Movement networks

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INTRODUCTION

"Movement networks" are defined broadly as public right-of-way networks, accommodating land-based movement by a range of movement modes. Earlier guidelines have referred to "movement networks" as "road layouts".

While the guidelines presented in the previous version of the "Red Book" (1994) were intended for application in both high- and low-income residential development, its guidelines on road layout planning were drawn directly from the initial "Blue Book" (1983). It was acknowledged in the subsequent "Green Book" (1988) that the "Blue Book" had been prepared for "developed communities" or "municipal townships", not "developing communities". In the review of the previous "Red Book" (in 1995), its road layout planning guidelines were criticised for being car-oriented and for largely ignoring the movement needs of those sectors of the South African population without access to private motor cars.

The intention of this sub-chapter is therefore to provide guidance on the design of local area movement networks in both higher and lower income areas that are primarily convenient for pedestrians and public transport users, while at the same time restrictive of unwanted and potentially dangerous fast-moving through-traffic. The guidelines have been prepared for application in predominantly residential, but also mixed, land-use developments that seek to be consistent with current housing, transport and land-development policy objectives.

A different approach to those of past guideline documents has been adopted in that

- public right-of-way networks (as opposed to road layouts) are the focus of planning and design;
- reference to conventional road classifications such as "access roads", "collectors", "local distributors" or "arterials" is avoided to prevent preconceptions regarding the functions and cross-section of any particular public right-of-way; and
- continuous, pedestrian-friendly, public right-of-way networks are promoted ahead of conventional discontinuous suburban road layouts.

These differences are consistent with recent shifts in international practice - which have included site layout design as one of a series of "travel demand management" (TDM) strategies - often referred to as "transit-oriented" or "(neo)traditional" design. These design ideas have emerged largely in response to growing automobile dependency and associated efficiency and equity problems, and to the prospect of global warming as a result of increasing greenhouse gas emissions (to which vehicle tailpipe emissions are a significant contributor). Government authorities and professional institutions in various parts of the world have begun either replacing or supplementing their design codes to take account of these ideas. The list of key literature at the end of this sub-chapter provides references to some examples of these design codes.

The sub-chapter is divided into five sections. The first section clarifies what is meant by the term "movement network". The second discusses the role movement networks play in human settlements, and the qualities they should have. The third section provides guidance on how these qualities can be achieved in the configuration of movement networks in general. The fourth section provides guidance on the contextual factors that should inform the configuration of a movement network on a particular site. The final section provides guidance on the adaptation and conversion of movement networks to accommodate changing patterns of movement demand and right-of-way functions.

These guidelines should be read in conjunction with Chapter 7 on geometric design, as well as the Department of Transport's "Transport planning guidelines" (TPGs) - particularly TPGs 1, 5, 9, 12 and 14 on "integrated transport plans", "spatial planning", "travel demand management", "transport systems management", and "traffic calming" respectively. Further guidelines on road design, which adopt an approach similar to that of the earlier Blue Book, can be found in the former Committee of Urban Transport Authorities' (now replaced by the Committee of Land Transport Officials) "Urban transport guidelines" (UTGs) - particularly UTGs 1, 5, 7 and 10 on "urban arterial roads", "urban collector roads", "local residential streets", and "commercial and industrial local streets", respectively.

ELEMENTS OF MOVEMENT NETWORKS

Local movement networks are made up of (a) links and (b) junctions of public rights-of-way or reserves. These links and junctions contain overlaid systems of "ways" for different movement modes - including footways, roadways, pathways, cycleways, and sometimes railways (see Figure 5.1.1). Viewing a movement network as a network of public rights-of-way, as opposed to simply as a network of roads, is central to the planning approach presented in this sub-chapter; it is argued to be essential to the design of local movement systems that move away from being car-oriented.

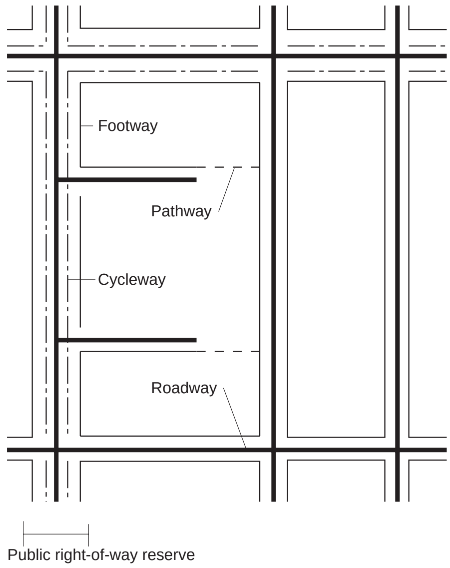

Figure 5.1.1: Diagram illustrating a movement network as a series of overlaying "ways"

Links

This network of public rights-of-way within a local mixed land use development has numerous functions - including the facilitation of movement by different modes, accommodating utility services, providing commercial activities with exposure to potential consumers, and so on. The configuration of movement networks and the functional differentiation of links therefore needs to be informed by a variety of socio-economic factors (e.g. the accommodation of street trading, child play and social interaction), as well as movement factors. Movement networks, based on a functional road hierarchy that is tiered solely on the basis of traffic distribution, do not take into consideration - and often cannot accommodate - all the functions the network needs to perform.

In order to avoid overlooking or excluding some of the functions they perform, public right-of-way links are broadly categorised below on the basis of the users they accommodate. More detailed functional differentiation should occur on a context-specific basis.

- There are links within a movement network where the needs of longer distance vehicular traffic predominate over those of other users and functions, and these links therefore need to be designed to accommodate motorised modes only. These *vehicle-only links*, corresponding with major arterial roads or freeways, should be designed to provide uninterrupted vehicular channels which accommodate the needs and requirements of fast-moving inter- and intra-settlement traffic. The need for uniform operating conditions and high levels of safety requires, inter alia, control over direct frontage access and intersection spacing, and frequently grade separation at intersections.

- On the bulk of the remainder of links within a network it is necessary to achieve a balance between the variety of social, recreational, economic and movement functions the link performs. These *mixed-mode links*, which may be collector or local roads, should therefore be planned to reconcile the diverse requirements of a multiplicity of users, with the recognition that inevitably no one function will operate with optimum efficiency. In terms of vehicular traffic circulation, different mixed-mode links perform a variety of access, collection, and even shorter distance mobility functions. Higher order mixed-mode links would be those designed to accommodate the shorter distance distribution and stopping of relatively large volumes of mixed traffic (often referred to as "activity" or "main" streets). Middle order mixed mode links would be those designed to collect traffic onto vehicle-only distributors. Lower order mixed-mode links would be those designed to provide access to individual properties - some of which would be designed primarily for pedestrians, and vehicle behaviour would essentially be determined by a set of pedestrian rules (e.g. *woonerven*). Conventional hierarchical road classification systems therefore fall within this categorisation of higher, middle and lower order mixed-mode links - arterial roads fall within the category of higher order mixed-mode links, collectors fall into the category of middle order mixed mode links, and local streets (also known as "access roads") fall into the category of lower order mixed-mode links.

- As some routes accommodate only motorised modes, other routes accommodate only non-motorised modes (e.g. pedestrians and cyclists). The entrances to such *pedestrian-only links* are typically designed to prevent access by vehicles. The links themselves are, however, often designed to enable the movement of occasional emergency or service vehicles. The functions of pedestrian-only links can vary significantly, from those links abutting and accommodating intensive commercial activities (e.g. "pedestrianised" streets in city centres), to links performing a primarily pedestrian- or bicycle-access function within "superblocks" or across soft public open spaces.

An understanding of the potential range of functions that each link within a movement network may be expected to perform enables the appropriate number of lanes, the pavement structure, the footway width, the on-street parking provisions, and the intersection configurations and spacings, etc, to be selected. Contextual factors that inform the derivation of mixed-mode link functions include:

- the existing and expected composition, volume and destinations of motorised and non-motorised traffic on the "external" movement network surrounding the site, the degree to which this traffic may wish to pass through the site, and the routes they select;

- the number of consumers that may wish to pass through the site, and the exposure of local entrepreneurs to potential non-local consumers along the routes they may select;
- the composition, volume and destinations of motorised and non-motorised traffic that is likely to be generated and attracted by the expected land use pattern on the site, and the routes they may select; and
- the alignment of existing and anticipated "external" road-based public transport services, how these services may be integrated into and through the site, and points at which modal interchange is likely to occur.

Junctions

Junctions, as in the case of links, perform a variety of movement and non-movement functions. With regard to movement functions, the carrying capacity of an urban roadway network is determined by intersection capacity, not by route capacity, and it is therefore intersection performance that often determines the operational efficiency of the roadway network as a whole. The non-movement functions of junctions relate primarily to economic activity. Each quadrant of a junction is exposed to two adjacent movement routes, and consequently is the site of maximum potential consumer exposure in the immediate area.

THE ROLE OF MOVEMENT NETWORKS IN HUMAN SETTLEMENTS AND THE QUALITIES THEY SHOULD HAVE

The role of a movement network in the process of settlement-making is essentially to provide the basic spatial framework within which a number of urban processes that involve the physical movement or reticulation of people, goods and services, find spatial form. A measure of the performance of a movement network should therefore be the degree to which the network can effectively accommodate a variety of changing urban processes.

The role of a movement network in the daily operation of a settlement system is essentially to enable the convenient, efficient, affordable and safe movement of people, goods and services and, in doing so, to satisfy the needs of a variety of users and facilitate the effective operation of local space economies. A further measure of the performance of a movement network should therefore be the degree to which the network minimises the demand for movement, and hence the degree to which ease of access is increased. Movement should not be seen as an end in itself, but as a means through which needs can be satisfied.

In performing these roles, a local settlement movement network should have the following basic qualities:

- A movement network should prioritise the needs of non-motorised modes most sensitive to distance, as well as the needs of public transport services depended upon by those sectors of society without access to private motor cars.
- A movement network should be able to maintain convenience, safety and multiple-use patterns over time, as the nature of movement demand and network use inevitably changes.
- As mentioned earlier, apart from a limited number of links that accommodate the requirements of fast, longer distance vehicular traffic, a movement network should accommodate a range of movement demands and socio-economic functions.

GUIDELINES ON THE CONFIGURATION OF MOVEMENT NETWORKS (IN GENERAL) TO ACHIEVE THESE QUALITIES

In order for movement networks to perform these roles and have these qualities:

- certain basic relationships need to be created between vehicle-only, mixed-mode, and pedestrian-only links; and
- public right-of-way networks need to be configured in particular generic ways.

The relationship between vehicle-only, mixed-mode, and pedestrian-only links

The purpose of interconnections between vehicle-only and mixed-mode links is essentially to provide higher-speed route alternatives. They enable longer distance, higher-speed traffic to avoid mixed-mode links (or portions of mixed-mode links) that experience relatively high, but lower speed (i.e. "stop-start"), vehicular traffic volumes. In practice, lower levels-of-service (i.e. slower and denser vehicular traffic) will be acceptable on links that have a higher capacity route alternative. Wherever possible (Figure 5.1.2):

- Higher order mixed-mode links should therefore run parallel to high-capacity vehicle-only links. This enables through-traffic to "opt-in" or "opt-out" of travelling along the higher order mixed-mode link, depending on the range of urban activities to which access is required.

- The higher order mixed-mode link and the vehicle-only link should ideally be close enough to make it relatively easy for vehicles to move between the two routes, yet ensure that the fragmentary impact of the higher order facility, particularly if it is a freeway, does not prevent commercial and public facility activities from locating on either side of the mixed-mode link.

- Access interchanges between vehicle-only links and higher order mixed-mode links, as well as system interchanges between vehicle-only links themselves, should be designed to facilitate safe and uniform operating conditions. These interchanges perform a "mobility" function, which precludes locating any activities that require direct frontage access adjacent to the intersection. The spacing of interchanges along vehicle-only freeways should be determined by the need to prevent joining traffic streams from disrupting traffic flow and reducing traffic speed, creating unsafe operating conditions.

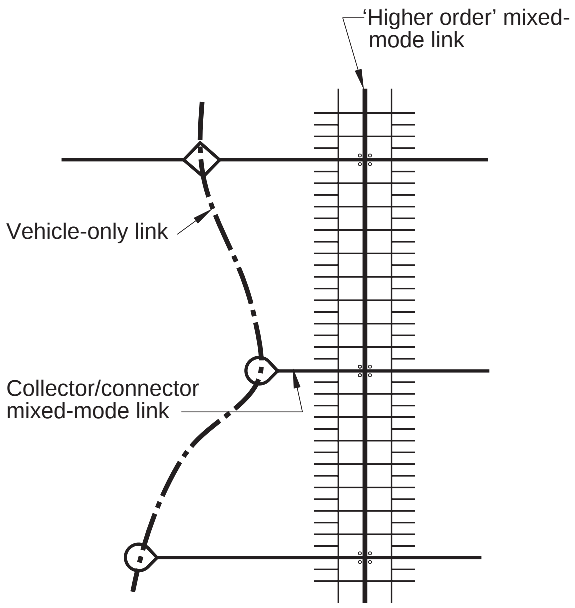

Figure 5.1.2: Diagram illustrating the relationship between vehicle-only and mixed-mode links

On mixed-mode links that accommodate higher traffic volumes, the following should be noted:

- The spacing of intersections should be greater than on links carrying lower traffic loads. In order to avoid excessive disruptions to the traffic stream, greater intersection spacings can be achieved by aligning blocks parallel to - as opposed to perpendicular to - higher order links (and, where required, providing pedestrian-only access through the middle of these blocks).

- Intersections between two mixed-mode links that accommodate larger volumes of traffic are points of greatest accessibility, and are therefore points where commercial opportunities are often largest. The relative accessibility of a particular intersection is determined not only by the type and nature of passing traffic, but by the ability of traffic to stop. Consequently, in order to create trading opportunities, vehicles (including public transport vehicles) should be able to stop and park or offload passengers within a reasonable walking distance from the intersection, and buildings should not be prevented from fronting onto the intersection.

- Taking vehicular access close to the intersection, however, increases the potential for conflict and should be avoided. The volume of traffic on many of these intersections necessitates some form of intersection control which, in turn, through eliminating potential conflict points, enables greater use of four-legged junctions.

On mixed-mode links that accommodate lower traffic volumes, the following should be noted (Figure 5.1.3):

- Intersection spacing should be influenced more by, inter alia, pedestrian circulation, block subdivision and internal utility service reticulation considerations than by traffic circulation considerations. By limiting straight, unbroken stretches of roadway in which vehicles are able to pick up speed, network configurations can be used as traffic calming mechanisms, which enhance the ability of pedestrians to use streets for social and recreational purposes.

- Low traffic volumes do not usually justify investment in intersection control, in the form of traffic signalisation. T-junctions can therefore be used as a way of breaking long stretches of roadway.

- Intersections between two mixed-mode links that accommodate smaller volumes of traffic, are less accessible and therefore provide opportunities for less intensive trade and collective servicing points. Activities should not therefore be prevented from locating close to the intersection.

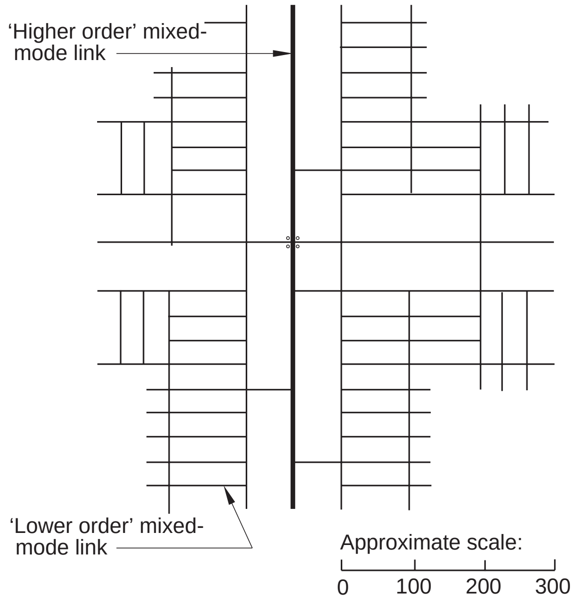

Figure 5.1.3: Diagram illustrating the relationship between higher and lower order mixed-mode links

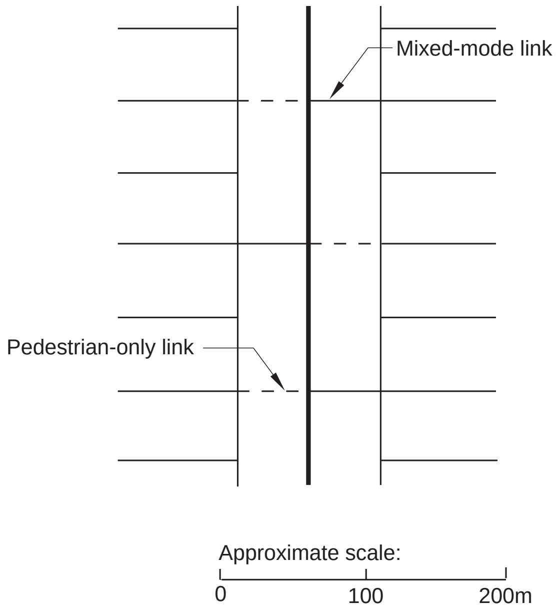

Figure 5.1.4: Diagram illustrating the relationship between pedestrian-only and mixed-mode links

Note: The diagram illustrates public right-of-way links, not roadways. The junction of two right-of-way links does not therefore necessarily imply the intersection of two roadways. See Figures 5.1.8 and 5.1.9 for illustrations of roadway systems that prevent or manage through-traffic on lower order mixed-mode links.

The purpose of interconnections between mixed-mode and pedestrian-only links is essentially to maintain easy multi-directional pedestrian and bicycle access, in situations where the roadway network is discontinuous to prevent large quantities of vehicular through-traffic from using certain routes (Figure 5.1.4). The network of pedestrian footways, crossings, pathways and cycleways should always remain convenient and direct. Intersections between mixed-mode and pedestrian-only routes typically take the form of footways joining with short pathways that run through longer blocks or open spaces.

The configuration of links and junctions into networks

A continuum of basic network-configuration options can be identified on the basis of network connectivity (Figure 5.1.5). On either end of the continuum are closed and open networks. A closed network consists of a hierarchy of links, within which links intersect only with other links equal to - or one below or above - it in the hierarchy. This system establishes clearly defined movement routes between any two points, but offers no equidistant alternatives. An “open” network on the other hand, consists of a system of links of differing hierarchical importance intersecting freely with one another. This system offers a choice of alternative equidistant routes between any two points within the network.

Studies of the impact of open and closed networks on travel behaviour and residents’ quality of life, have indicated that different configurations have both advantages and disadvantages. On the one hand, studies have shown that while open networks (in

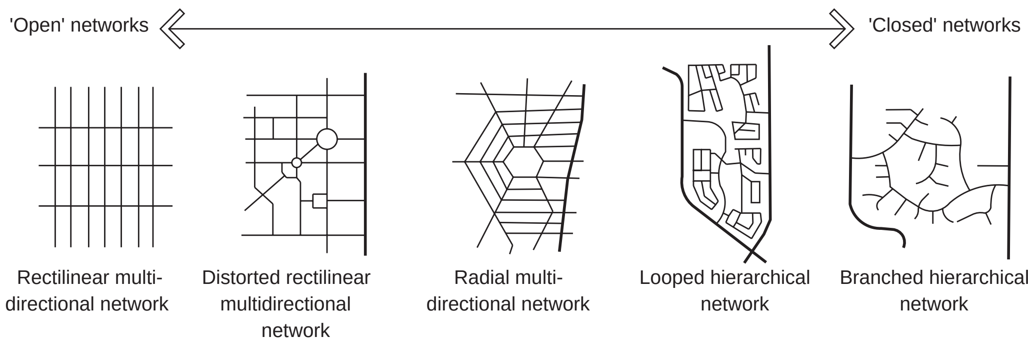

Figure 5.1.5: Generic network configurations

conjunction with mixed land-uses) improve levels of accessibility to local destinations, reduce total vehicle kilometres travelled and increase the walking and public-transport share of the modal split; they can also result in numerous problems associated with the intrusion of fast-moving through-traffic (e.g. safety and noise). On the other hand, studies have shown that, while closed networks manage through-traffic effectively, they can also isolate neighbourhoods and reduce the viability of smaller neighbourhood commercial activities, as well as increase trip lengths for non-motorised modes and necessitate road-based service vehicles to either back-track or frequently accord priority to other vehicles.

Central to the planning approach presented in this sub-chapter is the argument that the configuration of public rights-of-way into networks that are multidirectional, enables different way systems within the movement network to either incorporate or avoid the above-mentioned advantages and disadvantages. It is possible, for instance, for a *multidirectional* movement network to maintain easy and direct pedestrian and bicycle circulation in all directions (through the design of the footway, pathway and cycleway component of the network as an open system), while preventing or limiting the safety and intrusion problems associated with extraneous vehicular traffic (through the design of the roadway component of the network as a closed system - see Figure 5.1.6).

A multidirectional configuration (and the associated patterns of public and private land ownership) further enables the various "way" systems within the movement network to be adapted to become more open or closed as modal split and dynamic land-use development processes alter the nature and pattern of movement demand and the functions of particular links. Network configurations, to a large extent, determine the pattern of land sub-division, which in turn forms the basis for title registration and the allocation of development rights. Given that large-scale expropriation and compensation is required in order to significantly alter patterns of land ownership and development rights, discontinuous or "dendritic" public right-of-way networks are extremely difficult to adapt and are inflexible. A multidirectional movement network is thus able to prioritise the needs of non-motorised modes and public transport users, as well as maintain convenience, safety and multi-use when conditions and movement needs change. It is important to note that a multidirectional movement network is not necessarily an orthogonal grid.

Figures 5.1.7, 5.1.8 and 5.1.9 provide an example of how the individual "way" systems within a hypothetical multidirectional movement network (see Figure 5.1.7) can be configured to manage motorised traffic on lower order mixed-mode links through either volume management measures (see d, e and f of Figure 5.1.8), or speed reduction measures (see Figure 5.1.9), while maintaining direct pedestrian and bicycle circulation in all cases (see a, b and c of Figure 5.1.8). It should be noted that the management of traffic volume and traffic speed is interrelated, and it is not the

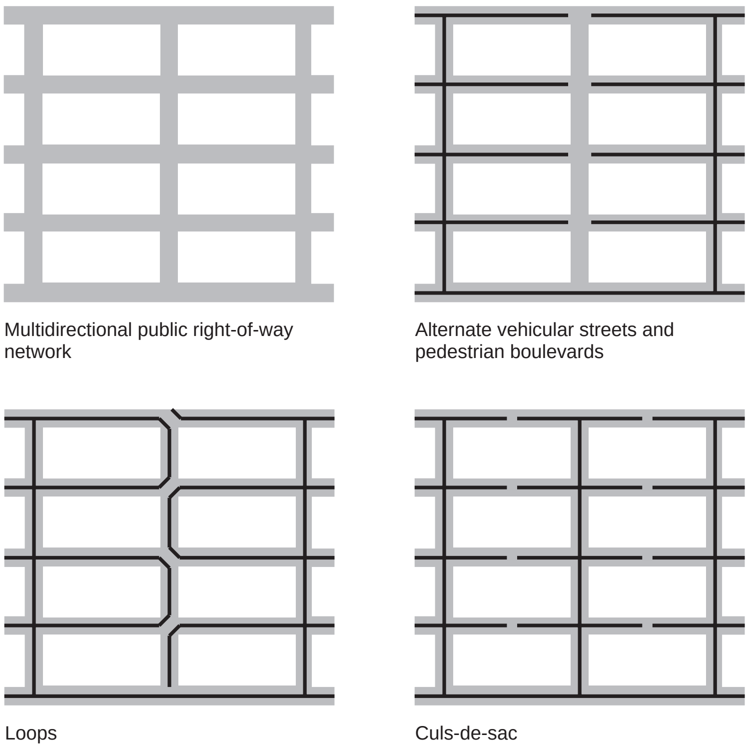

Figure 5.1.6: Conceptual examples of closed roadway system options within a multidirectional public right-of-way network

intention of the figures to suggest that they should be considered independently. Studies on the impact of traffic volume and speed management measures have shown that speed reduction on particular links almost inevitably leads to volume reduction as well. The use of roadway closures and diverters which restrict through-traffic are therefore not regarded as mutually exclusive from the use of measures that reduce speed (e.g. tables, pinch points and chicanes), and vice versa.

It should also be noted that in all the different configurations represented in Figures 5.1.8 and 5.1.9, a continuous footway and pathway network with 18 pedestrian entrance/exit points is maintained. The pathways are also all relatively short and straight, and surrounding properties overlook them. The public transport route is direct, and pedestrian access to the public transport stop is unhindered. In the case of roadway systems, the minimum spacing between T-intersections involving minor arterials and service/collector routes is ± 100 m, the minimum spacing between T-intersections involving collector and local access routes is ± 25 m, and the minimum spacing between cross-intersections involving collector and local access routes is ± 50 m.

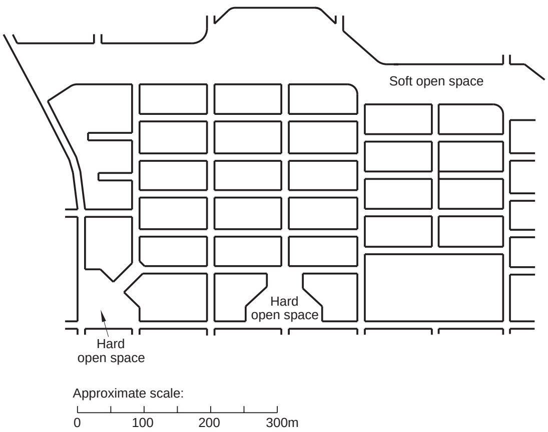

Figure 5.1.7: Hypothetical example of a multi-directional public right-of-way network

The exact configuration of a multidirectional movement network is dependent on context-specific factors like topography, the distribution of traffic-generating activities in surrounding areas, car-ownership levels, and the modal split of the population on the site as well as the surrounding population - these contextual factors are discussed in the following section.

GUIDELINES ON THE CONTEXTUAL FACTORS THAT INFORM THE CONFIGURATION OF A PARTICULAR MOVEMENT NETWORK

An analysis of the pattern and mix of existing and anticipated land-use activity surrounding the particular site, as well as the pattern and mix of higher order land-use development that is to be encouraged within the site, will indicate spatial patterns of movement demand (known as "desire lines") across, into and from the site. In order to identify movement-demand desire lines, it may be useful to establish a map which indicates possible future patterns of movement demand (both motorised and non-motorised) between existing and anticipated areas of land-use activity. This desire-line map essentially consists of bands which represent the major movement flows between appropriately scaled zones - delimited on the basis of a simple grid, or on the basis of clusters of dominant land-use activity. The beginning and end points of the band indicate the origin zone and the destination zone, and the width of the band indicates the relative magnitude of the anticipated movement demand. Such movement desire-line maps can be prepared for different times of the day or week, in order to indicate temporal fluctuations in movement demand. An indication of the nature of these patterns of movement demand can be used to inform

- the need for, and alignment of, higher order movement routes across the site; and
- the need for, and alignment of public transport connections across the site.

An analysis of the pattern and mix of existing and anticipated land use within the site, the demographic and income profile of the existing and "target" population on the site, as well as the biophysical features of the site, will indicate, inter alia, land-access requirements, the nature of movement demands, and topographical constraints on network configuration. In the case of in-situ upgrade projects, the existing pattern of informal movement channels will be a major internal informant of movement-network configuration. An indication of these requirements and constraints can be used to inform

- the modes of movement that will need to receive priority in the configuration of the network;
- local economic development considerations in the configuration of the movement network;
- the land-access requirements associated with the pattern of land subdivision;
- place-making considerations in network configuration; and

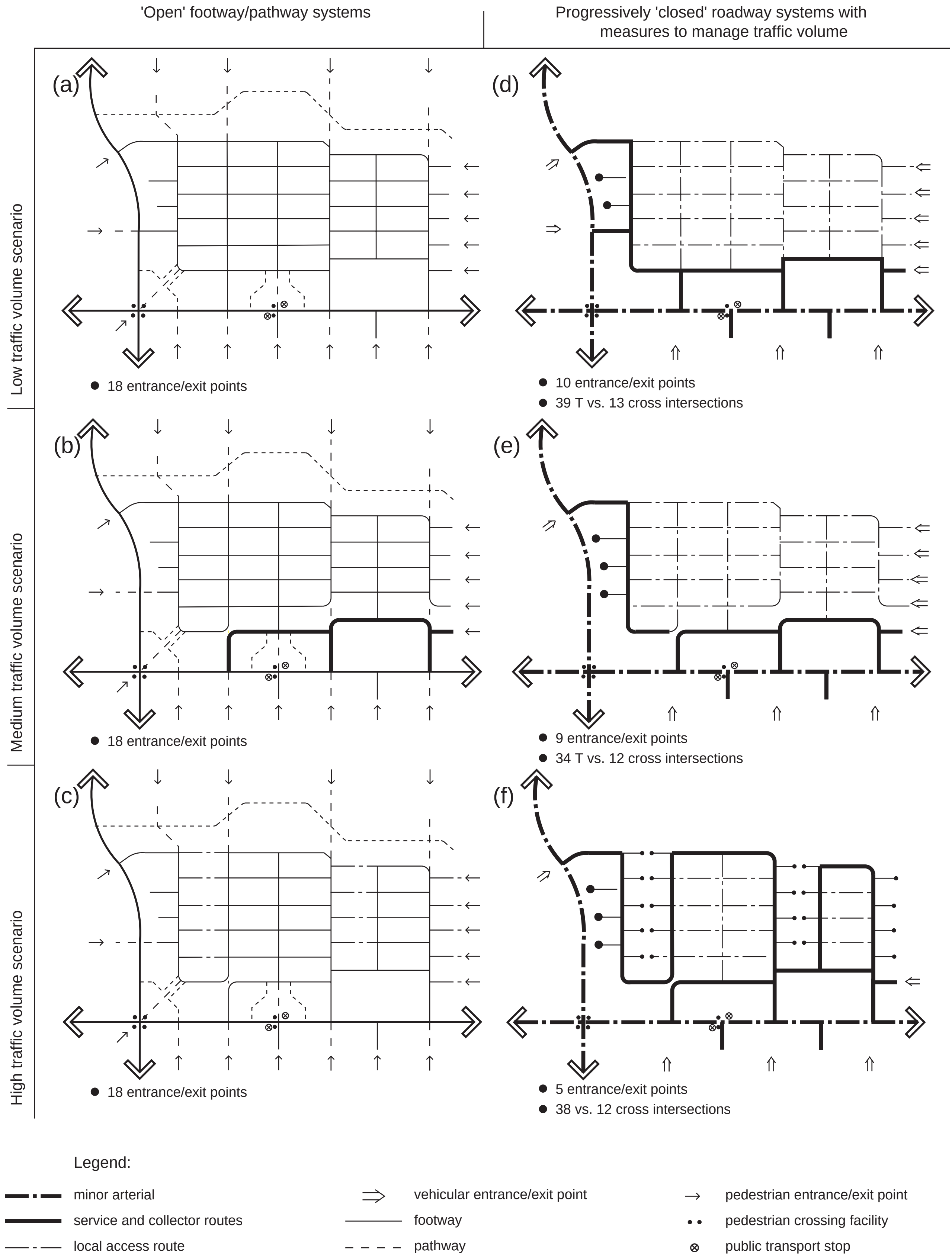

Figure 5.1.8: Possible configurations of foot/pathway and roadway systems within a public right-of-way network that respond to different traffic volume situations

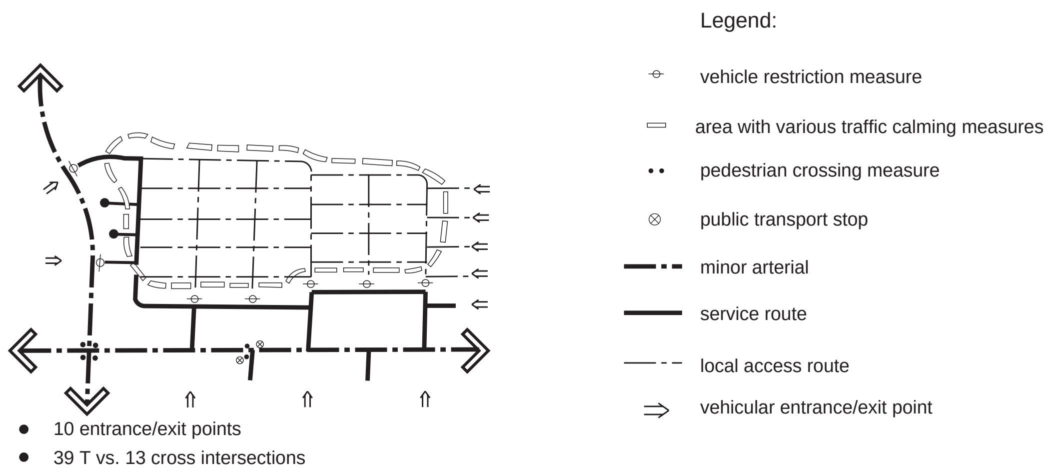

Figure 5.1.9: Possible use of measures in a public right-of-way network's roadway system to manage traffic speed

- the network configuration requirements of internal services reticulation, particularly gravity-based wastewater and stormwater drainage.

Higher order movement route connections

Higher order movement routes, in the form of vehicle-only links or mixed-mode links carrying greater volumes and densities of vehicular traffic, which lead to, across, and out of the site, facilitate longer distance intra-settlement connections. In many cases the need for, and the alignment of, these higher order movement routes across the site will already have been identified in metropolitan or sub-metropolitan plans. In these cases, the proposed higher order routes need to be accommodated within the site, and the planning and design of the local movement network needs to be done in relation to these dedicated alignments. Of particular importance, is the fact that when these higher order routes take the form of vehicle-only links, the opt-in-opt-out relationship between vehicle-only and higher order mixed-mode links, discussed earlier, needs to be considered.

Public transport service connections

Public transport service connections that lead to, across, and out of the site represent an important way of integrating the local environment with the surrounding movement system and land-use pattern. The planning and design of the local network should provide opportunities for increased coverage and penetration of road-based public transport operations, through extending these into and across the site. In order to identify the need for increased public transport coverage and penetration, it may be useful to establish a map which indicates areas that are served and not served. The area served by public transport is delimited on the map as that which is within convenient walking distance of public transport stops. A convenient walking distance is often interpreted as maximum walking time of 5-10 minutes, and a maximum walking distance of that involving 400-500 metres. Such a map illustrates the area of coverage, and suggests where additional service routes and stops might be placed.

Network configuration requirements of vulnerable modes

- Public policies relating to desirable modal split, as well as the existing or anticipated level of car ownership among the site's population (and associated dependence on walking or public transport services), will provide an indication of the relative importance that different modes will need to assume in movement-network design within particular contexts. In order to design networks that are capable of prioritising particular - while effectively accommodating all - modes, it is useful to consider the specific network-configuration requirements of dominant modes (i.e. motor cars, walking, public transport vehicles).

- Motor cars are the most flexible of all movement modes, able to undertake any length of door-to-door trip. It is argued therefore that the configuration of local movement networks should be informed by the needs of more vulnerable, gradient - and distance-sensitive modes, particularly pedestrians.

- Walking trips can only cover relatively short distances (i.e. 1-2 kms), and are often associated with the beginning and end portions of public transport trips. Pedestrian movement is accommodated primarily within footways, pathways and roadways. In order to facilitate efficient pedestrian movement, these "ways" should be configured in the following manner:

    - Footways should be configured into multi-directional networks which enable pedestrians to choose relatively direct and equidistant trip routings, that either avoid or select roads that accommodate greater traffic flows and greater commercial land-use activity, and to orientate themselves within settlements they do not know well.

- Blocks, within multidirectional network configurations, should be short to medium in length, to enable more intersections where cars must stop and pedestrians can cross, and more direct routing of walking trips. For ease of pedestrian circulation, block lengths should be in the region of 100 m.

- When block lengths are significantly longer than 100 m (in the region of 200-300 m) because of land use or traffic management considerations, short and direct pathways through the centre of the block (known as "pass-throughs") should be provided, in order to maintain the ease of pedestrian circulation.

- When culs-de-sac (or road closures) are incorporated within the movement network because of traffic management considerations, pathways should be provided which connect the end of the cul-de-sac with the nearest foot/roadway, in order to maintain multi-directional pedestrian circulation.

- On mixed-mode links where roadways and footways are separated by kerbs, footways should be provided on both sides of the roadway, and should connect with pathways that cut across large soft open spaces, to facilitate continuous and multidirectional pedestrian circulation.

- Pedestrians tend to choose travel lines of least resistance - cutting corners and keeping their routes as direct as possible. Pedestrian pathways within soft open spaces (that accommodate non-recreational trip functions) should therefore be as direct and short as possible.

- On roadways experiencing relatively high traffic flows, pedestrian crossings should be provided at regular intervals, and should be located at points where pedestrian desire lines cross the roadway, in order to maintain adequate levels of pedestrian safety.

• Public transport vehicle trips typically take the form of shorter feeder, and longer line-haul or express trips. The number and spacing of stops establishes the line-haul or express nature of the public transport service. The network configuration requirements of express public transport vehicles are similar to the requirements of motor cars undertaking longer distance trips. Public transport vehicles are accommodated within roadways and railways. In order to facilitate efficient public transport movement, these "ways" should be configured in the following manner:

- Effective line-haul public transport service operations are quick, frequent and predictable. Roadways carrying road-based bus and light rail services should therefore be as direct as possible, to avoid the delays associated with continuous backtracking, and frequent turning movements where giving priority to other vehicles needs to be accorded. Direct road alignments also make the introduction of dedicated public transport lanes less complex than on circuitous roads, and enable numerous service operations to be routed along the same road for portions of their service length - thus enhancing the frequency of services along the route.

- Parallel road-based feeder public transport service routes should be spaced at maximum intervals of 800 - 1 000 m, to maintain a maximum convenient walking distance to these services of 400 - 500 m.

- At bus service terminals, vehicles may stand for some time and need to turn around. It is preferable to provide a turning area off the roadway, unless there is a suitable nearby roundabout which can be used.

- Where rail lines are an integral part of the movement network, or where a site is being developed adjacent to an existing railway station, every opportunity should be taken to structure a set of road-based public transport routes to interchange or end at the railway station, in order to facilitate inter-modal transfer.

Network configuration impacts on local economic development processes

The spatial organisation of local economies is influenced by a number of complex socio-economic, financial, security and development control factors. It is important that the configuration of the movement network maximises opportunities for small entrepreneurs, and does not disadvantage, or preclude, certain types of entrepreneurs and spatial patterns of economic activity from occurring. Movement networks define the spatial pattern of exposure and access to passing consumers, and therefore influence spatial patterns of economic opportunity (i.e. points of greatest commercial viability that are largely, but not exclusively, dictated by relative levels of exposure and access to passing consumers). Movement networks that create a cellular settlement structure and channel all through-movements onto arterials along which fronting access and on-street parking is not allowed, for instance, tend to create a nodal (as opposed to linear, or randomly scattered) pattern of economic opportunity. Given the limited number of such nodes within a local area, this pattern of economic opportunity frequently results in commercial activities organising themselves into shopping centres. Small independent entrepreneurs with limited capital are typically unable to meet the relatively high overhead costs associated with trading within shopping centres, and are therefore denied access to most of the viable trading locations created by the network configuration. In order to put in place one of the spatial preconditions necessary to create opportunities for small independent entrepreneurs, movement networks should be configured in the following way:

- The local movement network should be integrated into the surrounding movement system and land-use pattern, so that flexible and complex patterns of intra - and inter-district shopping can develop which enable consumers to move directly and conveniently into, and out of, the local area - thus avoiding monopolistic and oligopolistic trading conditions in which local retailers are able to charge inflated prices to a relatively captive market. Local multidirectional road networks should therefore be stitched into, and form an integral part of, the system of movement in the larger area, and should not be regarded as an independent sub-system.

- The network configuration should incorporate links that enable shorter distance through-traffic to move through local areas, and at the same time ensure that, where necessary, through-traffic has the option of travelling along high-speed vehicle-only routes. Shorter distance through-traffic and local traffic should be concentrated onto continuous integrating main streets that accommodate road-based public transport services, in order to create the passing consumer thresholds that are necessary to support viable, fronting, small-scale commercial activities. Vehicular and pedestrian traffic can be concentrated onto main streets through the alignment of different public transport modes and services along shared routes for a portion of their service length, and the location of movement generators like major public facilities and public transport modal interchanges along the route. While not necessarily dictating the spatial pattern of economic activity within a local area, this network configuration creates a more dispersed, linear pattern of economic opportunity that can accommodate a range of types and sizes of entrepreneurs and commercial investment patterns.

Land-access requirements

A central informant of the planning and design of the site's movement network is the need to ensure that there is adequate access to all erven within the site - typically in the form of a passing roadway and footway to which private pathways and driveways (or private roads, in the case of estates) can connect. What constitutes "adequate" access is subject to debate, however. Conventionally, all erven are provided with vehicular access but, in some instances, due to steep topography or low levels of car ownership (especially in in-situ upgrade developments), "adequate" is interpreted as being a relatively short public pedestrian pathway leading from a public road. The expected nature and mix of land-use activity on the site will, through an iterative process, indicate the width, and in some instances the length, of blocks that need to be incorporated in the network. To facilitate the efficient subdivision and utilisation of land, movement networks should be configured in the following way:

- In the absence of topographical or other constraints (e.g. infrastructure servitudes), local movement networks should be broadly rectangular, to yield the greatest possible number of erven from blocks. Sharply curving road alignments, which result in curved blocks, make the efficient subdivision of land difficult.

- Blocks defined by the configuration of the local roadway network should, wherever possible, be modular in order to enable larger blocks to fit into a pattern of smaller pedestrian-scaled blocks. Land-use activities like schools, shops and parks consume relatively large parcels of land that often do not fit into pedestrian-scaled blocks.

Place-making considerations

The way in which a site's movement network is configured can contribute to the creation of a "sense of place". The concept of a sense of place is complex, crudely referring to the images and feelings associated with the uniqueness of a particular part of a settlement, an entire settlement, or even a collection of settlements, that are embedded in collective memory, and to the way in which individuals respond psychologically, to the way public spaces within settlements are made. It follows therefore that the attainment of a sense of place cannot be achieved through standardised planning and design. Place-making essentially involves recognising the natural and cultural uniqueness of a particular environment and its population, and incorporating - and enhancing - this uniqueness in planning proposals. More specifically, in order to contribute to the creation of a sense of place in settlements, movement networks can be configured in the following way:

- Straight tree-lined avenues or boulevards can be aligned towards, and terminate at, important cultural or symbolic public buildings, public art displays or objects of public remembrance, in order to create vistas (i.e. visual axes) and enhance gateways to public spaces. Road alignments that create vistas can therefore help establish a series of landmarks that make a settlement memorable. By giving important objects visual dominance in the settlement, they become reference points - thereby reinforcing their symbolic importance.

- Road alignments can, where appropriate, respond to the natural features of the site, and incorporate it visually into the settlement. The alignment of roads can be used as a means to create vistas to natural features like established trees, *koppies*, or distant mountain peaks, and to retain existing landscape features.

Network configuration impacts on internal utility service reticulations

Reticulated utility services, in the form of water supply, sewerage, stormwater drainage, electricity supply and telecommunications are conventionally - either entirely or partially (in the case of mid-block reticulation) - accommodated in road reserves. The configuration of the movement network therefore has an impact on the reticulation of these channels, pipes and cables. The aspects of movement-network configuration that have the greatest impact on efficient service reticulation are: (1) road curvature, and (2) road gradient.

The curvature (or horizontal alignment) of the road reserve has the greatest impact on piped gravity-based services (i.e. sewerage and stormwater drainage), and above-ground electricity and telecommunications cabling. In order to facilitate the efficient reticulation of these services, movements networks should be configured in the following way:

- Notwithstanding the need to follow contours, road reserves accommodating below-ground pipes and above-ground cables, or dictating the pattern of reticulation in the middle of blocks, should generally be as straight as possible to facilitate the shortest relative service line lengths per erf, for straight trenches, and to minimise manhole and poling requirements. Curving road reserves require more sewer and stormwater manholes to provide access to pipes for cleaning (see discussion below), and necessitate extra poles in above-ground public lighting and electricity-supply systems, to ensure cables do not hang over the roadway.

- Notwithstanding the need for larger blocks to accommodate a range of non-residential land uses, blocks should generally be ± 100 m long, to minimise the number of sewer and stormwater manholes. The primary function of sewer or stormwater manholes is to provide access to pipes so as to clear blockages. It is conventional practice to provide manhole access to a gravity pipe at horizontal and vertical changes of direction, junctions between main and branch pipes (but not at junctions with erf connections in the case of sewerage), the head of a reticulation system, and at intervals on straight stretches of pipe. Manhole spacing on straight stretches of pipe is normally restricted to the length of hand-operated cleaning rods (typically 50 m), which are pushed along the pipe. Rods can bend to negotiate curves in a pipe but, if the curve is too tight (with a curve radius of less than 30 m), the rods tend to damage the wall of the pipe. The maximum spacing of manholes on straight stretches of road reserve, where pipes are cleaned with hand-operated rods, is therefore ± 100 m. When blocks are ± 100 m long, manhole access would be required at 100 m or so intervals to accommodate the junctions between main and branch pipes anyway. Limiting the length of blocks to ± 100 m therefore reduces the necessity for manholes on straight stretches of pipe.

The gradient (or vertical alignment) of the road reserve also has a great impact on gravity-based services (i.e. sewerage and stormwater pipes and channels). In order to facilitate the efficient reticulation of these services, movements networks should be configured in the following way:

- T-junctions or culs-de-sac at the down-stream end of steep roads should be avoided, in order to maintain “positive drainage” and avoid flooding.

- Very steep or completely flat road gradients present problems relating to the circulation of larger service vehicles (in the form of congestion), and the self-cleansing flow velocities of gravity-based services (in the form of clogging and road scour). Maximum grades are set by vehicle manoeuvrability requirements (provided the surface runoff velocity that results from the grade is less than 3 m/s), while minimum grades are set by drainage requirements. Maximum grades vary according to the volumes and speed of traffic and the nature of the terrain - generally grades should not exceed 5-6% (or 1:20-1:16) in flat terrain, 10-12% (or 1:10-1:8) in hilly terrain and 12-15% (or 1:8-1:7) in mountainous terrain. Minimum grades of road reserves accommodating pipes should generally not be below 0,4% (or 1:250). In hilly and mountainous terrain, in order to achieve these grades, and avoid deep cuts and high fills, blocks and their associated fronting road reserves should follow contour lines, and traversing roads should intersect roads above and below them at an angle sufficient to maintain an acceptable maximum grade. When blocks are aligned with contours, provided toilets are located close enough to the rear of the erf, mid-block sewer trenches can be dug to ensure that both lines of erven within the block are served by the same sewer.

GUIDELINES ON THE ADAPTATION AND CONVERSION OF MOVEMENT NETWORKS TO ACCOMMODATE CHANGE

As indicated in the previous section, a range of contextual features will inform the configuration of a site's movement network. In particular, with regard to the roadway component of the movement network, the actual and desirable level of car use and associated modal split of the site's (and surrounding) population will inform the degree to which the system is open or closed to through-traffic. This section discusses the anticipation of patterns of movement demand to inform the configuration of roadway systems and the adaptation and conversion of roadway systems to accommodate changing modal split, and changing movement patterns associated with dynamic spatial patterns of land-use activity.

The anticipation of patterns of movement demand within sub-metropolitan and local movement networks

The pattern of movement demand within a sub-metropolitan or local area is directly affected by the nature and form of the movement network. In the case of a closed hierarchical roadway system, it is possible to predict the volume and pattern of traffic (associated with a static spatial pattern of land use and modal split) that will use each road in the system with some degree of certainty, as the system presents no choice of potentially equidistant routes between any two points. While it is not possible, in the case of a more open system, to predict the volume and pattern of traffic with any degree of certainty - due to a greater choice of local and through routes - a more open system is more flexible and integrates the site into its surrounding environment better. There is however a trade-off between flexibility, integration and cost. The ability of more numerous links within a movement network to accommodate a dynamic range of social, recreational, economic and movement functions over time, has capital cost implications - and in many instances greater road reserve width and stronger roadway pavement structure will be required. Every link in a network cannot therefore be designed to accommodate large increases in traffic volumes.

To avoid the excessive road construction costs associated with total flexibility and greater integration, it is necessary, within limits, to predict the possible range of movement demand conditions (or scenarios) a more open road network proposal may be expected to accommodate. More specifically, the need is to identify those links expected, in the short term at least, to accommodate a wider range of functions and greater traffic volumes. Without a reasoned estimate of the traffic load a particular link or intersection will be required to accommodate, it is not possible to make informed decisions relating to the design of appropriate roadway cross-sections and pavements, or the selection of appropriate intersection-control systems. The direction, volume and mode of movement generated and attracted by a proposed development will be influenced by variables like household size and composition, areas of employment, levels of car ownership, and use of public transport services. It is important that an understanding is gained of the extent of change which is realistically possible within these variables, so that the network can be designed to accommodate such changes.

Patterns of movement demand on vehicle-only links, as well as mixed-mode links expected to accommodate larger volumes of traffic, can be predicted through a four-step modelling process, in which future traffic load, at a point in time (typically 15-20 years into the future), is assessed on the basis of a desirable, as well as the existing, land-use pattern. It is important to note that the modelling of future patterns of movement demand is sensitive to transport and land-use policy. Extrapolations of current patterns of movement demand should therefore be tempered by the settlement qualities to be created in a particular environment, and assumptions relating to the ability of the public sector to manage transport-related market forces. The conventional "four-step" modelling process is dealt with in detail in the Department of Transport's TPG 7 and can be broadly summarised as follows:

- estimating the number of trips that will be generated or attracted by each zone (often on the basis of the anticipated population of the zone multiplied by an average trip rate),
- estimating the number of trips that will occur between different zones (often represented in the form of an origin-destination matrix, and a desire-line map),
- estimating the relative proportion of modes through which trips between zones will occur, and assigning the trips moving between different zones, by different modes, to particular routes.

Patterns of movement demand within a particular site can be crudely predicted through the following five-step simulation:

- estimating the number of trips that will be generated or attracted by each erf within the site (often on the basis of assumptions relating to average number of workers per household and per business unit, and the average number of schoolchildren per household);
- estimating how many of these trips are local trips, and how many are into, and out of, the site;

- establishing trip directions on the basis of the location of major movement attractors (e.g. schools, employment and commercial centres) within the site and in the surrounding area;
- estimating the relative proportion of modes through which trips in different directions will occur; and
- assigning the trips moving in different directions, by different modes, to particular routes.

This simulation process can be conducted for peak and off-peak conditions, to establish temporal variations in the nature and pattern of movement demand. The patterns of movement demand identified can then be used to establish link volumes and turning movements.

Given the uncertainty of future predictions of future land-use development patterns and associated movement demand, and the need for movement networks to perform more than simply movement functions, it is important that the modelling processes described above be used to test the likely consequences of movement-network proposals, and not used as the basis for formulating proposals (beyond minor adjustments to network configuration). Demand-driven approaches to movement-network planning and design, based on the traffic load forecast, run the danger of either entrenching existing inefficiencies and inequalities, or of simply basing proposals solely on potentially erroneous predictions of future development patterns.

The management of changing patterns of movement demand within sub-metropolitan and local movement networks

The uncertainty of future predictions of movement-demand patterns also makes it important to monitor change (in terms of variables like traffic volumes, speeds and accidents) over time and, where necessary, to adapt or convert movement networks to accommodate this change. It is important that initial movement-network designs consider and facilitate possible future adaptations. Such adaptations or conversions are essentially aimed (a) at managing or "calming" the increased volumes and speeds of vehicular traffic associated with changing patterns of movement demand - more specifically to prevent large volumes of high-speed, longer distance traffic from cutting through quieter, predominantly residential areas, and to slow traffic on roads that experience a high mix of pedestrian and vehicular traffic, and in doing so, (b) at maintaining the ability of links to accommodate a range of movement and non-movement functions. As mentioned earlier, an advantage of multidirectional movement networks is that a variety of traffic calming interventions can be applied to convert the roadway network into a closed or speed restricted system which controls through-traffic, while maintaining an open footway and cycleway network, and which still enables the roadway network to be converted back to an open system should this be required. The achievement of greater flexibility therefore has implications for the operational capacity of local authorities, in terms of being able to monitor change, as well as for the configuration of movement infrastructure, and cost.

Within local movement networks the ongoing traffic-management objective is essentially to keep the speed of appropriate volumes of traffic low and, in doing so, to make the road as safe as possible for pedestrians. Traffic management, or calming, therefore takes two basic forms. The first is the reduction of speed through adaptations to the cross-section and horizontal and vertical alignment of the roadway. The second is the reduction of traffic volumes on certain roads through converting roadway network connectivity. It is important to note, however, that roadway adaptations can also reduce traffic volumes by making the route less attractive to through-traffic, and connectivity conversions can similarly reduce traffic speed.

The introduction of these traffic management measures are warranted when the monitoring of patterns of movement indicates that certain traffic speeds or volumes along certain routes have increased to levels that are not compatible with the range of social and economic functions the route is required to perform (see TPG 14 on "traffic calming"). Internationally, speed reduction measures on local roads are typically deemed necessary when maximum speeds exceed ± 30 km/h, and on mixed-mode arterials when maximum speeds exceed ± 55 km/h. Typically, volume-reduction measures are deemed necessary on local roads when traffic volumes exceed ± 600 vehicles/h. At slower speeds, drivers have greater opportunity to perceive and react to a situation, thus helping to reduce the number and severity of collisions. Roadway systems can be adapted to manage traffic speed, through the introduction of traffic-calming measures as illustrated in Figure 5.1.10.

Roadway systems can be converted to manage traffic volume, through the introduction of traffic calming measures as illustrated in Figure 5.1.11.

Empirical studies on the effectiveness of traffic management measures indicate that legal speed limits (in the form of "speed zones") have little effect on driver behaviour, and that it is rather the physical or operational characteristics of the road that determine driver behaviour. Traffic management measures should therefore be self-enforcing. Studies suggest that different self-enforcing measures have variable impacts on traffic volume and speed - apart from speed humps and speed tables, "adaptation" measures tend to have a greater impact on traffic speed, than on traffic volume, and "conversion" measures have a significant impact on both speed and volume.

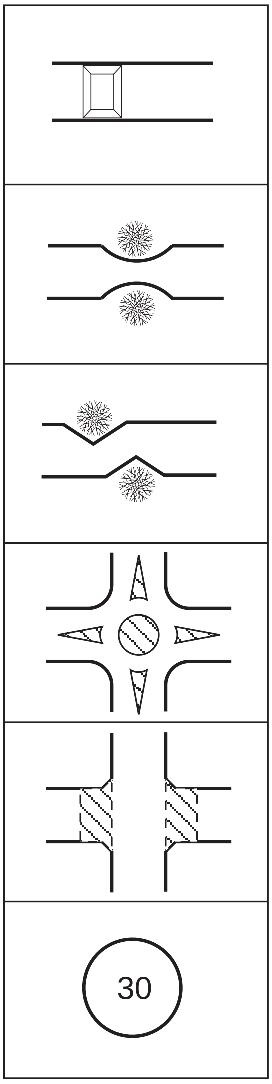

Figure 5.1.10: Roadway adaptations to manage traffic speed.

* The partial of full closure of roadways at the end or middle of the road
* The restriction of traffic movement to selected directions only, in the form of diverters (also known as diagonal road closures) and median closures
* The conversion of two-way roads into one-way roads

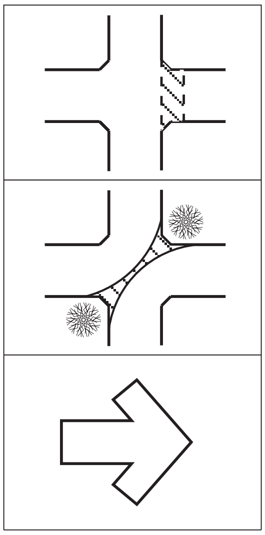

Figure 5.1.11: Roadway adaptations to manage traffic volumes.

The introduction of adaptation and conversion measures requires careful consideration, however. If local area traffic management measures, particularly conversion measures that alter network connectivity, are introduced on an ad hoc or area-specific basis, they can have a negative effect on the performance of the movement network as a whole. For instance, the closure of roadways that accommodate slower speeds, and shorter distance through-movements, increases trip lengths, and can lead to congestion on vehicle-only routes, and can reduce the viability of abutting formal and informal economic activities that depend on exposure to passing non-local consumers. The adaptation of individual roads can simply divert problems to nearby parallel routes, and the introduction of speed humps can have a negative impact on the operation of road-based public transport services and emergency service vehicles. Traffic management measures therefore need to be monitored and applied on an area-wide basis.

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