MODELLING TRAFFIC FLOWS AND TRAFFIC PERFORMANCE IN DENSE NETWORKS

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Abstract: This paper describes the nature and use of dense network models for traffic systems. A dense network is one in which both major roads and minor streets are included, and for which modelling is concerned with detailed traffic performance for links, intersections and turning movements. These models have been used to study the performance of alternative traffic management plans for small scale networks, and to estimate the traffic impacts of new development projects. Modern interests in Advanced Traffic Management Systems (ATMS) and Travel Demand Management (TDM) and the new tools and technology for traffic management stemming from Intelligent Transport Systems (ITS) are placing new focus on the capabilities of dense network models. This paper examines applications of the TrafikPlan dense network model to a variety of problems in traffic systems control, management and design.

1. INTRODUCTION

This paper describes the nature and use of dense network models for traffic systems. A dense network is one in which both major roads and minor streets are included, and for which modelling is concerned with detailed traffic performance for links, intersections and turning movements. Dense network models such as SATURN, CONTRAM and MULATM/TrafikPlan have been in existence for some years. New models, such as Paramics, have recently emerged. These models have been used to study the performance of alternative traffic management plans for small scale networks, and to estimate the traffic impacts of new development projects. The modern interest in Advanced Traffic Management Systems (ATMS) and Travel Demand Management (TDM) as well as the new tools and technology for traffic management stemming from Intelligent Transport Systems (ITS) are placing new focus on the capabilities of dense network models. This paper examines applications of the TrafikPlan model (now known as TrafikPlan 2000), to a variety of problems in traffic systems control, management and design.

2. DENSE NETWORK TRAFFIC MODELS

Modern dense network models need to accommodate a wide range of travel demand and traffic management techniques and tools, and to indicate traffic behaviour in the face of such measures. They must also account for traffic systems objectives in TDM and traffic calming. This requires some new approaches to network description (e.g. the allocation of physical road space between different road users such as public transport, high-occupancy vehicles, bicycles and general traffic) and the inclusion of dynamic or demand-responsive traffic control strategies.

The broad usage of the dense network models is in traffic impact assessment, either from a traffic engineering perspective or from a traffic planning perspective. For traffic engineering purposes, the dense network model is used to evaluate alternative schemes for traffic control and traffic management in a study area. In traffic planning, the dense network model may be used to assess the ability of an existing network to cope with additional traffic loads stemming from new land use developments in the study area. In each case, the model may help in the design of a new traffic management and control system for the area, to meet existing and future traffic demands and to satisfy planning objectives for transport efficiency, environmental protection, or social cohesion.

The paper focuses on the changing nature of traffic management technology and the underlying objectives behind traffic management practice. Changing needs and model capabilities, in terms of the evolution of traffic management technology and practice are discussed, which points the way to future model developments.

2.1 Dense network definitions

Dense networks as so called because they include link representations of a substantial part of the local street system in a given study area as well as the major roads. This differentiates them from strategic level networks which are concerned only with the major routes and corridors, and may thus be termed as 'sparse networks', in terms of link density per unit area. Dense network models, sometimes called 'local area models', include both trip assignment models and models for creating synthetic origin-destination matrices. This level of the hierarchy introduces a direct demand response to changes in system performance (for example, deviations in route, destination, mode and trip timing choices as the characteristics of the transport system are modified).

The dense network is one in which all of the street and road sections in the area need to be considered for inclusion. Such networks are needed in local area traffic planning, for the traffic impacts need to be assessed in both transport planning and traffic engineering terms. Dense networks possess the following characteristics:

(a) there is a general one-to-one correspondence between the links in the network and the actual road and street sections in the study area;

(b) the turning movement flow (i.e. how many vehicles turn right, left or travel straight through an intersection) is the basic measure of traffic volume;

(c) trip generation takes place along the links of the network, rather than at specially designated nodes (the 'zone centroids' of strategic networks). In the real world, at the dense network level, travellers begin and end their journeys at some point along a street section, e.g. where they park their cars, or enter or leave a driveway;

(d) intersection delays (as they pertain to each turning movement) are important and may dominate in the determination of travel times;

(e) traffic management controls and devices need explicit recognition and possible differentiation within the model, so that

(f) the dense network model is a hybrid of transport planning, traffic flow theory and traffic engineering.

The basic unit of a dense network is thus the turning movement, as indicated in Figure 1. In this figure the intersection of interest is node *j*. Arc *e* from node *i* is an approach leg to *j*. Arc *f* from *j* to node *k* is a departure leg. Turning movement (*m*) connects arc *e* to arc *f* at node j. Associated with each turning movement are the movement volume (by vehicle type), delay, queue length (if any) and capacity. Link volumes may be found by summing and comparing the turning movement volumes entering and leaving the link. Travel time on a link consists of the time required to traverse the link itself, and the delay times associated with the departure (turning) movements from that link. This level of detail is required because a dense network model must be able to distinguish between (1) different classes of roads and streets, (2) various design standards for streets, (3) different intersection controls, (4) turning and through traffic at intersections, (5) different vehicle types, and (6) different classes of traveller (e.g. local or through traffic, single occupant or multi-occupant vehicles, etc).

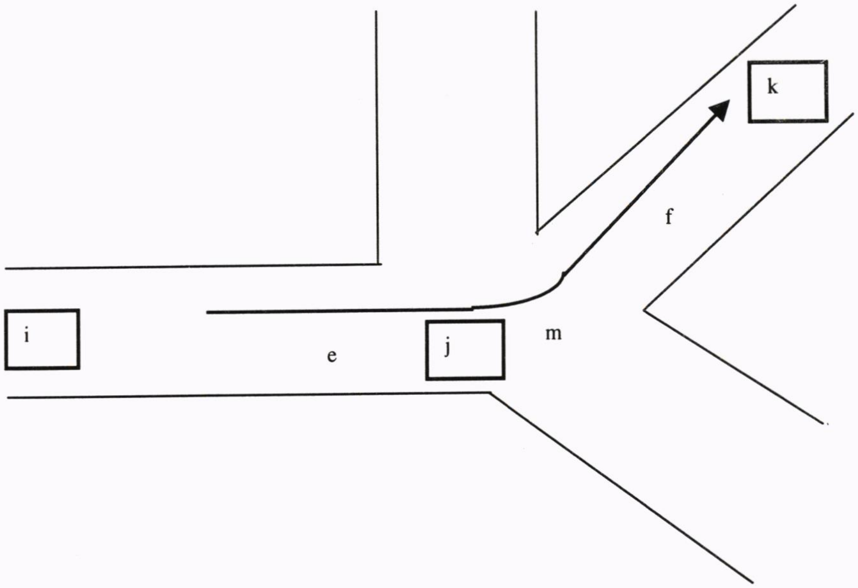


Figure 1.The turning movement is the basic unit of a dense network

2.2 Typical applications of dense network models

Specific applications of dense network models usually fall into one of two broad categories:

(a) assessment of the traffic and environmental impacts of site development proposals at the local level TIA, traffic impact assessment), and
(b) evaluation of alternative traffic management plans for a study area.

In the case of development proposal assessments, the modelling task is to superimpose traffic generated by the new facility on the existing traffic in the area. The analyst will then test for the adequacy of the existing network to cope with the increased traffic and the new interactions in the traffic, and examine the potential for increased adverse environmental impacts, such as traffic noise, air pollutant emissions from traffic sources, community severance, loss of residential amenity, and disruption to pedestrian movements. These investigations need to be made on the grounds of the types of land uses in the area, and must thus consider transport-land use interactions at the local level.

In the evaluation of alternative traffic management schemes, the dense network model serves as a laboratory test bed, enabling a wide range of alternatives to be considered. The model provides both a 'screening sieve' to eliminate unsuitable options and an evaluation framework for comparing feasible options. In this way the planner can eliminate much of the need for expensive and sometimes controversial field trials. Locations and intensities of traffic control devices can be adjusted, in the search for a scheme that meets a (possibly) wide range of study objectives.

Inherent in these applications is the development of a database of the existing network inventory (road types, intersection controls, traffic control devices and systems, parking control and parking provision, etc) and traffic conditions (volumes, speed, travel times and delays in different time periods) for the study area. This database development is an essential part of any planning investigation. In the end this leads to what is perhaps the fundamental use of dense network models in traffic planning and management; the development of a traffic network decision support system (DSS) for a local planning authority. The DSS will be of general use and will assist in the examination of specific issues relating to an area, such as road safety (e.g. Affum and Taylor, 1997) and environmental impact analysis (e.g. Klungboonkrong and Taylor, 1998).

2.3 Examples of dense network models

Dense network models first appeared in the late 1970s. Allsop (1985) provided an overview of the needs for and development of such models. The CONTRAM (Leonard, Tough and Baguley, 1978) and SATURN (Van Vliet, 1982) models from the UK are archetypal dense network models. The TrafikPlan(/MULATM) model (Taylor, 1979, 1992) was developed by the author at the same time. TrafikPlan meets all of the desired characteristics of dense network models described above. It also provides a good example of a dense network model that has evolved into a traffic database system. Models of this genre generally use macroscopic flow relationships to compute intersection delays and link travel times which are then used in the assignment of an origin-destination trip matrix to the network, to model the flows in the network.

The late 1990s has seen a revival of interest in dense network models, usually in connection with the application of Intelligent Transport Systems (ITS) technology or Travel Demand Management (TDM) plans. Some new model developments have occurred as a result, spurred on by the enhanced capabilities of the new computer and information technologies. One of these developments is the use of microsimulation methods at the dense network level. The Paramics model (Quadstone 1997) is one such model. Originally implemented (of necessity) on supercomputers, the rapid increase in personal computing power has seen Paramics become available on a variety of platforms, including Pentium II personal computers. This opens the door for the 'desktop' use of the package in applications to real world dense network problems. Paramics fulfils the dense network characteristics described previously. It has many attractive features, including a microsimulation implementation of probit-based stochastic user equilibrium assignment, as well as flexible trip generation characteristics, the ability to include variations in individual driver behaviour, and powerful interactive three-dimensional interactive graphics displays, enabling the user to watch the traffic movements in 'real time'.

Given the applications of dense network models as decision support systems for local area traffic planning and management, the development of appropriate tools for direct assistance in decision making may also be expected. The integration of dense network models with a Knowledge-Based System (KBS) is of particular interest in this regard. You and Kim (1998) presented one such prototype system, for forecasting link and route travel times in a road corridor. The SIMESEPT (Spatial Intelligent Multicriteria Environmental Sensitivity Planning Tool) model is a KBS designed to identify network links at risk of environmental degradation from road traffic (Klungboonkrong and Taylor, 1998). It operates at a link-by-link level to examine the present environmental condition and the propensity for future degradation of each link, identifying those links most at risk. To do this, it considers three factors known to be good indicators of environmental condition with respect to road traffic: traffic noise, pedestrian delay, and difficulty of access. These factors are considered for each link, in terms of the road geometry, traffic volumes and speeds (by vehicle type), the abutting land uses, provisions for pedestrians, and building facade setbacks. The environmental sensitivity factors are assessed using an inference engine (which encapsulates a knowledge base provided by a set of human experts – see Klungboonkrong and Taylor (1998) for details) and a 'composite environmental sensitivity index' (CESI) is then determined for each link. Links with high CESI values, or values exceeding a specified threshold, may then be identified. SIMESEPT uses a Geographic Information System (GIS) to store and display its network database (MapInfo is the particular GIS). Present research is seeking to integrate TrafikPlan and SIMESEPT. In this integrated system TrafikPlan will provide the traffic volume, speed and travel time data to SIMESEPT, which in its turn will make assessments of existing and potential environmental impacts.

3. EVOLUTION OF TRAFFIC MANAGEMENT

Contemporary traffic planning practice focuses on assessment of the traffic, economic, environmental, energy and social impacts of new land use developments and traffic management and control schemes, with requirements for community acceptance (and, for truly successful planning and implementation, community ownership) of the final proposal, that can only be achieved through active programs of community participation in the planning process (e.g. Westerman, 1990). Traffic planning in the 1970s and 1980s was driven by the concept of a 'road hierarchy', with major routes (freeways and arterial roads) providing mobility (vehicle travel across a region) and local streets and roads providing access to dwellings, shops and businesses. This useful concept remains in place but, as indicated by Westerman (1990), there are problems with roads in the middle of the hierarchy (e.g. the collector roads) that have both mobility and access functions. In the early 1990s the concept of 'traffic calming' became significant (Brindle 1991), with the objective of restricting the nature of traffic movements (e.g. speed of travel) to levels deemed commensurate with the surrounding environment and meeting community needs and aspirations whilst still providing for traffic throughput. Traffic congestion also emerged as a significant issue for many cities around the world, with an especial interest in non-recurrent or 'incident-based' congestion (e.g. Pfefer and Raub 1998). More recently, the advent of ITS technologies has seem the development of Advanced Traffic Management Systems (ATMS), offering real time monitoring and dynamic traffic control strategies as potential solutions to problems of congestion, accessibility and adverse environmental impact.

In parallel with the 1990s 'supply side' developments such as ATMS have come initiatives relating to travel demand, notably TDM, aimed at influencing individuals' travel choices and decisions so that better use can be made of existing network infrastructure (e.g. IEAust 1996). Wholesale construction of new infrastructure to alleviate traffic problems is not sustainable and is no longer seen as providing full solutions to such systematic problems.

The level of application in planning and design that encompasses the above concepts for a typical study area is that of the dense network, representing the interface between the regional road transport network (e.g. freeways and arterial roads) and the local street system. The systematic implementation of traffic plans and schemes at this level is not possible in practice without the availability of suitable traffic network planning tools and the means to employ them.

3.1 Goals of traffic management

Traffic management is the application of traffic control techniques, within a defined policy framework, to the road network in a given area or over an extended length of road, to achieve a specific set of community objectives. Original applications of traffic management were intended to make the best use of traffic facilities, by maximising traffic throughput under conditions of physical constraint on the provision of additional road space. In more recent times traffic management objectives have broadened out to include active consideration of environmental impacts and energy consumption, equity considerations for different road user groups, consideration of local traffic accessibility whilst minimising through traffic usage of minor roads and safety. Thus there may well be a specific set of objectives set for any given traffic management scheme. Specific objectives may include:

- improvement of traffic conditions, reduction of congestion, and facilitation of traffic flows, usually for traffic management on heavily-used arterial roads where efficiency of traffic flow is of high priority;
- enhanced safety of a route or area, following analysis of accident frequency and patterns, or from direct community concern (especially in residential areas);
- improvement of safety for specific road user groups, such as commercial vehicles, public transport vehicles, pedestrians, cyclists, children and the elderly;
- improvement of the amenity of residential areas by reducing vehicle speeds, traffic noise, air pollution, and volumes of through traffic;
- improvement of access to commercial, retail and recreational activities, and
- amelioration of parking problems.

In some cases the traffic management scheme will be devised in response to an obvious problem or set of problems, and the required measures will also be obvious. In other cases, the issues may be complex and sometimes conflicting, and a number of alternative traffic management schemes will need to be developed and analysed. In this latter case the dense network models are of significant use, as they provide the basic tools for analysis and comparison of alternative traffic management schemes.

3.2 Allocation of road space

One hallmark development of traffic management in the 1990s, reflecting a substantial shift in the practice of traffic engineering, has been the explicit allocation of parts of the available road space to specific road user groups. Lanes for general traffic usage are progressively replaced by lanes reserved for different users and vehicle types: buses, high-occupancy vehicles (HOV), bicycles, and other besides. Coupled with traffic calming measures such as kerb-side protruberances (e.g. to improve pedestrian crossing opportunities and safety), the allocation of road space has become a major tool in traffic management, often linked with broader transport planning initiatives in TDM.

3.3 Travel demand management (TDM)

TDM broadens the range of measures and techniques for optimising the utilisation of existing road infrastructure, beyond physical measures alone. TDM measures may be classified into four general categories:

- improved asset utilisation, which includes measures for encouragement of peak spreading and increased vehicle occupancy;
- physical restraint, including measures for area limitation (e.g. removal of through traffic), link limitation (such as ramp metering and signal timing), and parking limitations;
- pricing, including road pricing, parking pricing, and taxes, and
- urban and social changes, including more efficient urban forms, social attitudes to (say) motor vehicle usage, and technological change (and resulting travel substitution, e.g. by telecommunications).

Travel demand management may be seen as an extension of traffic management principles and implementations, certainly in terms of the goals and objectives of TDM, and as such modern dense network models need the capability to include representations of TDM measures. Providing the capacity for informed decision making by travellers is presently seen as a major goal of TDM. New technologies applied to transport systems, some to support TDM, are collectively known as Intelligent Transport Systems (ITS), are providing a further impetus to TDM.

3.4 Intelligent transport systems (ITS)

The application of new sensing, computing, telecommunications and information technologies to the monitoring, management, operations and control of transport systems is known as ITS. There are an increasing number of ITS implementations aimed at influencing traffic network behaviour, including dynamic area-wide traffic control, Driver Information Systems (DIS), incident detection and management systems, and electronic road pricing. Those implementations directed towards traffic control and traffic management may be described as Advanced Traffic Management Systems (ATMS). The ability to represent ATMS in dense network models is thus a requirement for the contemporary use of such models.

4. APPLICATIONS

Two recent studies involving the use of the TrafikPlan model may be used to indicate the range of applications of dense network models. These applications are:

- the use of TrafikPlan to test the traffic and environmental impacts of lower speed limits in suburban areas, and
- application of TrafikPlan to the design of a traffic management scheme for the central business district of the City of Adelaide, South Australia.

4.1 Effects of lower speed limits

Recent studies (e.g. McLean *et al* (1994)) have indicated that lower urban speed limits offer significant road safety benefits. An issue which has arisen in assessing the importance of these benefits is the likely impacts of lower speed limits on other aspects of road travel, such as mobility and travel time, fuel consumption and emissions. Modelling provides a general indication of the possible effects of reduced speed limits on these factors. The TrafikPlan model was used to consider the effects of lower speed limits and speed zoning, as applied to a range of urban road and street types, on journey times, mobility and accessibility, and fuel consumption and emissions, based on an hypothetical road network representative of Australian suburban areas. Model runs were made under different speed limits, with comparisons made of relative performance between the speed limits under different traffic control strategies (e.g. peak direction signal coordination) and different levels of traffic congestion.

A number of parametric measures of traffic performance were used to assess the network under its different operating conditions. At the network-wide level the principal parameters of interest were mean trip travel time, mean travel speed and mean system delay (Taylor *et al*, 1996, p.233). Link-level parameters were also considered, as follows. The control variables for each link (e) in a given network under a specified traffic control regime are: (1) a congestion factor (σ), which has the values 0, 1, 2 and 3, (2) the speed limit (V), given as 60, 50 or 40 km/h, and the signal coordination status (Z), defined as 0 for isolated signal control and 1 for coordinated control. The congestion factor σ indicates the total level of traffic activity as a factor $(1 + \sigma)$ of a base traffic demand, i.e. it is a scaling factor applied to an initial O-D matrix, to increase the level of traffic congestion in the network. Given the link and traffic variables link length x_e, unit travel time $u(e, \sigma, V, Z)$, and free flow travel time $u_0(e, \sigma, V, Z)$, then link delay, congestion and flow quality parameters may be defined as follows.

Mean system delay on a link, $d(e, \sigma, V, Z)$, is given by

$$d(e,\sigma,V,Z) = x_e\left[u(e,\sigma,V,Z) - u_0(e,V,Z)\right] \qquad (1)$$

Average delay may also be expressed in terms of a dimensionless, non-negative congestion index, $CI(e, \sigma, V, Z)$ where

$$CI(e,\sigma,V,Z)=\frac{d(e,\sigma,V,Z)}{x_e u_0(e,V,Z)}=\frac{u(e,\sigma,V,Z)}{u_0(e,V,Z)}-1 \tag{2}$$

These parameters are for a given network with its specified traffic control regime (signal coordination plan and speed limit). In order to make comparisons between networks under different traffic control regimes, other parameters must be introduced. The assumed datum is a network with a 60 km/h general speed limit and uncoordinated signals. The parameters could then include the following.

The delay time with base $u_0(e, 60, 0)$, described as $d60(e, \sigma, V, Z)$, which is the difference in travel time on a link in the specified network and on that link with a 60 km/h general speed limit and uncoordinated signals:

$$d60(e,\sigma,V,Z)=x_e\left[u(e,\sigma,V,Z)-u_0(e,60,0)\right] \tag{3}$$

The congestion index relative to base $u_0(e, 60, 0)$, i.e. $CI60(e, \sigma, V, Z)$, defined as

$$CI60(e,\sigma,V,Z)=\frac{d60(e,\sigma,V,Z)}{x_e u_0(e,60,0)}=\frac{u(e,\sigma,V,Z)}{u_0(e,60,0)}-1 \tag{4}$$

which may be compared to $CI(e, \sigma, V, Z)$ - see equation (2). Note that $CI60(e, \sigma, V, Z)$ can take both negative and non-negative values. In addition, comparisons between link travel times may be useful. Two such parameters are: (1) the change in free flow travel time compared with a 60 km/h speed limit and isolated signal control, $\Delta t_0(e, V, Z)$

$$\Delta t_0(e,V,Z)=x_e\left(u_0(e,V,Z)-u_0(e,60,0)\right) \tag{5}$$

and (2) the change in actual travel time compared with a 60 km/h speed limit and isolated signal control, $\Delta t(e, \sigma, V, Z)$

$$\Delta t60(e,\sigma,V,Z)=x_e\left(u(e,\sigma,V,Z)-u(e,\sigma,60,0)\right) \tag{6}$$

The parameters u, CI, CI60 and Δt_0 were taken as an overall representative set of parameters:

- the unit travel time (u, min/km) represents travel times on links in the network, and thus travel time for journeys through the network. The reciprocal of u is the average journey speed on each link;
- the congestion index CI indicates the proportion of travel time on the link that is delay time (i.e. excess travel time above the free flow travel time). This parameter represents system delay. It can be applied over each link in a network or between networks;
- the relative congestion index CI60 indicates the difference between the travel time on a link for a given speed limit and the free flow travel time on the link when a speed limit of 60 km/h is applied. It represents traffic delay relative to the 60 km/h speed limit, and
- the difference in free flow travel time (Δt_0, min) for each link between the case of a specified speed limit and the 60 km/h limit provides a measure of the change in minimum possible travel times.

In addition, external impacts of the traffic system need to be considered. Two factors, average fuel consumption and the emission of carbon monoxide were selected - these factors were available from the TrafikPlan outputs. Fleet composition was not included as a control variable in the modelling, so unleaded petrol consumption and carbon monoxide emissions were studied (using Taylor and Young's (1996) running speed models).

A two-dimensional grid network of arterial roads and local streets, with the arterial roads at 1.6 km spacings, was selected as a general representation of a suburban road system (in an Australia city). Figure 2 shows the 'network C' configuration used in most of the model runs.

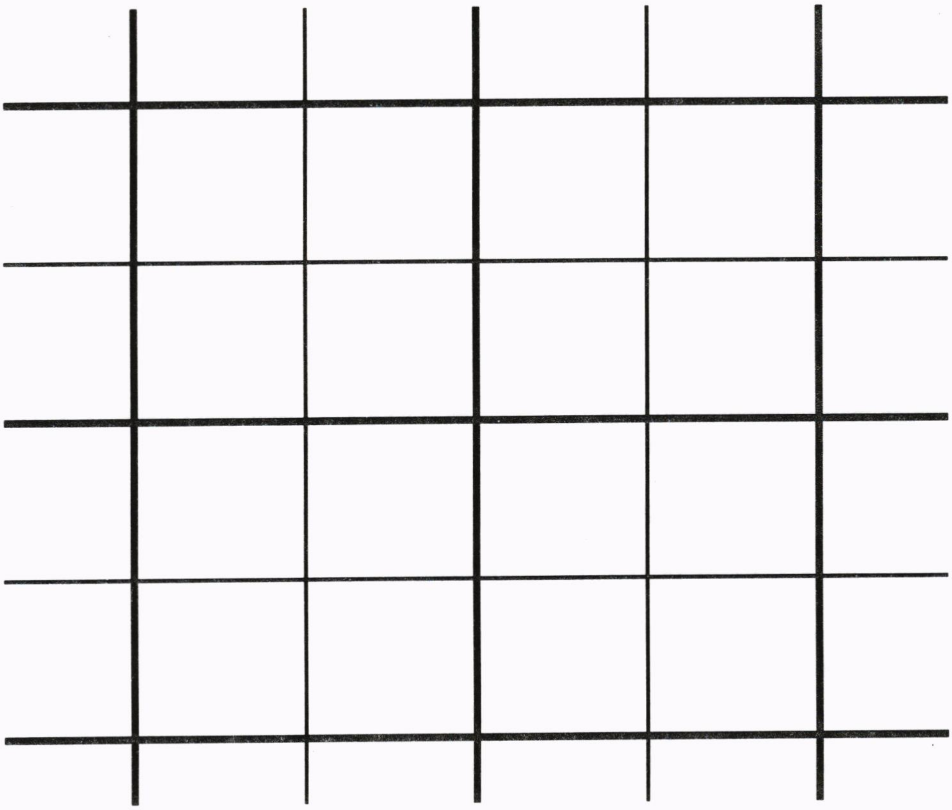


Figure 2. Network C used in the speed limit modelling tests

A hypothetical origin-destination trip matrix for a one hour period was developed for the travel demand in the network. This matrix could be scaled to represent different levels of traffic congestion in the network (Taylor, 1998). TrafikPlan then assigned the trip demand to the network, under the different traffic congestion, traffic control and speed limit regimes. Model results were then examined. The following results were found.

The modelled values for the network-wide parameter mean travel speed are shown in Figure 3. This shows the mean journey speed for each traffic congestion level, speed limit and signal control strategy. The first overall result to emerge is that journey speeds through the networks are considerably less than the set speed limits. For example, Figure 3 indicates that, even for coordinated signal control, the mean journey speed in the network at congestion level 0 and 60 km/h speed limit is 49.1 km/h. Overall journey speed accounts for all time spent in queues and in accelerating to or decelerating from the cruise speed.

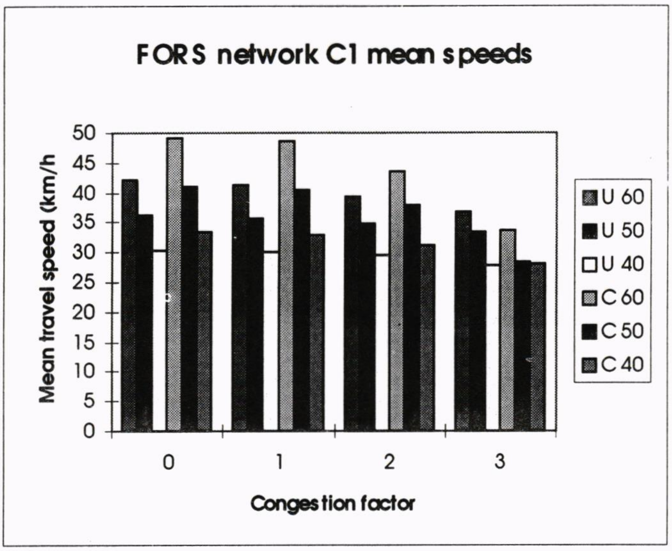


Figure 3. Mean journey speed in Network C [40, 40, 60 (km/h) are the speed limits, U = isolated signal control, C = coordinated signal control]

Secondly, the differences in overall travel speed for the different speed limits are somewhat less that the differences in the speed limits themselves. Thus, for network C (see Figure 3) the overall mean speed for the 40 km/h speed limit with isolated signal control is 29.4 km/h, with that for the 60 km/h speed limit being 40.0 km/h - a difference of 10.6 km/h compared to the 20 km/h difference in speed limits. The differences between speed limits decrease as the congestion level increases, as the opportunities to reach the higher speeds on the main roads are lessened and intersection delays increase. Signal coordination leads to higher speeds in almost all cases, although signal coordination becomes less effective at congestion level 3, as parts of the network are then oversaturated.

The results for the mean journey delays are also of interest. A general result was that delay times are reduced under the lower speed limits. Now, care needs to be taken to review the definition of delay time - see equation (1). The delay time reported by TrafikPlan is the system delay, which is the excess of the actual travel time for a link or route above the free flow travel time for that link or route. The model suggested that this amount of excess travel time compared to the free flow travel time, was less for the lower speed limits than for the 60 km/h limit. This result applied generally for both isolated and coordinated signal control, and the only exception from the model runs was seen where oversaturation occurred). The inference is that, under this definition of delay, delays were reduced at lower speed limits, even though total travel times were higher. This suggests smoother progression of traffic flow was being achieved at the lower speed limits. The complication in using this result is one of driver perception. Driver compliance with a lower speed limit might be assisted by an indication of this improved evenness of progression along a road?

More information on the relative performances of the synthetic networks can be gauged by considering the link-based parameters of traffic flow (equations (1)-(6)). The results may be summarised as follows. Link travel times, congestion indices, fuel consumption and carbon monoxide emissions rise with increasing traffic congestion, as expected. Signal coordination brings benefits, with significant reductions in travel time, fuel and emissions when compared to isolated signal control. Lower speed limits lead to longer travel times, as indicated from the considerations of the overall network traffic performance parameters described in the previous section. In addition, fuel consumption and emissions are also higher for the lower speed limits. The difference between the fuel and emissions rates for different speed limits under the same congestion levels are small, but systematic. The congestion index, a non-parametric measure of system delay time, is the one parameter that improves with lower speed limits, again in keeping with the overall network performance results discussed earlier. Figure 4 provides a summary illustration of these results, in terms of a 'star plot' which combines the relative performance measures of the test network under the different speed limit regimes, for a given traffic congestion level.

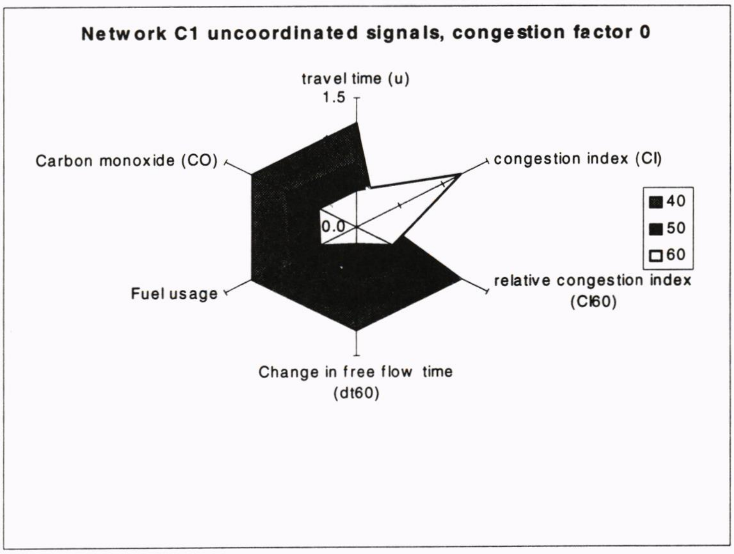
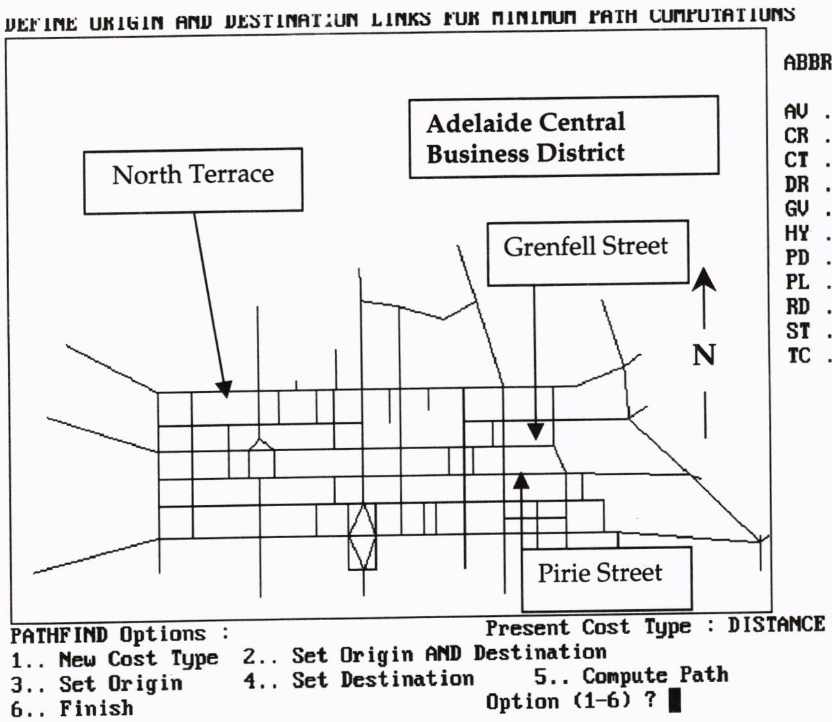


Figure 4. Example 'star plot' of link-based traffic performance parameters
[speed limits are 40, 50, and 60 km/h]

4.2 Central city traffic management

Another recent application of TrafikPlan was in the evaluation of a number of alternative proposals for traffic management in the Adelaide CBD, especially concerning traffic progression along North Terrace. Figure 5 shows a TrafikPlan schematic layout of the network.

An important question related to the role of North Terrace in the study area network, especially the relative amounts of through traffic and local (city access) traffic using the road. Following extensive traffic surveys in the area, including peak period origin-destination surveys, it was concluded that through traffic comprised no more than 25 per cent of the total traffic usage of North Terrace. Previous traffic management schemes had been based on a premise that most traffic on the road was through traffic. The survey results suggested that this was not the case. A number of alternative traffic management schemes were then examined using the network shown in Figure 5, to provide a better environment for local access and for pedestrian movement in the North Terrace precinct.



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DEFINE ORIGIN AND DESTINATION LINKS FOR MINIMUM PATH COMPUTATIONS

ABBREVIATIONS

AV .. AVENUE
CR .. CRESCENT
CT .. COURT
DR .. DRIVE
GV .. GROVE
HY .. HIGHWAY
PD .. PARADE
PL .. PLACE
RD .. ROAD
ST .. STREET
TC .. TERRACE

PATHFIND Options :                      Present Cost Type : DISTANCE
1.. New Cost Type  2.. Set Origin AND Destination
3.. Set Origin     4.. Set Destination     5.. Compute Path
6.. Finish                              Option (1-6) ? █
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Figure 5. TrafikPlan schematic of the Adelaide CBD network

The alternatives included reducing the numbers of lanes for through traffic, installing additional pedestrian crossings, and redesigning intersections to better handle turning traffic. Three of these alternatives were:

- Scheme A, the removal of one through lane for each direction of flow on North Terrace (i.e. a reduction from three through lanes to two lanes for each direction of flow);
- Scheme B, which comprised Scheme A with the addition of three new signalised pedestrian crossings along North Terrace, and
- Scheme C, which was Scheme B coupled with the development of a transit mall in Grenfell Street, the nearest parallel through road to North Terrace. With the transit mall Grenfell Street would be blocked to through private cars.

These alternatives were modelled and compared to the existing situation. O-D demand for the network is assumed to be fixed. A registration plate O-D survey was conducted in April 1998, which indicated that about 75 per cent of vehicles had a trip end within the study area. A summary of the results is given in Tables 1 and 2 – refer to Figure 5 for road locations.

Table 1. Changes in screenline flows in morning and evening peak hours

Station	Existing (veh/h)		Alternative traffic management schemes (% change)					
			Scheme A		Scheme B		Scheme C	
	am	pm	am	pm	Am	pm	am	pm
North Terrace	3360	3210	-2.0%	-1.0%	-5.0%	-1.9%	+23.5%	+23.7%
Grenfell Street	2850	2740	+0.4%	+3.3%	+2.0%	+1.8%	-84.9%	-83.3%
Pirie Street	2160	2090	+1.0%	0.0%	+1.8%	+0.3%	+35.2%	+50.7%

Traffic management schemes:
A = removal of one through lane for each direction of flow on North Terrace
B = scheme A plus new signalised pedestrian crossings on North Terrace
C = scheme B plus transit mall in Grenfell Street (i.e. Grenfell Street blocked to through private cars)

Table 2. Travel times and percentage changes on North Terrace

	Morning peak		Evening peak	
	East-bound	West-bound	East-bound	West-bound
Existing travel times (min)	3.21	3.27	2.99	3.54
Percentage changes:				
Scheme A	+6.9%	+4.0%	+2.0%	+4.5%
Scheme B	+18.4%	+16.5%	+15.0%	+5.6%
Scheme C	+26.8%	+26.6%	+31.1%	+16.1%

Traffic management schemes:
A = removal of one through lane for each direction of flow on North Terrace
B = scheme A plus new signalised pedestrian crossings on North Terrace
C = scheme B plus transit mall in Grenfell Street (i.e. Grenfell Street blocked to through private cars)

The existing scheme has lower travel times than all of the traffic management alternatives – but note that these alternatives were developed as part of traffic calming initiative associated with an urban redevelopment plan aimed at improving the pedestrian environment and streetscape of North Terrace. Thus increases in travel time (and delay) were seen as acceptable as long as they did not impose substantial new burdens on drivers, or cause major disruptions to traffic flow elsewhere in the network.

The model runs suggested that under Scheme A and B the (local) traffic and pedestrian functions of the precinct could be substantially improved, without significant adverse effects on through traffic (or on other parts of the network) and on the local environment. Some small diversions of traffic to other roads would occur, with the resultant travel times on North Terrace increasing by up to 18 per cent. However, Scheme C would direct substantial additional traffic to North Terrace, negating the environmental benefits gained by the redesign of that road. Travel times would also increase significantly, perhaps by 30 per cent. As a result the City Council decided not to pursue the transit mall option, but to concentrate on streetscape improvements to North Terrace. The advantage of the modelling using the TrafikPlan dense network model was that urban planning, transport planning and traffic engineering issues could be considered simultaneously within the mode framework.

5. DISCUSSION AND CONCLUSIONS

Dense network modelling is becoming increasingly relevant and important and traffic planning and traffic management become more sophisticated and complicated – both in terms of the multiplicity of issues to be considered and the availability of new technologies for travel and traffic management, monitoring and control. This paper has attempted to define the role and application range of dense network models, and to illustrate these with some recent applications of the TrafikPlan model. There is continuing scope for further research and development to refine and extend the dense network modelling genre.

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