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Before and after Sydney's M4 Motorway: did it make the city more sustainable?

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BEFORE AND AFTER SYDNEY'S M4 MOTORWAY: DID IT MAKE THE CITY MORE SUSTAINABLE?

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Keywords

Urban motorways, induced traffic growth, mode shifting

Abstract

This paper presents an examination of traffic volumes on Sydney's western road network before and after the opening of the Mays Hill to Prospect section of the M4 Motorway. The aim of the examination is to identify any possible traces of *induced traffic growth*, or new motor vehicle trips generated in response to the quicker travel times made possible by the increase in road capacity.

The data show that average daily volumes on the M4 Motorway and Great Western Highway grew from just under 80,000 vehicle movements per day in 1991 to around 100,000 in 1992 after the new motorway section opened. Once business-as-usual growth (3,000 vehicles per day), road traffic reassignment (7,000 vpd) and possible mode shifting from the rail network (6,500 vpd) are taken into account, a residual volume of around 3,500 is left. This is likely to be redistributed or induced traffic growth.

Induced traffic growth has significant implications for the sustainability of urban systems. These are discussed in tandem with a brief review of the debate that has taken place around induced traffic growth.

INTRODUCTION

The focus of this paper is an examination of changes in road traffic movements that took place after the opening of the M4 Motorway section from Mays Hill to Prospect in Sydney's west. In particular, this empirical analysis aims to gauge the extent and calibre of any additional road traffic generated in response to the quicker travel times made possible by the increase in capacity. This effect is often referred to as *induced traffic growth* and it has significant implications for the sustainability of urban systems.

Induced traffic growth can be most easily observed in urban systems where congestion levels are high and the opportunities for people to make exchanges is greatest. The effect occurs when the prevailing speed of a transport network is increased. Like a thermostat in a hot water heating system that sends feedback signals to the heating element to either add more heat to the system (positive system feedback), or reduce the amount of heat entering the system (negative system feedback), congestion works to regulate the amount of travel that people are prepared to undertake. When prevailing congestion levels are reduced and speeds increase, the travel times for standard trips becomes less. Attracted by the opportunity to meet more people and make more exchanges at new destinations with the time they have saved, some people choose to make more trips or travel further (positive system feedback). As more people choose to do this, congestion levels rise and travel times increase. This has the effect of discouraging people from making more trips (negative system feedback).

The existence of induced traffic growth has been a point of debate in transport studies for some time. Interest heightened during the 1980s and 90s when many new urban motorway projects were opened both in Australia and overseas and traffic volumes appeared to increase dramatically. Despite a rich and extensive array of case studies for European Union and North American cities, there are few equivalents for Australian cities. Luk and Chung (1997) point to this gap in the literature and provide a Melbourne case study. Problems with data parity and boundary conditions were encountered in their analysis. They found no evidence of induced traffic growth or mode shifting. There is one other Australian case study by Mewton (1997) that provides an analysis of before and after conditions of the Sydney Harbour Tunnel and Gore Hill Freeway[1]. With more extensive data, fewer problems

[1] To the best of my knowledge this is the case, however if other case studies have been undertaken, I would be grateful for information regarding them.

with data parity and fewer holes in the boundary conditions, Mewton did find evidence of induced traffic growth. His findings are consistent with those in this study.

While the organising principles that underpin urban travel behaviour are generic to all urban systems, the implications of a problem always seem more real when demonstrated in your own city. Increasing the number of induced traffic growth studies for Australian cities is therefore an important objective of this paper and it is hoped that this case study may encourage more.

This paper has three parts. The first examines the politics that surrounds this topic. Given that everyone uses transport systems in some way, induced traffic growth and the problems it creates has attracted wide scale public discussion. Urban transport is also an area involving billions of dollars of both public and private sector investment. The politics that arise from this mix affects the science. A familiarity with the politics helps to clarify many of the points raised in relation to both empirical analyses, such as that reported here, and policy outcomes.

The second part of this paper presents the results of a case study that examines conditions on the road network and rail line of western Sydney before and after opening of the Mays Hill to Prospect section of the M4. Empirical analysis able to provide conclusive confirmation of the effect is difficult to achieve owing to the nature of the system and the inherent difficulties in measuring it. These are explained step by step and where estimates have been extrapolated from time series data, these are undertaken in a conservative manner. But even so, a residual volume results that is likely to be additional or longer trips.

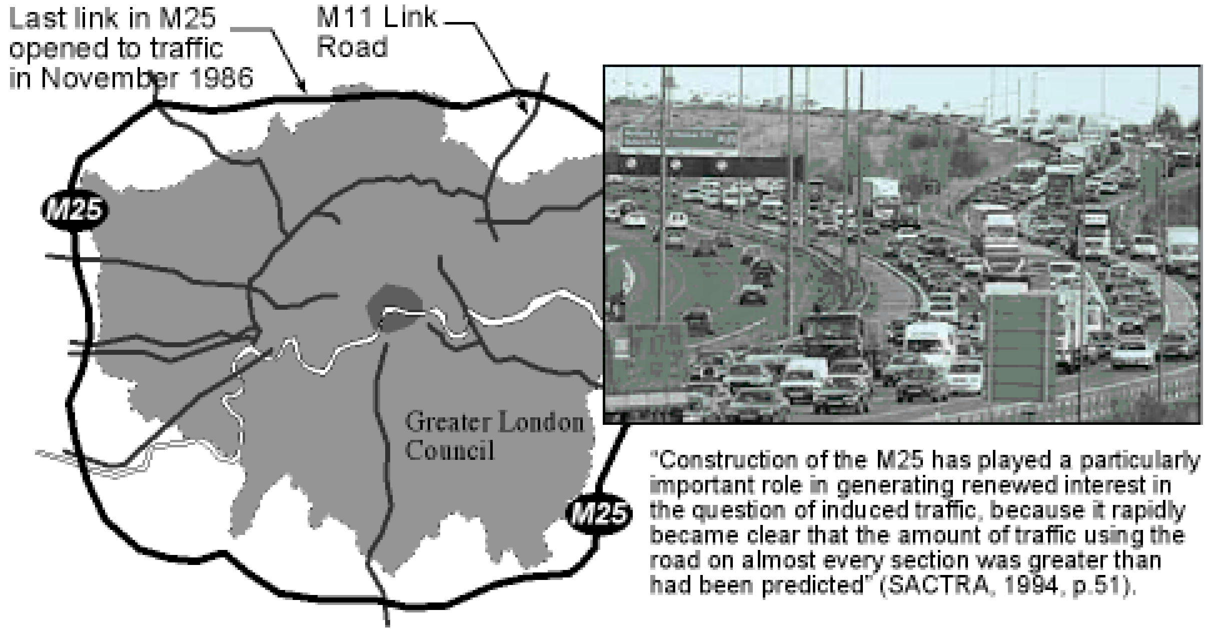
The third part of this paper reviews the policy implications that urban motorway development has for the sustainability of urban systems like Sydney. As with the science, policy is obviously affected by the politics that takes place around this topic. The paper concludes that the M4 Motorway has not been conducive to improving the sustainability credentials of Sydney and policy should be recast to reflect this.

1. Is induced traffic growth real? The impact of public opinion on transport science and professional practice

In engineering terms, induced traffic growth is simply a form of positive system feedback (Luk and Chung, 1997, p.3). The General Systems Theory (GST) used to define what system feedback is, how it works and why it occurs, is fundamental to all engineering disciplines, making the phenomenon fairly unremarkable (Wisdom, 1956, p.111–112). But despite the ease of this explanation and articulate accounts by scholars like Downs (1968), Plowden (1972), Thomson (1977), and Mogridge (1990), to name but some, but government road and transport agencies often deny the existence of induced traffic growth (SACTRA, 1994, p. 55).

The critical event that triggered a change in this position was the opening of the last link in London's M25 orbital motorway. Although this took place in the UK, it affected discussion worldwide. After opening it was clear that the amount of traffic on almost every section of the ring-road was greater than before and much higher than predicted (SACTRA, 1994, p.51). Longer delays and congestion resulted, as did a change in public opinion, which subsequently turned on the claim that motorway building was a solution to road traffic congestion. In an effort to appease public objections the British Government commissioned a special study into the question of whether motorways generated more traffic. This was undertaken by SACTRA — the Standing Advisory Committee on Trunk Route Assessment — who produced a report entitled *Trunk roads and the generation of traffic* (SACTRA, 1994). The report was a landmark study, was influential both in the UK and internationally, and provided a comprehensive summary of the many issues surrounding the phenomenon and science that explains it.

Figure 1 London's M25 Orbital Motorway



To guide their investigations, SACTRA identified four key questions, the first and primary one being:

> "Does the provision of improved trunk roads and motorways give rise to induced traffic — is it a real phenomenon?" (SACTRA, 1994, p.i).

In answer to this, SACTRA concluded that:

> "… induced traffic can and does occur, probably quite extensively, though its size and significance is likely to vary widely in different circumstances" (SACTRA, 1994, p.ii).

This conclusion was drawn from a mix of empirical analyses and logical inference. The committee found that empirical evidence alone could not answer the question because of the complex nature of urban systems and the inability to make conclusive measurements (SACTRA, 1994, p.ii and pp.29–31). In the past this problem had been cited as reason for dismissing the phenomenon (SACTRA, 1994, p.85). However by the time of SACTRA's inquiry, several empirical case studies had been undertaken which showed that despite problems with data availability there was an empirical case to be answered (for a summary see Pells, 1989 and SACTRA, 1994, pp.51–85). To bridge the gap, SACTRA also appealed to the logic of economic theory to support its conclusions (SACTRA, 1994, pp.111–122). The combination of empirical evidence and theory enabled SACTRA to confirm in a qualified way that induced traffic growth does occur and that changes to assessment procedures were necessary.

While the effects of the M25 compelled the British Government to respond, it is important to remember that SACTRA conducted their investigation against a backdrop of extraordinary public protest. As the members of SACTRA deliberated on the issues surrounding induced traffic growth, several hundred citizens were refusing to move out of homes earmarked for demolition to make way for construction of the M11 Link Road through London's East. Hundreds camped on roofs while others cemented themselves into basements to stop demolition gangs from moving in. At the height of the campaign, over 600 police in riot gear came on site to remove protestors (Anon, 1994, p.57). This made for disturbing imagery on the evening news. Feature articles appeared in magazines questioning the authority of arguments used to justify road building. These cited evidence to contradict the Department of Transport's claim that motorway construction solves the problem of congestion (for example Tickle, 1993).

Some media commentators trivialise community campaigns, but in reality actions like these make governments uneasy. After questioning in the British Parliament, it was revealed that £2,204,906 had been spent on policing the M11 Link Road protests (Hansard, 1994, column 379). The promise of other bruising conflicts at Twyford Downs and Newbury heightened the sense of crisis (Weekly SchNEWS, 1994 and Williams, Van Vliet and Kim, 2001, p.1058). At the time, £25billion had been committed to road and motorway construction under the *Roads to Prosperity* program. Many projects were put on hold while the Thatcher/Major Governments reconsidered their policy options. Within this political climate, decision makers were more amenable to acceptance of the science that accounts for induced traffic growth and so backed down[2].

Urban motorways in Australian cities have provoked similar criticisms and public unrest. Resident protests against Sydney's M2 and M5 Motorways held up construction for years. But no Australian government has commissioned an official

[2] This observation was made by Prof John Whitelegg from the Stockholm Environment Institute at the University of York in a telephone interview I had with him on 9 January 2004.

investigation into the effects of urban motorway construction along the lines of SACTRA. Nor is there a robust academic tradition of empirical investigation of motorway construction under Australian conditions. NSW Government inquiries into particular motorways have identified the problem of induced traffic growth and recommended against construction (see for example Kirby, 1980), but these findings were not acted upon.

Because of its geology, Sydney is a city where tunnelling is easy. Once a motorway is put underground, opposition from residents who would lose homes or green space is largely removed and confined to arguments over emissions from exhaust stacks (Main, 2003, p.29). Tunnelling is the course the NSW Government has taken in Sydney since the M5East. The primary drawback however is that construction costs increase significantly, posing a high opportunity cost to other areas of government responsibility in need of capital investment. The question of value for money soon poses a significant dilemma for road building advocates.

Figure 2 Community protest over Sydney's M2 Motorway

▲ Most anti-motorway protests include a popular explanation of the causal relationship between road space and car use, or induced traffic growth. Note the placard to the far right of this photograph.

Photo courtesy of Ivan Lewis, Beecroft, May 1995.

Like the Carr Government in Sydney, the Blair Government in the UK is avoiding politically sensitive areas. There has been a reduction in the number of new surface road proposals through residential communities or environmentally sensitive areas. Instead, they are widening existing roads. Changes to the configuration of projects have been accompanied by a reinterpretation of SACTRA's conclusions by some academics. Many community groups interpreted SACTRA's findings as confirmation of their arguments—that motorways generated more road traffic, congestion and pollution, while taking away passengers and capital from more efficient and sustainable forms of public transport development. But there have been very different interpretations of SACTRA. For example Foster (1995) has argued:

> "The [SACTRA] Report scarcely mentions those cases where inclusion of induced traffic improves the case for more road building and for building and improving roads to a higher capacity … If the demand forecast for any product is revised upwards there will be a stronger case for investment to meet it … subject to an overall cost benefit test. The valid exception is where the cost of additional capacity required is high enough to negate the return on investment … The adoption of road pricing would alter what is optimal" (Foster, 1994, pp.27 and 29).

SACTRA's reliance on mainstream economic theory also opened the way for a repositioning of the economic arguments for building new roads and advocacy of demand management practices like road pricing (see for example Williams, Van Vliet and Kim, 2001). These will be discussed in more detail in section three of this paper. But suffice it to say, this shift in the debate has heralded a new, albeit cautious, approach to road building. Almost 10 years after publication of SACTRA's report on induced traffic growth, the Blair Government is proposing to add further lanes to the M25 to combat high levels of congestion. In light of past empirical and political outcomes, this seems politically risky and technically problematic. It has apparently been made at the insistence of the commercial business sector[3] — people more readily persuaded by explanations couched in economic terms like those put by Foster and who are unfamiliar with the wider set of system feedback effects that

[3] This point was made by Prof John Whitelegg.

include mode shifting from public transport as described by practitioners like Mogridge (1997) and cited by some resident and environmental advocacy groups.

But why bother with a discussion of politics when presenting an empirical case study? Surely a simple statement of the results is sufficient?

Understanding this history is essential to any empirical case study because the phenomenon and its implications are contested. Politics can and does affect what is permissible as empirical evidence or proof. Careful attention to definitions and boundaries used to frame analysis can overcome many criticisms. As SACTRA found, critics often raise possible explanations requiring data that are unavailable. Doubt is then used to refute the induced traffic growth hypothesis. This case study leans heavily on SACTRA's accounts of these criticisms, using the definitions outlined by them to make the analysis more robust and systematic. Fortunately, data are available in some cases to test for these other possibilities, but at times it is fractured and incomplete. Where this occurs, values have been estimated from other points in the time series data and choices made between higher or lower values. Where this has taken place, the decision always errs on the side of caution, settling for the option that results in a lower estimate for induced traffic growth.

The second reason for reviewing the politics is that despite gaps in the empirical record, decisions to either proceed or not proceed with urban motorway constructions in Australian cities have to be made. Or in other words this cannot be treated purely as an interesting intellectual problem involving urban systems science. As the history shows, governments and transport agencies more readily acknowledge induced traffic growth and its attendant problems when public unrest is high. Once that opposition recedes, the urgency to address the problem also recedes, arguments change course, and the problem is repositioned, as are its implications. Politics and ideology do not alter the material reality of the effect and nor does our success at measuring it. So from a practitioner's point of view, understanding the politics is vital when drawing conclusions about whether or not the evidence and science is sufficient to warrant a change in policy. Familiarity with the politics and convolutions in the debate helps to distinguish criticisms that are the product of healthy scepticism and honest inquiry from counter arguments that are motivated merely to maintain an ideological position. These will be addressed in section three.

2 Before and after Sydney's M4 Motorway from Mays Hill to Prospect

Broadly, there are two ways of testing for the presence of induced traffic growth. The first is to survey a sample population and document changes in origins and destinations, arrival and departure times as well as trip rates for travel undertaken before and after a particular development. Studies by Kroes et al (1996) and Wilcock (1988) provide good examples of this approach. A second method involves monitoring changes to traffic volumes on particular points across a network before and after a capacity change. Most case studies seeking to identify induced traffic growth use this second method. Good examples are provided by Wurtz (1992), Evans, Lee and Sriskandon (1986) and Purnell (1985). The two Australian case studies by Luk and Chung (1997) and Mewton (1997), also use this approach.

The benefit of the first method is that because data on origin and destination changes are collected, the results are able to distinguish between traffic redistribution and induced traffic growth. The drawback is that in isolation this method cannot provide estimates of changes in net volumes and so significance is difficult to gauge. By using the second method that analyses changes to traffic volumes across specific points in the network, differences in net volumes can be assessed. The drawback to using this method is that the precise nature of the traffic that makes up any residual or additional volume is unknown, so an assumption needs to be made about its source. Bonsall (1996, p.32) has argued that a combination of these two methods — surveys and traffic volume counts — would need to be used to provide near conclusive proof of the existence and extent of the effect.

The approach taken in this analysis of Sydney's M4 is one that might be called *identification by attrition* where explanations for the large increase in road traffic volumes are systematically deducted from the total. The full extent of the increase is first established; business-as-usual growth is estimated and subtracted; traffic reassignment from other routes is identified and subtracted; volumes from mode shifting are calculated and likewise subtracted. The result is a residual volume that is likely to be new or longer trips generated in response to the quicker travel times made possible by the increase in capacity.

At the outset it is important to realise that the generation of new trips is but one of many different outcomes that can occur after the opening of a new motorway section. Distinguishing this from other forms of system feedback needs to be done by carefully setting boundary conditions and clarifying definitions of other possible explanations, which is what the next two sections are intended to do.

2.1 Definitions of different traffic types

Breaking down the traffic stream into its constituent traffic types is critical. Setting boundary conditions needs to be done in such a way that these can be captured and accounted for. It is for this reason that SACTRA consulted widely and directed careful consideration to this point, which is why their conclusions have been used here. SACTRA defines the different traffic types in the following way:

Traffic reassignment

Refers to traffic that shifts from other routes to the new route. In this instance no additional trips are being made, but the route choice changes because the same trip can be made in a shorter period of time. The origin and destination of trips remain the same and there may even be a decrease in the distance between the two so that Vehicle Kilometres Travelled (VKT) is reduced (SACTRA, 1994, pp.19 and 53).

Traffic redistribution

Refers to cases where commuters decide to access more distant destinations because these can be reached within shorter time periods. No additional trips are made, but new origin and destination combinations result, where the distance between the two is increased so that VKT increases. SACTRA classifies this as a form of induced traffic growth because of the increase in VKT (SACTRA, 1994, pp.18 and 53).

Mode shifting

Refers to traffic that shifts from one mode to another, such as from rail to the road. Once again this occurs as a result of faster travel times on the new route and mode compared to those on the old (SACTRA, 1994, pp.18 and 53). In cases such as the M4, this results in an increase in road vehicle VKT but a decline in rail passenger kilometres.

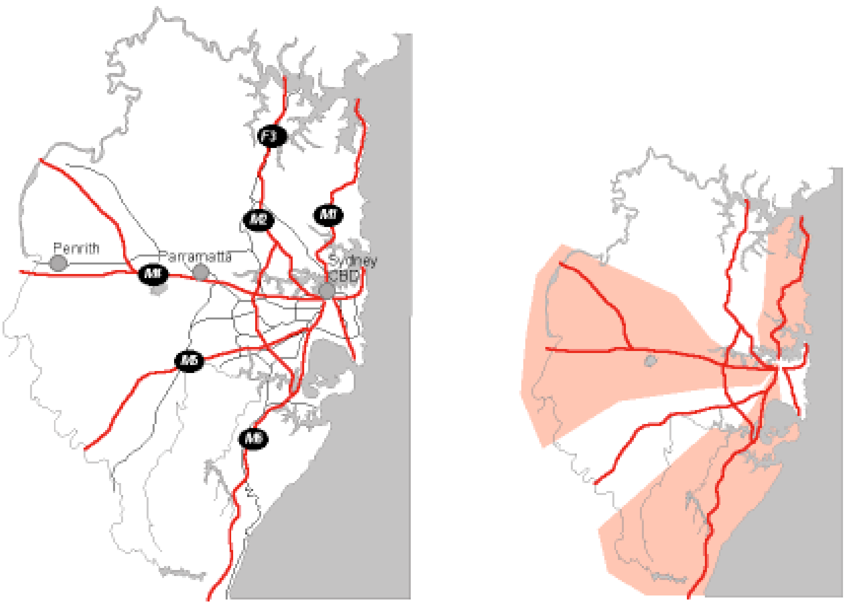
Induced trips

Refers to cases where people undertake new and additional trips. Because the network speed has been increased, some people choose to make more trips as part of their typical routine (SACTRA, 1994, pp.20–22 and 53).

2.2 The structure of the Sydney transport network and identification of boundary conditions

The Sydney metropolitan area radiates from the Central Business District along a series of radial road and rail trunk routes. Like spokes on a wheel the trunk routes distinguish each of Sydney's geographical sectors. Figure 3 shows the Sydney regional trunk route system as laid out in the County of Cumberland Scheme in the early 1950s. The Scheme was Sydney's first legislated plan and was dominated by a proposed series of radial motorways, the geometry of which laid the foundation for trunk road and motorway development from that time to the present.

Figure 3 County of Cumberland Scheme trunk route structure plan for Sydney, 1954



Adapted from: Ashton, P. & Waterson, DB. 2000, *Sydney takes shape: a history in maps*. Hema Maps Pty. Ltd., Brisbane, pp.53 and 59.

Understanding the motorway network structure and its influence on movement throughout the region is important when establishing boundary conditions for the purposes of analysis. Boundary conditions identify the partition in a system that distinguishes inputs from outputs. In this case the aim is to assess the amount of traffic moving through the system before the capacity increase with volumes after the increase. The route used to cross the boundary will change for some traffic and a way needs to be found to distinguish traffic reassignment from redistributed and induced traffic.

In traffic studies, boundary conditions are set by the location of *screenlines*. A screenline is a conceptual line drawn across a section of the urban system that attempts to capture all traffic movements between the same broad set of origins and destinations. Where several different routes could be taken for the same trip, a screenline draws a boundary across all of these, thereby accounting for all the traffic moving in and out of the areas on either side. As mentioned earlier, each motorway in the Cumberland Scheme is sited in the middle of a geographical sector as depicted in Figure 3. Although the rest of the road network is not shown in this diagram, there is a complex network of unrestricted access trunk routes as well as local collector roads. Some of these have radial alignments and also provide access for regional traffic movements in the direction of the M4 alignment. A screenline needs to cut across the entire sector and all possible routes in order to assess the true extent of changes. The screenline of particular significance in this study is Screenline12 as shown in Figure 4.

Screenline12 captures regional, or longer distance, traffic movements from the outer edge of the western sector to key centres like Parramatta and the CBD in the east. To do this it has to cross a large area — just on 40 kilometres in length, or 20 kilometres either side of the M4 Motorway. Technical staff at the NSW Roads & Traffic Authority (RTA) identified Screenline12 where it is used to assist in traffic monitoring programs and modelling tasks[4]. Figure 4 shows the position of Screenline12 and lists the roads that cross it.

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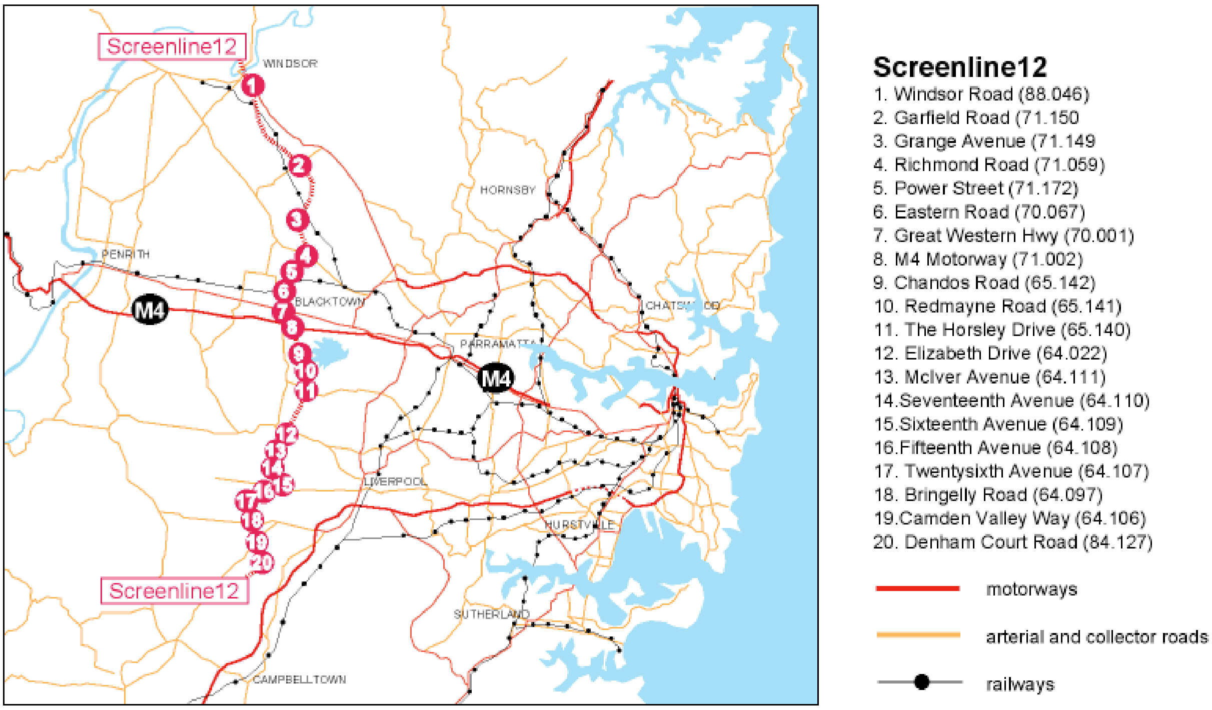
[4] I am indebted to Mr Matthew Wilson from the Roads & Traffic Authority of NSW for having taken the time to discuss features of the agency's road traffic model with me.

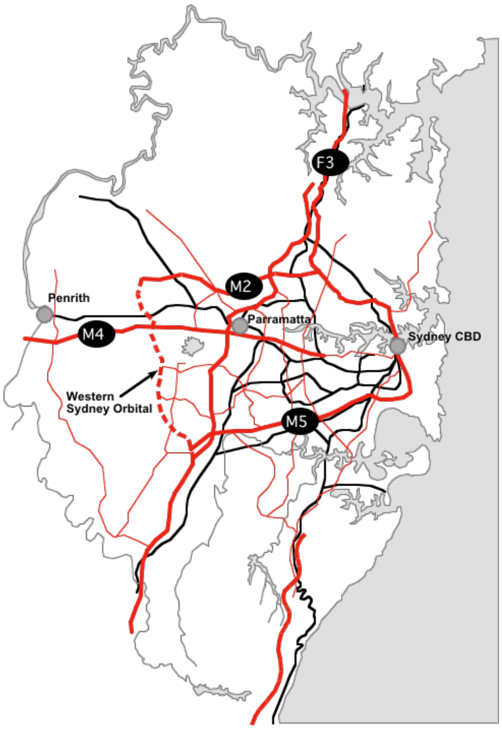
Figure 4 Position of Screenline12



Source: RTA. 2000, *Traffic volume data for Sydney Region 1999, Volume 2.* Roads & Traffic Authority of New South Wales, Sydney.

While construction of several of the County of Cumberland Scheme motorways has taken place, the built configuration has been altered in some parts with the most substantial taking place after 1990. This occurred in response to criticism that radial motorways funnel traffic into the central city. It was believed the motorways should direct traffic around congested centres instead. A new concept called *The Sydney Orbital* was developed in response to this criticism. This is shown in Figure 5 and comprises the Cumberland motorway network with additions to the M2 and a Western Sydney Orbital. This was meant to take traffic around the city — the demographic centre being Parramatta. Given that the city's operational centre is still the CBD in the east, attracting more traffic than Parramatta, the network still functions as a radial network and so screenlines are configured to capture these movement formations (compare these with screenline configurations used to monitor London's M25 orbital for example SACTRA, 1994, p.52).

Figure 5 The Sydney Orbital, 2000



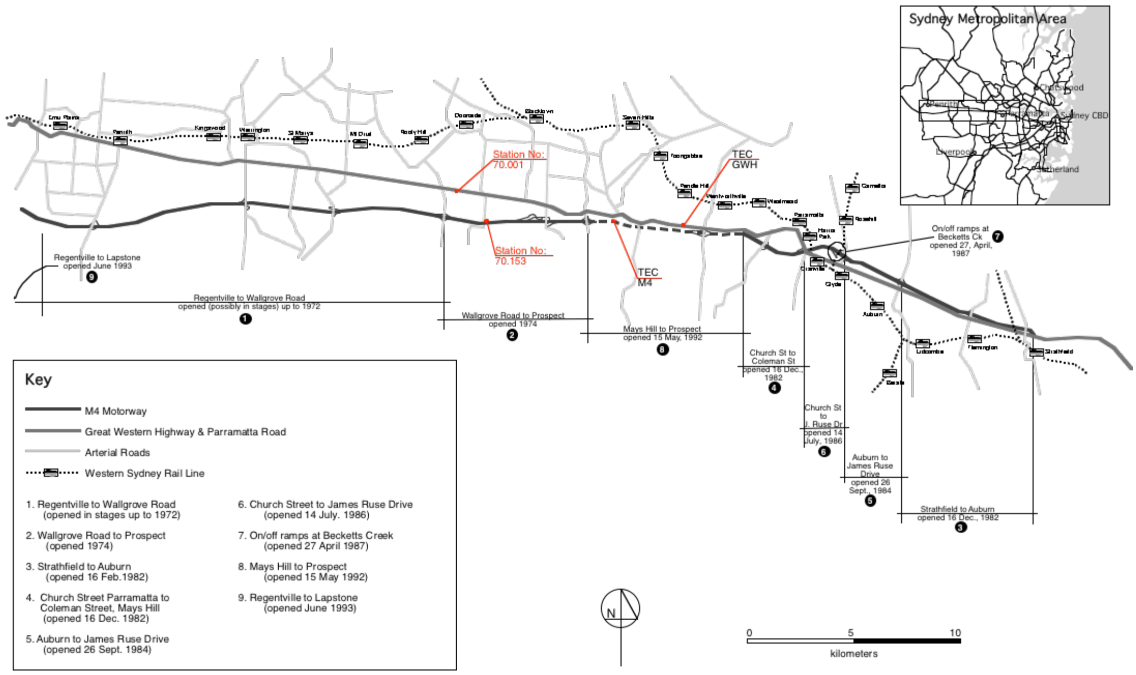
Source: NSW Government (1998), *Action for Transport 2010: an integrated transport plan for Sydney*. Department of Transport, p.30.

Regrettably, comprehensive time series data were not collected at all the points on Screenline12 during the study period from 1985–1995. As will be shown, the most dramatic changes to traffic volumes occurred on the Great Western Highway and M4 Motorway that sit at the centre of the western sector and which accommodate the greatest traffic volumes. Data for these points is relatively complete, so to begin, these primary trunk routes will be considered.

2.3 Road data for the Great Western Highway and M4 motorway 1985 - 1995

Three trunk routes dominate the western sector of Sydney. These comprise one unrestricted access carriageway, starting in the east at Parramatta Road which dog-legs onto Church Street at Parramatta before joining the Great Western Highway (GWH); the M4 Motorway, which is a restricted access carriageway in the form of a tollway, and; the Western Sydney Rail Line (WSRL). Together these provide for long distance commuting along the western axis of the Sydney region, continuing through to the Blue Mountains. The relative alignments of these are shown in Figure 6.

Figure 6 Sequence of M4 Motorway section constructions



Source: Zeibots, ME. (2003a), *Before and after opening of the M4 Motorway from Mays Hill to Prospect: an empirical analysis.* Working Paper. Institute for Sustainable Futures, University of Technology, Sydney, p.11.

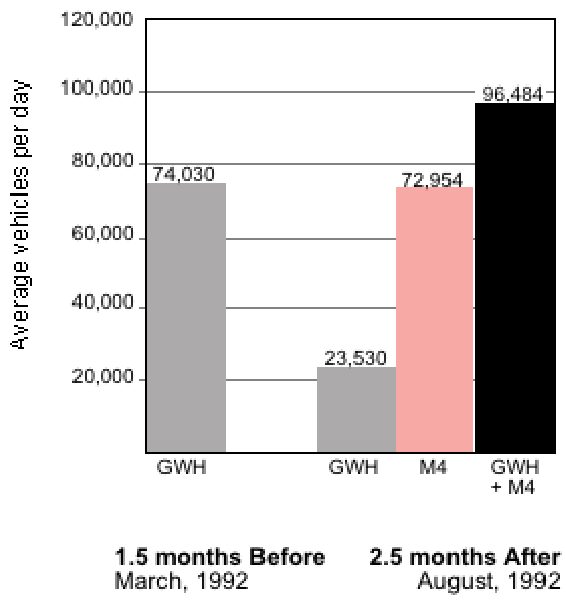
As can be seen in Figure 6, the M4 motorway was built in stages, beginning in 1972. The last section between Mays Hill and Prospect was opened to traffic on 15 May 1992. The data used to monitor changes in road traffic volumes were obtained from the RTA that has a regular traffic monitoring program, recording volumes at around 2,000 points in the Sydney Metropolitan network. Of these, some 140 are permanent counting sites — see notes on road data in Appendix I of Zeibots (2003a). Figure 6 shows the position of permanent counting stations 70.001 and 71.002. These sites are located on Screenline12.

Data were also obtained from a report commissioned by the RTA and undertaken by TEC Consulting. Pneumatic tube counters were used by TEC to obtain data. The locations of these temporary sites are indicated in Figure 6 as TEC:GWH and TEC:M4.

The primary difference between data collected at each of the sites is that RTA data comprise Annual Average Daily Traffic (AADT) counts that include data for weekdays and weekends, whereas data collected by TEC are for average weekday traffic only. The value for AADT is generally lower than for Average Weekday Traffic (AWT).

Figure 7 shows before and after average weekday road traffic volumes for the M4 and GWH from the report undertaken by TEC Consulting. These have been disaggregated according to vehicle type. The RTA data could not be disaggregated in this way.

Figure 7 Comparison of before and after Average Weekday Traffic classification counts for sites in the Great Western Hwy and M4 Motorway



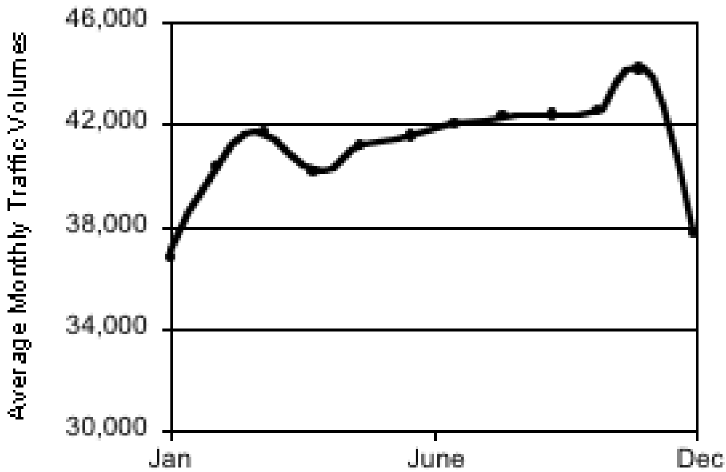
Location	Before (March, 1992)				After (August, 1992)			
	light	rigid	artic.	total	light	rigid	artic.	total
Great Western	69,204	2,720	2,106	74,030	22,862	418	250	23,530
Hwy	93%	4%	3%	100%	97%	2%	1%	100%
M4 Motorway	-	-	-	-	68,119	2,648	2,187	72,954
					93%	4%	3%	100%
TOTAL				**74,030**	**90,981**	**3,066**	**2,437**	**96,484**

Source: TEC Consulting. 1992, *Traffic changes associated with new M4 Motorway works.* NSW Roads & Traffic Authority, Table 3.1.

For the month of March—immediately before opening of the new motorway section—and the month of August—after opening—the data indicate a significant increase in traffic volumes over the two road routes. Average Weekday Traffic (AWT) on the GWH for March was 74,030. After opening of the M4 from Mays Hill to Prospect the AWT on the GWH dropped to 23,530 for August, while the AWT for the M4 reached 72,954. Combined, August AWTs for these routes were 96,484. This constitutes an increase of 22,454 vehicle movements on average per day for working weekdays.

By far the greatest increase is in light traffic volumes, that is, private motorcars, motorcycles and utility vans. These volumes increased by 21,777, or 31 per cent. Rigid and articulated heavy vehicles increased by 346 and 81 respectively, or thirteen and four per cent.

Figure 8 Seasonal fluctuations in traffic volumes on the Great Western Hwy (70.001) 1985

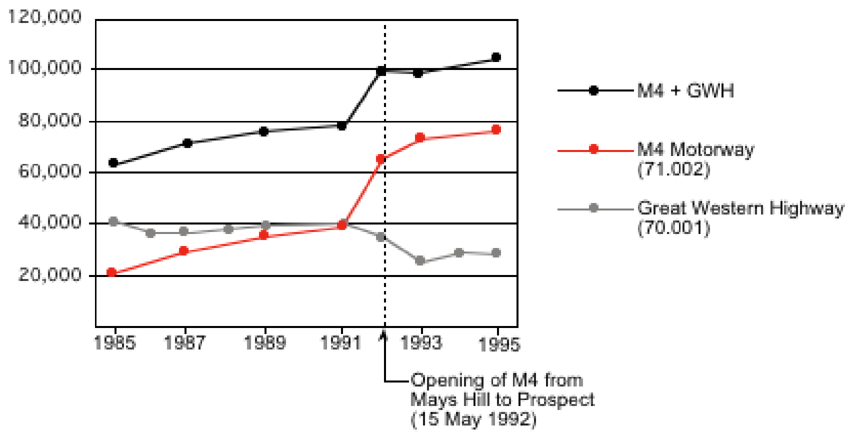


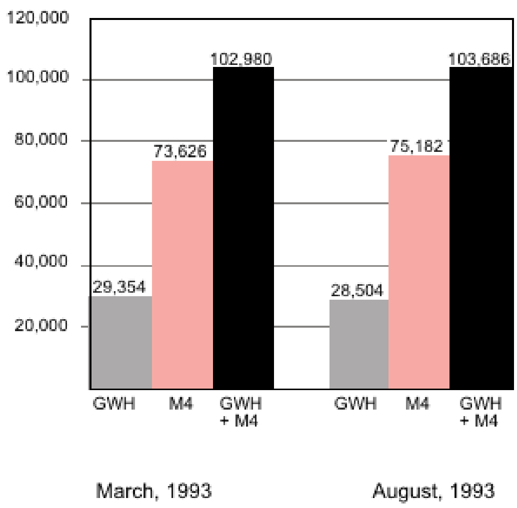
Source: RTA. 1986, *Traffic volume data for Sydney Region 1985.* NSW Roads & Traffic Authority, Sydney.

The increases in heavy vehicle traffic are relatively small and quite possibly fall within the range of typical fluctuations for the corridor. Figure 8 shows seasonal traffic volume fluctuations typical of this corridor when no changes in capacity took place. As can be seen, volumes during March are lower than those for August but this difference is only in the order of a few thousand vehicle movements. The 'saddle-back' pattern that results can be seen on most roads across the metropolitan network. With respect to light traffic, fluctuations of the magnitude shown in Figure 7 are unusual and fall well outside typical growth rates or seasonal fluctuations.

Figure 9 shows Annual Average Daily Traffic (AADT) volumes for the RTA sites 70.001 and 71.002 for the years 1985 to 1995. Until 1992, combined traffic volumes were increasing from between three and four per cent per year, or from between 2,129 and 2,753. The exact volumes are shown in Appendix I of Zeibots (2003a). Volumes for the GWH suggest the road had been operating at capacity for some time. Where there had been increases, lane widening had taken place. A distinct jump in the road traffic volumes for 1992 can be observed. This coincides with the opening of the Mays Hill to Prospect section of the M4.

Figure 9 Annual Average Daily Traffic for the M4 Motorway and the Great Western Hwy at Pendle Hill 1985–1995

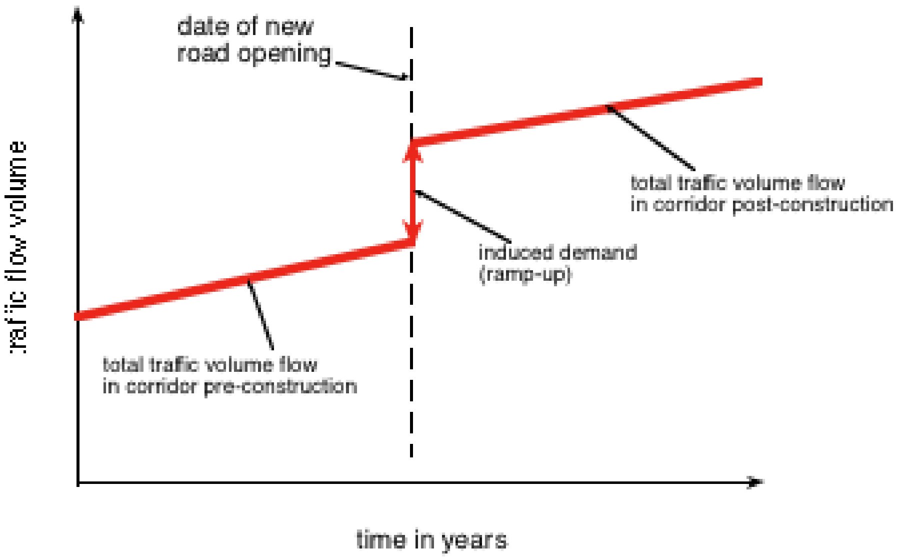




Source: RTA. 1995, *Traffic volume data for Sydney Region 1993.* Roads & Traffic Authority of New South Wales, Sydney.

The distinct jump in the time series data is referred to as *ramp-up*. Figure 10 shows a conceptual outline of this phenomenon as it typically appears on time series graphs of road traffic volumes like that shown in Figure 9. Where the increase occurs, a distinct 'ramp' appears, hence the term ramp-up. The diagram suggests the increase in volumes occur almost instantly. This is not the case. The *ramp-up period* takes many months until growth rates stabilise so that the slope of traffic volume increases becomes less steep. Changes in daily traffic volumes would need to be analysed in order to assess the period over which ramp-up took place. The duration of the ramp-up period is interesting for several reasons, the primary one being that because it takes place over a relatively short period of time, population increases and demographic changes can be ruled out as causes.

Figure 10 Conceptualisation of induced demand due to road capacity increases



Source: Luk, J. and Chung, E. 1997, *Induced demand and road investment—an initial appraisal*. ARR 299. Australian Road Research Board, Vermont South, p.10.

Potentially, a portion of this increase is comprised of *induced traffic growth*. At a glance it is possible to see that large volumes of traffic previously using the GWH, began using the M4 instead. This shift is in the order of 50,500 on average per weekday at the TEC Consulting sites. In the case of the RTA sites identifying the precise scale of the shift is difficult. This is because data for the years prior to 1992 at site 71.002 were collected via non-permanent or sample counters. As outlined in Appendix I of Zeibots (2003a), in addition to only measuring a sample, the data records axle pairs and not vehicle numbers. This means that counts prior to 1992 read higher than they would if they were of the same type as those for site 70.001.

Figure 9 compares AADT figures for 1991 with those for 1992. If counts for site 71.002 are adjusted to account for heavy vehicle traffic, then the difference is 19,885. The adjustment was made by reducing volumes prior to 1991 by 11.25 per cent. This rate was derived using a method described in Appendix I of Zeibots (2003a). This is based on the heavy vehicle make-up of traffic measured in the TEC data while at the same time acknowledges that the two sites are in different locations with the RTA site likely to be affected by higher percentages of heavy vehicle traffic accessing the industrial and logistics sites at Eastern Creek. This is conservative in the sense that the larger the adjustment figure, the greater the reduction in traffic volumes and therefore the larger the volume difference that must be accounted for by either mode shifting or traffic reassignment.

The growth of 19,885 is lower than the 21,777 estimated by the TEC sites. However, it should be noted that the TEC data are AWT counts whereas the RTA data are AADT counts that include weekends. This has the effect of reducing averages and therefore differences. As has been shown, traffic reassignment from the GWH to the M4 is able to account for some of the dramatic increase after opening. The remaining increases need to be accounted for by first examining losses in traffic volumes from the other roads in Screenline12.

2.4 Road data for remaining roads that cross Screenline12 1985–1995

Data for the remaining roads in Screenline12 is incomplete and there is the complicating problem of changes to counting station types, and therefore data typology, at the time of the new motorway opening. Adjustments to data had to be made to accommodate this in the same way that they were for station 70.002 on the M4 Motorway.

These adjustments are explained and examined in detail in Appendix II of Zeibots (2003a). It should be stressed that although a simple method has been employed to estimate volumes for those years where data were unavailable, great care has been taken to ensure that estimates are conservative. Table 1 provides a summary of the volume estimates for traffic reassignment from other routes on Screenline12.

The primary roads from which traffic is likely to have shifted are Windsor Road, Richmond Road, Elizabeth Drive and Bringelly Road. The heavy vehicle make-up of traffic on these roads is unknown. In the method devised to calculate the adjustment figure for the M4 data, four figures were calculated in all. The lower of these were eight and five per cent. These were both used to adjust the non-permanent counting station data for the other sites along Screenline12.

Table 1 Traffic reassignment estimates for remaining roads in Screenline12

Road	AADT volumes between 1992 and 1993	Reassignment estimate AADT (5 and 8 per cent)	
Windsor Road		▼ 3,316	▼ 3,423
Garfield Road	Cross-regional route discounted from tally	-	-
Grange Avenue	Cross-regional route discounted from tally	-	-
Richmond Road		▼ 1,329	▼ 2,487
Power Street	Cross-regional route discounted from tally	-	-
Eastern Road	Cross-regional route discounted from tally	-	-
Chandos Road	Small local road, discounted from tally	-	-
Redmayne Road	Small local road, discounted from tally	-	-
The Horsley Drive	No apparent deviation from typical growth patterns, discounted from tally	-	-
Elizabeth Drive	Data unavailable for 1992 and 1993. See notes in Appendix II, pp.34–35.	Not available	
McIver Avenue	Small local road, discounted from tally	-	-
Seventeenth Avenue	Small local road, discounted from tally	-	-
Sixteenth Avenue	Small local road, discounted from tally	-	
Fifteenth Avenue	Small local road, discounted from tally	-	-
Twenty Sixth Avenue	Small local road, discounted from tally	-	-
Bringelly Road		▼ 2,365	▼ 2,442
Camden Valley Way	South-western radial orientation discounted from tally	-	-
Denham Court Road	Cross-regional route discounted from tally	-	-
TOTAL		**▼ 7,010**	**▼ 8,352**

The exception to the problem of patchy data was Eastern Road. At this site, data were available for all years and the station type remained the same. Eastern Road shows a sharp increase in volumes that coincide with the opening of the M4 section from Mays Hill to Prospect. This is because it functions as a feeder route for traffic to the M4. What is particularly significant about this road, is that where the lower conversion estimate was used, an AADT volume is returned that appears to be above the ceiling capacity for this feeder route. The higher conversion rate of eight per cent returns an AADT volume that is more plausible given later AADT counts. This is outlined in more detail in Appendix I in Zeibots (2003a).

This provides a check for the adjustment levels used and some guidance as to their veracity given the different data typologies. The reason the rate of 11.25 per cent was used to adjust the M4 data and not the other roads on Screenline12 is because heavy vehicle numbers on restricted access carriageways are generally higher than on unrestricted trunk routes or main roads and so the number of axle pairs is higher. Consequently, a lower percentage must be used. The difficulty is that there is no sure way of knowing what these varying rates were at the time of the M4 section opening. The data are more internally consistent if an adjustment rate of eight per cent is used and so the results are more likely to be realistic.

An added problem is that no data are available for Elizabeth Drive during the crucial years of 1992 and 1993. On examination of the time series for the period it appears that Elizabeth Drive had reached its ceiling capacity. If there had been any significant decline in traffic volume numbers on that route, they recovered very quickly and so it is possible that any capacity that was freed up by traffic reassignment from Elizabeth Drive to the M4 Motorway was quickly taken up by new traffic generated in the immediate vicinity of Elizabeth Drive and this appeared on the network by 1994. This amounts to a form of 'knock-on' induced traffic growth and further reassignment from other routes as the effects cascade through the system after changes on the primary trunk routes where speeds are higher. It should also be taken into account that the M5West opened in the same year as the M4 from Mays Hill to Prospect. Traffic volumes from Elizabeth Drive are likely to have shifted to the M5West as well. There is no way to distinguish reassignment from Elizabeth Drive to each of the motorways.

Several roads that cross Screenline12 do not have the radial orientation of Windsor Road, Richmond Road, Elizabeth Drive and Bringelly Road. Instead they perform a cross-city function and in some cases, like Eastern Road saw an increase in road traffic volumes as they acted as feeders to the motorway. These roads have been discounted from the tally in Table 1 otherwise the analysis would include the double counting of some traffic.

If the large increase of 19,885 AADT has normal growth subtracted from it — 2,753 was the highest annual growth rate — then 17,132 AADT remains. If the reassignment estimate of 7,010 from these other roads is taken into account and subtracted, then there is a residual of 10,122. This is still well above what might normally be expected on this route.

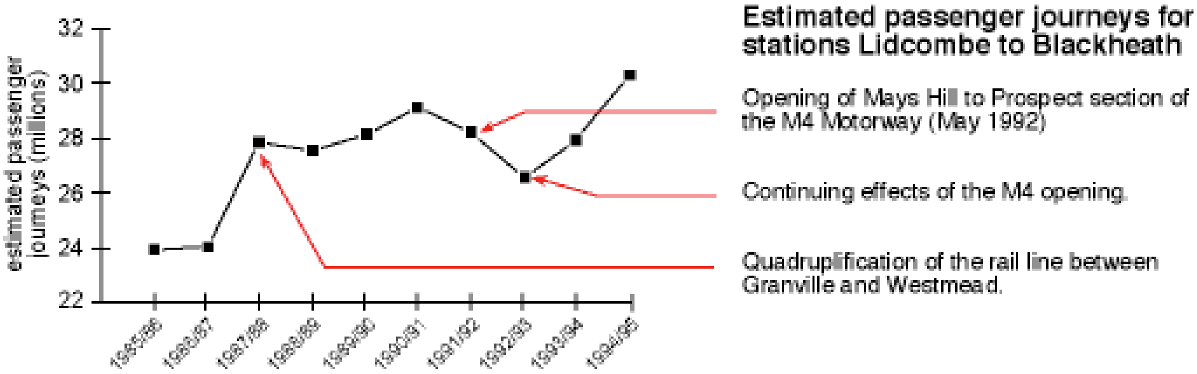
There are other possible explanations for the sharp increase. These have to be progressively ruled out and the numbers accounted for so that any residual is potentially new trips that have been generated because of the change in travel times brought about by the additional capacity. The next section outlines what these other possible explanations are.

2.5 Rail data for the Western Sydney Rail Line 1985-1995

The time series data in this set consist of passenger journey estimates. These have been calculated from records of ticket sales for stations on the WSRL. These have been assembled for the purposes of identifying large changes in rail passenger journeys, or commuter volumes, on the line. Where changes occurred during the study period, explanations for significant increases or decreases in rail passenger journeys have been sought.

Figure 11 shows plots of estimated passenger journeys made on the WSRL between the financial years of 1985/86 and 1994/95. The raw data are tabled in Appendix V of Zeibots (2003a). The method used to calculate the Annual Average Daily Passenger Journeys (AADPJ) is outlined in Appendix IV of Zeibots (2003a).

Figure 11 Estimated passenger journeys for the Western Sydney Rail Line 1985–1995



Zeibots, ME. (2003a), *Before and after opening of the M4 Motorway from Mays Hill to Prospect: an empirical analysis.* Working Paper. Institute for Sustainable Futures, University of Technology, Sydney.

As can be seen in Figure 11, there are five financial years in which distinct jumps or changes in passenger journey numbers occurred and these generally coincide with changes in infrastructure capacities and service levels and consequently relative travel times. The correlation and magnitude of the jumps are summarised in Table 2.

Table 2 Coincidental changes in rail passenger journeys, infrastructure capacities and service levels

Infrastructure Change	Changes in estimated rail passenger journeys	Changes in AADJP*
Quadruplification of rail track between Granville and Westmead 1986/87 to 1987/88	Lidcombe to Blackheath from 25,371,563 to 29,294,733	▲ 10,748
Opening of the M4 (Mays Hill to Prospect) 1990/91 to 1992/93	Lidcombe to Blackheath from 30,747,100 to 27,914,766	▼ 7,760
Changes to service levels 1993/94 to 1994/95	Lidcombe to Blackheath from 27,914,766 to 31,568,694	▲ 10,011

*** Annual Average Daily Passenger Journeys**

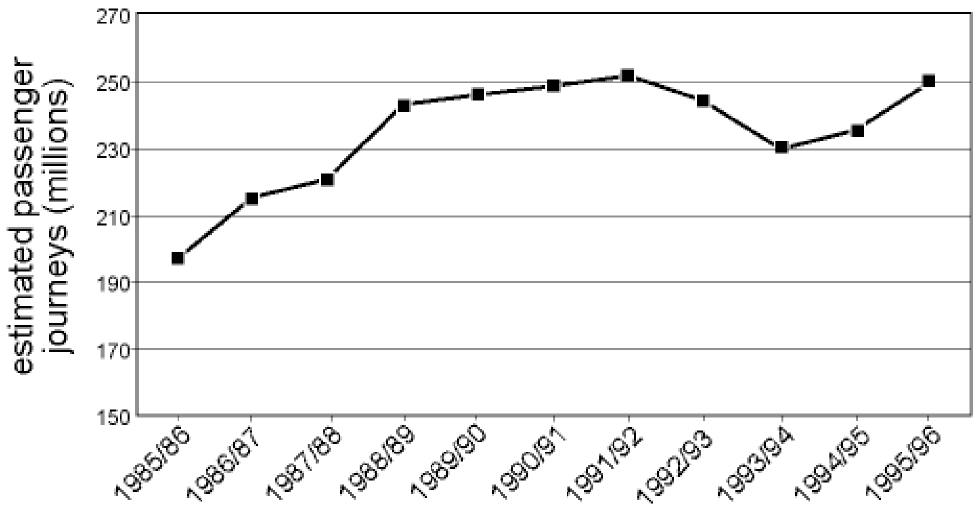
A decline of particular interest occurs between 1990/91 and 1992/93. Passenger journeys declined at both metropolitan and Blue Mountains stations over this period.

The decline coincides with the opening of the Mays Hill to Prospect section of the M4 Motorway and so it seems reasonable to assume the most likely cause of the decline was mode shifting from rail to road.

From the available rail passenger journey data it appears that the decline is in the order of 7,760 AADJP. As with previous data, there are issues of data parity. Whether AADT and AADJP data can be compared with each other is problematic. For example, two or more rail passengers could equate to only one car journey. The average vehicle occupancy rate for all trips by private car in Sydney is 1.4. For peak hour trips the rate is 1.2. If the lower rate of 1.2 is used to convert all rail passenger journeys to car trips, a figure of 6,467 vehicle trips is generated.

While the peaks and troughs in passenger journeys for the WSRL coincide with changes to the transport network in that region, it should also be noted that similar peaks and troughs can be seen in aggregate passenger journey statistics for the entire Sydney Rail Network as shown in Figure 12. This suggests that changes specific to the western sector are not entirely responsible for the fluctuations on WSRL shown in Figure 11. This gives rise to two alternate explanations, both of which would decrease mode shifting estimates and therefore increase the residual volume.

Figure 12 Estimated passenger journeys for the Sydney Rail Network 1985–1995



Source: State Rail (2001), *A compendium of CityRail travel statistics.* Third edition. State Rail, Sydney, p.8.

The first possible explanation is that the peaks and troughs are just following general fluctuations in levels of economic activity, which means that the cause of declines in rail passenger journeys for 1991/92 and 1992/93 would not be confined to the M4. In which case the mode shift estimate is too high and the residual road traffic volume should be greater. If the cause is a fluctuation in economic activity then this would also affect growth rates of road traffic volumes. In which case the estimates for road traffic reassignment outlined earlier would be lower than stated, which once again would have the effect of increasing the residual estimate for induced traffic growth.

The other explanation for the aggregate trend in rail passenger journeys is that several new motorway sections were opened at around the same time in Sydney. These include the M5West, which affected rail passenger journeys on the East Hills Line, and the Sydney Harbour Tunnel and Gore Hill Freeway, which affected rail passenger journeys on the North Shore Rail Line. The effect of these three motorways all opening during 1992, and the mode shifting that resulted, may have been sufficient to leave a sizeable mark on aggregate rail statistics.

In addition to mode shifting from rail services, it is possible that passenger volumes on bus services throughout the region may have declined as a result of people shifting from these to the motorway. Regrettably, no data for these was could be accessed for this study. Most of these services act as feeder routes to the heavy rail trunk route. So if there was a decline of these, it would be necessary to assume that many would form part of linked trips that also involved rail journeys.

2.6 Conclusions

In summary, this analysis found that an unusually large increase in road traffic volumes occurred after opening of the M4 motorway section from Mays Hill to Prospect. The increase could be attributed to the following causes:

Expected growth on M4 + GWH	2,753
Reassignment from roads on Screenline12	7,010
Mode shifting from WSRL	6,467
Total	16,230
Difference in AADT volumes between 1992 and 1993	19,885
Residual volume	**3,655**

The residual volume of 3,655 could be induced traffic growth, or longer trips encouraged in response to the quicker travel times made possible by the increase in road capacity. In practice, this volume is likely to be higher than estimated here because of the conservative way that estimates were produced for those roads where there were gaps in the data.

3. Did the M4 from Mays Hill to Prospect make the city more sustainable?

On environment and social grounds, urban motorway development is seen as having highly deleterious effects on communities and the environment. Public opinion and academic research on this point has generally converged. But sustainability is not just concerned with social and environmental impacts. It is also concerned with economic impacts, and it is on this point that motorway advocates now focus most of their attention when debating the need for further motorway expansion. Indeed it is on this point that SACTRA focussed its attention in the late 1990s when they released their report entitled *Transport and the economy* (SACTRA, 1999).

The most widely cited definition for sustainability is that provided in the findings of the World Commission on Environment and Development, often referred to as the Brundtland Report:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland, 1987).

Although widely cited, the definition provided by the Brundtland Report does not prescribe how to steer a given area of activity, enrich a community or protect an ecosystem so that their intrinsic values and essential functions can be sustained over time. It merely says that this should be done.

The Report played a pivotal role in stimulating debate and galvanising international action on sustainability issues. One of the key outcomes of this debate has been the intellectual segmentation of the natural world and human development into three categories of concern often referred to as the *triple bottom line*, or environment, social and economic. Although in practice it is ultimately one contiguous system that is being discussed, this segmentation has been done in the interests of making the analysis and solving of problems manageable. It also matches different disciplines, their respective theories and analysis methods. But often the outcome is to draw a set of conclusions that sit within each of these intellectual partitions in a way that puts them at odds with each other, resulting in a tension between policy objectives in each of the categories.

The most common is the competing tension between economic development and environment protection. Physical and biological science theories might be used to understand and document the processes and relative health of a natural ecosystem or human health issue, but mainstream economic theory is used to assess the status of economic conditions pertaining to the project or development issue.

Transport is particularly vulnerable to this intellectual partitioning because of the complicated role it plays in shaping the character and spatial structure of cities and ultimately the economic activities that take place within them. Economic analysis is often performed on some bit-part or abstract aspect of a transport system to the neglect of its wider role and functions. When discussing issues to do with economic sustainability, current procedures delete many factors from the equation.

Induced traffic growth is essentially people making social and economic exchanges that they did not previously make because congestion levels and longer journey times prohibited them from doing so. While induced traffic growth generally represents an increase in Vehicle Kilometres Travelled (VKT) that incorporates increases in the use of non-renewable energy sources, emission of pollutants and possible damage to the natural environment, there is also supposed to be an increase in economic activity. So that on the one hand there is said to be a range of negative outcomes and impacts, but on the other hand there is said to be positive economic benefits that entail an increase in exchanges and general economic activity. These two are then set against each other.

During project assessment the problem is represented using the language of Cost Benefit Analysis (CBA). A key part of CBA is valuing travel-time savings. In the economic evaluation of motorway projects for example, the amount of time that would be saved for journeys using that route is calculated, assigned a monetary value and then multiplied by the number of trips being made (Zeibots, 2003b, pp.23–24). This benefit is then off-set against the cost of construction and sometimes externalities that constitute a negative impact. The number value determined for the value of travel time savings is usually very large. The argument that supports this practice relies on the claim that the value of time saved acts as a proxy for the utility of time spent on something else and this includes additional travel to other destinations where a greater utility is derived from the new destination that is now more accessible (Goodwin, 1981, pp.99–100).

The problem with this conception of what takes place is that it only assumes positive system feedback effects utility transfers within the urban system. It ignores all the negative feedback effects and disutilities that a new motorway introduces. For example, a loss of patronage on parallel public transport services generates a reduction in farebox revenue for that service. This could lead to a decision to reduce service levels on that line, In which case, passengers who did not shift modes after the motorway opened are subjected to a service with slower travel times. This constitutes a disutility that has never been incorporated into evaluations of Sydney motorway proposals (this process are outlined in some detail by Mogridge, 1997). Similarly, changes to the commercial viability of businesses and services orientated around rail stations might see a drop in customers and therefore viability leading to closure, as passenger numbers on the rail service decline. This in turn could lead to situations where individuals who accessed those local services on foot are compelled to use others at more distant locations, so that in the final equation, the population affected by a motorway development will include individuals who can access preferred destinations as well as people who can no longer access their destinations of choice[5]. In this way, the negatives of the project are not confined to environmental externalities and the possible loss of social amenity, but extend to losses in economic utility as calculated by current economic assessment techniques and which sit at the heart of the transport function and arguments about economic utility.

The critical point here is that while those advocating urban motorway development cite the serious business of economic development in support of their case, they do so on the basis of a method that is highly abstract and ignores other serious parts of the economic development process. A competent understanding of the system using General Systems Theory — which is less abstract — reveals these as central to economic activity and not simply problems to be listed as externalities and relegated to the other categories of environment or social impact.

Negative system feedback effects like these take place when the structure of an urban system is undergoing a transformation, or phase transition, to use the language of General Systems Theory (see Zeibots, 2003b, pp.16–20 for a more detailed account). So when asking the question whether the M4 made Sydney's west more sustainable in an economic sense, it is as well to ask whether the many other aspects of urban structure, accessibility profiles, market catchment configurations, access to jobs, infrastructure maintenance and operating costs and system adaptability that grew on the back of that motorway, are preferable to and more

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[5] While I am unaware of a specific study that records these effects in the western sector after the opening of the M4, I am aware that a decline took place of the small local centres focussed around rail stations on the Western Rail Line that runs parallel to the M4.

sustainable than an alternate pattern of development that would have emerged if different modes of transport had been developed by government transport agencies.

One of the obvious problems in asking such a question is that the tape recorder of history cannot be rewound and rerun without the M4. Similarly, it cannot be rerun with an alternate form of mass-transit infrastructure development so that we might compare the different outcomes along the lines of the empirical analysis presented in section two. While this paper cannot conclude conclusively that the M4 Motorway had negative economic effects for the people of Western Sydney, it does raise the possibility that it didn't generate any significant or positive benefits either.

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