volumes. Under low traffic conditions, the durability of bitumen is affected by evaporation of volatile compounds, oxidisation by atmospheric oxygen, age hardening, and polymerisation. Each of these factors serves to reduce the life of bituminous surface courses. If the other parts of the pavement are not overstressed by traffic the life of a residential street will frequently be determined by the durability of the bitumen surface binder. Accordingly pavement life should be determined by the expected life of the surface course binder of sealed roads or in multiples of this period allowing for resealing or resurfacing to rejuvenate the failing surface course.

Type of Pavement

A wide variety of pavement materials are used in pavements for residential streets, but in general the specifications and conditions relating to materials are similar to those used for arterial roads carrying heavy traffic. The lighter wheel loads which use residential streets impose considerably lower pressures and stresses on pavement materials and the repetitions of loads are substantially less; relaxation of some of the materials' properties would not impair their performance for these types of streets.

At present, crushed rock is used by most local authorities in Melbourne and Sydney. The increasing cost of such high quality material and the general indication from authorities that lower quality and cheaper materials would serve inadequately, calls for a close examination of the availability and suitability of alternative pavement materials. Some industrial by-products such as slag and ash which are dumped or unused at present may also be suitable. These materials may present some difficulties in their handling during construction but their wider use might be cost-effective. Stabilisation of natural materials and subgrades by using lime, cement or bitumen could also prove satisfactory and economic for the purpose. The use of sub-soil drains and waterproofing could reduce moisture contents in pavements and subgrades and hence improve their performance as pavement materials, but possibly at a higher overall cost.

Traffic Service

Apart from the structural strength requirements of pavements to carry the anticipated traffic on residential streets, the service to traffic, both vehicular and pedestrian, is affected by the surface characteristics of the carriageway. Many soil types commonly encountered in urban areas are prone to be dusty in dry weather and muddy in wet weather. Although dust may not necessarily impede traffic except as it affects visibility, it is a nuisance to the comfort of both residents and to traffic. Pavements in residential streets are therefore required to be relatively dust free and not prone to becoming muddy in wet weather.

In some streets with relatively low traffic volumes the use of unsealed gravel pavements may be feasible; in fact in some areas these are now being demanded by residents. This usually occurs when residents are prepared to accept a lower level of service in relation to dust and mud in order to reduce the level of traffic service to a point which is still acceptable for their limited use but which tends to discourage unwanted through traffic.

Another aspect of traffic service is vehicle operating costs. However, a relatively low proportion of total travel by vehicles is undertaken on purely residential streets and changes in operating costs due to different pavement types would be negligible. Accordingly, conditions which might increase operating costs slightly may be quite acceptable if there were compensating advantages in amenity and aesthetic considerations.

SAFETY

Apart from the effects on safety of dusty or muddy roads as mentioned above, the safety characteristics required of residential street pavements are resistance to skidding and absence of serious irregularities which affect riding characteristics and pedestrian travel. The conventional treatments of providing smooth sealed surfaces will obviously be still generally required for these purposes, but in low volume traffic conditions some pavement materials would be suitable in an unsealed condition.

EFFICIENCY - CONSTRUCTION AND MAINTENANCE

Major economic considerations, apart from vehicle operating costs, are the capital costs of construction and the cost of maintaining the road and street pavements. Capital costs are principally affected by the design life, pavement type and thickness, and the surfacing used on the road or street. Design life and pavement type and thickness have been discussed in the preceding section.

Currently, developers in all States are required by Councils to construct all roads in new residential sub-divisions and under this system the householder pays for the capital cost of the road. There are indications that the Councils demand unduly high standards of construction for residential streets in order to reduce subsequent maintenance which is Councils' responsibility.

The principal cost of maintaining sealed pavement surfaces is the cost of occasional re-seals. On low volume traffic streets the period between re-seals will vary between once every five to ten years and represents a cost of between $700 and $1,150 per kilometre per year.

Maintenance of open-surface gravelled pavements would consist mainly of occasional grading, watering and rolling, patching of potholes, repairing drainage scours, and in some circumstances, the application of dust alleviating palliatives. For lightly trafficked streets, the annual cost per kilometre would generally not be higher than for sealed roads, and in many cases could be considerably lower.

Unduly high costs of street construction is inconsistent with the aim of lowering housing costs. Further, from the new residents' point of view, a high initial road cost can cause financing problems for people with limited savings or income.

A further problem from the residents' point of view is that when the road is constructed by the developer, the residents have no say in the type of construction which they would prefer. There is a significant number of cases where residents have indicated strong preferences for low-cost, environmentally-attractive roads.

It appears desirable that the institutional procedures should be modified to reduce the possibility of over-designing and over-constructing residential streets and to increase the opportunity for residents to express their preferences concerning the type of construction. One possibility would be for developers to be permitted to vary the construction standard of purely residential streets and hence, presumably, the price of individual allotments. Council rates would be higher on those streets which needed more frequent maintenance, thus giving new residents the opportunity to trade off lower initial cost against higher future rates (see chapter 2 for a discussion of standards).

ENVIRONMENT

In relation to the hydrologic characteristics of an area, sealed pavements increase rainfall run-off and reduce ground water infiltration. Unsealed streets, although they may increase run-off in relation to the original natural conditions, would have considerably less effect than sealed streets. Increased rainfall run-off caused by sealed streets also contributes to the pollution of streams and waterways, as discussed in Chapter 7 and Appendix 2. Some research has been undertaken recently into the design and use of porous sealed pavements and the drainge advantages of unsealed streets. The advantages and disadvantages of these types of pavements - particularly their effectiveness and costs - have not been fully established as yet. The promotion of additional research and demonstration projects in the use of these pavements could lead to worthwhile results for use in residential streets.

A second environmental consideration is the aesthetic aspect of road pavements. The implied preference of many people to live in low density conditions reflects in part the preference for an attractive 'rural-type' open-air environment. Street construction practices in new subdivisions on the fringes of urban areas, with regular and straight streets, kerbs and gutters, sealed pavements, etc. and the removal of natural trees and vegetation, destroy any remaining rural environmental characteristics. Belated actions to plant street trees - in regular rows - and to plant garden shrubs and trees is usually not a very good substitute for the natural environment. The use of narrower pavements, with irregular alignments as discussed in earlier parts of this Report, would enable natural vegetation to be preserved. In addition, the use of unsealed pavements in such circumstances could result in a more natural and aesthetically pleasing environment which would add to the social and environmental advantages of an area.

LIFESTYLE

The social amenity of a residential area can be reduced if the street pavements cause anxiety and insecurity to the residents. Such anxiety and insecurity could arise from hazardous street pavements and from inconvenient and unreliable access to properties. Earlier sections of this chapter discussed the ways in which safety, reliability and convenience of a road are affected by pavement design and construction features.

SUMMARY

The following points have evolved from the considerations of residential street pavements:-

1. pavement life is un-related to the traffic;
2. highway type design for heavy traffic is inappropriate for residential streets;
3. thinner pavements than currently specified by many Councils can work satisfactorily;
4. research into the design of residential street pavements is necessary;
5. lower quality materials and testing might be appropriate;
6. the effects of sub-grade moisture to prevent failures in residential streets, and sub-grade stabilisation should be investigated;
7. stage construction related to short-term and long-term traffic anticipated to use residential streets might be effective, efficient and acceptable;
8. pavement design must be related to the design of the whole street;
9. unsealed pavements will be satisfactory and acceptable in many residential streets with low speed/volume traffic;
10. porous pavement should be considered.

These conclusions point to the need to research both the design and operation of pavements in residential streets. There is a serious doubt regarding the validity of pavement design methods, criteria and testing methods related to pavements as they are currently used in Australia. Research is continuing on suitable design methods for heavily trafficked roads, but little is being done for low-volume/low-load pavements.

Research into all aspects of the design and construction of pavements for lightly trafficked residential streets should be undertaken. Particular emphasis should be given to the costs of construction (including materials), the effects pavements have on hydrology (drainage), and the effects of moisture content on sub-grades and various pavement materials.

Subsequent to theoretical formulation, design methods must be tested for in-service pavement performance. Few local government authorities will have the resources to undertake the construction and monitoring of test pavements individually. A co-ordinated program, with funds perhaps made available through the Transport Planning and Research Act, would be necessary.

Since research results would not be available to street designers for some considerable time, the first stage of rationalisation of pavement design would be to adapt and change existing design parameters by relating them to the field performance of pavements of residential streets.

APPENDIX 1

APPROACHES TO COMMUNITY PARTICIPATION

The importance of involving the local community in decisions relating to changes to existing street networks has been stressed throughout this Report.

There are a number of techniques available for involving the public in planning such network changes. These include use of community forums, advisory panels, co-option to council committees, consultation, community development officers, search conferences, and information centres. The characteristics of each of these, together with suggestions as to where each may be appropriate, are given below.(1)

COMMUNITY FORUM

In most neighbourhoods there exist a number of groups and organisations which, while strictly local in orientation, have been formed for very different purposes, e.g. Progress Associations, Chambers of Commerce, church groups, and sports or social clubs. A community forum is a way of organising the interchange of information and ideas between such groups, and between the local council and these groups. Furthermore, there are things which a community forum can do better than the formally convened local council, e.g., it can operate more informally as there are fewer rules and safeguards to be observed.

However, it must be realised that a community forum can only provide an avenue of participation to established and organised groups - groups that, invariably, are articulate in their demands and already have influence with local councils. A community forum will only be attractive to those members of the community who are already involved in some form of community activity. As such, this approach to participation is a chance for such groups and organisations to air their views. It can have no executive function and should not alone be used to justify, or give legitimacy to, a local Council's planning decisions.

ADVISORY PANEL

Groups consisting of knowledgeable people in the community and/or appropriate experts can be drawn together by local Councils to advise on a particular topic or range of topics. Such advisory panels do not have the broader base of the

(1) For further detail see for example A. Sinclair, Public Participation in Transport Planning (in Australia), Occasional Paper No. 20, Bureau of Transport Economics, A.G.P.S., Canberra, 1978.

community forum or search conference, nor do they provide a means of general participation.

CO-OPTION

The power to co-opt non-councillors onto Council committees is useful but it is not seen as providing a channel for participation in any real sense. Co-option cannot be comprehensive and any attempt to make it so may lay the Council open to accusations of partisanship from those not chosen. Co-option is seen principally as a means of allowing contribution by persons of talent who do not happen to be councillors. Under most circumstances, the advisory panel technique is a more satisfactory means of providing a Council with advice and information not available to it directly through councillors.

COMMUNITY DEVELOPMENT OFFICER

The communication channels described so far will generally reach only those people active, at least to some degree, in community affairs. Other methods are needed to reach those people who for various reasons do not normally become involved outside the polling booth. These methods - the information centre, search conference, discussions, etc., - should be managed by a person such as a Community Development Officer.

The responsibility of this type of local government official would be to give information, to receive and transmit reactions and ideas, and to be a link with existing groups or to promote new ones which would provide for the needs of particular groups of citizens and take part in the Council's participation program. It is vital that any such officer be seen not as a mouthpiece for Council propaganda, but as a means of providing direct access to Council for ideas and reactions from local residents and the business community.

Some Councils already employ a Community Development Officer (under a variety of job-titles). Others could do so, on a part-time basis, if embarking on a street scheme and there seems to be scope for neighbouring Councils to co-operate so that one Community Development Officer can 'manage' several schemes. Broadly, the officer's duties would involve running an information centre, organising search conferences, arranging media coverage, discussing the issues and ideas with interested groups and individuals, generating interest and involvement within the community, and organising data collection.

SEARCH CONFERENCE

The search conference is a technique for obtaining the views of people who are not active in community activities. It is structured only to the extent that it identifies specific issues of concern in the neighbourhood as the participants see them. For example, it could well be that streets are not regarded as the most important issue and there could even be indications that a street scheme is not appropriate to the area.

The technique involves selecting thirty or so people to represent most groups, including children and people of different ethnic origins. The conference is held over one or two days in a local hall and would include a session on discussing how people see the area, what it means to them and how it is changing. Such a session is then followed by group discussion of specific issues raised earlier and a plenary session in which groups report their findings. Of course, these findings are recorded and considered in the decision making process.

In using such a technique, it is important that the organisers reach and actively involve individuals and ethnic and socio economic groups who are not normally participants in community planning. Some tangible inducements to become involved may need to be offered to such people. For example, it is necessary to ensure that these possible participants perceive that the outcome and findings of such a conference will have a real effect on the final planning decision. (This is true of all techniques available to foster community participation).

If no concerted effort is made to attract people who are traditionally non-participants, or if the search conference is not structured to ensure that these people are heard (that is, if no means are instigated to help them overcome feelings of alienation or to off-set lack of information), then any such conference will be dominated by the more articulate, more powerful groups in the community. Such an outcome would defeat the whole purpose of a search conference, which is to involve and give a voice to the traditional non-participants.

INFORMATION CENTRE

As the name implies, these are places where people, particularly those not involved through other public participation techniques, can obtain information and explanations or state their views (including objections to proposals).

When street schemes are being considered an information centre should be set up, preferably in the area affected, but if that is not practical then in a prominent position in the shopping centre or near the transport terminals which serve the area. Even if the local authority has a permanent information centre in the Civic Offices it would be well advised to rent a small shop, or place a caravan, in a location which will catch the attention of people who would not normally go out of their way to seek or to give information.

An information centre should not only be appropriately located but also sufficiently eye catching to attract people of all interests and ages, including school children. The displays in the information centre should be attractive and should be designed to ensure that all the ramifications of the proposal being exhibited will be clear to all people and to ensure that real interest is generated.

The information centre should be run by the Community Development Officer or, under his direction, by volunteers from local Progress Associations or other such groups, provided that these volunteers are sufficiently involved in other parts of the participation program to be able to explain proposals and to answer questions.

CONSULTATION

Consultation, both on an individual level and in small groups, is argueably the best technique available to ascertain the needs and desires of those members of the community not normally involved or represented in community affairs. In particular, consultation and discussion with small groups that are homogeneous in terms of ethnic background, socio-economic status, etc., gives an opportunity for the less vocal, less involved groups of individuals to express their views and have their needs understood. And, most importantly, it gives them this opportunity in surroundings and circumstances that are somewhat familiar and, thus, less threatening.

This is not to say that direct and more personalised consultation should be limited to these groups. Discussion with other groups and individuals such as local business people, police and other civil service providers, and others who may have relevant local knowledge and information would also provide the planner with much important data. Care must be taken that these more traditional sources of information and influence do not monopolise the planner's time nor unduly dominate the whole process of community participation.

APPENDIX 2

DRAINAGE OF RESIDENTIAL STREETS

The purpose of this Appendix is to re-examine the case for urban drainage, to assess the appropriateness of traditional techniques for draining residential areas and streets, and to develop a design approach to enable selection of drainage systems which are responsive to safety, efficiency, and environmental objectives.

The functioning of drainage systems is a complex interaction of climatic conditions, rainfall intensity and dispersal, together with the catchment's soil type, slope and vegetation cover. This interaction results in a balance between the effects of flooding and the maintenance of plant and animal life. Residential development causes changes to this balance and the hydrological cycle; the effects are dependent on the drainage method used to cope with stormwater flows.

Traditionally, urban drainage schemes have been designed to maximise flood protection and public health cirtieria. This, however, has usually been at the expense of other less readily recognised long term needs such as downstream channel stability, protection of native plants, aesthetic quality and environmental objectives.

THE HYDROLOGICAL CYCLE

Rainfall, runoff and evaporation is a continuous but random process. There are a number of principles relating to this hydrological cycle. The hydrological cycle is shown diagrammatically in Fig. A2.1.

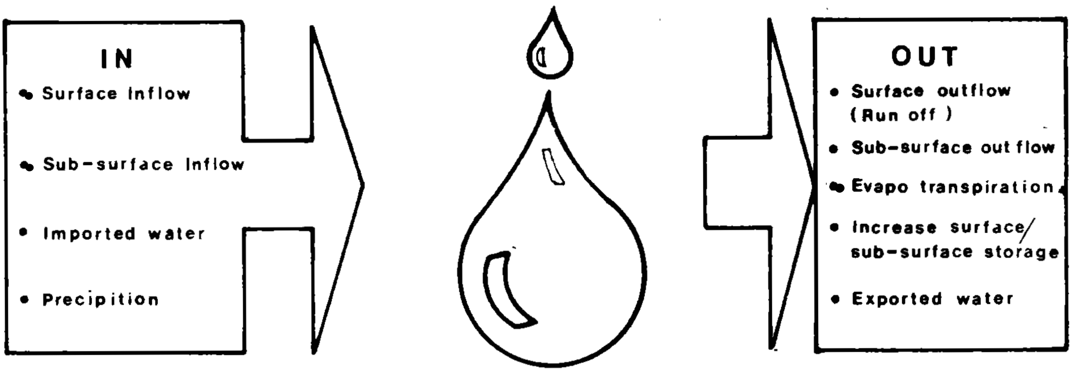


FIGURE A2.1 - THE HYDROLOGICAL CYCLE

A number of studies have been undertaken on the concentration and distribution of storms and have been reported by the Bureau of Meteorology and others. In all cases the results show that:-

1. storm intensity (mm/hour) reduces with increasing storm duration; and
2. probability of occurrence of a storm of a particular intensity decreases with increasing intensity.

Using this information it is possible to estimate the intensity of a storm of a given duration which is likely to be experienced within the catchment in a given return period. Return periods, for residential design purposes, vary from 3 to 100 years depending on the probable consequences of flooding in terms of risk to life and property.

Runoff is a function of the physical characteristics of the catchment (soil type, surface permeability, vegetation cover, stream pattern and pondage) and of the climatic conditions peculiar to the catchment being examined. Concentration of runoff in streams and rivers, the factor of particular interest to urban designers, is a complex relationship between the slope and nature of the catchment and the preceding storm pattern. These complexities have been reduced to a simplified relationship for urban stormwater design in which the catchment is described by two variables.

The first, termed the time of concentration (t_c), is defined as the time required for stormwater from the most remote part of the catchment to reach the point of discharge. The time of concentration is used in determining the peak runoff volumes. The greater the time of concentration and the lower the rainfall intensity, the lower is the peak rate of runoff from a given area. Consequently, if hydraulically efficient stormwater carriers are constructed, the stormwater is speeded up, t_c is reduced, and the peak runoff volumes will be increased.

The second variable, coefficient of runoff, is an estimate of the proportion of total rainfall which eventually occurs as flow. This coefficient represents that portion of the rainfall which occurs as runoff after the requirements of infiltration, interception and evapotranspiration have been met. High coefficients of runoff of impervious surfaces result in comparatively high runoff volume. The usual design method tacitly assumes that a storm of duration t_c will result in peak discharges from an area. More elaborate methods, generally used on large catchments, attempt to estimate the variation in discharge, for storms of various precipation patterns based on rainfall records for catchments of similar characteristics.

URBANISATION AND CATCHMENT HYDROLOGY

Change of land use, particularly from rural to urban, represents a significant alteration to a catchment's hydrological pattern, as indicated in Figure A2.2. There are quite large increases in the absolute quantity of rainfall emerging as runoff and, more critically, in the magnitude of peak discharges. These increases are a direct result of the higher proportion of impervious surfaces - roads, houses and other paved areas - and reductions in times of concentration due to channel and stream improvements associated with residential development, as indicated in Figure A2.3.

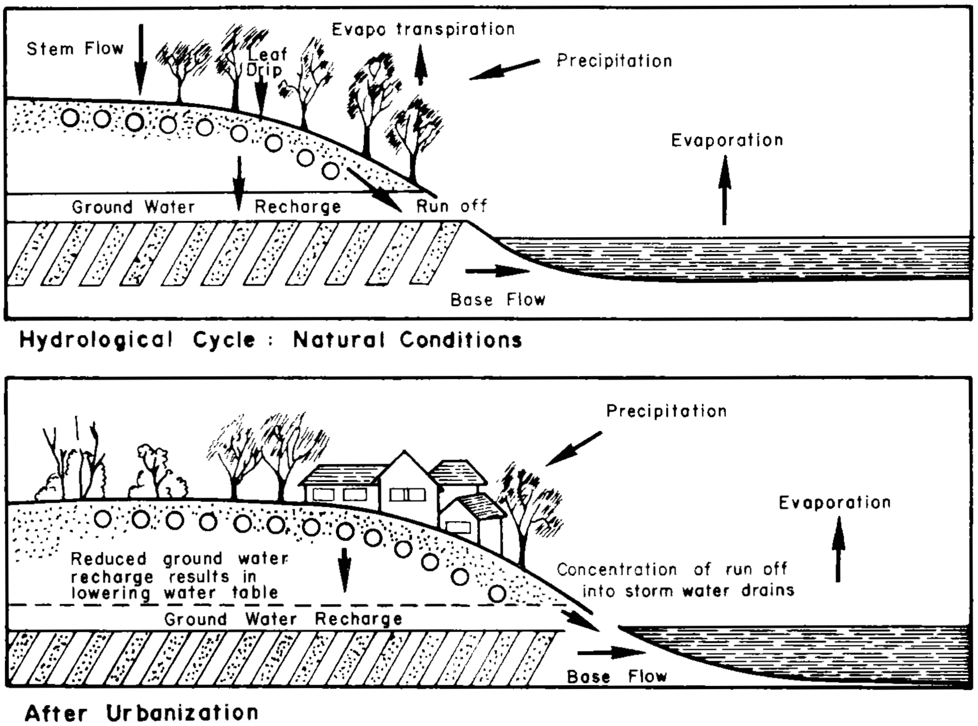


FIGURE A2.2 - ALTERATION TO THE HYDROLOGICAL PATTERN

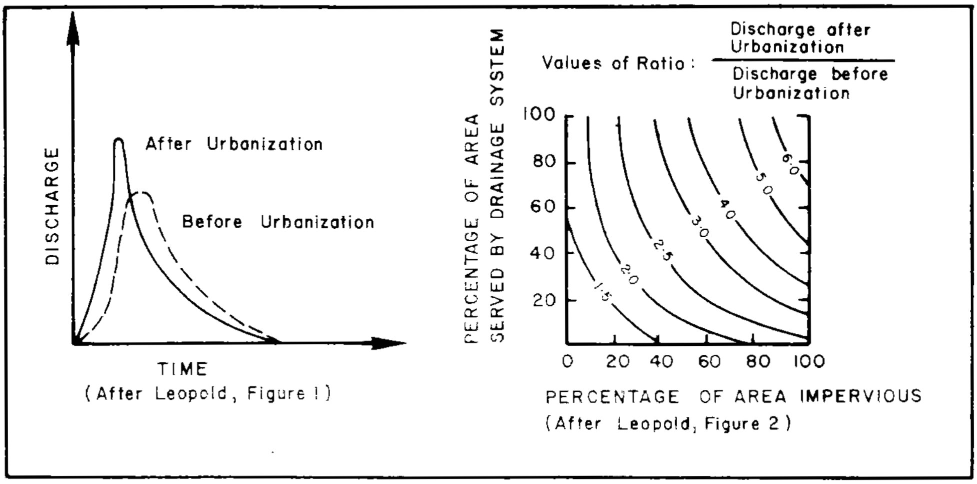


FIGURE A2.3 - EFFECT OF URBANIZATION ON DISCHARGE

The most critical phase in the development of an area is immediately following construction; ground surfaces are compacted and pipes and channels relatively clean. However, as an area matures vegetation cover is replaced, and drainage hardware becomes hydraulically less efficient, with the result that peak discharges are decreased in magnitude and duration; with a concomitant increase in the frequency of pipe/channel surcharge.

The direct consequences of increased runoff are greater flooding risks and downstream erosion. This in turn can result in destruction of vegetation and siltation of flood plains. Rapid removal of surface flow combined with a high proportion of paved surfaces can also reduce the quantity of water which permeates the surface and recharges groundwater aquifers. This has the effect, over long periods of time, of altering micro-climatic conditions and damaging plant and animal life.

A secondary, but important change also occurs in the quality of water discharged by the catchment. Urbanisation changes the pollutants entering a water course as a result of:-

1. washing of accumulated particles from roofs and pavements during storms;
2. seepages of untreated effluent from septic tanks which ultimately reach natural water courses; and
3. the possibility of groundwater and stormwater infiltration of sewers, with the result that sewerage treatment plants are overloaded and effluent treatment quality is reduced, and discharging of raw sewage to stormwater as a result of flooding of the sewerage system.

On the other hand, pollutants from agricultural or pastoral activities will decrease.

THE CASE FOR ALTERNATIVE DRAINAGE SYSTEMS

Drainage improvements associated with current residential development comprise between 25 and 35% of the cost of converting rural land to serviced allotments: for example, \$1650 per block in Canberra and \$1440 per block in Waverley, Victoria (1978 prices). This cost will vary depending on subsurface strata, scale of development and incidence of major stream works. The maintenance costs of these systems are practically negligible since discharge velocities are high and capacities are generally sufficient to avoid serious ponding of water.

Despite the apparent 'efficiency' of conventional drainage systems, there appears to be an increasing concern amongst urban planners to adopt alternative approaches. These alternatives generally aim to reduce the quantity and concentration of stream discharge by retarding flows at various locations throughout the catchment.

Attention has been focused on systems more consistent with natural conditions prevailing before development for two broad reasons.

Firstly, as an attempt to reduce flooding consequences downstream of new development where the potential for river improvements is extremely restricted. An illustration of this approach is offered by a design proposed for an outer urban area in Victoria. The runoff hydrographs shown in Figure A2.4 show that with the system incorporating retarding basins, downstream areas have been given substantial protection. Similarly, though on a somewhat larger scale, the Dandenong Valley Authority in Victoria has constructed retarding dams aimed at reducing the flooding hazards aggravated by rapid urbanisation in the upstream areas of the catchment.

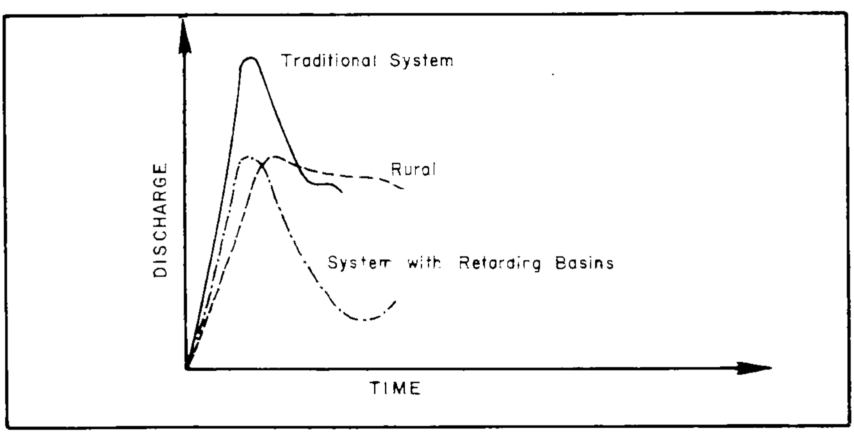


FIGURE A2.4 - RUNOFF HYDROGRAPHS FOR VARIOUS DRAINAGE SYSTEMS

The second issue relates to a concern for the physical environment - particularly the preservation of natural characteristics which can complement the urban landscape. Related to this attutude is an increasing awareness of the potential for combining land uses; e.g. sports grounds and parks acting as retarding basins during intense storms. Varying residential development densities to better suit the topographic and vegetative conditions of the site can also reduce the impact of development on the site.

Previously, drainage schemes have been devised to alleviate localised problems within a larger catchment, whereas the advent of developments which encompass large catchments has necessitated total catchment hydrological planning. This total catchment planning concept has provided the opportunity to develop and adopt methods of alleviating some of the undesirable effects of urbanisation on down-stream waterway systems and communities.

Concern for preservation of natural characteristics, where appropriate and consistent with urban land use objectives, is shared by private and public development authorities.

The remainder of this Appendix is devoted to a discussion of the principles to be followed in the planning and design of drainage systems in response to a wider range of objectives than previously considered.

OBJECTIVES FOR URBAN DRAINAGE

A systematic approach to the design and assessment of alternative drainage schemes requires the formulation of a set of objectives reflecting current and expected community values, which can be translated into evaluation criteria.

Objectives should be reappraised at regular intervals to ensure that community desires and attitudes are adequately represented. As a starting point, however, the following set of objectives arising from discussions with practising engineers is proposed as appropriate and consistent with the broad goal of ensuring that the runoff characteristics of an area have minimal detrimental effects on residential development.

Safety

Minimise Hazards to Life: Hazards to life, resulting from stormflows, are twofold. The first relates to risk of being trapped by unexpected rises in fast-flowing, open, unprotected channels. The second is concerned with the health risks of stagnant pools of water. Measures of effectiveness in relation to thisobjective are depth of flow, velocity of flow and capacity of the system to effectively drain all parts of the catchment.

Minimise Risk of Property Damage: Property damage is a function of depth and extent of flooding; the critical measurement criteria is system capacity, i.e., greater capacity leads to reducing risks. Consideration must be given to the hazard and damage resulting from the system's capacity being exceeded. The system should be capable of controlling these extra flows to minimise any potential hazard or damage. A system's ability to control extra flows is proxied by the extent amd velocity of the flood flows.

Efficiency

Minimise Construction and Maintenance Costs: The objective here is to achieve an optimum balance between construction and maintenace costs. The major difficulty, however, is that although construction costs can be estimated with some confidence the same is far from true for maintenance costs. As yet there appears to be a lack of effective monitoring procedures to maintain a record of operational costs associated with drainage schemes.

Maxmimise Potential of Catchment for Residential Development: Development costs are significantly influenced by drainage costs and, hence, the yield of residential land per unit of drainage cost (hectares per $ or allotments per $) will be an appropriate measure. The multi-use of drainage facilities increases efficiency since land that would have been used as open space can be made available for residential use.

Environment

Minimise Change to the Hydrologic Cycle of the Catchment : By minimising the increased runoff from an urbanised area, the drainage system need not be highly engineered and the external effects of draining that area will also be minimised. Increases in the area of impervious surfaces and reductions in times of concentration are direct measures of performance in regard to this objective.

Minimise Adverse Downstream Effects of Drainage Improvements : This objective is related to the extent to which drainage schemes are considered in the context of schemes for adjoining sub-catchments. Changes from 'natural' discharge magnitude and duration are appropriate performance measures.

Maintain Groundwater Recharge : This aspect is important for the conservation of flora and fauna, and for the maintenance of stream base flows; a continuing supply of borewater can also be important for human use and stock-watering. Increased impervious areas and reduced times of concentration are again direct measures of performance.

Minimise Pollution and Erosion : Through minimising the increased runoff, erosion and the transportation of pollutants can be reduced. The maintenance of slow flow velocities will enable many pollutants to settle from the flow or naturally break down before being discharged into a watercourse. Erosion is similarly minimised by low runoff rates and velocities. Increased runoff rates and velocities are measures of performance.

The above objectives are not necessarily mutually exclusive and in some cases are in conflict. Classification into the broad categories of safety, efficiency and environment have been adopted for this analysis.

EVALUATION OF ALTERNATIVE DRAINAGE SYSTEMS

In the urban scene, drainage schemes comprise house, street, trunk and stream-works; the respective ordering corresponds to the downstream flow of runoff as shown diagrammatically in Figure A2.5.

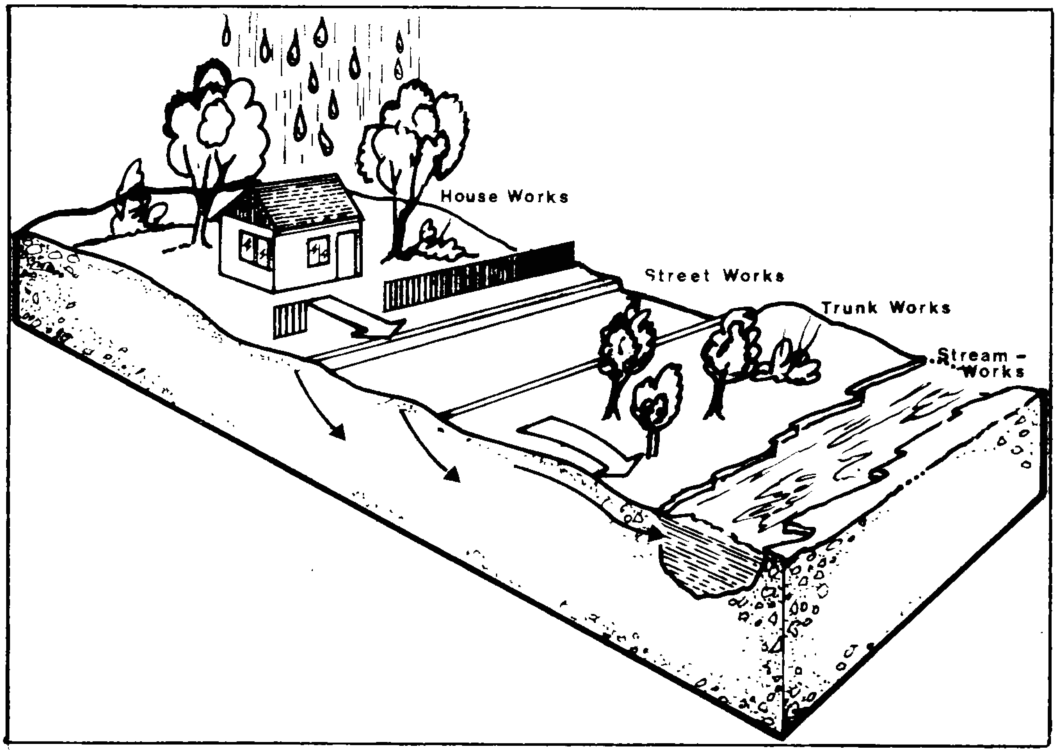


FIGURE A2.5 - COMPONENTS OF THE DRAINAGE SYSTEM

For each of these 'works', there are a number of alternative components available to control the runoff. Tables A2.1, A2.2, A2.3 and A2.4 illustrate the alternatives for each of these four works respectively. Comments on features of each component indicate the performance relative to the objectives of each component, when considered in isolation from the abutting upstream and downstream works.

For the purposes of evaluating alternative drainage systems, the complete system (not just the individual components as shown in the above tables) must be considered. However, it is not necessary to consider all possible combinations of house, street, trunk and stream components as several combinations are inherently incompatible. Thus the evaluation can be performed in two parts - one for house/street work systems and one for trunk/stream work systems.

TABLE A2.1 - HOUSE WORKS

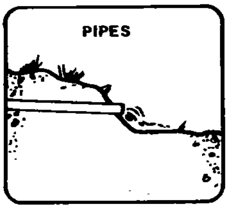
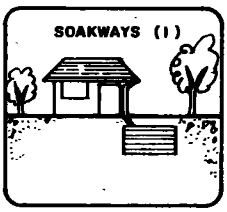
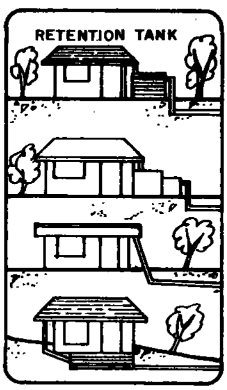
COMPONENT	DESCRIPTION	OBJECTIVE	PERFORMANCE
	Underground pipes take runoff to street or trunk works.	Safety	T_c much less than natural. Peak runoff high.
		Environment	Little overland flow. Lowers ground water table.
		Efficiency	High capital cost. Generally low maintenance costs.
	Runoff flows onto the ground or into a soak pit to soak into the ground. Surface flows could be ponded to increase infiltration.	Safety	Some overland flow if pit not used.
		Environment	T_c not decreased. Peak runoff low. Recharges ground water.
		Efficiency	Runoff from house block minimised. Low capital cost. Low maintenance cost.
	Above or below ground tank collecting roof runoff which is stored for domestic/ garden use and/or discharged through a small pipe to street or trunk works. Flat roofs can be built up to store rainfall for slow discharge or basement storage can be used if the loading on the structure would be too great.	Safety	Little overland flow.
		Environment	T_c minimally decreased. Peak runoff low. Ground water table lowered. Reduces total runoff particularly if water is stored.
		Efficiency	Moderate to high capital cost. Low maintenance Cost. Provides water for domestic/ garden use. Perhaps less water reticulation required.

TABLE A2.2 - STREET WORKS

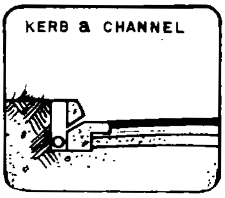
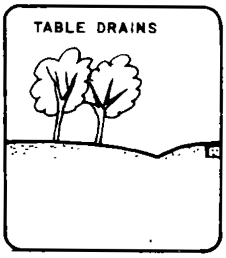
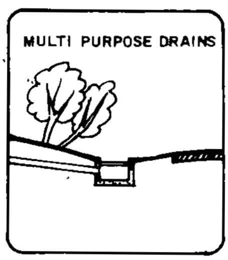
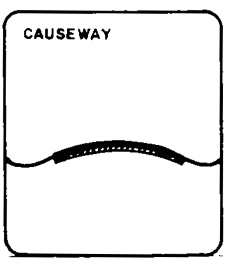
COMPONENT	DESCRIPTION	OBJECTIVE	PERFORMANCE
	Kerb and channel collects road runoff which is discharged into underground pipes (also performs other traffic and pavement functions which are unrelated to drainage). Overflow from blocks is also collected.	Safety	Water removed efficiently. Peak runoff high.
		Environment	T_c greatly reduced. Lowers ground water table. Increases pollution of watercourses.
		Efficiency	High capital costs. Low maintenance costs. Restricts alternate uses of street.
	Grassed channel collecting road runoff.	Safety	Subject to ponding if invert is undulating.
		Environment	T_c decreased slightly. Aids ground water recharge. Aids in reducing watercourse pollution. Can blend into landscape. Probably unsightly if roof runoff is carried due to: (a) weed growth (b) size required to carry runoff.
		Efficiency	Low capital cost. Low maintenance costs (likely to be done by residents). Does not inhibit multi use of street.
	Shallow table drains collecting road runoff above a trench containing a pipe and crushed rock. The table drain takes flash flows while slower flows seep into the trench containing a perforated pipe acting as a subsoil drain into which roof runoff can be directed.	Safety	Not subject to ponding. Peak runoff low (house runoff may need regulating).
		Environment	T_c slightly decreased. Aids ground water recharge (if pipes are not on the trench invert). Aids in reducing water course pollution. Blends into street scape.
		Efficiency	Moderate capital and maintenance costs (surface maintenance likely to be done by residents). Drains pavement base and surface. Scrap materials can be used in place of crushed rock. Does not inhibit multi use of street.
	Pavement on an embankment to project it from subsurface moisture and flooding. No drainage provided for road runoff.	Safety	Ponding probable but only for short periods if soil is porous.
		Environment	T_c not decreased. Aids ground water recharge. Reduces watercourse pollution.
		Efficiency	Blends into street scape. Constructed cheaply and easily (resident participation). Does not inhibit multi use of streets.

TABLE A2.3 - TRUNK WORKS

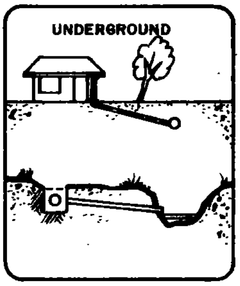
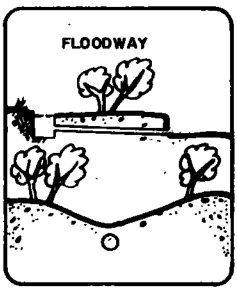
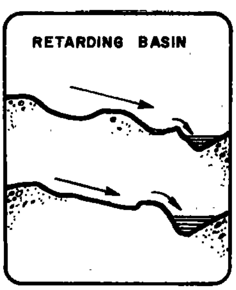
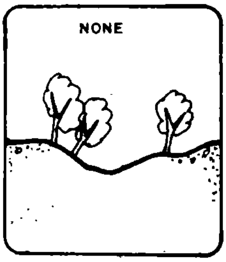
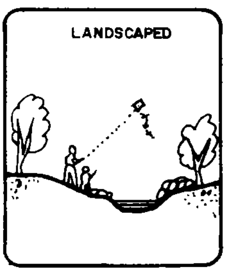
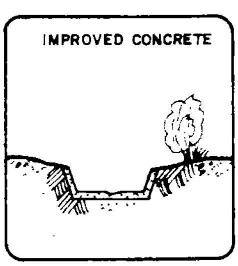
COMPONENT	DESCRIPTION	OBJECTIVE	PERFORMANCE
	Collects runoff from house and street works in pipes and transports flow to water course.	Safety	No provision for flows greater than capacity of pipe. Greatly increased peak runoff. Little overland flow.
		Environment	High capital costs generally. Low maintenance costs but high replacement costs.
		Efficiency	Unavailable for alternative uses.
	House and street works runoff collected by a floodway constructed so that either: (a) all flows travel overland; or (b) low flows are piped underground while the excess from greater flows are taken as overland flows.	Safety	Flows greater than capacity can be controlled. Low surface flow velocity provides pedestrian safety and erosion control. Overland flows follow a designated route.
		Environment	Tc possibly reduced depending on the % of piped flow. Some protection from pollution occurs. Ground water table lowered slightly.
		Efficiency	Moderate construction and maintenance costs. Floodway available for open space/ recreation use.
	Storage dam formed to slow flows or to convert peak runoff into reduced flow over a longer period.	Safety	Large flows can be controlled. Low flow velocities provide pedestrian safety and erosion control. Peak runoff decreased.
		Environment	Tc can be increased. Reduces pollution of watercourses. Maintains ground water table.
		Efficiency	Generally simple and cheap construction with moderate maintenance costs. Available for open space/ recreation use.

TABLE A2.4 - STREAM WORKS

COMPONENT	DESCRIPTION	OBJECTIVE	PERFORMANCE
	Stream left in natural condition.	Safety	Does not itself increase peak runoff. Does not increase chance of downstream flooding. Depth and velocity of flow increases slowly in times of flood. Flows generally slow and shallow.
		Environment	T_c unchanged, but may reduce if increased flows scour the bed. Aids ground water recharge. May be subject to increased erosion. Minimises transportation of pollutant downstream.
		Efficiency	Zero initial cost. Low to moderate maintenance cost. Useful for open space/recreation.
	Landscaping and erosion protection.	Safety	Does not itself increase peak runoff. Does not increase chance of downstream flooding. Depth and velocity of flow increases slowly in times of flood. Flows generally shallow and slow.
		Environment	T_c unchanged. Aids ground water recharge. Protected from erosion. Minimises transportation of pollutants downstream.
		Efficiency	Moderate capital and maintenance costs. Landscaping increases accessibility to open space/ recreation.
	Watercourse Re-aligned if necessary and excavated to an hydraulically efficient cross section. Some concrete lined.	Safety	Increases peak runoff. Depth and velocity of flow increase quickly in times of flood. Flows are often fast and deep. Often unsafe and unattractive for open space/recreation use.
		Environment	T_c greatly reduced. Ground water table greatly lowered. Protected from erosion. Transports pollutants downstream.
		Efficiency	High capital costs. Low maintenance costs. Often unavailable for alternative uses.

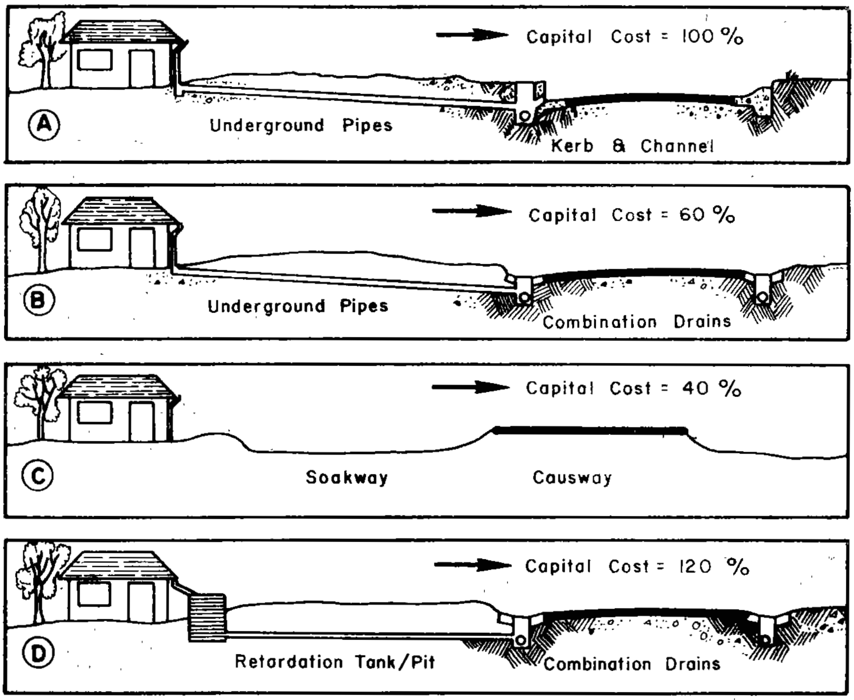


FIGURE A2.6 - ALTERNATIVE HOUSE/STREETWORK SYSTEMS

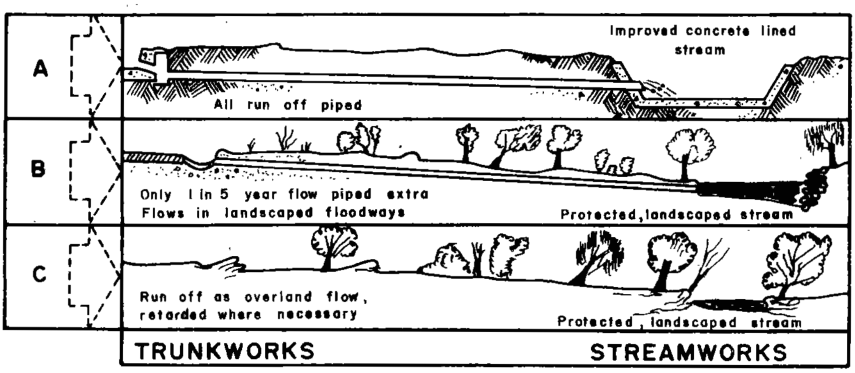


FIGURE A2.7 - ALTERNATIVE TRUNK/STREAMWORK SYSTEMS

Considering first the house/street work system, the four alternative systems shown in Fig. A2.6 are compared. Each may be considered to drain away the runoff of a 5-year return period storm from a residential area comprising ten houses and their access road.

In evaluating these four alternatives, maintenance costs need not be included since they are difficult to determine and depend upon factors external to the system, such as the standard of maintenance, delegation to residents, etc. Similarly, external costs (e.g. pollution) need not be considered in a relative evaluation.

Table A2.5 shows how each of the four house/street work alternatives shown in Fig. A2.6 performs in relation to the objectives developed earlier.

Clearly, there is no objective way of stating which of these alternatives is "best". Selection of one of these systems would depend upon the relative importance placed on each objective; this weighting will probably change with time to reflect different community values and views.

With respect to a trunk/stream work evaluation, the three alternatives shown if Fig. A2.7 have been compared in Table A2.6. For comparison each system is designed to carry the runoff from a house/streetwork system experiencing a once in 100 year storm; 500 m of trunkworks and 1000 m of streamworks are to be constructed; land used for floodways is a small proportion of the total area and unsuitable for residential development - its opportunity cost is therefore assumed negligible. Maintenance costs have not been included for the reasons enumerated above. Similarly external costs of pollution and downstream flooding have not been incorporated.

However, there are a number of variables that affect the operation of particular components of a drainage system, and hence their suitability for inclusion as part of a system. The drainage characteristics of each individual area are affected by the following site conditions:-

1. rainfall characteristics,
2. ground slope,
3. vegetation,

TABLE A2.5 - EVALUATION OF HOUSEWORKS/STREETWORKS SYSTEMS : ASSESSMENT OF THE PERFORMANCE OF FOUR CONCEPTUAL DRAINAGE SYSTEMS [1]

Objective		System A	System B	System C	System D
Safety	Possibility of Stagnant Water	Improbable	Unlikely	Possible	Unlikely
	Likelihood of Fast and/or Deep Flows	Probable	Unlikely	Improbable	Unlikely
Efficiency	Capital Cost (relative to System A)	100%	60%	40%	120%
	Potential for Alternate Uses	Nil	Good	Good	Good
Environment	Likely Groundwater Recharge	Very Small	Good	Very Good	Good
	Extent of Impervious Area Increase	Significant	Some	Some	Some
	Probable Change in t_c	Greatly Reduced	Reduced	Little Overall Change	Reduced Slightly
	Likely Effect on Pollution Transport	Greatly Increased	Slight Increase	Little Transportation	Slight Increase

1. See Figure A2.6

TABLE A2.6 - EVALUATION OF TRUNK/STREAMWORKS SYSTEMS : ASSESSMENT OF THE PERFORMANCE OF THREE CONCEPTUAL DRAINAGE SYSTEMS[1]

Objective		System		
		A	B	C
Safety	Likelihood of Fast, Deep Flows	Most Probable	Possible	Possible
	Degree of Control of Extra Flows	Nil	Good	Very Good
Efficiency	Capital Cost (Relative to System A)	100%	80%	40%
	Potential for Alternative Use	Nil	Good	Good
Environment	Likely Ground water Recharge	Nil	Some	Considerable
	Likelihood of Increased Downstream Flooding	Most Probable	Possible	Unlikely
	Probable Change in t_c	Greatly Reduced	Slightly Reduced	Can be Increased
	Likely Effect on Pollution Transport	Greatly Increased	Increased	Little Transportation

1. See Figure A2.7.

4. proportion of impermeable area,

5. soil type, and

6. saturation from preceding storms.

All but soil type will be affected to greater or lesser extents by urban development, although, once development has occurred, all will have reached a virtual steady state situation.

Rainfall, general ground slope and vegetation significantly affect the detailed design of a scheme; that is, the size and location of drains. Usually these can be varied only slightly, if at all, to affect the regulation of runoff. Impermeable area and soil type drastically influence the type of control to be used; for instance, soak pits will be unsatisfactory in clayey soils unless bores into lower pervious strata can be used or may not be capable of dissipating the runoff from large impervious areas. The influence of these factors is considered in the following Section.

Summary

In summary a highly engineered system should not be adopted just because it is conventional practice to do so. Rather, such systems should be chosen only where they are evaluated as having the best performance relative to the set of predetermined objectives.

Alternative drainage systems are available and should be considered for every drainage project in view of the possible benefits of safety, efficiency and environmental conservation. Despite the lack of technical data regarding some drainage systems, experience and empirical knowledge can be used for their design until supplemented by design principles derived from research.

Design of a drainage system must recognise external effects that result from its construction. The number and magnitude of externalities increase as the magnitude of construction increases. To minimise the external effects as well as improve efficiency, a natural drainage design method should be adopted: this approach is typified by the drainage scheme adopted for the Woodlands project in Texas; as Everhard (1973) explains:-

"As much as possible, runoff will be recharged to the ground, as near as possible to the point where the rain falls. This will be achieved by a 'natural drainage concept'. This concept includes the following:

(i) The existing natural drainage system is utilized to the extent possible, and as much as possible in its "unimproved" state;

(ii) Where drainage channels are required, wide shallow swales (table drains) lined with existing native vegetation are used instead of cutting narrow, deep drainage ditches;

(iii) Flow retarding devices such as retention ponds and recharge berms are used where practical to minimise increases in runoff volume and peak flow rate due to urbanization; and

(iv) Drainage pipes and other flood control structures are used only where the natural system is inadequate; e.g. high density urban activity centres."

Drainage systems cannot be considered in isolation. Individual systems must conform to an area drainage plan in terms of the rates and quality of runoff they are permitted to discharge.

DESIGNING A DRAINAGE SCHEME

The foregoing conclusions point to the need to design drainage schemes to "preserve rather than correct nature" and to harmonize ecology and development. This will be achieved where drainage is controlled as near as possible to its source.

General Consideration

Generally the soil type and the proportion of impermeable area will show whether or not a particular component will satisfactorily control the runoff; rainfall, ground slope and vegetation affect only the detailed design of the component (size, shape, precise location). Relatively impervious soils will mean that components that primarily encourage infiltration (such as ponds) will dissipate the runoff too slowly and would generally be inadequate for the job. Similarly, the volume of runoff generated by large impermeable areas may be considered to be too great to be handled by some components e.g. shallow table drains.

The design process indicated below is a step by step method. The four parts of the drainage scheme (house, street, trunk and streamworks) are each designed separately, but in conjunction with the works upstream and with consideration of the probable downstream works. For each part of a scheme, the most desirable component relative to the drainage objectives is proposed and should be adopted. Where it can be shown that this best solution would operate unsatisfactorily (through inappropriate soil type or insufficient capacity) the next best solution is proposed for adoption.

In many situations one part of a drainage scheme will not be able to give the control required. The maximum control possible should be attempted nonetheless, with the parts further downstream designed to anticipate the deficiency.

All drainage scheme designs must ensure that the control exerted by individual parts aggregate to the required amount of control required from the drainage scheme.

Calculation of Runoff

For small catchments, the "rational method" of runoff estimation has proved satisfactory while for large catchments the "unit hydrograph" method is more appropriate. Both methods are described in detail in "Australian Rainfall and Runoff" (1958). Hydographic/hydrologic methods have been proposed as desirable alternatives to the rational method by the Road Research Laboratory (1962), Wood (1959) and Tonkin (1971). But for small catchments these methods have not shown significant improvements over the rational method. Consequently, for small catchments the rational method is considered suitable at present.

When estimating runoff using the rational method the times of concentration (t_c), runoff coefficients (C) and rainfall intensities should be derived using the procedures outlined in "Australian Rainfall and Runoff". Local experience may indicate the need for some modifications to the value derived. Modifications to the extent of adopting averaged or standardised values of t_c and C must not be undertaken since individual design attention is to be given to each drainage component.

Each part of the drainage scheme is designed to have a capacity sufficient to cope with the runoff from storms of a certain storm frequency. The frequency to be used for each part of the scheme is listed below; if evidence exists for the need for greater protection a design storm of less frequency should be adopted.

1. Houseworks - once in 5 years,
2. Streetworks - once in 5 years,
3. Trunkworks - once in 25 years,
4. Streamworks - once in 100 years.

Houseworks

The objective is to aim for minimum impervious area. The following guidelines are directed towards this objective:-

1st Preference : Roof runoff discharges onto ground surface. Check dams may be needed (but some distance from house foundations) to:

(a) keep the runoff over the pervious area until it infiltrates; and

(b) prevent any increase in overland flows into adjoining properties.

2nd Preference : Runoff discharges into soak pit(s), providing infiltration drains if necessary (only suitable in sandy soils). One must ensure that:

(a) capacity of pit is related to permeability of soil (i.e. proportion of voids);

(b) seepage will not affect buildings at a lower level; and

(c) seepage will not affect house foundations.

3rd Preference : Runoff discharge into retarding/storage tanks above, below or beside the dwelling ensuring that:

(a) capacity of tank determined from capacity = estimated inflow (roof runoff) - permitted outflow; and

(b) tank overflows must be allowed for by ponding or by overland flow away from dwelling.

4th Preference : Runoff removed via underground pipes or smooth drainage channels, but this:

(a) offers no control of runoff and decreases t_c - control must be effected by the downstream components.

Streetworks

Aim for low velocities and minimum impervious area - using porous surfaces for footpaths and road pavements (see U.S. Environmental Protection Agency (1972) for the design of porous pavements). Design of the streetworks should take account of the consequences of flooding when they are surcharged.

1st Preference : Overland flows directed into unlined table drains. The following points need to be watched:

(a) drains must be shallow and flat sided to facilitate maintenance;

(b) drains should be grassed to protect them from scour and to restrict flow velocities;

(c) houseworks pipes or smooth channels should not enter these drains unless it is certain that the increased flows will not deepen or scour the drain;

(d) invert of drain should not be undulating, otherwise water may pond (surface protection or crossings at driveways will be required);

(e) soil under drain should be sufficiently permeable to permit any water that ponds to infiltrate before becoming stagnant.

2nd Preference : Runoff directed into combination drains; the table drain dissipates short duration, high intensity flows while the trench acts as a soakway for less intense storms and the "agricultural" pipe removes the intense house runoff. These points need watching:

(a) the "agricultural" pipe in the trench should be designed to remove only the runoff that will not infiltrate into the soil i.e. the capacity of pipe = estimated runoff volumes - infiltration. The trench should be expected to act as a long soak pit rather than a drain and can be designed in conjunction with a porous pavement;

(b) the "agricultural" pipe should not be laid on the trench invert otherwise water will flow through the pipe rather than infiltrate through the trench invert and walls;

(c) the drain should not act so as to retain excess moisture near the carriageway to the detriment of the pavement;

(d) house connection pipes must be above the "agricultural" pipe and not physically connected to it;

(e) any flows from house connection channels entering the table drain must not scour the drain;

(f) soil used as top dressing within the table drain must be porous to permit infiltration into the trench; and

(g) the drain must be shallow to facilitate maintenance and grassed to reduce flow velocities and scour.

3rd Preference : Road runoff is collected by kerb and channel to be discharged into underground pipes; house connections can be made to either the channel or underground pipes. The following two points are relevant:

(a) design should be in accordance with Australian Rainfall and Runoff. Inlet pits of the side entry type at a maximum spacing of 100 m are favoured. It is acceptable to design for 1 in 5 year flows in the channel to overflow by 2 metres onto the road pavement

(b) this option provides little control of runoff and decreases t_c; control would need to be effected by the downstream works.

Trunkworks

Natural depressions, water courses and water storage areas should be retained if possible, design must take account of the situations when the trunkworks will be surcharged and the consequences of resultant flooding.

1st Preference : All flows are overland along natural depressions retarded where necessary by catch dams or larger retarding basins. Points to watch are:

(a) Scour must be prevented by ensuring that the velocities of flow can be tolerated by the vegetation. For economy of design, these low velocity requirements should not be exceeded by flows of a once in 10 years frequency, but can be exceeded by the less frequent once in 25 years design storm flows;

(b) The design flows should be carried within the floodway reserve, but consideration must be given to greater, less frequent flows. Flows of the once in 100 years storm should be carried in the floodway and gardens of abutting properties, but dwellings should be permitted only above this flood land; and

(c) In the design of retarding basins or areas allowance must be made for maintenance and cleaning. The siting, size and shape should also be sensitive to the basin's intended open space and recreational uses; the public must have reasonable access to it. If the basin is not to have water in it continuously, signing is required to warn people of possible flooding. Subsoil drainage will be required if the area is to be used as a sports ground.

2nd Preference : Minor flows are taken by underground pipes; other runoff is taken as overland flow above the pipes. All flows are retarded where necessary by retarding basins. The route of the floodway would often not be that of a natural depression and would be specifically constructed. Points to watch are:

(a) the pipes should have sufficient capacity to handle the nuisance flows resulting from frequent storms, up to once in 5 year frequency; and

(b) see points (a) to (c) of 1st Preference above.

3rd Preference : All flows from house and streetworks enter underground pipes via inlet pits. Pipes discharge into retarding basin(s) but:

(a) since the pipes reduce the time of concentration, the peak runoff volume, and hence the required retarding basin capaity, will be greater than for the overland flow situations; and

(b) design of the retarding basin(s) should be as above, except that more extensive safety precautions will be required to protect users of the retarding area(s) from the runoff which will rise rapidly due to the pipes.

4th Preference : All flows enter undergound pipes, as above, and discharge directly into the streamworks but:

(a) this option provides little control of runoff and decreases t_c. The onus for control is placed on the streamworks.

Streamworks

Natural water courses are utilised and flows are regulated so that greater floods than natural are most unlikely.

1st Preference : Existing natural water course is left in its natural state. However:

(a) this is suitable only where the volume and velocity of runoff entering the water course are virtually identical to those before the drainage scheme was introduced;

(b) points of entry for runoff may require careful design so that erosion of the stream bed is not increased;

(c) provided that naturally occurring flood damage will not significantly reduce capacity, no repairs should be affected; and

(d) dwellings should not be constructed at levels below the 100 year flood level.

2nd Preference : The natural water course is landscaped and protected at points of likely erosion, but:

(a) the stream bed should remain in its natural state to maintain groundwater levels in equilibrium and to retain long times of concentration;

(b) some regulation must be imposed by the upstream works on entering runoff since the streamworks can provide partial runoff control only; and

TABLE A2.7 - DRAINAGE DESIGN FEATURES

Component		Rainfall Intensity			
		Low to Moderate		Moderate to High	
Impermeable Area	Works	Deep Sandy Soil	Clayey Soil	Deep Sandy Soil	Clayey Soil
Low 0-30%	house	discharge onto ground	retarding tanks	discharge onto ground	1. retarding tanks 2. pipes
	street	table drains	combination	table drains	combination
	trunk	overland flow	1. overland flow 2. pipe low flow	overland flow	1. overland flow 2. pipe low flow
	stream	natural	natural	natural	1. natural 2. landscape/ protected
Medium 25-70%	house	1. discharge onto ground 2. soak pits	retarding tanks	1. discharge onto ground 2. soak pits	1. retarding tanks 2. pipes
	street	1. table drains 2. combination	combination	1. table drains 2. combination	1. combination 2. kerb and channel
	trunk	overland flow	1. overland flow 2. pipe low flow	overland flow	1. pipe low flows 2. pipe where necessary to retarding basins
	stream	natural	natural	natural	1. natural 2. landscape/ protected
High 60-100%	house	1. soak pits 2. retarding tanks	1. retarding tanks 2. pipes	1. soak pits 2. retarding pits	1. retarding tanks 2. pipes
	street	combination	1. combin- ation 2. kerb and channel	combination	1. combination 2. kerb and channel
	trunk	pipe low flow	pipe low flow	pipe low flow	pipe to retarding areas
	stream	landscape/ protected	landscape/ protected	landscape/ protected	1. landscape/ protected 2. improved creek with retarding areas.

NOTES: Numbers 1 and 2 refer to first and second preference options.

(c) regular inspections will be required to ensure that erosion is not occurring, but material brought downstream by floodwaters should be allowed to remain so long as it does not significantly reduce the stream's capacity.

3rd Preference : The stream is constructed for greater hydraulic efficiency (uniform cross-section, possibly lined) and discharges into a retarding area. Points to watch are:

(a) the design of the retarding area would be similar to that outlined above;

(b) flood waters will rise quickly due to the improved channel. Extensive warning to this effect must be provided along the channel and at the retarding area, even if it is not intended to be a recreation area; and

(c) fencing of the facility and hand hold rungs may be required if public safety is likely to be endangered.

4th Preference : The stream is constructed for greater hydraulic efficiency (no retention facilities constructed). This results in:

(a) no control of runoff;

(b) runoff volumes are significantly increased;

(c) a likely requirement to mitigate downstream flooding;

(d) a necessity for measures to ensure public safety;

(e) the need for ingress and exit ramps for debris cleaning equipment; and

(f) the need for protective fencing.

Proposed Drainage Systems

The above considerations are summarised in Table A2.7. Soil type and extent of impervious area will generally affect the suitability of components for a given locale. Intensity of rainfall affects the physcial dimensions of the component; the more intense the rainfall, the greater the runoff and the larger the required system capacity. Although a component may operate satisfactorily, the physical size required to provide sufficient capacity could be unacceptable; wide table drains in a narrow street for example. As a result, the proposed drainage systems presented in Table A2.7 make allowance for these variables.

Ground slope and vegetation have not been incorporated in the table. As far as the operation of a drainage system is concerned, the predominant effects of these two variables will be on the velocity of runoff, thereby influencing the detailed design of erosion protection and retardation measures. In areas where high velocities could occur the proposed system may require modification to ensure compliance with erosion and slow flow objectives.

APPENDIX 3

RESIDENTIAL STREET PAVEMENTS

The purpose of this Appendix is to examine the role of pavements in the development and operation of residential areas, to assess the appropriateness of present design and construction techniques, and to suggest alternative approaches which could be followed in the development of new areas.

Street pavements for the purpose of this discussion are defined as the area on which vehicles travel (the travelled-way) or park; this area in conjunction with adjoining kerbs is generally termed the carriageway. The provision of pavements in residential areas is, in most cases, the responsibility of local governments; the exceptions being in the Australian territories. Local Government Acts, passed by state government, empower municipalities to require developers to construct streets as a prerequisite to subdivisional approval. Alternatively, in areas subdivided before such legislation was enacted, municipalities are empowered to prepare and implement residential street construction schemes subject to public exhibition of design proposals.

In both cases, the capital cost of providing street pavements is borne by the abutting land owners, although there are a few exceptions where street construction has to be financed by local government. Maintenance almost universally is a municipal responsibility and is funded from general rate revenue.

Investment in residential street pavements comprises about 20% of the development cost of a residential allotment. Street pavement costs range from $10 to $35 per square metre of pavement and appears to be inordinately high when compared with maintenance costs estimated to be 15¢ to 20¢ per square metre per annum.

It is in the context of this tendency toward over capitalization in street construction and a call for reductions in the infrastructure costs of urban development that a re-examination of pavement selection is considered appropriate. The annual expenditure on construction and reconstruction of urban residential pavements is estimated, on the basis of results of the Australian Roads Survey, to exceed $12 million. The potential savings derived from the rationalisation of pavement designs could be substantial because of the magnitude, length and cost of residential streets built annually.

PAVEMENT DESIGN AND CONSTRUCTION OBJECTIVES

The broad goal behind the provision of street pavements is to facilitate movement of people and goods to, from and within residential areas in a safe and efficient manner. Movement and interaction is a secondary but vital residential function, the demands for which vary both with time and according to location.

This goal can be translated into a number of objectives as discussed below. These objectives have been derived from discussions with engineers and planners with an interest in residential street design but nevertheless are subject to amendment or addition in response to changes in the expectations and the values of the Australian community.

Access

Undoubtedly, the primary function of street pavements is to provide reliable all-weather access to residential allotments. This objective dominates other considerations. One has only to recall the reaction to the 'heartbreak' conditions of poorly serviced subdivisions which proliferated in the early 1950's.

Efficiency

This objective, in a total community cost sense, has received the least amount of attention in previous developments. Institutional responsibilities associated with street construction provide an incentive to minimise maintenance costs regardless of the consequences in terms of capital and operational costs. Road pavements are prolific users of resources - crushed stone, bitumen, labour and equipment. As the costs of these resources increase, the need to find an efficient balance between capital and maintenance costs is heightened. The performance criterion for this objective is the sum of construction costs and discounted costs of maintaining (including resurfacings and/or reconstructions) adequate access to residential allotments.

Safety

Residential street pavements are used by pedestrians, cyclists and motorists. It is an area sometimes used for play by children and in many cases serves as an all-weather pedestrian path in the absence of footpaths.

Safety objectives are assisted by:-

1. providing non-slip surfaces, which is important for pedestrian and vehicular stability;
2. providing surfaces free of projections or holes which could be hazardous to pedestrians, cyclists and motor vehicles; and
3. the use of different surface textures and colours as a cue to motorists that the street is residential rather than arterial and that the pavement is used by pedestrians and playing children.

Versatility

Traffic type and volume generally change according to the stage of development reached within the residential area serviced by a street. The three types of traffic in a developing area are:-

1. relatively heavy vehicles associated with road and abutting house construction;
2. mixture of builders' trucks and private cars; and
3. mainly private cars with occasional emergency, delivery or service vans and trucks.

A pavement will carry the third type of traffic over the majority of its life. From a 'typical' outer suburban residential area, around 10 vehicle trips per day per residence can be expected (see Chapter 5). From a 100m long street, traffic volumes will be about 200 vehicle trips per day. If correctly planned, heavy non-local traffic is prevented from using the street;

perhaps on average fewer than one reasonably heavy truck per day would enter. Hence, the pavement should be designed to serve light vehicles which comprise the vast majority of trips, accepting increased maintenance during the relatively short period of heavy truck usage while the dwellings are being constructed.

Drainage

As the proportion of impervious surface in an area is increased, the volume and intensity of stormwater runoff is correspondingly increased and greater drainage capacity is required. In addition, the impervious surface of sealed pavements allows accumulated pollutants to be washed from the road surface into drains and thence to natural watercourses. (See 'Drainage of Residential Streets' - Chapter 7 and Appendix 2.) Desirably, the pavement should be designed to cause as little change in natural conditions as possible. Every effort should be made to increase the time of concentration by using shallow overland flow, pondage or other measures where appropriate.

Environment

The aesthetic appeal of a street is strongly influenced by the type and extent of its pavement and by the treatment of the pavement edges and verges. Quantitative performance measures are difficult to identify although area and colour are known to be determinants. Visual impact should, however, be a consideration in the selection of pavement types and must be related to individual streets since the impact will be different for each environment.

Multiple Use

Residential streets are characterised, at least in well planned subdivisions, by low traffic volumes and a low incidence of parked cars. Whilst still undesirable from a safety point of view, the street reserve and the pavement are highly accessible to children and will be used as play areas. This is often preferred by parents to the use of reserved play areas if they are farther from the dwelling.

PAVEMENT DESIGN METHODS

This section provides a general model for road pavements in terms of physical components, structural behaviour and interaction with physical environments. The following description is a somewhat simplified summary of sophisticated design techniques which have been derived from many years of empirical and theoretical examination by a large number of organisations. Hence, the concepts will be well known to practicing road engineers.

Road pavements in practice consist of layers of mechancially placed, granular materials over-laying excavated natural subsurface material (subgrade) and held in place by mechanical compaction (see Figure A3.1).

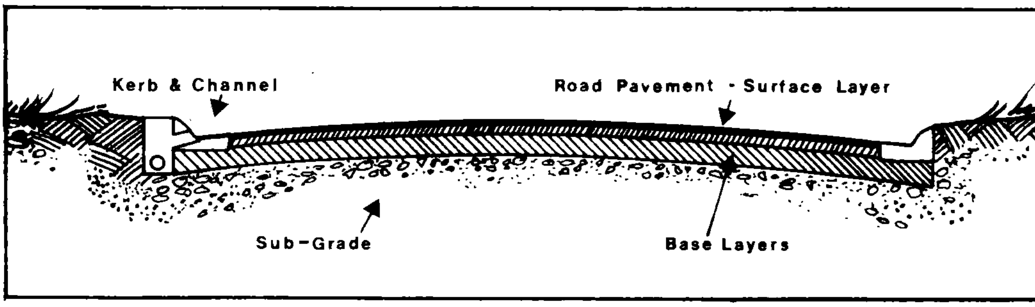


FIGURE A3.1 - PAVEMENT COMPONENTS

The surface and in some cases the upper layers of the pavement are generally bonded by bitumen or cement to provide an even, wear resistant surface. Naturally occurring materials, sometimes strengthened by the addition of lime or cement are used in the base or subgrade.

The performance of each layer in a pavement is a function of:-

1. the magnitude and frequency of wheel loads on the pavement; the failure rate of pavements increases with increasing repetitions of load. Some age hardening of bituminous binders does occur but this has an insignificant effect on the life of the pavement except where there is almost complete lack of traffic;

2. the strength of the subgrade material; the total required thickness of all layers being a function of the strength of the subgrade.

3. the moisture content of the pavement and subgrade materials; this might be the natural moisture content or an increased moisture content due to rain water entering through cracks in the surface or water from underground pipes.

Road pavement design methods commonly used are empirical and may be grouped under three headings:-

1. California Bearing Ratio (C.B.R.) based methods. These are used widely for high grade road and airfield pavements and are based on experience with roads heavily trafficked with vehicles with high axle load and high tyre pressures (e.g., Victorian Country Roads Board Bulletin 26, Road Note No. 29). Design charts derived from empirical data relate the sampled C.B.R. value to a required pavement thickness for given traffic loadings.

2. Group index methods (e.g., N.S.W. (DMR) Department of Main Roads, MR Form 76). With these methods laboratory tests undertaken on subgrade samples indicate the index properties of the subgrade. Empirically derived formulae then relate these properties to the thickness of pavement required; these vary according to the volume of heavy traffic expected.

3. Experience based design rules. Subgrade materials are divided into broad soil groups such as gravel, sand, silt and clay and the pavement thickness provided is based on the local behaviour of pavements constructed overlying each particular soil type.

Generally design criteria have been developed in response to the problems created by high volumes of truck traffic. The repetition of high axle loads has been identified as the prime reason for pavement deterioration and failure and, consequently, designs have been aimed at achieving strengths to withstand the expected number of heavy vehicles which will use the pavement during its design life.

Formulae and charts for highway pavement design originated from the U.S.A. where the lowest design traffic volumes used are 150 commercial vehicles per day. As Australian rural roads generally have lower volumes of traffic, the range of the design charts has been extended in this country to include roads with commercial volumes as low as 45; and in some cases 15 commercial vehicles per day.

The standard axle load generally adopted for design purpose is 8160 kg. The axle loads which frequently occur in low volume streets, range from 400 kg to 1,000 kg; thus the 'destructive effect' will be very small compared to the standard loads. With the low volumes of traffic typical of residential pavements the effect of normal traffic loadings would be less than one standard axle load per day based on estimates of the 'destructive effect' (Solomon, 1970 and Currer, 1974).

Design methods which are based on the incidence of heavy vehicles are not appropriate for residential streets when the numbers of such vehicles are so low. A different design approach is required. Peattie (1974) concludes that "it is obvious ..... that the damaging effects of private cars are insignificant ... in the assessment of design and performance".

This conclusion was also reached by Scala (1970). After examining residential streets in two areas of Melbourne he concluded "..... it is possible to conclude that traffic has ..... a negligible effect on these pavements. However, age does appear to be significant". Again this is borne out by the results of the Australian Roads Survey 1969-74. From sample surveys carried out in capital and major provincial cities, no correlation was found between the reported lengths of structurally deficient residential roads and the traffic volumes using them.

An appreciation of relevant factors - subgrade properties, construction methods, material characteristics, etc. - will enable a pavement to be designed which will perform satisfactorily. However, it is considered that often the pavement provided will be thicker, and hence more expensive, than is necessary to give it a reasonable life.

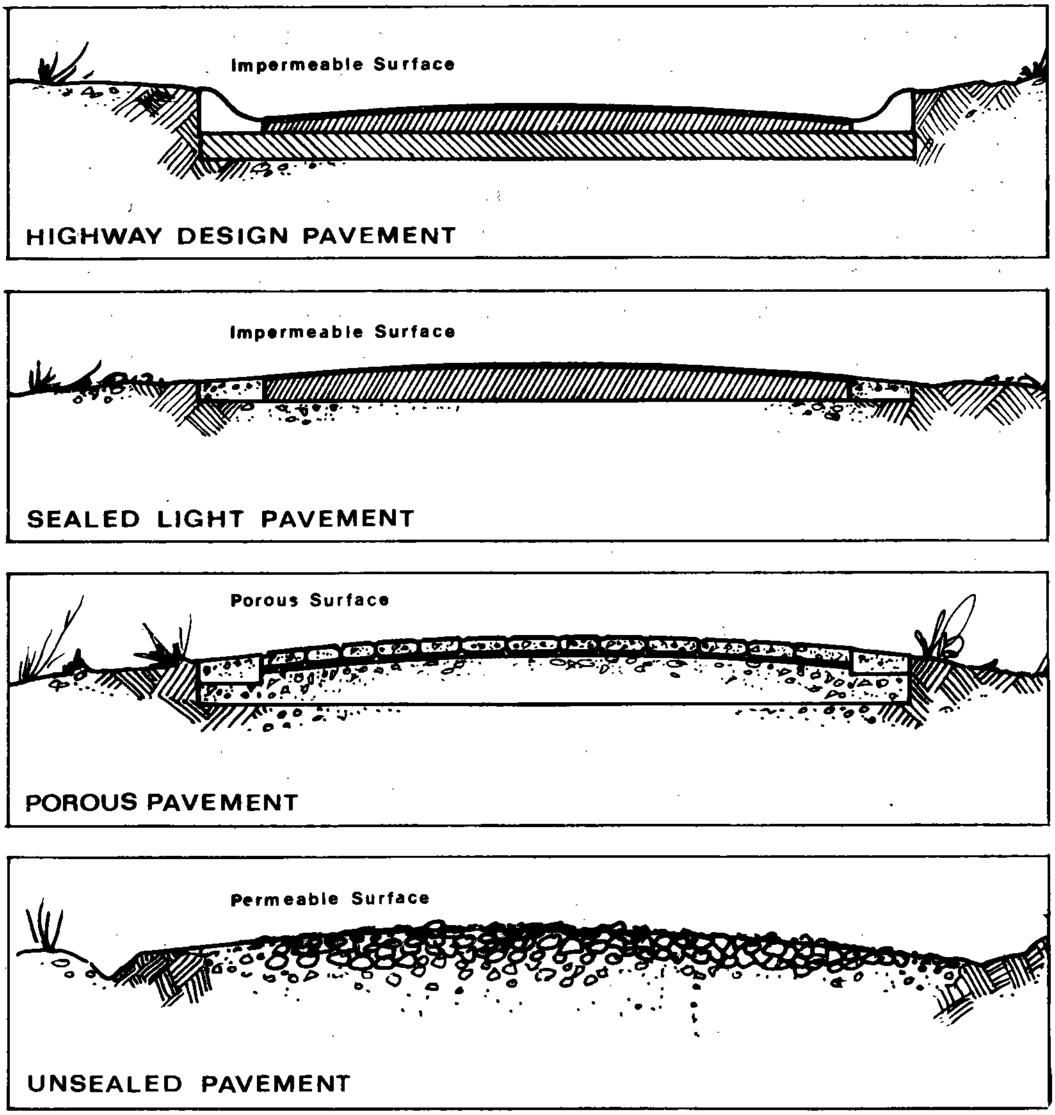


FIGURE A3.2 - PAVEMENT TYPES

There is a definite need to quantify the criteria used in pavement design in accordance with the requirements of residential streets. In particular, the estimation of subgrade strength and prediction of equilibrium moisture content and their relation to the required pavement will determine thickness for residential streets.

PAVEMENT TYPES

This section discusses types of pavements which are currently used, or proposed for use, in residential streets, and examines the performance of these pavements in terms of the objectives outlined above. The four types considered are 'highway design' pavements, sealed light pavements, porous pavements and unsealed pavements (shown diagrammatically in Figure A3.2).

'Highway Design' Pavements

The dominant features of this type of pavement are sealed impermeable surfaces over layers of granular material of varying quality. Pavement thickness is based on design curves derived from experience with pavements used on major arterial roads which have a relatively high incidence of laden trucks. In residential streets, kerbing (probably kerb and channel) is required to support the pavement edges; alternatively shoulders may be provided.

Most objectives are achieved through the use of 'highway design' pavements. They provide a high standard of all-weather access, smooth safe surfaces, have multi-uses and are available for use by pedestrians and bicyclists, but are deficient as far as cost efficiency and drainage are concerned.

An indication that this type of pavement generally results in overdesign is substantiated by the observation that residential street pavements have suffered considerably less damage than arterial roads. As part of the Australian Roads Survey 1969-74, an assessment was made by the road authorities of the predicted structural condition of pavements, in the capital cities as at June, 1979. Table A3.1 compares the proportions of residential and arterial streets forecast to be structurally deficient in 1979.

TABLE A3.1 - ESTIMATED PAVEMENT STRUCTURAL DEFICIENCIES AT JUNE, 1979

City	Deficient Residential Streets (% of length)	Deficient Arterial Roads (% of length)
Sydney	24	59
Melbourne	13	25
Brisbane	27	22
Adelaide	27	33
Perth	8	23
Hobart	13	15
All State Capital Cities	17	35

It can be seen that residential streets are much less prone to failure than are arterial roads.

Similar indications of relatively over-designed pavements are provided by the information obtained from the Residential Street Survey conducted as part of the present study. Variations, in the required minimum pavement thickness from 200mm to 300mm, were indicated for adjacent municipal authorities, while variations, from 220mm to 330mm, and in one case 300mm to 450mm, were indicated for municipalities having the same general soil types. The conclusion is that more conservative authorities are passing on unnecessary road construction costs to the consumer; pavement reductions in the order of 30% could apparently be achieved in many municipalities without reducing pavement life.

Although pavement failures in residential streets are infrequent, a most common cause is claimed to be the occurrence of excessive moisture in sub-grades and base layers, resulting in a loss of structural stability. However, since the sealing of pavements followed by adequate maintenance, particularly repairs of road openings for services, should protect lower layers from moisture infiltration, allowing for soaked subgrade conditions probably leads to excessive thicknesses and inefficient investment in road construction.

Sealed Light Pavements

Comprising a prepared subgrade, nominal thickness of base material and an impermeable smooth surface, these pavements will be suitable for lightly trafficked streets. So long as the subgrade is not very weak, pavements of the order of 100mm compacted thickness of base material and a bituminous seal will suffice. Pavement support by kerbing, either pitchers or concrete, is not required if some width of shoulder is constructed.

Light pavements have been used, to a limited degree, based on experience of local conditions. For example, around Adelaide many pavements of 100mm thickness were constructed prior to changes in the South Australian Local Government Act. These pavements are similar in form to highway design pavements except thinner layers of gravel have been used. Although some structural deformation can occur the street will achieve most of the proposed objectives, such as quality of access, multi-use and safety.

Performance in regard to drainage is similar to highway design pavements. In addition to possible reduction in costs through the use of thinner pavements there is the potential to reduce construction costs further by the judicious use of lower grade materials. Current highway design methods usually require the use of high quality construction materials with resistance to crushing, weathering, abrasion, loss of adhesion, cracking and plastic deformation on the basis of empirical evidence from experiments with high wheel loads.

Because of the demands of the building industry generally and limitation of quarry sites for environmental reasons, the supplies of good quality rock are in short supply. Hence, the use of "second class" material such as sandstones and shales should be considered, each material being tested for its suitability as a pavement material. Shales need special caution due to the possibility of deterioration under sealed surfaces. Also, a number of waste products (e.g. slag, ash, etc.) could be used separately, or blended with naturally occurring materials for use in residential pavement construction. The stabilising of road materials with lime, cement and bitumen may also be an efficient means of providing base courses of required properties.

With currently designed pavements, the initial construction costs are high at around $14 per square metre (though, reportedly ranging from $10 to $35 per square metre) while maintenance costs are low at about 15¢ per square metre per annum. Adoption of thinner pavements may necessitate somewhat greater maintenance, although this appears unlikely provided that drainage is adequate and the surface is not allowed to deteriorate. The cost of maintaining sealed pavement surface is generally the cost of occasional reseals, On low traffic volume streets this will vary and range between once every 5 to 10 years approximately. This can represent between $700 and $1150 per year per kilometre of street (that is, 9¢ to 16¢ per square metre).

Significant cost savings are possible ; currently however, there is limited knowledge of the performance characteristics of light pavements to develop reliable design methods. However, it is likely that since existing pavements perform so well under residential traffic conditions, considerably thinner pavements will serve equally well, particularly if surface durability is a governing factor.

Porous Pavements

Porous pavements are constructed of materials which will permit rainfall on the paved area to flow through the pavement and enter the underlying subgrade The subgrade must be sufficiently permeable to enable the pavement layers to drain in a reasonable time.

Porous pavements are laid on a permeable base or sand; the thickness depends upon the volume of water to be stored; that is, the reservoir capacity. Efficiency of construction can be increased by utilising second class or waste materials for the base course (for example broken bricks or ceramic wastes).

Bituminous surfaces can be formed from an open-graded mix; mixed and laid by machines customarily used for constructing conventional bituminous concrete pavements. A substantial reduction in drainage runoff volumes ensues from the water retention properties of the pavement; groundwater recharge is also considerably increased.

All porous surfaces reduce the effect of pavements on an area's hydrology by storing much of the water that falls on the pavement; this water then soaks away. Though stormwater runoff will be increased by all forms of paving, the degree of increase is significantly less than for impermeable pavements. Pollutant transportation is also reduced since pollutants are taken into the pavement by the rain water and either breakdown naturally in the pavement or are taken by the infiltrating water into the sub-soil.

In streets, where pavements are mainly required to provide dust and mud-free conditions, porous sealed pavements would be appropriate. The U.S. Environmental Protection Agency (1972) has researched the design and use of porous pavements. Porous pavements are not only advantageous hydrologically, but can also result in significant cost savings. These savings accrue through the elimination of kerb and channel and through a reduction in the capacity required of the artificial drainage system. Rougher surfaces, associated with some porous pavements, will however reduce the performance of these streets in relation to other uses such as play areas and pedestrian routes. To some extent, this disadvantage will be compensated by the opportunities to provide more aesthetically pleasing designs, through the use of coloured, and usually softer materials.

Porous bituminous surfaces provide a smooth surface similar to impermeable surfaces, and are therefore available for alternative uses.

Unsealed Pavements

This type of pavement is characteristic of a large proportion of rural and outer urban roads in Australia, many of which perform satisfactorily. Such pavements can be either of natural surface, or formed to some extent and gravelled; in many locations a nominal 50mm of gravel would generally be sufficient. Adequate surface drainage of the pavement is important. Although most stormwater will infiltrate through the pavement, in flat areas table or subsurface drains may be required to remove runoff which would otherwise accumulate. Construction economy can be achieved through the use of second class materials (e.g. shale and sandstone), or industrial waste products (e.g. slag, ash, broken concrete).

Stage construction, although frequently used in rural areas, is not normally adopted for urban residential streets. However, with unsealed residential street pavements, opportunities will exist for stage construction and could prove efficient in two ways. First, cost of constructing the ultimate pavement can be reduced by selecting a pavement thickness consistent with expected car traffic. Second, if heavy construction traffic is a significant factor, stage construction will allow correction of failures after initial use by heavy traffic has ceased.

In some areas local resident groups have opposed the reconstruction of existing residential roads to higher standards. Demands by some residents are for the roads to remain unsealed. This is satisfactory in short streets, but may not be if large volumes of traffic are expected; dust is created and becomes a nuisance to both the residents and motorists. Mud is also a nuisance, since minor ponding will probably occur. However, the opposition by residents to conventional pavements indicates that at least some sections of the community want a lower level of service in order to protect the amenity of their environment through more natural street-scapes, discouragement of fast traffic, and lower costs.

One disadvantage of lower standards of access, which is probably not recognised by residents, is that of increased vehicle operating costs. On high quality sealed pavements vehicle operating costs are about half those on unformed roads and about 80% of the costs on gravel pavements. However, as a relatively small proportion of total vehicle travel is undertaken on minor residential streets, slight increases in operating costs are probably acceptable if offset by gains in amenity and aesthetics.

Maintenance of open surface (unsealed) pavements will mainly consist of grading, rolling and patching of potholes or drainage scours after storms. If rutting or corrugations are likely to be a problem, consideration could be given to reducing maintenance by stabilising the surface with commercially available rock or soil binders. For lightly trafficked streets maintenance costs are estimated to be only marginally higher than for sealed roads and in many cases total costs could be considerably lower.

SUMMARY

In summary, a number of conclusions have been drawn from the foregoing discussion on the design of residential street pavements:-

1. Other than methods based on highway design practice or experience, no recognised design method exists for lightly trafficked pavements.

2. The practice of designing pavements from considerations of traffic only is inappropriate.

3. The use of highway design practices generally leads to over-design and economic inefficiency; pavements thinner than required by many municipal authorities perform satisfactorily.

4. Unsealed pavements are suitable for streets where traffic speeds will be low.

5. Porous pavements may be used where subgrades are suitable. These surfaces could be used to good affect for short roads. Cost savings of between 10% and 30% with little if any increased maintenance, are possible when compared with the construction of an impervious pavement and associated drainage facilities.

6. The efficient use of resources for pavement construction requires investigation. In particular, the minimisation of capital and maintenance costs over the actual life of the pavement, the suitability of stage construction, and the use of second class or waste materials are possible ways in which economies may be affected.

Tentative guidelines developed from the findings of the preceding analysis are presented in Table A3.2 to provide the practising engineer/planner with information on which design decisions can be based.

TABLE A3.2 - PROPOSED USE OF TYPES OF PAVEMENTS IN RESIDENTIAL STREETS

Natural Conditions			Street Type (1)		
Soil Type	Topography	Rainfall	1 & 2	3(a)	3(b), 4 & 5
Sandy	Flat (<3%)	Low	HD (2)	1. Unsealed (3) 2. Light	1. Unsealed 2. Light
		Moderate	HD	1. Porous 2. Light	1. Unsealed 2. Porous
		High	HD	1. Porous 2. Light	1. Unsealed 2. Light
	Hilly (>3%)	Low	HD	1. Unsealed 2. Light	1. Unsealed 2. Light
		Moderate	HD	1. Porous 2. Light	1. Unsealed 2. Porous
		High	HD	1. Porous 2. Light	1. Porous 2. Light
Clayey	Flat (<3%)	Low	HD	Light	1. Unsealed 2. Light
		Moderate	HD	Light	Light
		High	HD	Light	Light
	Hilly (>3%)	Low	HD	1. Light 2. Highway	1. Unsealed 2. Light
		Moderate	HD	1. Light 2. Highway	1. Light 2. Highway
		High	HD	1. Light 2. Highway	1. Light 2. Highway

1. Street types defined in Table 5.1 as follows:-
   1. Collector
   2. Major Local
   3a Minor Local (Loop)
   3b Minor Local (Cul-de-sac)
   4. Mews
   5. Driveways

2. HD (highway design) - thickness depends on subgrade tests
   Unsealed pavement - 50 mm gravel
   Porous pavement - thickness depends on required reservoir capacity
   Light pavement - 50 mm granular material plus 50 m bituminous concrete or 100 m base material plus bituminous seal

3. Numbers refer to order of preference where second preference alternative depends upon local attitudes, experience and costs.

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