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Cycle Route Network Planning Using GIS

Abstract

Cycle route network planning is usually a fairly subjective process, with local or regional council staff and perhaps cycling advocates identifying popular routes or strong desire lines for cycling. Cycle planning maps are included in cycling strategies and funding approval for individual facilities is often dependant on the route being identified in the cycle planning map.

ViaStrada (formerly Traffix) has developed a more objective tool for identifying cycle routes and networks, working with the Auckland Regional Transport Authority (ARTA) and VicRoads, Melbourne. The technique uses a geographic information system (GIS) to manage, analyse and display relevant transport and demographic data in a spatial environment. The tool allows the merits of different potential routes or entire networks to be compared. This approach ensures that expenditure on designing and building cycle networks will be better spent if planning aligns with data-based predictions of where people may want to use cycle facilities, if they were to be provided.

This paper describes how demographic data (population, employment and school rolls), conventional transport planning computer model data, road and cycle route networks and other data can be analysed using the power of a GIS. This tool can be used to recommend where cycle routes and networks should be located to provide better service for more people. Like any good model, the ARTA and VicRoads cycle route network GIS models improve our understanding of a complex, underlying system (in this case the fabric of our cities) as much as it provides us with specific answers to specific cycle route network questions.

Melbourne

Auckland

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Acknowledgments and Disclaimer
The projects on which this paper is based were undertaken for ARTA and VicRoads by MWH New Zealand Ltd and Beca Infrastructure Ltd in late 2005 and 2006; their assistance in authorising use of the findings of the projects is acknowledged. Andrew Macbeth was the principal technical specialist for these projects, with clients Tricia Allen (until July 2007, Active Transport Project Leader with ARTA) and Tony Barton (Manager, Walking and Cycling Programs with VicRoads). The views expressed in the paper are the authors’ alone, however, and do not necessarily represent the views of ViaStrada, ARTA, VicRoads or the other consultants.

1. Introduction

Cycle route network planning is usually a fairly subjective process, with local or regional council staff and perhaps cycling advocates identifying popular routes or strong desire lines for cycling. Cycle planning maps are included in cycling strategies and funding approval for individual facilities is often dependant on the route being identified in the cycle planning map.

Cycle route network planning in Auckland and Melbourne has become a little more objective through the use of geographic information systems (GIS) in recent projects for the Auckland Regional Transport Authority (ARTA) and VicRoads. ARTA is responsible for operational planning for integrated road and passenger transport infrastructure and services for the Auckland region, amongst other things. VicRoads is the main roads authority for the state of Victoria and manages the cycle route network for Melbourne. The process used a variety of data managed and analysed in an “intelligent” map for each city, including:

1. general topographical features such as rivers, coastlines, railways and town or activity centres;
2. municipal boundaries;
3. centrelines of roads and cycle route networks (both on-road and off-road);
4. conventional transport planning computer model zone boundaries;
5. population and employment data from Census records, aggregated into transport planning zones;
6. school rolls, aggregated to zone level; and
7. cycle crash locations for the last five years (Auckland only).

An initial understanding of the city was gained by plotting population (home location) density. In both cities, the older, inner suburbs have higher population densities than the newer, more remote suburbs. Similar plots were done of employment location density, and both cities exhibited high densities in their central business districts (CBDs). Education data were also plotted for these zones. Combining these data gives an indication of where people live, work and study. Calculating “demographic density” per hectare indicates where human activity is most concentrated and can help rationalise cycle route network planning. Demographic density for part of Melbourne is illustrated in Figure 1.

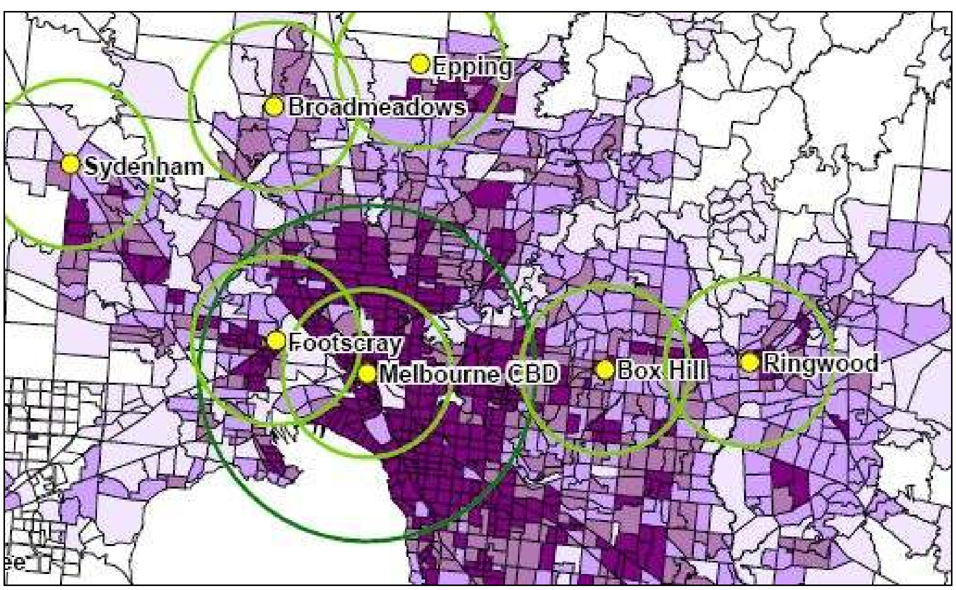

Figure 1: Melbourne Demographic Density

The small circles have a 5 km radius; the larger circle centred on the Melbourne CBD has a 10 km radius. The darkest colour shading indicates the highest demographic densities (over 40 persons per hectare), while the black lines show the transport planning zone boundaries.

Existing or planned cycle networks were then analysed to see how much "demographic coverage" they provided. A more extensive network that runs close to more people's work or home locations would exhibit higher demographic coverage. Demographic coverage was calculated in the GIS by determining how many people (based on their homes, workplaces or schools) were within a fixed distance of the cycle network.

For Auckland this distance was set at 500 m. An underlying assumption was that someone living or working within 500 m of the cycle network has access to it by cycle, although in reality some people would be prepared to cycle further to access the network, and other people might not be prepared to cycle that far. This distance would take an average commuter cyclist between 90 seconds and 2 minutes to cycle (assuming a cycling speed of 20 km/h and 15 km/h respectively). It also assumes that once on the network, a certain level of service for cycling is available such that most cyclists are satisfied with cycling conditions there to undertake their trips. It is also true that some people within 500 m of a cycle route "as the crow flies" would need to travel further than 500 m to reach the route, following roads and paths.

So a city with cycle routes spaced evenly across it at 1 km spacings would provide 100% demographic coverage (in that every home or work location in the city would be within 500 m of a cycle route). This might still not be a very good cycle network, as it might provide only for north-south travel, and not east-west.

However, demographic coverage does provide a way of comparing one cycle network (for example, the existing network) with another (such as a proposed network). It can also be used to measure the effectiveness of options within a proposed cycle route network to determine where effort should be concentrated in future network expansion.

Figure 2 shows part of the draft Auckland regional cycle network with a 500 m buffer around each route in the network. The orange dots are cycle crash locations between 2001 and 2005 inclusive. The red lines are regionally-significant cycle routes (as identified by the councils) and the green areas are 500 m buffers around each element of the network.

Figure 2: Part of Auckland Draft Regional Cycle Network with a 500 m buffer

This map gives a visual impression of the coverage of the network. However, the GIS is able to calculate the demographic coverage as a percent of total people (residents, jobs and school students). For this network, demographic coverage was calculated as 82%, which means that 82% of all home, work and school locations lie within 500 m of this proposed cycle route network.

2. Auckland Regional Cycle Network

2.1 Analysis of Alternate Regional Cycle Network Models

Analysis in the ARTA project focused on Auckland's four cities (Auckland, Manukau, North Shore and Waitakere), although some analysis was done of the three districts (Franklin, Papakura and Rodney) that are also included in the region. For this paper, the discussion is confined to the four cities. The overall data for the cities are shown in Table 1:

Table 1: Summary Statistics

	Auckland City	Manukau City	North Shore City	Waitakere City	Total
Population (2016 projection)	442,000	347,000	243,000	204,000	1,236,000
Education (2016 projection)	317,000	141,000	99,000	55,000	612,000
Employment (2016 projection)	147,000	75,000	57,000	37,000	316,000
Land area (sq. km)	154	244	128	367	893
Road length (km)	1,354	1,300	804	937	4,395
Regional roads (km)	146	87	72	35	340
Cycle crashes (2001 – 05)	642	188	173	135	1,138

Population accounted for 57% of the demographic total, employment was 28% of the total and education was 15% of the total. This was considered appropriate – weighting population higher than the other two demographic factors reinforces the fact that more cycle trips are likely to have the home as one or other end of a trip than either work or school.

The project in Auckland involved comparing four different models of a potential regional cycle route network:

- **Model 1: "The sum of the parts"** – a combination of all of the local cycling networks from each of the four cities that had published networks (Auckland, Manukau, North Shore and Waitakere Cities);
- **Model 2: "Regionally strategic parts of Model 1"** – those parts of Model 1 identified by territorial local authorities (TLAs) as regionally strategic;
- **Model 3: "Town centres"** – this model assumed that about 20 town centre areas which had been identified for increased "walkability" would also be the best places to prioritise for increasing "cyclability";
- **Model 4: "Town centres linked by regional links"** – a blend of Models 2 and 3, this model assumed that cycle improvements in the town centres would best enable more people to cycle, but that regional links would be needed to ensure connectivity for longer trips.

Demographic coverage was calculated in the GIS for each cycle route network model using a 500 m buffer. Similarly, "safety coverage" was calculated for each model by calculating the proportion of all cycle crashes on[1] the network.

[1] A buffer of 50 m was used to account for any minor discrepancies in digitising crash locations in relation to the cycle route network.

A network that included more crash locations was deemed better than one that included fewer crashes, using the assumption that a well-designed cycle facility would improve cycle safety.

Demographic and safety coverage were then combined arithmetically to give a raw model score. Each score was then divided by its network length in kilometres, so that longer networks did not necessarily score higher simply because they had more “coverage”. These results are shown in Table 2:

Table 2: Comparison of Models

	Model 1	**Model 2**	**Model 3**	**Model 4**
Demographic Coverage	82%	47%	55%	74%
Safety	74%	24%	60%	80%
Raw Score	155	71	115	154
Cycle Network Length	854	375	1,192	1,420
Final Score (normalised by length)	**0.18**	**0.19**	**0.10**	**0.11**

Dividing each raw score by the network length (“normalising” by length) was, in effect, a surrogate for cost. This is a crude approximation for cost, as it assumes that all types of cycle facilities cost the same per kilometre. This is obviously incorrect, as, for example, off-road cycle paths typically cost ten or more times as much per kilometre to construct than cycle lanes. However, it was considered better to use this assumption than to not correct for length or cost.

A variation on the regionally strategic cycle network model (Model 2) was recommended, but the project also recommended that further work be done by all TLAs to identify the most effective and useful cycle routes at both a local and regional level. Model 2, while the best of the four analysed, was not considered to be as good a “regionally strategic” network as it could be.

The analysis identified differences amongst the TLAs’ networks in the lengths of cycle network compared to the road network and in the apparent effectiveness of the networks in providing demographic coverage and safety. In particular, Auckland and Waitakere had identified significantly less cycle route (as a proportion of total road length) than Manukau and North Shore so the network was not homogeneous across the region. It was recommended that each TLA review its network and aim to identify between 12% and 15% of the length of road network as regionally strategic cycle routes.

2.2 Refinement of the Regional Network

The second phase of this project involved analysing the revised regionally significant cycle route network developed by the TLAs after the first phase. The revised network from the cities was much more homogeneous than the initial TLA suggestions, and was comprised as shown in Table 3:

Table 3: Cycle Route Length for New Model

	Total Road Length (km)	**Cycle Route Length** (km)	(percent of city)
Auckland City	1,354	247	18%
Manukau City	1,300	169	13%
North Shore City	804	119	15%
Waitakere City	937	131	14%

The vast majority of the network is “proposed”, with about 13% being existing facilities. The final score of this network increased from 0.19 for the earlier Model 2, to 0.26 (a 37% increase), as shown in Table 4:

Table 4: Summary of Analysis of New Model

Demographic Coverage	82%
Safety Coverage	92%
Raw Score	173
Cycle Network Length (km)	666
Final Score (normalised by length)	**0.26**

The two phases have significantly improved the coverage of the network in Auckland in terms of both the numbers of people served and the cost-effectiveness of the network. Further work is needed to identify which routes on this network (that have not yet been built) should be developed first, as some will no doubt provide higher demographic coverage per kilometre of route than others.

3. Melbourne Cycle Network

3.1 Introduction

The initial task in Melbourne was to help develop “a new set of principles for identifying priority bicycle routes in Melbourne”, and then to test these on a series of representative case studies of parts of Melbourne. The city has a Principal Bicycle Network (PBN; mostly cycle lanes) of which about 35% has been completed since its identification in 1994. Besides the PBN, Melbourne has a Metropolitan Trail Network (MTN; mostly off-road paths) which complements the PBN.

As for Auckland, the initial work involved building a GIS to manage and understand the city, its demography and its road and cycle networks. Table 5 shows demographic data for the Melbourne metropolitan area.

Table 5: Melbourne Demographics

	Number of People	Percent
Population	3,333,994	62%
Employment	1,306,583	24%
Education	725,030	14%
Demographic Total	**5,365,607**	

As for Auckland, population accounts for about 60% of the demographic total and employment about 25%. In the CBD, very high levels of employment there result in the demographic density being correspondingly high, as illustrated earlier in Figure 1.

3.2 Case Studies

Three cities were selected by VicRoads in consultation with the project team and Bicycle Victoria (“a self-funded community organisation, dedicated to getting more people cycling more often” in Victoria) to test the GIS methodology and the usefulness of the principles in identifying the PBN.

The cities selected were Maribyrnong, Boroondara and Casey, representing suburbs with different ages, proximity to the Melbourne CBD and socio economic conditions. The PBN was plotted for each case study. On the same map the demographic density was plotted, as illustrated for part of Maribyrnong in Figure 3.

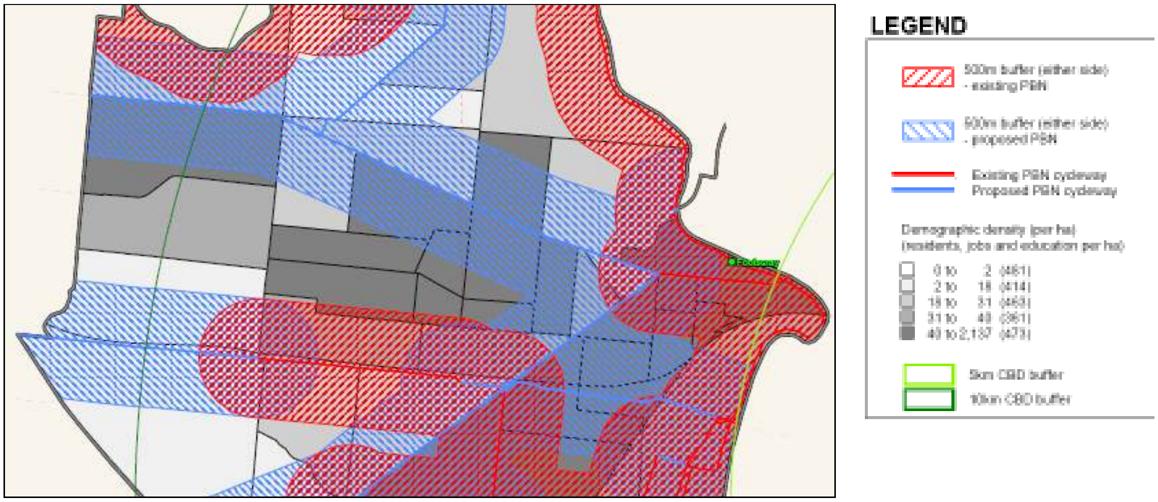

Figure 3: Demographics and PBN Coverage for Part of Maribyrnong

By visual inspection, it can be seen that a proposed route (blue) running from top left to the middle right traverses a reasonably dense part of Maribyrnong and would appear to improve the usefulness of the cycle route network if connected to other part of the network. The shaded blue area surrounding the proposed route indicates the demographic coverage for this route using a 500 m buffer. Red lines indicate the existing network and associated demographic coverage.

Demographic and other data for the three case study cities are shown in Table 6.

Table 6: Demographic and Cycle Networks in each Case Study City

City	Demographics	Density (persons/ha)	Length of PBN (km or %)		
			Existing	Proposed	% Complete
Maribyrnong	98,174	31	17	40	30%
Boroondara	243,261	40	104	124	46%
Casey	234,484	6	25	215	10%
All Melbourne	5,365,607	2	1,234	2,251	35%

Table 6 shows a number of interesting statistics. The demographic density varies considerably across Melbourne, from 6 persons per hectare in Casey to 40 in Boroondara. Other cities or shires have lower and higher densities. Casey's PBN is only 10% complete, whereas the PBN is more complete in both Maribyrnong and Boroondara.

A subsequent analysis involved consideration of the incremental benefits (in terms of demographic coverage) achieved by adding proposed PBN network elements to the existing PBN. Space does not permit description of this in greater detail.

3.3 Transit Cities and "Gravitational Effects"

An objective of the project was to develop a new set of principles for identifying priority bicycle routes for the PBN, based on a number of considerations, including:

- "Providing access to key destinations such as the Central Activity Centre of Melbourne and other Activity Centres";
- "The number of trips that these destinations attract and are likely to attract and the distance that cyclists are prepared to travel to these destinations"; and
- "The population density and/or demographics of particular areas".

In discussion with VicRoads and Bicycle Victoria staff, it was decided that while the demographic analysis of the PBN and its 500 m buffers responded well to the second and third of these bullets, it would be important to relate the PBN to the Melbourne CBD and key activity centres, to satisfy the first bullet.

After considering Melbourne's "Transit Cities", "Principal Activity Centres" and "Main Activity Centres", it was decided to use the ten Transit Cities (including the CBD) as the key manifestation of activity in Melbourne.

Accordingly, an analysis of these centres was undertaken. The demographics contained within 2 km and 5 km of each Transit City were calculated, and after reviewing the "fit" between these circles and the underlying demographic density, a 10 km circle around the Melbourne CBD was added. From visual inspection it can be seen that a 10 km circle centred on the CBD with 5 km circles around the other Transit Cities provides reasonable coverage of the Metropolitan area. These circles, and the underlying demographic density, are illustrated in Figure 1. The GIS analysis and subsequent spreadsheet manipulation are summarised in Table 7:

Table 7: Transit City Demographics

Transit City	Sum of Demographics			Density (persons/ha)		
	2 km radius	5 km radius	5 km radius plus 10 km for CBD	2 km	5 km	10 km
Sydenham	23,493	87,528	87,528	19	11	
Footscray	43,867	273,730	In CBD	35	35	
Box Hill	50,359	270,297	270,297	40	34	
Ringwood	36,819	188,217	188,217	29	24	
Dandenong	45,234	175,976	175,976	36	22	
Frankston	28,527	104,933	104,933	23	13	
Werribee	28,495	77,257	77,257	23	10	
Broadmeadows	28,807	143,506	143,506	23	18	
Epping	12,276	116,036	116,036	10	15	
Melbourne CBD	308,960	678,069	1,470,788	246	86	47
Subtotal	**606,837**	**2,115,549**	**2,634,538**	**48**	**27**	
% of Melbourne in Transit City Buffer	**11.3%**	**39.4%**	**49.1%**			

The table shows that 11% of the demographics (population, education and employment) are within 2 km of the centres of the Transit Cities, 39% are within 5 km, and 49% are within 5 km of the nine outlying Transit Cities and within 10 km of the Melbourne CBD. These figures are approximate as there is a small amount of overlap and hence double-counting.

A choice of 5 km for the Transit Cities corresponds to a 20 minute cycle ride at a conservative 15 km/h, with the 10 km buffer to the CBD representing a 40 minute ride for an average to slow cyclist. It is understood that many central Melbourne cycle commuters travel between 5 km and 10 km to work.

The coverage provided by the Transit City circles can be enhanced by providing additional PBN elements within these areas and in some cases by providing cycling corridors between adjacent Transit Cities and between the cities and the CBD.

Using the Transit Cities as a key driver for the PBN effectively gives them a “gravitational attraction”, with the CBD being given significantly more weight as its 10 km radius buffer increases its area by a factor of 4 compared to the smaller Transit Cities.

3.4 New Principles

The new principles recommended for Melbourne were:

1. The PBN will maximise in a cost-effective manner the number of trips made by people riding bicycles for transportation in Melbourne.
2. PBN routes will be located so that they focus on Melbourne’s Central Activity Centre and Principal Activity Centres, plus significant residential, employment and educational areas.
3. PBN routes will maximise directness, separation and priority for people riding bicycles for transportation and may be located on State Roads, Municipal Roads or other locations.

3.5 Evaluation of Different Buffers

A subsequent project for VicRoads evaluated the effectiveness (as measured by demographic coverage) of three different buffers, 400 m, 800 m and 1,600 m. The study showed that 74% of Melbourne people (residents at their homes, employees at their workplaces and students at their schools) are within 800 m “as the crow flies” of the existing PBN. This “demographic coverage” figure rises to 92% within 800 m of the proposed PBN.

An illustration of the coverage of the three different buffers is provided in Figure 4. The extent of the 400 m buffer on the existing PBN (orange) is shown in yellow. The pale green shows the additional area included when the buffer is increased to 800 m and the dark green shows the increased coverage of the 1,600 m buffer. White areas (mostly around the periphery of greater Melbourne) represent land not covered by the buffers. These more distant areas generally have low demographic density. Transit cities are shown as maroon squares.

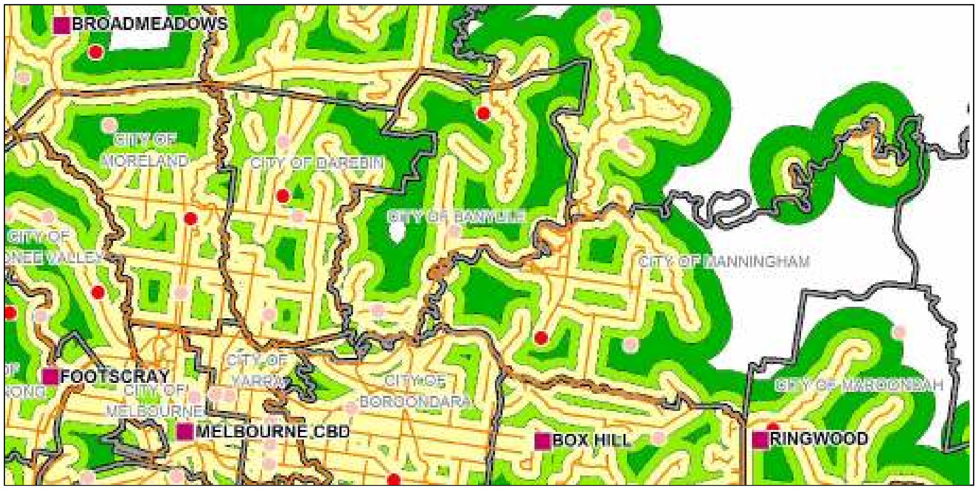

Figure 4: Coverage of Different Buffers for the Existing PBN

A number of conclusions and recommendations were made, including:

1. An 800 m buffer was generally recommended as a policy tool for the provision of the PBN. This corresponds to a spacing of 1,600 m between parallel routes.
2. A closer spacing of the routes of the PBN (a smaller "grain size") was recommended for the Melbourne CBD because of the very high demographic densities there.
3. Further work is needed to integrate the Metropolitan Trail Network (MTN) into the PBN and to look for other potentially beneficial links for inclusion in the PBN.
4. A tool should be developed to quantify the merits of adding a particular route (especially those identified as proposed routes in the PBN) to the network. This could be as simple as "demographics per km".

4. Conclusions

The Auckland and Melbourne projects have demonstrated the merits of a GIS-based analysis of cities, using transportation zones as the basic spatial unit of analysis. Combining population, employment and education data give a useful measure of urban activity and potential cycle trip generation.

Like any good model, the ARTA and VicRoads cycle route network GIS models improve our understanding of a complex, underlying system (in this case the fabric of our cities) as much as it provides us with specific answers to specific cycle route network questions.

References
1. *Regional Cycle Network Evaluation*, MWH New Zealand Ltd for ARTA, February 2006
2. *Principles for Identifying Priority Bicycle Routes in Melbourne*, Beca Proprietary Ltd in association with MWH New Zealand Ltd and Traffix (now ViaStrada) for VicRoads, December 2006
3. *Assessment of Buffers for the Melbourne PBN,* Traffix (now ViaStrada) for VicRoads, April 2007