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Rethinking transport evaluation methods: do we have the best tools to help us make cities more sustainable?

ZEIBOTS ME*

Keywords transport, mainstream economic theory, general systems theory

Abstract

Most planning and evaluation tools are derived from a theory that attempts to describe how the system in question works. The tools currently used to assess the relative merits of urban transport options are based on the logic of mainstream economic theory. But this theory is essentially a-spatial and therefore poor at describing all the changes that take place in an urban system once a new motorway or public transport link is opened.

This paper investigates the way two different theories can be used to explain the phenomenon known as induced traffic growth — the sharp increase in road traffic that occurs after the opening of a new urban motorway. First, an explanation using standard supply and demand theory is used to explain the cause and consequences of the effect. Then, General Systems Theory is used to explain the same process. The first explanation renders the outcome in a way that is physically abstract, providing a number value. The second articulates the outcome using spatial data, illustrating both positive and negative changes to land use sectors and patronage on more sustainable transport modes. It is argued that the latter method provides greater insights into the real consequences of motorway building and induced traffic growth, and with it the basis for more useful transport planning and evaluation tools.

The challenge for regional government is to recognize the shortcomings of current evaluation methods and reform them so that economic and environmental outcomes are more sustainable. This paper seeks to demonstrate the need for that reform and the direction it might take.

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* Michelle E Zeibots
Senior Research Consultant
Institute for Sustainable Futures
University of Technology, Sydney

Introduction

This paper examines a significant development problem known as induced traffic growth that affects urban transport networks. Induced traffic growth occurs when the capacity of a road network is increased to reduce traffic congestion, making travel times quicker. With the increase in speed, people are attracted to the new motorway or road upgrade, generating a large increase in the amount of travel. The phenomenon poses a dilemma for regional governments because with the increase in road traffic come increases in air pollution, greenhouse gas emissions, adverse effects on urban amenity, rises in per capita transport costs and ultimately a return to traffic congestion — all outcomes that generate the opposite effect to the reason for the development.

While induced traffic growth is a significant problem that regional governments should be more aware of, it is not the primary focus of this paper. The primary purpose is to compare the different kinds of theory that academics and professionals use to understand what causes the problem and what its economic implications might be. In this way it will be shown that different theories produce different tools, which in-turn favour different policies, leading to different outcomes for communities. Using different tools also affects our definition of what we think is sustainable while at the same time it helps us decide what forms of negative impact we are prepared to accept in order to generate a range of benefits.

A review of the day-to-day politics and debate surrounding the issue of induced traffic growth begins the analysis. This brief history will highlight the role that theories and tools can play in obscuring the cause of a problem and the kind of conflict that communities and governments can find themselves in when these tools fail. Following this, an explanation of what causes induced traffic growth will be provided using mainstream economic theory. The same problem and its cause will then be explained using General Systems Theory (GST).

Both mainstream economic theory and GST are widely used by practitioners and academic scholars to explain and clarify the causes of many phenomena encountered in human societies and the natural world. Neither of these tools is on the periphery of accepted scientific or professional practice. The concepts that form the basis of GST are rudimentary to a wide variety of social and physical sciences. As Figure 1 illustrates, GST is a form of conceptualising sited between language, which is predominantly a qualitative way of thinking about the world, and mathematics, which is quantitative. GST is concerned with the way

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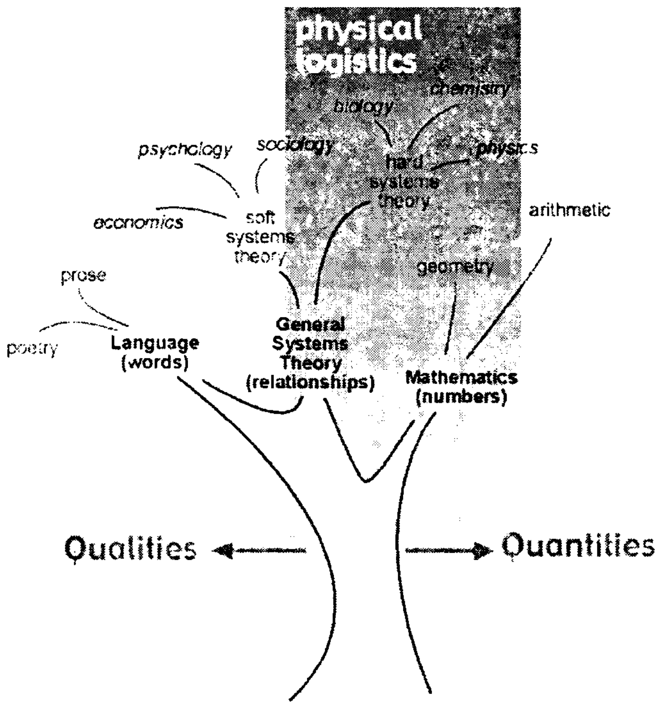
michelle.e.zeibots@uts.edu.au

different objects are related strategically to each other to form a system. There two main branches of GST are commonly refered to as hard and soft systems theory. Hard systems comprise relationships between physical objects where the object and focus of the study does not involve conscious thought. The behaviour of these systems is less random and more predictable because outcomes are dependent on relatively fixed and easy to identify properties. Physical sciences like physics, chemistry and biology are typical hard system theories. By contrast, soft systems comprise sets of relationships between people who, unlike material objects, are able to think and have goals. The ideas, opinions, beliefs and emotions that form the relationships that are the study focus, do not in and of themselves have fixed physical attributes — hence the term *soft*. They vary widely between individuals and so are difficult to predict. Mainstream economics is a form of soft systems theory because the mechanism that is said to cause change is made up of people's thoughts and decisions.

Figure 1 The tools of intellectual thought



Phenomena of urban transport systems, like induced traffic growth, are shaped to a large degree by the logistical[1] properties of the physical structure of the transport network. These present material conditions that direct behaviour by placing boundaries upon it. As will be

[1] The term logistical refers to the capacity, speed, alignment and other movement properties of the transport system. A road network and the motor vehicles that drive along it have different logistical properties to a rail line and the rolling stock that carries people and goods.

shown, explaining some transport phenomena can be difficult using economic theory because of the way fixed physical and spatial conditions affect outcomes. Given that economic theory attempts to explain these outcomes in terms of changes in attitude and preference, some aspects of the process get lost as the discussion in section three will show.

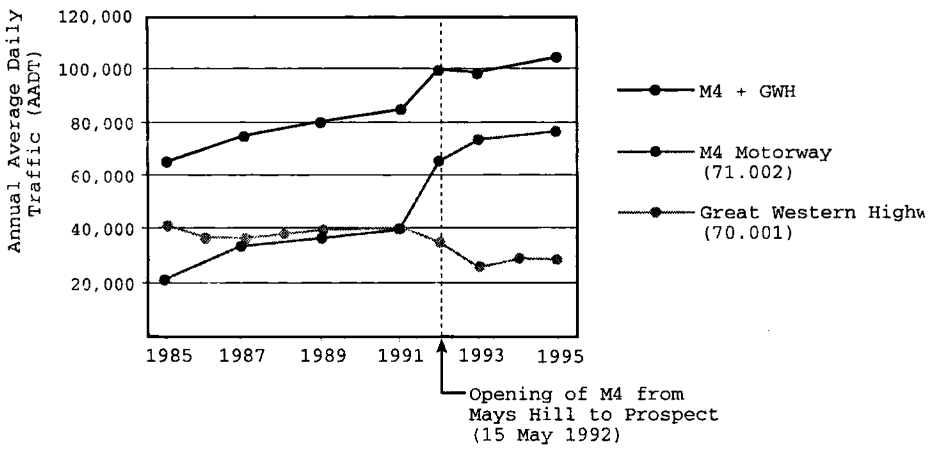
The first section of this paper sets out the political context against which public and academic debate over induced traffic growth has recently taken place. Politics may seem an odd place to start when discussing the logic and relative merits of scientific theories, but as will be shown, the problems that communities face and their reactions to them, often provide the grounds for questioning the descriptive power of theories and the assessment tools derived from them. Bound up in this history are the reactions of professionals and academics defending these tools, or if opinion is divided, alternate tools and ways of looking at the problem. Which theory prevails is ultimately a political decision where the interests of the competing parties are motivated differently. Understanding the nature of the political landscape helps to make these motivations more explicit. This reveals the source of authority and calibre of intellectual integrity on which acceptance of the science depends.

1. Is induced traffic growth real? A controversial problem for regional governments

Throughout the world, regional governments have for many years viewed the construction of urban motorways as a way of overcoming traffic congestion. The logic behind the decision to build usually follows this course: by increasing the capacity of a road, more space is made available so vehicles can move more freely at higher speeds. Journey times are cut so the cost and frustration of delays is greatly reduced. Or at least this is how events are supposed to unfold, but in practice something very different happens.

Figure 2 shows road traffic volumes over a ten year period for a motorway and arterial road in Sydney, Australia. Between the years of 1991 and 1992, Annual Average Daily Traffic (AADT) volumes for these roads changed dramatically. After the addition of a new motorway section volumes for the main road (shown in grey), declined as some traffic moved to the motorway where speeds were faster (shown in red). But traffic volumes for both roads combined (shown in black), reveal a dramatic increase overall. Where volumes had been growing from between 2,000 and 3,000 AADT, they grew by just under 20,000 AADT in the months after opening of the new motorway (Zeibots, 2003, pp.15–16). This example is typical of what happens when capacity is added to highly congested networks.

Figure 2 Before and after the M4 Motorway section from Mays Hill to Prospect in Sydney, Australia



Source: Zeibots, ME. (2003), *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.

Without the benefit of data, local residents saw this effect too. The increase in traffic created long queues where previously there had been none. People complained. On the front page of a local newspaper a headline appeared stating "The F4s[2] a dud", with the accompanying story, "Only months after the F4 was completed, it is now inadequate for traffic volumes and needs revamping." (Hutchings, 1992, p.1). The Government responded to public complaints by announcing that more lanes would be built to accommodate the new traffic. While the response seemed intuitively correct, empirically it was counter-productive as further lanes attracted further traffic. Many local people now refer to the M4 as a slow moving car park and the majority of Sydney residents believe that money spent on new roads would be better spent on public transport (Warren Centre, 2001, p.33).

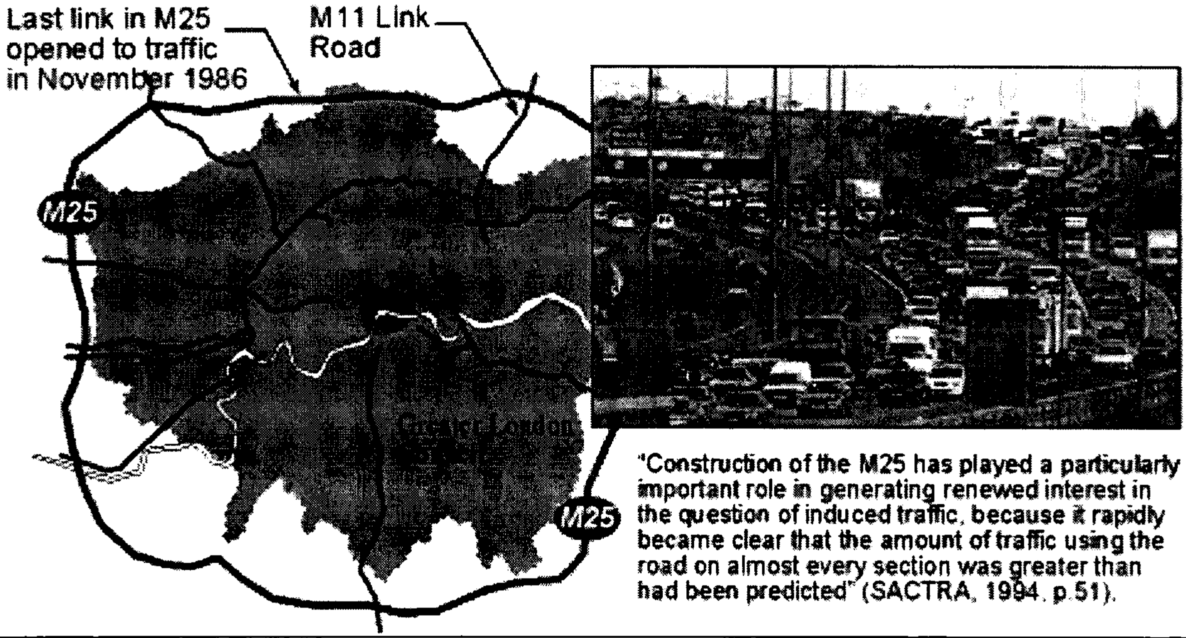
In the language of GST, this effect is simply a form of *positive system feedback*, a concept common in engineering disciplines (Luk and Chung, 1997, p.3) and which will be explained later in more detail. But despite the ease of this explanation and articulate accounts by scholars like Downs (1968), Plowden (1972), Thomson (1977), and Mogridge (1990), to name but some, many government road and transport agencies have explicitly denied the existence of induced traffic growth (see for example Transit New Zealand, 1994 and SACTRA, 1994, p. 55).

[2] The M4 was previously known as the F4. The name was changed after the state owned freeway was converted to a privately owned tollway.

The critical event that triggered a change in government 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 the amount of traffic on almost every section of the ring-road was so much greater than before, and so much higher than predicted, that the effect was undeniable (SACTRA, 1994, p.51). Public opinion 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 generate 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 and was influential both in the UK and internationally. In the introduction it states:

> "... 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).

Figure 3 London's M25 Orbital Motorway



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 conclusive measurements could not be made of such a complex system (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 by academics. These provided greater evidence to show 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 mainstream economic theory to support its conclusions (SACTRA, 1994, pp.111–122). The use of economic reasoning enabled SACTRA to make its case in an authoritative way. By confining their argument to economic considerations rather than broadening them to include environment and social, SACTRA wrong-footed conventional thinking. Road building is generally viewed as essential to economic efficiency and progress. The case against it on environmental and social grounds had been largely resolved in a Royal Commission into the effects of environmental pollution; the impacts are clearly negative (RCEP, 1994). SACTRA had also investigated the affects of roads on the environment with the release of their report in 1992 entitled *Assessing the environmental impact of road schemes* (SACTRA, 1992). But on economic grounds road building is viewed as as essential. The idea that this may not be the case challenged established beliefs, pressuring government to act.

Despite the apparent authority of SACTRA's conclusions, the committee's Environmental Advisor, Ms Audrey Lees, did not endorse the report. In a minority report Ms Lees stated:

> "...we [SACTRA] have not fully addressed the totality of our Terms of Reference ...Instead the Report has focused on the question of whether traffic is induced by the presence of new trunk schemes with, in my view, an undue emphasis on the methodology of economic assessment and modelling ..." (SACTRA, 1994, p.235).

To paraphrase, Ms Lees believed that greater attention needed to be given to the inter-action between transport and land use development where change is more difficult to measure and detect, but whose ultimate effects are more fundamental to the performance and sustainability of the urban system as a whole (SACTRA, 1994, pp.238–239). By broadening the analysis in this way, government would be informed as to what its full suite of policy options might be and budget for research appropriately (SACTRA, 1994, p.237). While statements in the introduction go to great pains to point out that Ms Lees did not wish to "...criticise the contents of [the] Report" (SACTRA, 1994, p.2), the narrow focus left many questions unanswered. This made room for later reinterpretations of SACTRA's conclusions, which, after some reform of modeling procedures, saw a return to old ideals.

As the members of SACTRA reviewed submissions from community groups, transport professionals, academics and government agencies, a long and protracted series of public protests were being waged in numerous towns and urban precincts throughout the UK against proposed motorway constructions. At the height of the protests, and on the eve of the release of SACTRA's report, 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 and bulldozers from moving in. Over 600 police came on site, many in riot gear, to remove protestors (The Economist, 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 motorways were a credible solution to the problems of congestion (for example Tickle, 1993).

The sense of crisis generated by the protests and the promise of other bruising conflicts at Twyford Downs and Newbury (Weekly SchNEWS, 1994) worked to ensure that SACTRA's findings were given due consideration and acted upon by government[3]. 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 Major Government reconsidered its policy options and began the work of reforming modeling and scheme evaluation methods as recommended by SACTRA (SACTRA, 1994, p.iv).

Figure 4 Community protest at Parliament House 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.

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[3] This observation was made by Prof John Whitelegg from the Stockholm Environment Institute at the University of York.

Photo courtesy of Ivan Lewis, Beecroft, May 1995.

Urban motorways in Australian cities have provoked similar criticisms. Resident protests against Sydney's M2 and M5 Motorways held up construction for years. Amidst the protests, there have been no less than three Commissions of Inquiry into Sydney motorway proposals (Kirby, 1981. Kirby, 1982 and Woodward, 1992). In each, after careful deliberation under the rules of evidence, the Commission found that the motorway in question should not be built, the prospect of induced traffic growth often cited as a key reason (Kirby, 1981, p.i). But unlike SACTRA's findings, these were ignored. Both the M2 and M5 motorways have been built[4]. But even so the protests left their mark. The Carr Government in Sydney simply found a different way to quell the political backlash.

Because of its geology, tunnelling is relatively easy in Sydney and the current Carr Government has used this to avoid political confrontation. Once a motorway is put underground, opposition from residents who would lose homes or green space is removed with argument largely confined to whether or not exhaust stack emissions should be filtered (Main, 2003, pp.29). While induced traffic growth continues to be cited as a problem by community groups, it is difficult to mobilise large numbers of people to oppose a general problem, and so footage of dramatic blockades does not appear on the evening news. The obvious drawback to tunneling is increased construction costs. These pose a higher opportunity cost[5] to other areas of government responsibility. But an increase in construction costs can be beneficial to some stakeholders. Indeed a steady supply of large capital works projects determines the very survival of some sectors of the construction industry and if motorways can be built as private tollways, arguments over opportunity cost can be downplayed.

Since the early 1990s, Sydney has played host to construction of four private tollways with two currently under construction and plans for two more. All of these are reliant on government subsidies. Most disturbingly, where private sector capital has been raised by the public listing of tollway companies on the stock exchange, the traffic estimates on which revenue flows are dependent, have been grossly exaggerated (MIIM, 1996, p.36). Traffic

[4] In a bid to stop the M5East, one community group undertook legal proceedings against the NSW Roads & Traffic Authority on the grounds that the configuration of the motorway described in the EIS was significantly different to that built so that another EIS should have been done and those residents affected by the new configuration given an opportunity to express their views on the way it would impact them. The community lost so that case law in New South Wales essentially allows government authorities to build infrastructures in formats without fully informing the community.

estimates for Sydney's Eastern Distributor were well above the physical carrying capacity of the road (Kaye and Willis, 1997). Established highway engineering science was ignored and volumes seemingly proposed to fit operating cost and debt repayment obligations in the financial model.

The practice of overestimating traffic volumes to justify construction is not confined to Australia. In Japan, it has taken on legendary proportions. Of the 58 tolled highways operated by the Japan Highway Public Corporation, 42 are below predicted volumes, 26 are operating in the red, 13 at less than half forecast estimates and on some highways, operating expenses are three, five and even 10 times toll revenues (Pearson, 2004, 27).

Most resident and public interest groups view induced traffic growth as a clear disbenefit, but for private tollway companies and the construction industry, it can be their salvation. Consequently, the commercial sector has been keen to have their interests attended to as community groups have done. Their view of induced traffic growth is different and interpretation of the implications of SACTRAs findings poles apart. In addition to the specific commercial interest is the general belief that more traffic means more economic exchanges — a point that SACTRA also raises (SACTRA, 1994, pp.129–131). 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, 1995, pp.27 and 29 as cited by Williams, Van Vliet and Kim, 2001).

SACTRA's reliance on mainstream economic theory 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). As will be discussed in section two, an assumption is made by some commentators, that all new traffic comprises people traveling to make more economic exchanges. Or in other words, a greater utility is derived out of the new road that facilitates positive economic activity and growth. But as will be shown in section three, with this positive system feedback, there are negative

[5] The term opportunity cost refers to other goods or activities that are foregone as a result of spending

forms that accompany it and mainstream economic theory has been very poor at identifying these. It is for this reason that SACTRA was set the task of analyzing the general effects that transport has on the economy. The results of these were published in 1999 in their report entitled *Transport and the economy* (SACTRA, 1999). An interim report had been published in 1997 to assist with to the development of broad and sweeping changes to evaluation procedures.

With the election of a new government in 1997 came the expectation and promise of change in the UK. On observing the political turmoil that has been the focus of the previous governments transport policy the Blair Government was keen to introduce a set of reforms to road evaluation methods. These were called the *New Approach to Transport Appraisal,* or NATA 5, owing to its five assessment areas of environment, economy, safety, accessibility and integration. These were each nestled within a Multi Criteria Analysis (MCA) framework that aimed to give consideration for natural heritage values, environmental pollution and public transport alternatives greater standing than had previous methods. But at the centre lay the old form of Cost Benefit Analysis (CBA) that monetises a select range of outcomes like travel time savings. These are given a money benefit. But NATA 5 does not monetise all considerations so that they might be offset against the travel time savings calculated for motorways. There is no clear guidance as to when undesirable qualitative outcomes should be prioritized[6] over quantitative monetised benefits (Rayner, 2003, p.2).

Like the Carr Government in Sydney, the Blair Government in the UK is avoiding politically sensitive options. The number of new surface road proposals that divide residential communities or environmentally sensitive areas has been reduced. 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 outcomes, this seems counter-productive and likely to fail. According to Prof John Whitelegg, it has been made at the insistence of the commercial business sector — people more readily persuaded by explanations couched in economic terms like those put by Foster.

The upshot of these changes is that the decision to build or not to build is deeply political. Where there is no prospect of damaging community protest, road building continues. Where there is, it stops if governments cannot find a configuration that reduces upset and political backlash from the community. But the question of whether motorways, and the induced

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on a chosen activity.

traffic they bring, contribute to the ultimate sustainability of cities and welfare of their resident and business communities remains unclear.

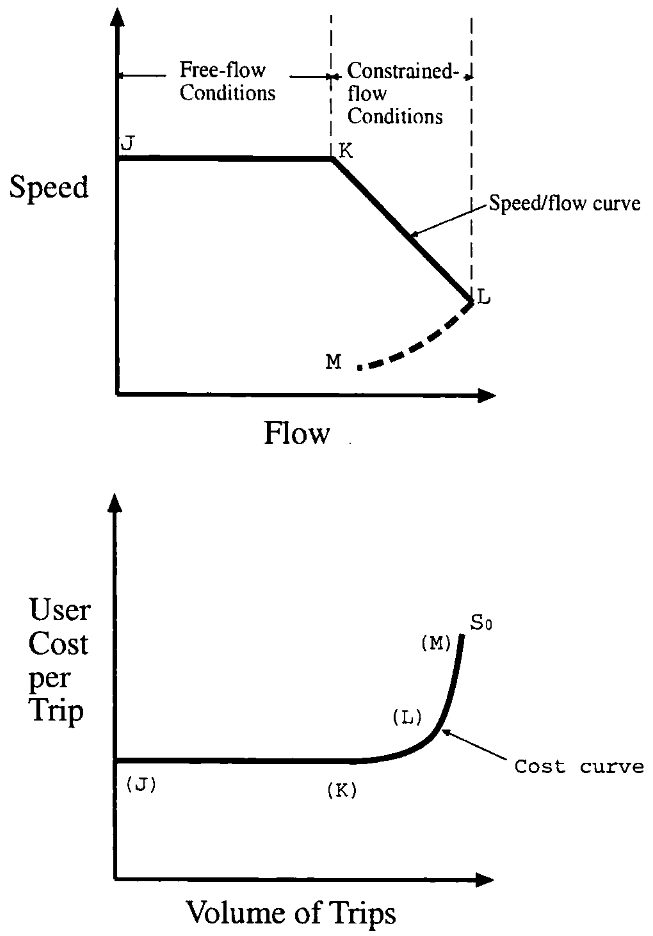
2. Explaining the cause of induced traffic growth using mainstream economic theory

As outlined in section one, SACTRA relied on the logic of mainstream economic theory to make its case. In this section, their explanation will be reviewed as well as the way they responded to arguments similar to those that will be outlined in section three of this paper SACTRA, 1994pp.111–120 and 123–129).

When evaluating road and transport projects, the process begins with the aim of trying to identify the benefits of a project so that they can be offset against the cost of constructing it. This is done within a Cost Benefit Analysis (CBA) framework, where the estimated benefits are divided by the costs and if a value greater than one is derived, the project is seen to be a worthwhile investment. But to do this, a way of estimating the benefits has to be found and this is where the use of mainstream economic theory is used.

Figure 6 The Speed-Flow-Cost relationship

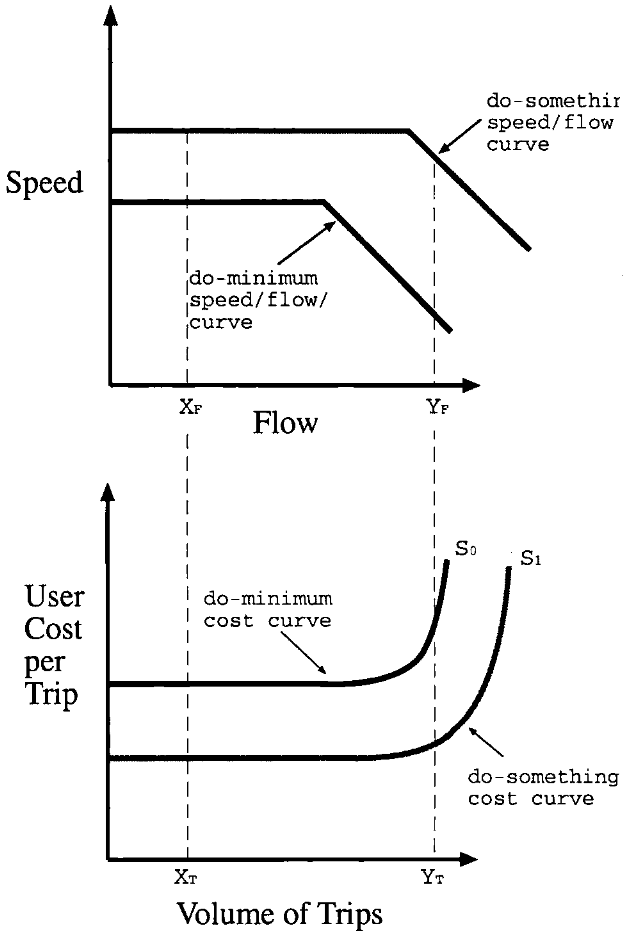
[6] One of the first projects to have the NATA 5 evaluation system applied to it was the Hastings By-pass. The by-pass would have destroyed an area of significant nature conservation value. The present Minister for Transport recently announced that plans to build the by-pass would not proceed.



Source: SACTRA. (1994), *Trunk roads and the generation of traffic. HMSO, London, p.116.*

For roads and motorways the basic characteristics of the infrastructure (supply curve) are set alongside behavioural responses of the people using it (demand curve). To derive the supply curve the relationship is defined between the speed that people are able to travel at and another critical factor known as flow, or the number of vehicles able to pass a given point. Figure 6 shows the form of this relationship. When only a few vehicles are using a road the speed at which they travel is set by a legal speed limit or what is referred to as the design speed of a road. The number of vehicles able to travel at this speed can vary which is why section JK of the speed/flow curve remains flat. But once vehicles reach a certain number, as indicated at point K, the speed begins to fall. This occurs because the stopping distances, or necessary headways between vehicles, begin to encroach on one another. When this happens vehicles have to travel at slower speeds to reduce headways if they are to travel safely. Eventually the road becomes *saturated*, headways are very small and speeds low, queues form and delays accumulate rapidly throughout section LM as traffic flow deteriorates and becomes unstable (SACTRA, 1994, p.116).

Figure 7 The effect of User Costs on road improvements



Source: SACTRA. (1994), *Trunk roads and the generation of traffic. HMSO, London, p.117..*

This speed/flow curve is equated with a cost curve as can be seen in Figure 6. Costs for a trip remain the same between JK irrespective of how many vehicles are on the road. These costs are defined as the operating cost of vehicles and the time of the people traveling in the vehicles[7]. In most road appraisals, the value of travel time savings is a critical factor comprising most of the monetised cost benefits. As conditions become congested, costs begin to rise as shown in KL. Where roads begin to reach saturation levels, costs rise more steeply primarily because of increases in journey times as indicated in LM. If a new motorway is built or a road is widened so that operating and travel time costs are reduced, the speed-flow relationship changes, as does the cost. These relationships are shown in Figure 7.

Broadly, there two ways that additional road space (shown in red as the do-something scenario) can effect the speed-flow relationship and hence costs. The first refers to cases where a motorway by-pass might be built for example, enabling people to travel at 110km/h

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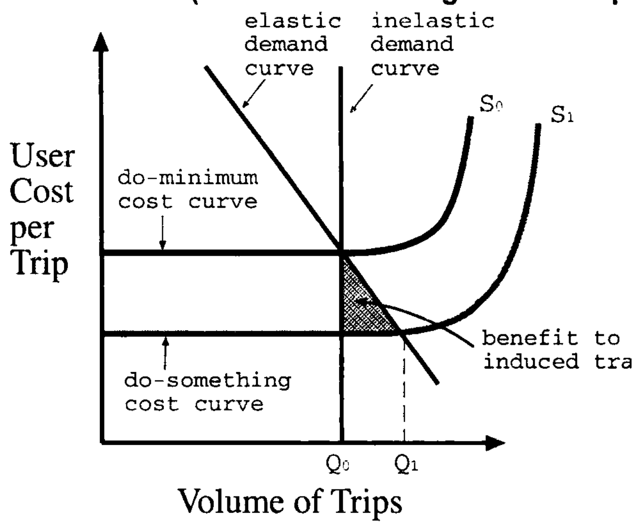
[7] Behind these costs sits an array of empirical analysis that examines the amount of money people are prepared to pay to save time. The value of travel time savings is based upon these.

instead of 70km/h. In this way the travel time component of the User Cost is reduced and shown as Case X in Figure 7. The second occurs when the addition of capacity enables vehicles to increase the amount of headway between them so that they can travel at higher speeds, reducing travel times in that way. In this case congestion is reduced and vehicles able to travel at improved service levels.

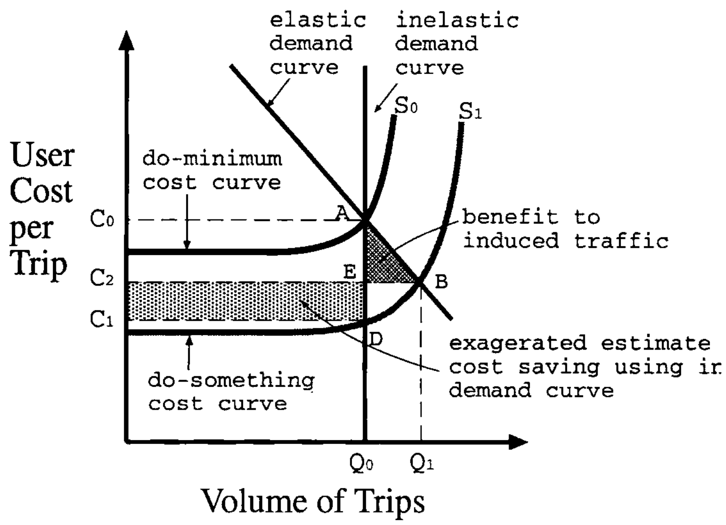
Figure 8 Addition of road space in uncongested conditions (Case X: increasing free-flow speed)



Source: Source: SACTRA. (1994), *Trunk roads and the generation of traffic. HMSO, London,* p.118.

Figure 8 considers the changes in User Costs as a result of a project that increases the free-flow speed of traffic, such as a by-pass. Because the trip is quicker, people may make that trip more often. The elastic demand curve shows this change and the section shown in red reveals the benefits to induced traffic growth. Because this increase in demand does not adversely impact on the flow of vehicles, any evaluation that did not include the possibility of induced traffic growth — one based on an inelastic demand curve — would return an underestimation of the benefits. But if the addition of road capacity is introduced under congested conditions, a different result is achieved.

Figure 9 Addition of road space under congested conditions (Case Y: increasing capacity and free-flow range)



Source: SACTRA. (1994), *Trunk roads and the generation of traffic. HMSO, London,* p.119.

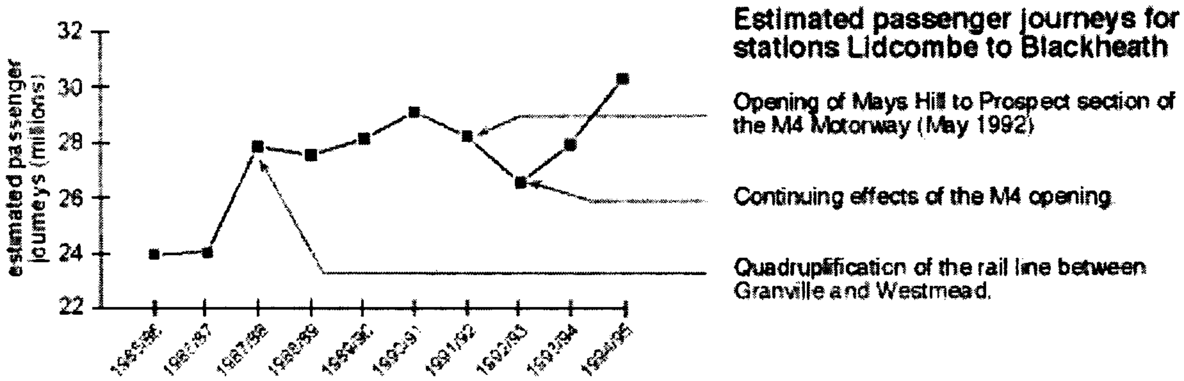
When an inelastic demand curve is used as shown in Figure 9, costs are reduced from C_0 to C_1. But when an elastic demand curve is used, User Costs are only reduced to C_2. The key difference between Case X and Y is the point at which the demand curve intersects the supply curve. The more elastic the curve is, the greater the degree to which estimated benefits are eroded. In Case Y, the benefits are exaggerated if an inelastic demand curve is used. In these cases the critical question becomes: Are the cost differences between C_1 and C_2 such that estimated benefits are not large enough to off-set construction costs?

This is how SACTRA was able to argue for the need to include induced traffic growth in the estimation of User Costs for inclusion in the CBA for projects. This argument was seen to have merit and as a consequence, there was agreement that government needed to upgrade their traffic modeling procedures.

SACTRA also considered two further arguments that they called *The Limiting Case* and *Mogridge's Conjecture*. The Limiting Case referred to instances where capacity is added to highly congested conditions so that volumes rapidly grow to fill the available road space and the network becomes saturated once again. Under these conditions demand would be perfectly elastic and there would be no benefit to users (SACTRA, 1994, p.126).

Mogridge's Conjecture refers to instances where the addition of road space and faster travel times attract people away from public transport and into cars. Given that public transport is subject to commercial constraints, as passengers and farebox revenue is lost, either fares or subsidies have to be increased, or else service levels cut (SACTRA, 1994, p.128). From an economic perspective this is a particularly bad result because it leads to the underutilisation of existing infrastructures while at the same time undermines service levels and increases user costs for other passengers using the public transport services. Apart from pointing out that this argument merits consideration, but is only applicable in a limited number of cases, SACTRA has very little to say on the subject and there are no supply and demand curves provided to explain what might cause changes of this kind (SACTRA, 1994, 129).

Figure 10 Estimates passenger journeys for the Western Sydney Rail Line 1985–1995

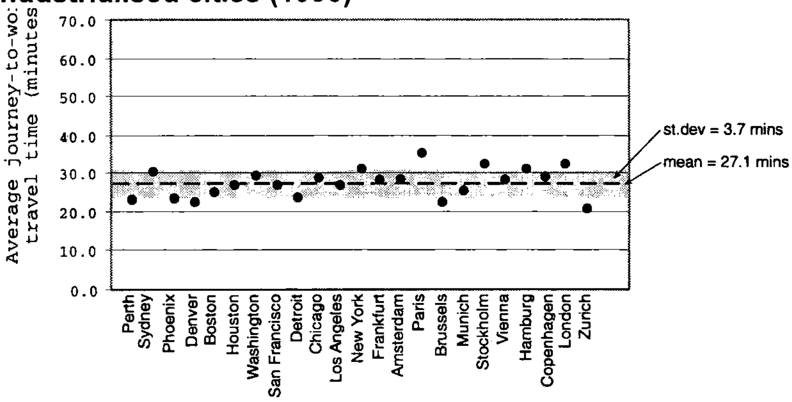


Source: Zeibots, ME. (2003), *Before and after opening of the M4 Motorway from Mays Hill to Prospect: an empirical analysis*. Working Paper. Institute for Sustainable Futures, University of Technology, Sydney.

Figure 10 shows passenger journeys for the rail line that runs parallel to the M4 Motorway in Sydney. Data for the M4 was shown previously in Figure 2. As can be seen in Figure 10, a substantial decline in passenger journeys occurs during the financial years of 1991/92 and 1992/93. This period coincides with the opening of the motorway section from Mays Hill to Prospect (Zeibots, 2003, p.16–17). Clearly, further investigation is required and similarly a theory needs to be provided that outlines the generic set of operating principles responsible for this behaviour. This will be done in the next section of this paper. But before doing that, it is useful to add some observations about the use of mainstream economic theory and the way that it treats time.

The justification of motorway projects is highly dependent on the monetisation of travel time as part of the User Costs. In some cases this can comprise up to 75 to 80 per cent of estimated benefits (Rayner, 2003, p.1 and Goodwin, 1981, p.99). A debate has taken place over this practice because for some projects travel time savings may be in the order of only a few minutes for each individual. Under these conditions it seems unlikely that any meaningful utility, or increase in labour productivity, could be exchanged for these travel time savings. In aggregate these small travel time savings produce a large money figure to off-set the high construction costs of urban motorways. Consequently, a great deal of argument has focused on the issue of what monetary value should be assigned to travel time savings (Welch and Williams, 1997). In the EU, different member countries use different values, or a sliding scale, for different types of traffic (Bristow and Nellthorpe, 2000, pp.53 and 55). But debate over which value should be used steps around the central point of concern that much of the discussion in section three will be focused around — the implications of an empirical phenomena called travel time budget constancy, an indication of which is provided in Figure 11.

Figure 11 **Average travel times for the journey-to-work in 23 industrialised cities (1990)**



Data source: Kenworthy, JR., Laube, FB., Newman, PWG., Barter, PA., Raab, T. Poboon, C. and Benedicto, G. 1999, *An international source book of automobile dependence in cities 1960-1990.* University Press of Colorado, Boulder, p.610.

Transport planners and engineers have for many years been interested in the observation that on average, most populations spend around 30 minutes on the journey to work. In the early 1970s, social scientists became keenly interested in the subject. One highly cited study found that, irrespective of ethnicity, culture, religion, level of industrialization or access to transport technologies, average journey-to-work times for most populations are around 30 minutes (Robinson, Converse and Szalai 1972, pp.114–117).

An obvious argument that follows from this observation is that if travel time basically remains the same, then surely valuing travel time savings in the manner outlined previously becomes pointless? SACTRA mention travel time budget constancy in their report, but make no comment as to what its wider significance might be for project evaluation (SACTRA, 1994, pp.39–40). As will be revealed in the next section, the implications of travel time budget constancy can only be understood within the context of the workings of the urban system as a whole.

Constants have a habit of being critical to the organisation of systems, for if the factors and relationships that keep the constant in position can be identified, the wider workings of the system can be understood. City systems are complex and it can be difficult to find a way of conceptualising the many different activities that take place and how they relate to one another. This is what section three will attempt to do using General Systems Theory, and the notion of travel time budget constancy sits right at the heart of this theory. This alternate explanation, casts doubt over the wisdom of using travel time savings as the primary economic justification for urban road proposals.

3. Explaining the cause of induced traffic growth using General Systems Theory (GST)

Like all languages, General Systems Theory (GST) has its own conventions and so at the outset it is useful to revue its fundamental terms. These include: system boundary, environment, system components, system attributes and relationships, signals, control and system feedback. An easy way to understand these terms is to think about how they apply to a simple example like a hot water heating system.

Figure 12 A hot water heating system

Diagram to be inserted

A hot water heating system comprises several different parts, or system *components*. These include a tank, heating element, thermostat and various pipes and wires that connect these components together. Water enters the system through a pipe and fills the tank, crossing the *system boundary* from the *environment*. The thermostat measures the temperature of the water, after which it then makes a decision about whether the water is at the temperature it has been designed to reach. If it is below the desired temperature, the thermostat sends a *signal* to the heating element located inside the tank. The signal turns on a switch that sends energy to the heating element. This increases the temperature of the water. When the thermostat senses that the water temperature is above its design goal, it sends another signal to the switch controlling the heating element to cut the energy supply. When the energy is reduced the water temperature stops rising. As water is taken out of the tank, or cools through general heat loss, the thermostat continues to monitor the water temperature and regulate the energy supply to the heating element.

In this example there are two different kinds of *system feedback* taking place — *positive system feedback* and *negative system feedback*. The difference between the two has to do with the *signals* sent between the different *components* in the system and how these make the components respond. When the water is too cold, the thermostat sends a signal to increase energy to the element, which in turn raises the water temperature. This is called *positive system feedback* because it involves *adding* to the system. When the water is too hot, the thermostat sends a signal to reduce the energy going to the heating element, stopping the water temperature from increasing. This is called *negative system feedback* because it involves resistance or *taking away* from the system.

The component that is central to instigating the different forms of feedback in this example is the thermostat. This critical component is called the *system controller*. In complex systems, controllers can be responsible for multiple forms of system feedback.

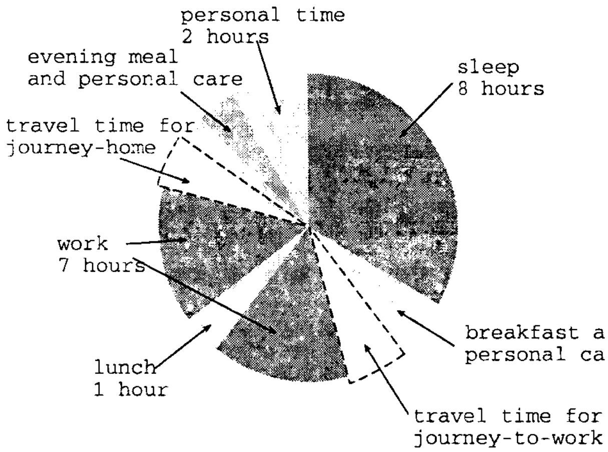
System controllers bring order to complex systems and generally work on the basis of some kind of constant, which acts as a reference point for all the other components of the system. If the raison d'etre behind a system controller can be understood, then the wider workings of the system are easy to comprehend. The raison d'etre for a hot water heating system is obvious — to heat water. Because it's an artificial system, designed by humans, the system feedback and logic behind it is also obvious. The fundamental reason for the existence of natural systems like cities and what factors control their operations can be more difficult to identify.

Travel time budget constancy acts as the system controller in a city and as will be shown it sits at the centre of many different forms of systems feedback that involve traffic flows and passenger volumes, patterns of landuse development, market catchment areas and phenomena like induced traffic growth.

In all of these processes, time is of central significance and bound up in the primary reason for building cities). By living in close proximity, people are able to make large numbers of exchanges within relatively short time periods. This is essential to the creation of what economists call the *division of labour*, where individuals specialise in different tasks to increase their combined output (Samuelson, 1992, p.704). Close proximity is essential to labour specialisation because other people must be present to do the tasks that an individuals' own specialisation prohibits them from doing (Zeibots, 2003b, p.4). This is why spatial conditions and cities are of fundamental significance to industrial production (Prud'homme, 1994, p.730).

Figure 11 shows average travel times for the journey-to-work for a selection of EU, US and Australian cities. The average for these cities is just on 27 minutes and there is a difference of only a few minutes between the averages. The explanation for why such similarity occurs is that the other demands on an individual's time, limits the scope for wide variation. Coupled with this is the motivation to try and reduce travel time so as to have more time at destinations, while there is also the motivation to spend more time travelling to access new and novel destinations, which is the whole point of living in a city. An examination of the tasks and activities that make up a typical day shows how these motivations fit within the framework of a daily routine. These are shown in Figure 12.

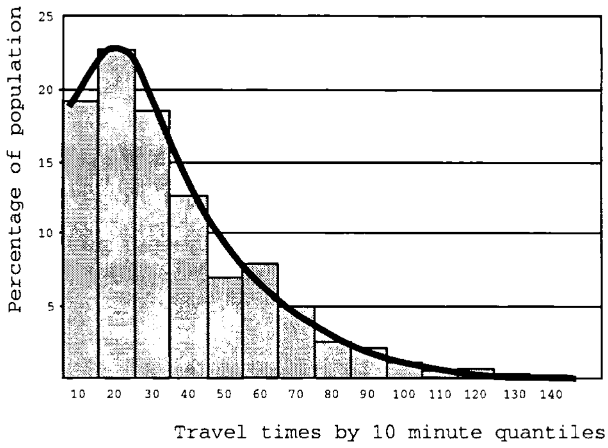
Figure 12 Typical tasks that make up a daily routine



Time allocations based on data in: Robinson, JP, Converse, PE. and Szalai, A. 1972, "Everyday life in twelve countries" in *The use of time: daily activities of urban and suburban populations in twelve countries*. Szalai, A. (ed). Mouton, The Hague.

Travel time budget constancy occurs because of all of these constraints. There are only 24 hours in a day, everyone has to sleep sometime, eat, maybe tidy up around the house and have a wash. As can be seen in Figure 12, once time spent at work is taken out of the equation, the window left for travel becomes quite narrow. The journey-to-work is not the only reason for travel and of the total number of trips undertaken in cities amounts to around 25 to 30 per cent. Travel time budget constancy also applies to travel time for all trips combined. Many studies have shown that on average populations spend somewhere between 70 and 75 minutes on total travel per person per day (Schafer, 1997, p. 459). But for the purposes of this paper, attention will be confined to the journey-to-work because it is the trip that relates to earning a living and most people undertake it at around the same time giving rise to congestion.

Figure 13 Journey-to-work travel time budget distribution for the Sydney workforce (2000)

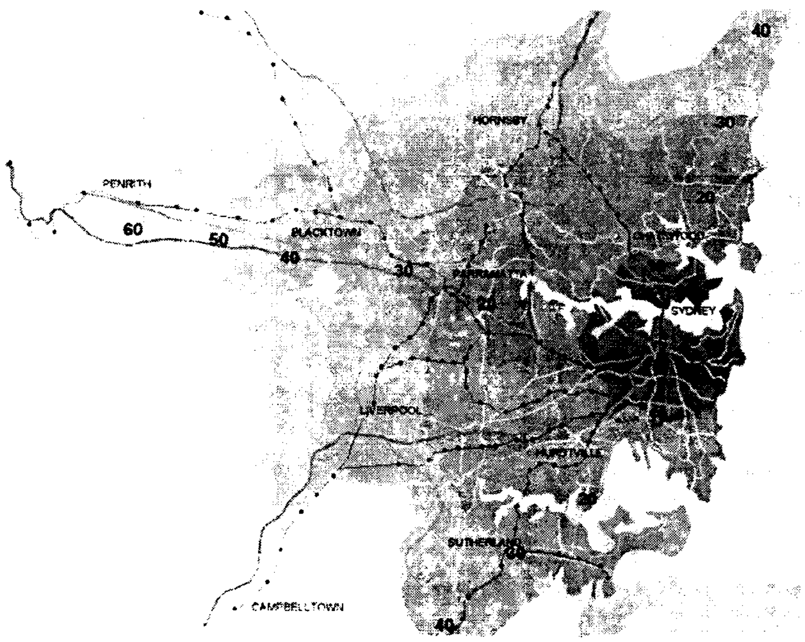


Data source: Transport Data Centre. (2001), Household interview survey for Sydney, 2000. Department of Planning, Infrastructure and Natural Resources.

Behind every average is a statistical distribution for an entire population. The distribution shown in Figure 13 is for the Sydney workforce. The significant characteristic of the distribution is its shape, for this is the real face of travel time budget constancy. Not an average, but different proportions of the community spending given amounts of time on their journey-to-work. In this example, around 19 per cent of the population spent less than 10 minutes travelling to work, 23 per cent between 10 and 20 minutes, 18 per cent between 20 and 30 minutes, 12 per cent between 30 and 40 minutes and so on.

In the journey-to-work distributions for other cities, the percentages of the population represented in each travel time quantile may not be exactly the same as those for Sydney, but they are very similar. Slight differences cause slight changes to averages. When average travel time budgets for the journey-to-work are presented as were shown earlier, it is important to keep in mind that each average is indicative of a distribution similar to that shown here for Sydney. The usefulness of this becomes apparent when the travel time budget quantiles shown in the statistical distribution are translated into spatial data and mapped to show the area that different percentages of the population are prepared to access.

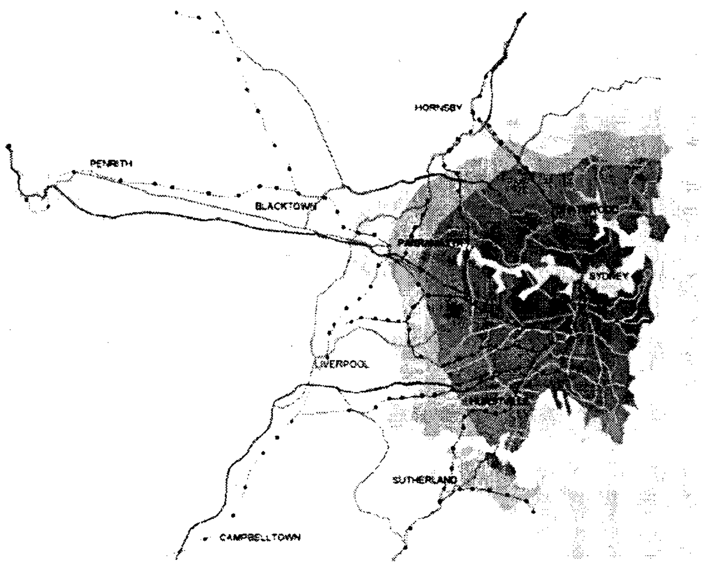
Figure 14 Travel time budget contours for journeys by car to the Sydney CBD (2000)



By mapping *travel time budget contours* it is possible to see how different transport systems produce differently shaped travel time contours that indicate different areas of access within given time periods. The area that falls within the range of the contours changes according to the speed and logistical properties of the mode in question.

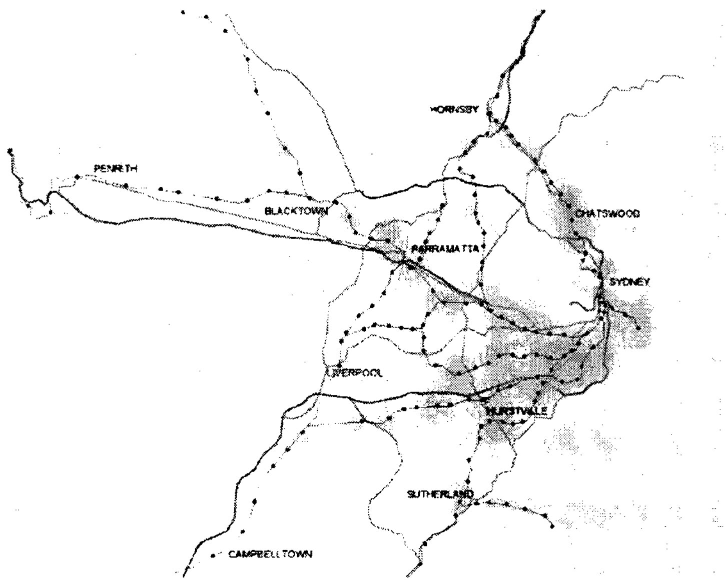
The map of the Sydney CBD and surrounding suburbs shown in Figure 14 identifies those areas that are accessible by car within the journey times that various proportions of the population are prepared to spend traveling to work. These contours were calculated on the basis that there was no congestion.

Figure 15 Travel time budget contours for journeys by car to the Sydney CBD in the morning peak period (2000)



In Figure 15 the accessible areas within travel time contours shrink dramatically because empirical data for morning peak period travel speeds was used. The higher number of cars on the roads causes congestion and slows down the road network. Travel time contours for rail and public transport services to the Sydney CBD show a very different pattern. These are shown in Figure 16. In the morning peak period, travel time contours extend far beyond those for the road network. Because they are quicker and extend over a much larger area, most people use public transport services if they work in the CBD — almost 80 per cent of the workforce (Transport Data Centre, 2001).

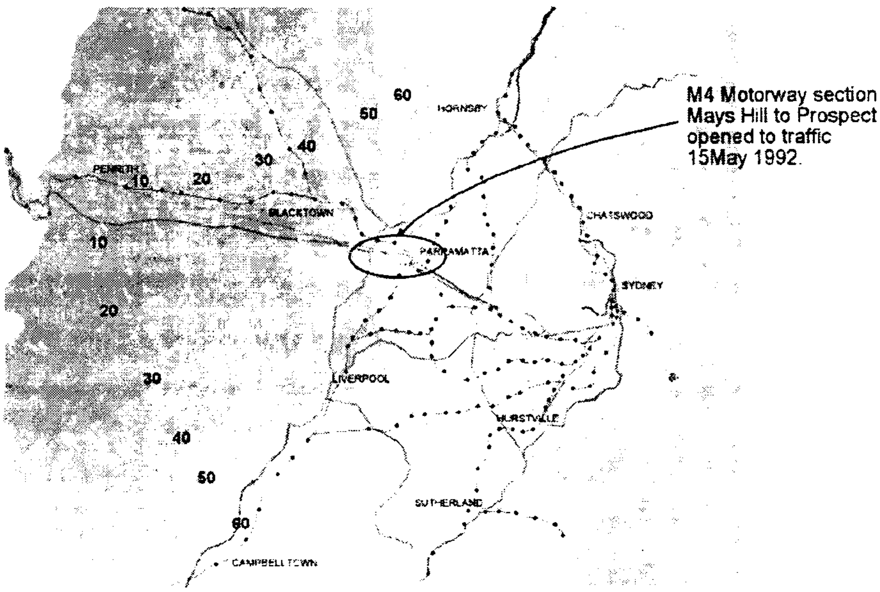
Figure 16 Travel time contours for journeys by train and walking to the Sydney CBD in the morning peak period (2000)



When the speed and capacity of urban transport services are altered, travel time contours also change. Empirical evidence shows that people change their transport mode to take advantage of the quicker travel times. These changes are dramatic and occur soon after changes to the network (Zeibots, 2003, p.14).

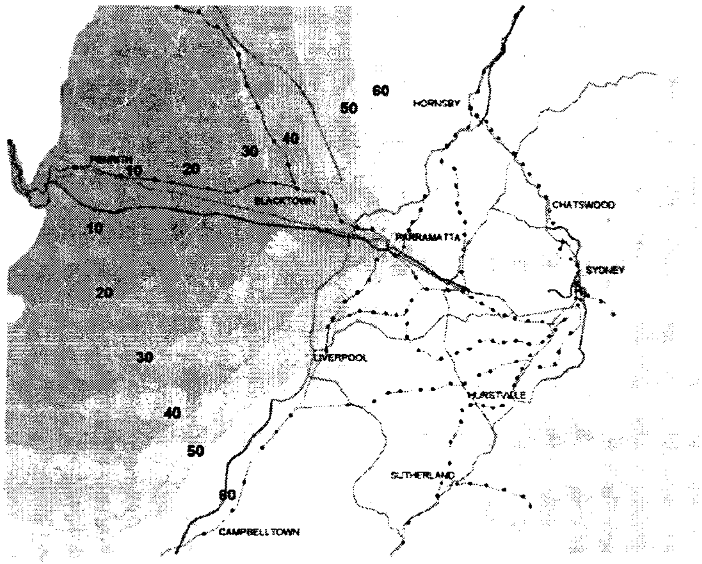
Figure 17 shows the travel time contours from Penrith in Sydney's outer west before the last section of the M4 Motorway was opened in May 1992. The bottleneck that occurs where traffic from the motorway joins the Great Western Highway can be seen where travel time contours become smaller. In Figure 18, the contours for car travel expand over a larger area and overtake those for rail services in some cases. This is because access by car became quicker for some people once the bottleneck had been removed. As a consequence they shifted from the rail to the road network.

Figure 17 Travel time budget contours for journeys by car from Penrith before opening of the M4 Motorway from Mays Hill to Prospect (1992)



In the months immediately after the new motorway section opened there was a sharp increase in car trips for combined volumes on the motorway and arterial road that runs next to it (Zeibots, 2003, p.16). This was shown in the time series road traffic volume data for the two roads, shown in Figure 2.

Figure 18 Travel time budget contours for journeys by car after opening of the M4 Motorway from mays Hill to Prospect (1992)



At the same time that car trips increased, rail passenger journeys declined. This can be seen in Figure 13. In this example, not all the increase in car trips can be explained as people shifting from rail to road. A portion of the increase was clearly caused by road users changing routes as they abandoned slower arterial roads for the new motorway. This is refered to as traffic reassignment (SACTRA, 1994, pp.19 and 53). Some of the increase is also explained as business-as-usual growth or increases due to population expansion. In previous years this growth rate was around 3 to 4 per cent (Zeibots, 2003a, p.3). But even after all these factors are taken into account, a portion of the increase in trips remains unexplained. These appear to be new and longer trips generated in response to the new regime of travel time contours. This is likely to comprise people making longer distance or additional trips refered to as *induced traffic growth* (SACTRA, 1994, p.7–8).

The urge to save time so that more exchanges can be made motivates people to change modes so they can have more time for doing other things. At the same time other people took advantage of the quicker speeds and made additional trips to make more exchanges or travelled to more distant destinations because the types of exchanges to be made were preferable. These divergent motivations explain the statistical distribution that is the travel time budget constant. All these responses constitute different forms of system feedback. The engine that drives these processes is travel time as encapsulated in the travel time budget constant, which acts as the system controller. The way to express this mechanism most clearly is to map it and understand it as spatial data rather than as a number value.

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