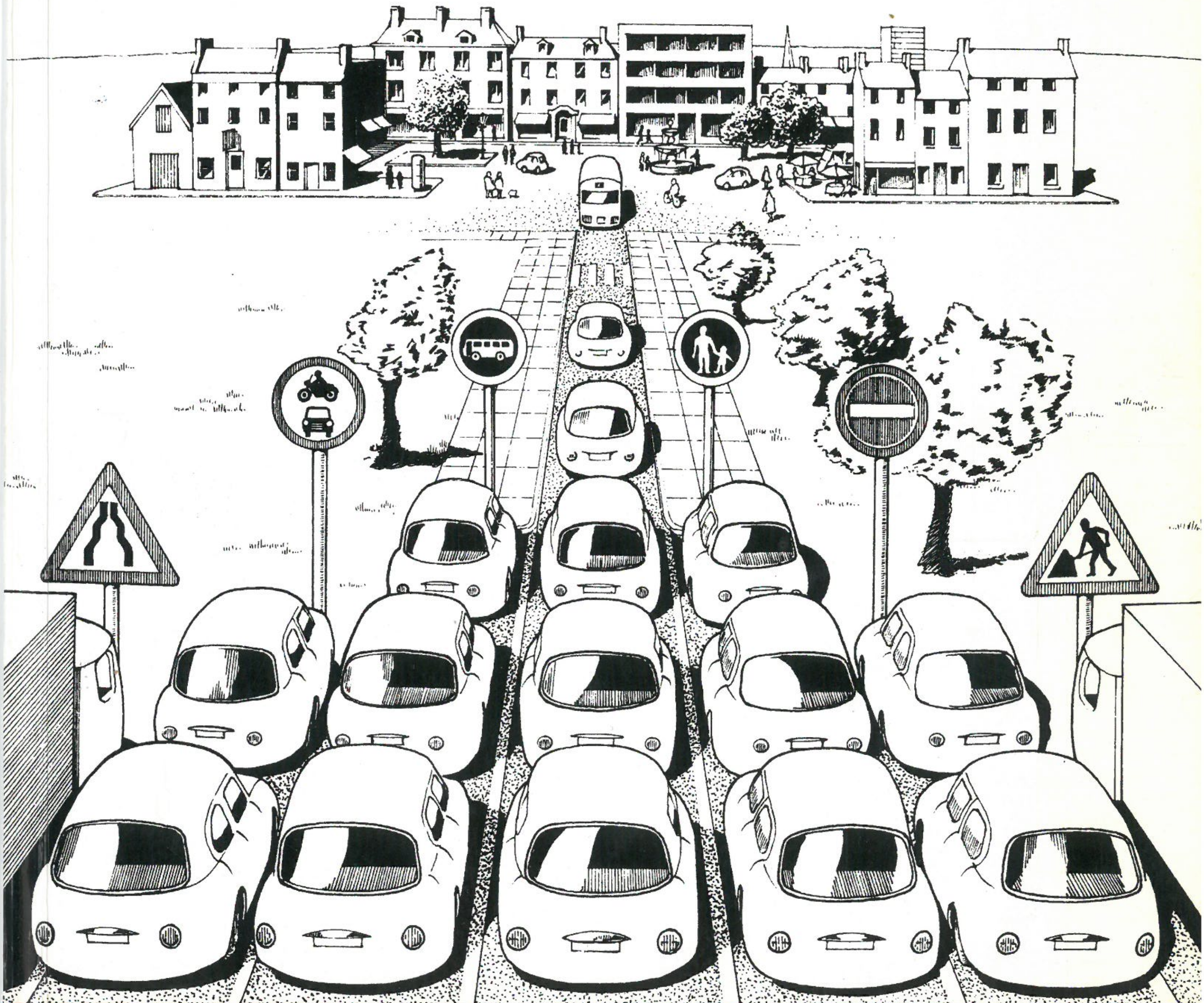
Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence

Sally Cairns, Carmen Hass-Klau & Phil Goodwin

with an annex by Ryuichi Kitamura, Toshiyuki Yamamoto and Satoshi Fujii



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Chapter 1: Overview

1.1 Policy context and research objectives

During recent years, developments in transport policy have often focused on the need for reductions in traffic growth, reductions to the level of traffic in specific locations, improvements to the attractiveness of public transport, and better facilities for walkers and cyclists. Such changes are seen as potentially able to help improve economic efficiency, air quality, and social cohesion.

The impacts of reductions in road capacity, or reallocations of road capacity from cars to other classes of traffic such as buses, pedestrians and cyclists, are therefore of major policy interest. The role and context for such measures will always require careful consideration, in order to ensure that benefits are maximised relative to costs, in both the short and long term. In situations where this condition is fulfilled, these measures could constitute useful tools for achieving a more efficient use of road space, improving the attractiveness of non-car modes, increasing accessibility to specific locations, bringing about environmental improvements, enhancing street attractiveness and improving safety.

Clearly, the public relations, political and social dimensions of such measures need careful assessment. But underlying these considerations is a practical issue: such changes can only be made if they are *technically* feasible.

The feasibility of a measure to reduce capacity has often been calculated on the assumption that all motor vehicle traffic displaced from one street will simply divert to another. Sometimes this has been assumed because the analyst judges it to be true. Sometimes it is thought that, even if not strictly true, any other changes in behaviour will be negligible. Forecasts made using this assumption sometimes result in predictions of such unacceptable levels of congestion on other roads, that they have been caricatured as 'traffic chaos'. On occasion, this expectation has been so strong that it has prevented a scheme going ahead.

At the same time, there is also a growing body of experience that such fears may be exaggerated.

At the practical level, there are examples of cities who decided to ignore forecasts of traffic chaos, went ahead with implementing a scheme, and found that the resulting traffic conditions were better than those predicted. A recurrent theme in informal reports of such experience has been the suggestion of 'disappearing traffic'.

At the technical level, the possibility that the total volume of traffic can be influenced by network conditions was always allowed for in principle in the Department of Transport's cost-benefit guidance, and estimated in some cases such as estuary crossings and assessment of major urban transport strategies. However, when appraising specific local schemes, such effects were often omitted, on the expectation that this would not significantly influence the net balance of costs and benefits. SACTRA (1994) re-examined this issue for the case of new or widened roads, and concluded that increases in road capacity in congested conditions were likely to generate (or, more precisely,'induce') extra traffic to an extent that did materially affect appraisal. Therefore, by symmetry, it might be expected that a reduction in capacity could lead to some overall *reduction* in traffic volume, so that the traffic impacts of capacity reductions would be less severe than expected.

However, the evidence about the impacts of highway capacity reductions remained scattered and unassessed. Therefore, London Transport, together with the Department of Transport (now Department of the Environment, Transport and the Regions), commissioned research to establish *"a practical and authoritative means of estimating the likely effect on traffic flows of selective reduction of highway capacity for certain classes of vehicles"*. It was intended that the work would *"review existing knowledge including both practical experience and theoretical principles, and should provide a convincing and defensible means to estimate the effects of capacity withdrawal"*.

This volume addresses the theoretical and empirical evidence collected and analysed as part of this research. A separate volume, by MVA, concerns the theoretical and practical issues for modelling.

The main question tackled here is: what really happens to traffic conditions when road capacity is reduced or reallocated? In pursuing the answer, interpretation of the evidence required consideration of a second question which had not featured so strongly in the original work-plan: what are the underlying changes in travel choices and behaviour that cause these effects?

This report does not address the wider political, cultural, social, economic and environmental issues of capacity reduction in any detail. These are obviously very important in the debate, and have been mentioned by many of those submitting evidence about local schemes. However, they fall outside the scope of the research commissioned.

1.2 The research approach: synthesis and caveats

The prime objective of this part of the research project has been to find real world experience where capacity reduction or reallocation has occurred, and has been accompanied by reliable monitoring and surveys. Evidence is not included from modelling exercises forecasting the effects of such measures, unless it could be compared with subsequent actual experience. To understand the effects of capacity reductions further, wherever possible, the results have been underpinned with in-depth information about the mechanisms and influences on travel choice when network conditions change.

It is reasonable to expect that the effects would be influenced by the prevailing conditions and the specific nature of the measures introduced. In discussions during the project, suggestions were made that crucial influences might include:

- the scope, scale and timing of the capacity reductions;
- the prevailing traffic conditions (including the amount of 'spare' road capacity available);
- whether reductions were planned as part of policy, or occurred due to accidents or events;
- the degree and type of advance publicity and/or marketing;
- the nature of the location, including the size and characteristics of the town or place;
- the geographical and topological features of the network;
- the time period when the impacts were observed (with a distinction between short and long run effects);

- the social, economic and cultural characteristics of the local population;
- other accompanying policy measures that have been introduced at the same time.

As discussed later, not all of these suggestions were clearly supported by the available evidence, but as far as possible, such hypotheses were kept in mind when examining it.

The evidence collected includes both theoretical and empirical studies, based on published and unpublished information that was originally collected for a wide range of different purposes. It relates to a broad range of capacity reductions which vary widely in scale, duration and stimulus. The project itself has not involved new surveys or data collection, but has included access to such work being carried out by other agencies in the UK and abroad.

The net has been deliberately cast as wide as possible, by literature search, direct contact with local authorities and individual experts in the field, advertisement in *Local Transport Today* supported by comment in the technical press, and general enquiries. Details of the approaches made are shown in Appendix B. As acknowledged there, the authors are indebted to the immense amount of help received from many people, and to their original work.

The two defining policy situations motivating the study were those where (a) road space has been allocated to priority vehicles like buses and/or cycles, and (b) road space has been converted to other uses, as during town centre pedestrianisation. Wherever possible, therefore, information has been sought on the real-world effects of these two sorts of measures. However, appropriate information can also be gleaned from other situations entirely, since it is the fact of capacity reduction that is relevant to the research, not its motivation. Therefore, information has also been collected about reductions in capacity due to road maintenance, bridge collapses, and natural disasters. Clearly, the political and public relations aspects, and in some cases consequential other changes (like disruption to employment), are quite different for unexpected emergencies compared with carefully planned capacity reductions. However, emergency cases *do* provide relevant information about what drivers actually do in response to changes in availability of road space, and are often quite informative about how behaviour changes over time, particularly when road capacity, and all other facilities, are subsequently restored.

- **Case studies**

The core of the empirical evidence is drawn from case studies of particular locations. Altogether, evidence from about 150 sources relating to nearly 100 locations has been used, including over 60 case studies which have contributed directly to the main research question. These are listed after the contents list and are summarised individually on the coloured pages of this report. Another 30 or so give narrower indications or insights into some specific associated questions, and are reported, as appropriate, in the main text.

The report on the Hanshin-Awaji earthquake, carried out by Kitamura *et al.* from Kyoto University, involved original research for this study, and is given in full as an Annex, as well as in summary.

It is unclear whether some cases qualify as examples of capacity reduction. For example, traffic zones, restricted access to residential areas, or the closure of through routes, may not reduce road capacity overall, but do reduce capacity for particular movements. In other cases, certain policies are commonly discussed as examples of capacity reduction, although they do not necessarily have that effect. For example, some argue that introducing speed limits is likely to have similar effects to reducing road capacity, since journey times increase. However, in some circumstances, lower speed limits can provide for greater traffic flows. It was expected that the American experience of High Occupancy Vehicle lanes would provide relevant information, but this was not the case, as Vuchic (1997) points out, because of:

"a court decision [in California] that a lane cannot be taken from general traffic. The highway lobby has happily used this case to claim that due to 'realities', High Occupancy Vehicle lanes can only be additional, rather than converted lanes...Thus, we have virtually no cases of closing general lanes for conversion to HOV facility".

- **General caveats**

As far as possible, bias, incompleteness, technical difficulties and ambiguities in the original sources have been considered. A summary of specific relevant known caveats is included with each case study summary, (though for a full assessment, the reader is referred to the original sources, as always). A discussion of more general sources of potential systematic bias is included in Chapter Three. The most important caveats identified are random variation, which leads to an exaggeration of extreme effects (producing both very high and very low results); traffic counts which do not fully reflect increased distance travelled on some journeys; and trend effects in which traffic growth due to income, car ownership or land-use changes is not separated from the consequences of the measures introduced. The net effects of these sources of bias can go either way, and not all of them are relevant to every study. Attention is drawn to these problems in discussion of each case study, and in the general section, but 'adjusting' any figures has been deliberately avoided, to avoid blurring the distinction between the figures collected and the interpretation of them made here.

The recurrent experience during the analysis was that the reports available did not easily reveal the information sought. Partly this is due to their original purpose. Typically, they have been written for a local audience, who would understand the short-hand names for streets, local policies and background. They are also usually geared to answer specific, controversial local questions, rather than make a more comprehensive contribution to research. Such studies are normally subject to very constrained budgets, both in terms of time and money.

However, a bigger reason became more apparent as the project developed. The further the analysis proceeded, the more it became clear that the results only make sense if it is accepted that behavioural responses must be more complex, and cover a wider geographical area, and take place over a longer time period, than *can* be revealed from simple before-and-after aggregate traffic counts, separated by a few months. The 'perfect study' (which would have to include traffic counts in a very large area, watertight screenlines, longitudinal monitoring of the changes in behaviour for specific individuals in a very large catchment area, all continued for five years or more) has never been carried out, (or, at least, was not revealed in the search for evidence). Collecting such data would cost more than many of the schemes for which the data would be used. Even specially designed research projects are unlikely to produce absolutely certain results, due to the complex range of other changes that are likely to be occurring at the time.

Finally, there are two important overall limitations on the scope of case study evidence available. First, there are many schemes which have never received serious consideration, because forecasts of unfavourable traffic effects led the authority concerned to abandon the idea - thereby destroying the opportunity to see whether the forecasts were well founded or not. Second, there are schemes which have been carried out with such confidence that no great problems would arise, that there was no motivation to carry out a research study into the effects. Again, data are therefore not available.

- **Supporting research**

On many important issues, particularly those relating to the way in which behaviour alters after changes in network conditions, only a few of the case studies included direct evidence. However, this has been a fruitful area of transport research generally, and it was possible to find survey and analytical evidence from other studies, carried out with a different focus, that enabled the differences between the case studies to be explored in more detail and the time scale of the implied behavioural changes to be clarified.

The result is that the overall analysis is a synthesis of many pieces of partial information, and the study has sought to judge the overall balance of evidence taken as a whole, rather than rely on clear-cut scientific proof drawn from any one analysis. This is somewhat similar to the SACTRA (1994) approach from which this project is, in part, derived.

1.3 Initial review of the evidence

A first broad review of the evidence looked particularly for any cases where reductions in traffic capacity resulted in the expected 'traffic chaos', which lasted longer than a relatively short adjustment period.

It proved to be very difficult to find such cases. Indeed, there have not so far been any references to long-term traffic chaos or prolonged gridlock resulting from taking space away from cars, even in the event of major catastrophic breakdowns due to earthquakes. This is surprising. There are certainly reports of initial chaos, and there are also very numerous descriptions of endemic, barely tolerable, congestion. These refer to situations where large parts of a network are operating at traffic levels fairly close to their maximum capacity, but these situations occur independently of whether capacity has been increased, reduced, or remains unchanged.

In consequence, no capacity reduction schemes have been identified which have got as far as implementation and then been withdrawn because they caused an unacceptable worsening of traffic congestion. However, a few schemes, (such as the Nottingham Zones-&-Collar experiment and Orpington High Street closure) have been halted or substantially modified because they did not deliver a hoped-for traffic improvement, or switch to public transport, or other intended benefit. It is important to establish why this is so in some circumstances and not in others.

The prevailing views on schemes which got as far as implementation may be summed up by the sample of quotations in Table 1A. These have been extracted from commentaries on a wide variety of road closures, narrowing, restrictions etc. Whilst none of the quotations should be taken at face value before more detailed examination, together they establish a movement in professional and political opinion away from the notion of a fixed total volume of traffic.

These comments reflect a body of opinion. The remainder of this report pursues the detailed figures that underlie this opinion, and seeks to test, interpret and explain the results, by detailed case-by-case examination of the circumstances from which such quotations were derived, and a consideration of their consistency, or otherwise, with other empirical research and theoretical explanations.

Table 1A: Reported impacts of reducing highway capacity

Place and date	Quote	Reference
Washington, 1964	'None of the surrounding roads experienced an increase in traffic, and most experienced some decrease. Nor was there any sign that the traffic had chosen more distant routes in other parts of the city; it simply disappeared'	Jacobs 1964
Nürnberg, 1972	'Nearly 80% of the car traffic simply disappeared and could not be accounted for in parallel streets'	Hass-Klau 1996b
Milan, 1985	'Generally, people perceived little change in traffic levels'	Gorla 1992
Munich, 1988	'The only jam which occurred was among the masses of reporters, camera teams and photographers who were all waiting for the traffic jam which never took place'	Hupfer 1991
Athens, 1995	"It was far better than expected, considering the considerable changes imposed to central traffic routes and public habits"	Daily Telegraph 12/4/95
Los Angeles, 1996	'Road transport experts are still trying to figure out where the 80,000 or so cars a day have gone'	UITP Express 1996
Leicester, 1995	'...concern that the main roads networks may not be able to cope with the extra traffic. To date, we have not observed such an effect'	Leicester Council 1995
Leeds, 1997	'We put some bus lanes in yesterday. Today it's murder on the streets - the drivers didn't believe any of our publicity, and there are long tailbacks. But we're not panicking. It'll be all right by Friday.'	personal communication
London:		
Grove Lane, 1985	'traffic flow was reduced...and there was no significant extra traffic in any other road'	GLC 1985
Peckham, 1985	'despite the fears of much extra congestion, there seem to have been relatively few complaints'	GLC 1985
South Wimbledon, 1985	'there has been an increase in congestion but it has not been as serious as suggested on three of the four approaches'	GLC 1985
Hammersmith 1997	'AA Roadwatch breathed a sigh of relief as the predicted traffic chaos failed to materialise. "It's not as bad as we feared", a spokesman said'.	Evening Standard 3/2/97

Chapter 2: Theoretical Considerations and Evidence

Although this report is primarily concerned with empirical evidence, assessment of theoretical evidence was also part of the brief, both in its own right and because interpretation of empirical evidence cannot be carried out without some theoretical underpinning. Therefore, five theoretical structures are now considered, in brief, which are relevant to the issue of reducing or reallocating road space. These are (i) the theory of traffic flow and assignment; (ii) analytical approaches exploring the conditions in which there could be provision of road capacity in excess of that warranted by strict economic appraisal; (iii) behavioural theory about travel choices and adaptation; (iv) theory about the evaluation of transport projects and policies; and (v) inference from the theory (and associated empirical evidence) developed for the opposite issue, the effects of road capacity increases.

2.1 Traffic flow and assignment theory

The theoretical basis for identifying circumstances in which it is appropriate to reallocate capacity from cars to buses derives from a seminal paper by Smeed and Wardrop (1964). This demonstrated the counter-intuitive result that, in spite of the fact that buses are almost universally slower than cars, overall journey times could be reduced if enough people travelled by bus instead of car. This is because buses make a contribution to congestion equivalent to about three cars, but can carry as many people as twenty to fifty cars.

The work did not explicitly consider the behavioural mechanisms that could bring about such a change, but implicitly demonstrated the difficulty of doing so, because for each individual making a choice there would be a personal disadvantage from switching modes unless enough other people also did so at the same time.

Other work by Wardrop (1952), later known as 'Wardrop's Principles', provided an apparent behavioural basis for much of the subsequent fears that unacceptable levels of congestion could result from policies like reallocating road capacity to bus lanes.

These principles suggested rules by which drivers would choose among alternative routes to minimise their journey time or, alternatively, everybody's journey time. The rules are at their simplest and most elegant if it may be assumed that the total number of journeys, and their distribution among available origins and destinations, are fixed, so that the only dimension of choice open to the driver is which route to take. The economy, efficiency, mathematical rigour and intellectual magnetism of traffic models using this simplifying assumption gave them an overwhelming advantage as a practical (albeit possibly misleading) tool which could be applied quickly and cheaply to assess traffic measures on a street or a small part of the network.

When this is done, all traffic displaced from its favoured route is assumed to take some other, previously rejected, route or routes, reducing the speed on each of them. If the other routes are operating close to capacity already, very substantial difficulties of congestion are predicted, even to the extent of finding it difficult to 'fit in' all the displaced traffic. In such circumstances, chaotic or gridlocked conditions may be predicted as a result of a significant reduction of capacity, with no apparent mechanism for resolving them.

Treating route choice as the only significant behavioural response to small changes in network conditions was originally only done as a temporary stage in a mathematical argument, during the theoretical development of traffic equilibrium analysis. The possibility of more complex reactions was always allowed for in principle in, for example, DETR guidelines on COBA cost-benefit procedures. However, in specific applications (particularly small schemes), it was often judged that changes in trip rates, destination choice, mode choice and other behavioural dimensions were likely to be negligible, or of insufficient magnitude to affect the appraisal.

Now, the currently prevailing view, in both the DETR and elsewhere, is that changes to other behavioural choices *are* of potential significance, including changes to the 'classical' choices of trip frequency, destination and mode, the choice of time of day for a trip (whose importance in increasingly acknowledged), and other responses which are discussed later in this report. A widely used theoretical framework and a number of implemented model structures exist for considering the equilibrium conditions which might result after many of these responses have settled down. These are discussed in the companion MVA report for this project. As research tools, these approaches all lead to a theoretical expectation that the volume of traffic could, to some extent, go up or down as capacity increases or reduces. This expectation, acknowledged but not implemented in the Department of Transport's 1989 National Road Traffic Forecasts, is now formally included in the DETR's 1997 National Road Traffic Forecasts, where forecast traffic levels are reduced (in a procedure called 'fitting on') by a proportion which is dependent on the elasticities used and the extent to which road capacity does not provide for predicted traffic.

In summary, the simplifying assumption that only the choice of route will change when road capacity alters had a particular theoretical importance, and practical advantage, in the development of an influential branch of modelling. There is no presumption that it is necessarily true.

2.2 Theoretical justifications for a reduction in overall road capacity

It should be emphasised that the Smeed/Wardrop argument on cars and buses is not essentially about a reduction in road capacity for motorised traffic, but a more effective use of it. Indeed, if capacity is considered in terms of potential for *people* flow rather than vehicle flow, then even quite drastic reallocation to public transport may be seen as an *increase* in capacity.

However, this question of definition does not alter the underlying problem since it is vehicles whose displacement could cause congestion elsewhere. From this point of view, it is right to consider the wider question - are there circumstances in which reductions in road capacity for motorised traffic in general might be theoretically warranted? These considerations are only briefly summarised here, acknowledging the obvious relevance of identifying circumstances in which road capacity reductions might be justified, but not delving more deeply into questions of economic evaluation in general.

The issue has some background, and five particular strands of theoretical work may be mentioned.

(i) *Possibility of excessive road provision.* The current level of road provision was constructed on the basis of assumptions built into separate scheme appraisals, which in most cases did not take account of induced traffic because (a) it was often thought to be of negligible size, or (b) the additional costs it might cause (for example, in eroding time savings) were not thought to outweigh the additional benefits from the extra mobility. In most cases, it was also not thought that traffic growth would be constrained, either by mounting congestion or by policy. If one were to rework such appraisals on the basis of present thinking on these matters, it is possible that some roads may have been approved that a more correct assessment would have rejected - which implies that people would now be better off if they had never been built. However, it does not necessarily follow that such a road should now be closed, and for practical purposes, the direct benefits from road closures, (like improvements for bus passengers or pedestrians), may be more important than the more abstract economic benefits described in this case.

(ii) *Braess's paradox.* There is a mathematical anomaly in the science of traffic flow, known as 'Braess's Paradox', (Braess, 1968). This states that there are certain properties of the links in a road network where provision of an extra road results in *increased* overall journey time. Removal of the offending road would then make everybody better off. It is not clear that any real-world road has ever been closed for these reasons, but the theoretical possibility has been established, on the basis of assumptions entirely consistent with traffic theory, so it is possible that there are real cases. If so, then a symptom would be an unexpected improvement in flow following a road closure which was implemented, perhaps, for other reasons.

(iii) *Positive feedback.* Mogridge *et al* (1987) observe that, as well as there being a conflict between individual and social priorities for mobility, there is a dynamic balance between car use and public transport over time. In equilibrium, car and public transport must be about equally attractive for the marginal traveller choosing between them. If a new road increases speeds this will attract some people to car from public transport. This reaction will reduce the speeds somewhat, but may also prompt the public transport operator, faced by falling demand, to reduce the frequency of the public transport or increase the fares. This encourages more people to use a car. A new equilibrium will not be reached until the increased traffic congestion has once again made the two modes equally attractive (or unattractive) for the marginal chooser. Since public transport must end up in a worse state than it was initially, so will traffic. The logic may be reversed. Suppose road capacity for cars is reduced. If this persuades some people to transfer from car to public transport, and if public transport operators then improve services, the new equilibrium will be one in which the attractiveness of public transport is greater and so are the conditions for car use. A necessary condition for the argument is that the dynamic process is, to some extent, reversible. This theoretical approach may be particularly significant for understanding the longer-term effects of capacity reductions on traffic and public transport use.

(iv) *Market distortion.* There is an economic argument made by Solow (1973), which highlights that the market price for urban land purchased for road construction does not represent the full economic resource costs, and that no charges are subsequently made for the congestion and environmental costs resulting from the road. Solow speculated theoretically that this means that too much road space could be provided near town centres. This argument does not relate to how people respond to a particular level of capacity, however it does implicitly underlie some of the motivation for pedestrianisation policies in town centres, where improvements to the economic operation of the centre (and making 'best use of the space') are recurrent themes of policy discussion.

(v) *Non-transport functions of streets.* There is now a greater understanding that streets have important functions other than movement, and act as locations for social interaction, commercial activity and utilities. As these factors are increasingly recognised as important contributors to individual and social welfare, it may be justifiable to allocate more space to them.

These theoretical arguments address a common theme. There may be cases where, in some sense, there is 'too much' road capacity, even though there is still a substantial degree of congestion occurring. These arguments are all of substance, and are taken seriously in the literature on traffic analysis and transport economics.

The most important contribution of this theoretical discussion to this research is to clarify that 'capacity reductions' may have three quite different results - first, reallocation of space from cars to buses may not actually reduce overall capacity at all; second, such reallocation may reduce private traffic capacity but increase total capacity, providing an overall benefit in terms of accessibility ('better use of road space'); third, it may trigger behavioural or system changes whose benefits are not in terms of faster travel, but more attractive conditions or different activity patterns, ('better use of space'). These distinctions prove to be helpful in understanding the evidence from the case studies.

2.3 Travel choice and behavioural response

The confidence with which theories of travel choice are often asserted is strangely out of key with the general level of understanding about the complexities of human motivation, and the methodological difficulties of investigating them. Those aspects of travel behaviour theory which are directly relevant to the evidence are reviewed in Chapter 4. At this point, the current state of the art of behavioural theory (as reviewed, for example, by Garling *et al*, 1998), can be simply defined by a number of negatives:

- It does not support the idea that route choice is the only, or necessarily even the main, response actually made by drivers to a reduction in the capacity facing them.

- It does not establish that models of trip generation, distribution, mode choice and assignment represent the universe of all the choices that can be made by travellers. Other choices can include time of day changes, trip consolidation, trip chaining, trip-swopping, life-style changes, car occupancy changes, car ownership changes and a list of other dimensions which may comprise some twenty or more responses, and is no doubt still incomplete. There is no theoretical case for establishing a universal hierarchy of the relative importance of all these choices, this being an empirical question which may vary from case to case.

- It does not support convenient assumptions that responses are instantaneous, in equilibrium at the time when they are observed, or based only on decision rules which can be fully encompassed in a generalised cost of travel or utility maximisation, as usually defined.

These assertions are not intended to determine a behavioural platform conditioning subsequent analysis. They serve only to allow for the *possibility* that behavioural responses to reductions in road capacity may be complex, wide-ranging, and take time to be revealed. In the normal way, it will be desirable to focus analysis and forecasts on the simplest possible set of responses consistent with the facts, but theory suggests that even that 'simplest possible' picture may be quite complex.

2.4 Evaluation of schemes

There is a reasonably well established body of practice for the evaluation of projects intended to increase road capacity. This is based on a cost-benefit evaluation designed to balance net economic welfare for both users and non-users against real resource costs. Environmental, social, equity and strategic policy objectives are also recognised, where they are not included in direct calculations.

The default position for assessment of projects which reallocate or reduce road capacity should be based on the same principles of evaluation as schemes which increase capacity, and both should include the most realistic assessment of the behavioural responses which is practical. If this is not done, there is a danger that evaluation may be biased between different sorts of schemes, to the sacrifice of overall benefit. (For example, if induced and suppressed traffic are both omitted, in congested conditions this is likely to overestimate the net benefits of increasing capacity and underestimate the net benefits of reducing it. If they are omitted in one case and included in the other, then fair comparison of measures is impossible). However, this default position would be inappropriate if there was strong evidence that responses to capacity decreases are smaller in scale, simpler, or different from responses to increases. There would, in that case, be far-reaching other consequences because of the abandonment of many axioms of economic evaluation that would follow.

Starting from the presumption that the criteria applied to capacity increase should be broadly comparable to those applies to decreases, it follows that account needs to be taken both of the travellers and non-travellers who benefit in each case, and those who lose. Drivers who change their route, time of day of journey, mode, trip frequency or destination as a result of a reduction in capacity will (in general) have some personal disadvantage from doing so, and this has to be balanced against the advantages to those who gain. Sometimes such calculations are fairly complex. For example, drivers who change mode may not be disadvantaged if the reallocation of road capacity has resulted in significantly better public transport, and the people who benefit from an improved town centre environment will be the same people as those making different arrangements to travel there. (The theoretical conventions of scheme appraisal also contain guidance on other complications. For example, individual benefits which from come from breaking the law are usually excluded, and a scheme which prevented people exceeding the speed limit would not be counted as a 'disbenefit' to the offenders).

Although such evaluation procedures are never perfect, they act as a useful framework for identifying the different categories of costs and benefits which one would want to take into account in appraisal, and relate to various categories of behavioural response of interest in the empirical case studies. Where evaluations of individual case studies were carried out, the available results are summarised.

2.5 Inference from the evidence on expanding road capacity

SACTRA (1994) gathered a very substantial body of knowledge and concluded that expanding road capacity can induce additional traffic at a level which, especially in congested conditions, can have a significant effect on appraisal. This conclusion is generally accepted in both policy and practice.

The starting point for the brief of this research project was the observation that - by simple reversal of the SACTRA argument - reduced road capacity could lead to the suppression, degeneration or deduction of some traffic, by individual or system responses that are similar to those producing induced traffic.

This reversal, though treated as axiomatic in the underlying logic of most forecasting and evaluation practice, could not be treated as axiomatic for this project. The first question was whether evidence about the effects of *increasing* capacity was truly relevant to the issue of *reducing* capacity. This depends on whether behavioural responses in the two cases are equal and opposite, *ie.* reversible.

Therefore, the SACTRA evidence (both as published, and in the background papers and subsequent follow-up research) was revisited, and reconsidered to assess what it might imply about the effects of reducing capacity. A report of this reconsideration is given in Appendix A to this report. The conclusions, in summary, were as follows.

(i) Some classes of evidence used by SACTRA were based on comparisons of simultaneously more and less congested conditions. These included observations of differential rates of traffic growth on more and less congested roads, inferences from demand elasticities and values of time estimated in the research literature, and calculations on data from cross-section surveys and models based on them. In these analyses, conclusions may be drawn about the implications for reduced capacity with the same degree of confidence (and the same caveats) as about the implications for increased capacity.

(ii) Other classes of evidence, based on changes over time, nearly all relate to the experience of increasing capacity. These included before-and-after case studies of particular road schemes, and time series analysis of aggregate statistics. The empirical results using such evidence tended to support the idea of time-dependent responses, notably that longer term demand responses were generally larger in size, and more complex in character, than shorter term responses. Such results are not compatible with a simple idea of reversibility, because they imply that responses to reductions in road capacity are unlikely to be *immediately* symmetrical with responses to increasing road capacity. However, this does not prevent a longer term symmetry, allowing the equilibrium effects of capacity reductions to be equivalent to the equilibrium effects of capacity increases.

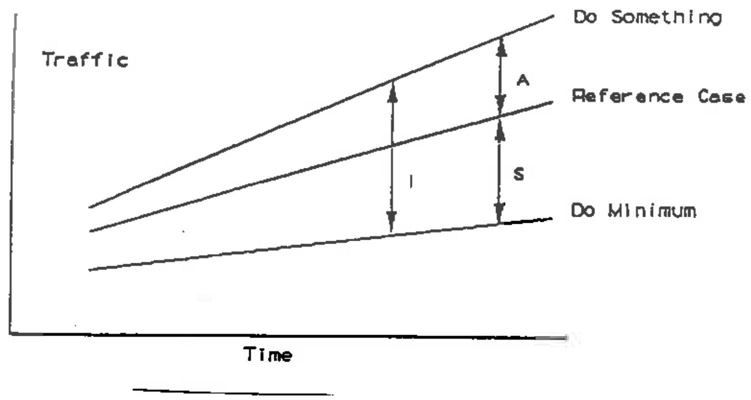
(iii) Thus, all the evidence cited by SACTRA, and related studies, is consistent with, although does not prove, the propositions that (a) the effects of increased and reduced capacity *may* be broadly symmetrical and reversible in the long run, but (b) are unlikely to appear so if comparing, for example, the equilibrium effect of a capacity increase with the short term effect of a capacity reduction.

Current (post-SACTRA) official policy is shown in Figure 2A, which is taken from the latest Design Manual for Highways and Bridges (1997) vol.12a, section 2, appendix A.

The device used in this diagram of relating both induced and suppressed traffic to a notional (but unobservable) norm in the middle has problems, but that issue is not pursued here.

The central conclusion given in the manual is that *"The mechanisms underlying suppression of traffic are the same as, but in the opposite direction to, those resulting in induced traffic...However, since the cause of suppression - increasing congestion as traffic grows - is cumulative and more diffuse than the cause of induction, the relative importance and timing of each response may be different."*

Figure 2A: The (official) relationship between suppressed and induced traffic



I - Overall induced traffic   S - Suppressed traffic
A - Additional traffic induced by scheme

This may be taken as a useful summary of the current 'official' guidelines. It is notable that the possibility of a non-symmetrical response to changes in generalised cost is attributed to the difference between the immediate effects of a new road, compared with the slow effects of mounting congestion. By contrast, in the case of reduced or reallocated capacity, the time scale of effects on the network may be rather similar to those of a new road, and this particular reason for expecting a different response does not apply.

2.6 Conclusion

The theory of traffic flow and assignment reveals circumstances in which the reallocation of capacity to specific users might give overall improvements in mobility and accessibility. Consideration of previous appraisal methodologies, network topology, market distortion, feedback effects, and the non-transport functions of streets also identify conditions where there may be the over-provision of road capacity, even in the presence of congestion. Emerging theory and practice related to travel behaviour suggests that people's responses to capacity reduction may be quite complex. Evaluation criteria for road building schemes also highlight the complex elements which probably need to be considered during capacity reductions. Re-examination of the SACTRA investigation of induced traffic suggests that people's responses to capacity reductions could be similar to their responses to capacity increases in general terms, but may not be exactly symmetrical, especially in the short term.

Hence, theoretical approaches, and their development in wider practice, give no *a priori* reason to rule out the potential usefulness of capacity reduction and reallocation, or to dismiss the possibility that such measures may reduce the volume of traffic

Chapter 3: Case Study Results and Analysis

3.1 Initial results

This chapter gives an overview of the case-study results, and is derived from more detailed summaries of individual places which are given on the coloured pages of this report. These summaries demonstrate that on the roads where capacity has been reduced, there have usually been, as expected, substantial reductions in traffic. The unweighted average traffic reduction on the affected roads is 41%, and extends to a maximum of 100% where roads have been closed completely. Observed increases in traffic on available alternative routes have then been considered, to calculate how much traffic reduction, if any, seems to have occurred overall. These calculations are described below. After presenting the results at face value, the remainder of this chapter discusses their interpretation, robustness, caveats of the data, sources of potential error and bias, and the influences of context and the specific circumstances of the studies.

Figure 3A and Tables 3A and 3B give the data for all those case studies where traffic counts were available for both the roads where capacity was reduced, and a set of other roads judged by the local investigators to be relevant alternative routes. The net change in overall traffic has been calculated as a percentage of the initial traffic on the road where capacity was reduced (column E) and as a percentage of the overall traffic on the 'corridor' of alternative routes (column F). As an indicator of overall traffic reduction, column E has been used to create Figure 3A, since the change in traffic recorded makes most sense in relation to the size of the prior traffic flow on the road where capacity was reduced. Moreover, the value of column F is very dependent on how wide an area has been judged to be the potential area of diversion[1].

As Figure 3A illustrates, the case studies produce a very wide range of results. As stated previously, the sample of case studies for which complete traffic information could be obtained shows an unweighted average reduction in traffic on the treated road or area of 41%. On average, less than half of this traffic then reappears on alternative roads, at the same or different times of the day. Thus, the average *overall* reduction in traffic is approximately 25% of that which originally used the treated road.

These averages are influenced by a few extreme results. In two cases the overall reduction in traffic was greater than all of the traffic originally travelling on the treated roads, and in seven cases there was an overall traffic increase, despite the capacity reduction.

The median traffic reduction (which is less affected by outlying results) indicates that in 50% of the places studied, overall traffic reductions of more than 14% were recorded. If the 9 exceptional cases mentioned are excluded, then in 50% of the remaining locations, there were overall traffic reductions of more than 16%. (For both results, traffic reductions refer to the proportion of the traffic which originally used the affected road).

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[1] ie. If a very broad area has been defined to ensure that all long-distance diversions have been recorded, the overall percentage change in traffic becomes much less, *not* because such diversions are commonplace, but because the base traffic flow becomes so much greater.

Figure 3A: Changes in traffic flows after capacity reductions, as a % of the previous traffic in the affected area

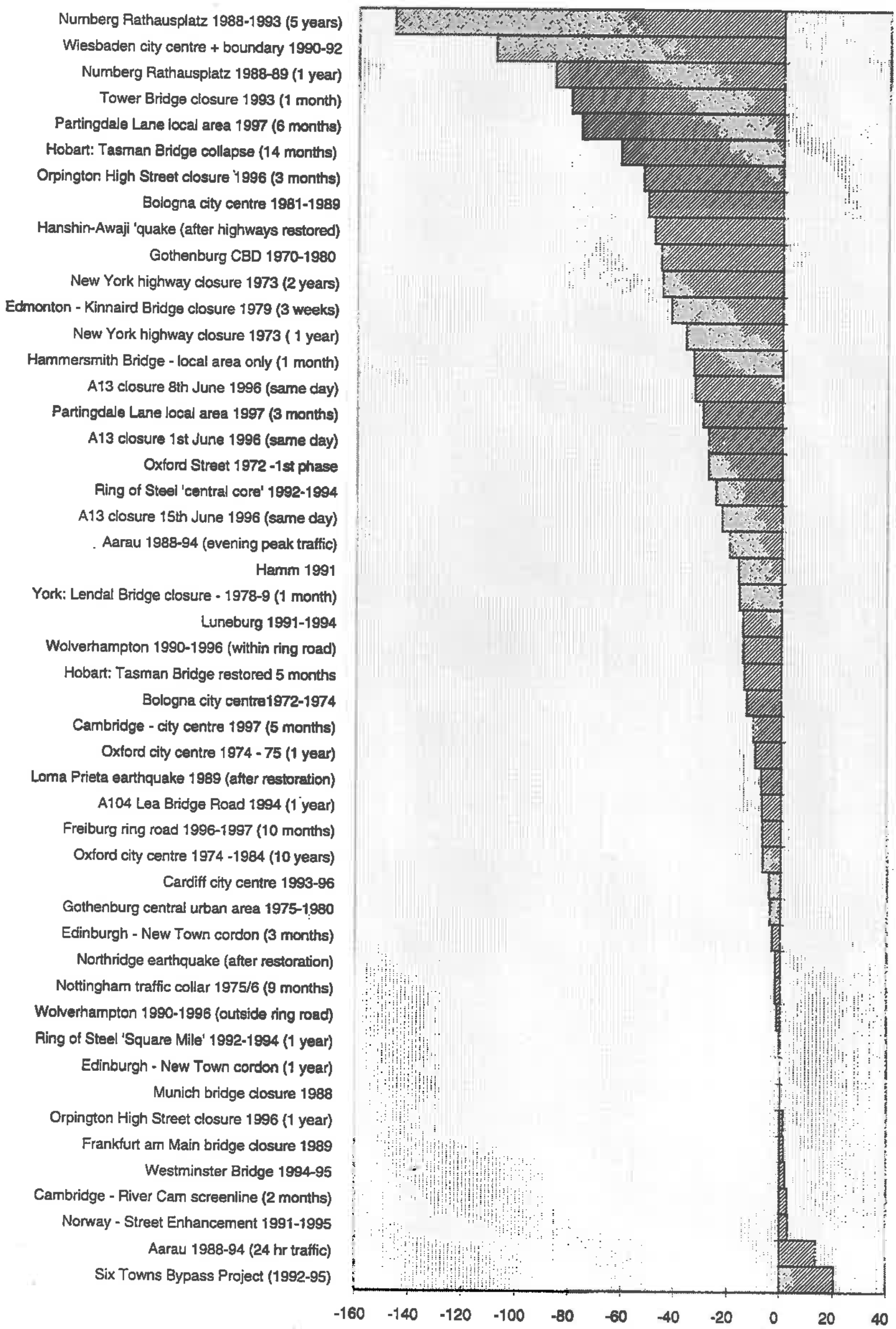

Table 3A: Changes in traffic flows after reductions in road capacity

A	B	C	D	E	F
		Traffic change, affected area (J-I)/I*100 %	Overall change (J+L) -(I+K)	Overall change as % of flows on: Altered location (D/I)*100 %	Entire area D/(I+K)*100 %
##	Nurnberg Rathausplatz 1988-1993 (5 years)	-100	-36,044	-146.6	-39.2
	Wiesbaden city centre + boundary 1990-92	-71.9	-1,414	-108.5	-14.5
##	Nurnberg Rathausplatz 1988-89 (1 year)	-100	-21,176	-86.1	-23.1
##	Tower Bridge closure 1993 (1 month)	-100	-35,505	-80.3	-24.1
##	Partingdale Lane local area 1997 (6 months)	-98.2	-754	-76.3	-21.5
##	Hobart: Tasman Bridge collapse (14 months)	-100	-26,930	-61.3	-61.3
	Orpington High Street closure 1996 (3 months)	-31.2	-582	-52.7	-7.1
##	Bologna city centre 1981-1989	-50.8	-90,000	-50.8	-50.8
	Hanshin-Awaji 'quake (after highways restored)	-59.2	-121,900	-48.2	-26.6
##	Gothenburg CBD 1970-1980	-46.0	-69,000	-46.0	-46.0
	New York highway closure 1973 (2 years)	-54.5	-50,000	-45.5	-7.7
	Edmonton - Kinnaird Bridge closure 1979 (3 weeks)	-100	-545	-41.9	-15.9
	New York highway closure 1973 (1 year)	-54.5	-40,000	-36.4	-6.2
##	Hammersmith Bridge - local area only (1 month)	-90.2	-10,290	-33.5	-7.6
	A13 closure 8th June 1996 (same day)	-59.3	-18,487	-33.0	-17.3
##	Partingdale Lane local area 1997 (3 months)	-97.9	-296	-30.0	-8.4
	A13 closure 1st June 1996 (same day)	-64.8	-15,615	-27.9	-14.6
	Oxford Street 1972 -1st phase	-47.2	-500	-27.8	-8.5
	Ring of Steel 'central core' 1992-1994	-25.0	-40,000	-25.0	-25.0
	A13 closure 15th June 1996 (same day)	-50.5	-12,249	-22.6	-11.5
	Aarau 1988-94 (evening peak traffic)	-21.6	-286	-19.8	-7.7
##	Hamm 1991	-16.3	-3,500	-16.3	-16.3
	York: Lendal Bridge closure - 1978-9 (1 month)	-100	-2,590	-15.9	-4.0
	Luneburg 1991-1994	-14.5	-15,405	-14.5	-14.5
	Wolverhampton 1990-1996 (within ring road)	-14.4	-11,750	-14.4	-14.4
##	Hobart: Tasman Bridge restored 5 months	*	-6150	-14.0	-14.0
##	Bologna city centre1972-1974	-13.0	-27,700	-13.0	-13.0
##	Cambridge - city centre 1997 (5 months)	-10.6	-2,480	-10.6	-10.6
	Oxford city centre 1974 - 75 (1 year)	-9.7	-5,864	-9.7	-9.7
##	Loma Prieta earthquake 1989 (after restoration)	*	-18375	-7.5	-7.5
	A104 Lea Bridge Road 1994 (1 year)	-8.7	-2,456	-7.2	-2.1
##	Freiburg ring road 1996-1997 (10 months)	-33.9	-2,400	-7.0	-2.4
	Oxford city centre 1974 -1984 (10 years)	-6.7	-4,085	-6.7	-6.7
	Cardiff city centre 1993-96	-4.3	-6,703	-4.3	-4.3
##	Gothenburg central urban area 1975-1980	-4.0	-12,800	-4.0	-4.0
	Edinburgh - New Town cordon (3 months)	-3.1	-6,942	-3.1	-3.1
##	Northridge earthquake (after restoration)	-4.0	-12000	-1.7	-1.7
	Nottingham traffic collar 1975/6 (9 months)	-1.7	-230	-1.7	-1.7
	Wolverhampton 1990-1996 (outside ring road)	-1.2	-2,600	-1.2	-1.2
	Ring of Steel 'Square Mile' 1992-1994 (1 year)	-0.2	-579	-0.2	-0.2
	Edinburgh - New Town cordon (1 year)	-0.1	-119	-0.1	-0.1
	Munich bridge closure 1988	-100	0	0.0	0.0
	Orpington High Street closure 1996 (1 year)	-32.7	16	+1.4	+0.2
	Frankfurt am Main bridge closure 1989	-100	500	+1.7	+0.3
	Westminster Bridge 1994-95	-1.1	895	+2.1	+0.7
##	Cambridge - River Cam screenline (2 months)	-9.7	964	+3.0	+1.3
##	Norway - Street Enhancement 1991-1995	3.3	500	+3.3	+3.3
	Aarau 1988-94 (24 hr traffic)	-5.7	2,533	+13.8	+5.7
##	Six Towns Bypass Project (1992-95)	-19.0	7,867	+20.6	+8.7

- please refer to comment or caveat given overleaf

Table 3B: Traffic counts before and after reductions in road capacity

G	H	I	J	K	L
		Vehicle flows on altered route/area:		Vehicle flows on parallel / alternative routes	
		Before	After	Before	After
##	Nurnberg Rathausplatz 1988-1993 (5 years)	24,584	0	67,284	55,824
	Wiesbaden city centre + boundary 1990-92	1,303	366	8,445	7,968
##	Nurnberg Rathausplatz 1988-89 (1 year)	24,584	0	67,284	70,692
##	Tower Bridge closure 1993 (1 month)	44,242	0	103,262	111,999
##	Partingdale Lane local area 1997 (6 months)	988	18	2,519	2,735
##	Hobart: Tasman Bridge collapse (14 months)	43,930	0	*	*
	Orpington High Street closure 1996 (3 months)	1,105	760	7,084	6,847
##	Bologna city centre 1981-1989	177,000	87,000		
	Hanshin-Awaji 'quake (after highways restored)	252,900	103,300	205,900	233,600
##	Gothenburg CBD 1970-1980	150,000	81,000		
	New York highway closure 1973 (2 years)	110,000	50,000	540,000	550,000
	Edmonton - Kinnaird Bridge closure 1979 (3 weeks)	1,300	0	2,130	2,885
	New York highway closure 1973 (1 year)	110,000	50,000	540,000	560,000
##	Hammersmith Bridge - local area only (1 month)	30,698	3,000	104,698	122,106
	A13 closure 8th June 1996 (same day)	56,000	22,800	50,800	65,513
##	Partingdale Lane local area 1997 (3 months)	988	21	2,519	3,190
	A13 closure 1st June 1996 (same day)	56,000	19,722	50,800	71,463
	Oxford Street 1972 -1st phase	1,800	950	4,050	4,400
	Ring of Steel 'central core' 1992-1994	160,000	120,000		
	A13 closure 15th June 1996 (same day)	54,200	26,804	52,200	67,347
	Aarau 1988-94 (evening peak traffic)	1,444	1,132	2,275	2,301
##	Hamm 1991	21,500	18,000	*	*
	York: Lendal Bridge closure - 1978-9 (1 month)	16,290	0	49,100	62,800
	Luneburg 1991-1994	106,002	90,597		
	Wolverhampton 1990-1996 (within ring road)	81,500	69,750		
##	Hobart: Tasman Bridge restored 5 months	43,930	*	*	*
##	Bologna city centre1972-1974	213,200	185,500		
##	Cambridge - city centre 1997 (5 months)	23,411	20,931		
	Oxford city centre 1974 - 75 (1 year)	60,684	54,820		
##	Loma Prieta earthquake 1989 (after restoration)	245,000	*	*	*
	A104 Lea Bridge Road 1994 (1 year)	34,070	31,102	81,609	82,121
##	Freiburg ring road 1996-1997 (10 months)	34,200	22,600	64,500	73,700
	Oxford city centre 1974 -1984 (10 years)	60,684	56,599		
	Cardiff city centre 1993-96	156,299	149,596		
##	Gothenburg central urban area 1975-1980	320,000	307,200		
	Edinburgh - New Town cordon (3 months)	221,953	215,011		
##	Northridge earthquake (after restoration)	698,000	670,000	*	*
	Nottingham traffic collar 1975/6 (9 months)	13,380	13,150		
	Wolverhampton 1990-1996 (outside ring road)	222,900	220,300		
	Ring of Steel 'Square Mile' 1992-1994 (1 year)	254,192	253,613		
	Edinburgh - New Town cordon (1 year)	221,953	221,834		
	Munich bridge closure 1988	32,000	0	71,000	103,000
	Orpington High Street closure 1996 (1 year)	1,105	744	7,084	7,461
	Frankfurt am Main bridge closure 1989	29,500	0	162,500	192,500
	Westminster Bridge 1994-95	41,739	41,284	90,276	91,626
##	Cambridge - River Cam screenline (2 months)	31,869	28,781	44,286	48,338
##	Norway - Street Enhancement 1991-1995	15,300	15,800		
	Aarau 1988-94 (24 hr traffic)	18,292	17,244	26,512	30,093
##	Six Towns Bypass Project (1992-95)	38,212	30,968	51,697	66,808

Where "*" are given in columns K and L, sources did not provide counts on alternative routes, but did quote the overall traffic changes.

Where columns K and L are shaded, traffic has usually been counted crossing a cordon around an area-wide scheme, (typically a town centre) so that there are no 'alternative routes' into the affected area.

ADDITIONAL INFORMATION FOR TABLES 3A & 3B

- **Understanding the table**

For many case studies, a wide range of traffic counts were quoted, relating to different streets, areas or time periods. To avoid overloading the table, only the most representative one or two results are shown here. Where possible, those highlighted by the original authors were selected, and relate to full day counts, include all motor traffic, and help to distinguish between short and long term effects. Where a time-period is shown (eg 3 months), this refers to the time after the capacity reduction occurred, not the intervals between before and after studies, which also vary.

- **Additional relevant case studies**

Other examples reported in the case study pages could not be inserted in the summary table, due to incomplete information. These include **Portsmouth 1995**, where a potential traffic reduction of 14% was implied, **Lucerne 1993-94**, where a traffic reduction of 10.5% took place on the treated road but none overall, and **Bern 1980**, where no overall traffic reductions were observed. In **Toronto 1990 (Bay Street)** , **Belfast 1994 (Ormeau Road)** and **Zurich 1991-92 (Europa Bridge)**, measurements were only made on the treated routes, and showed reductions of approximately 21%, 18% and 5% respectively. In **Bristol 1991-95**, traffic levels on particular corridors were reported as "static", or "increasing by only 2.4%, which is less than overall traffic growth". Other relevant evidence is also reported from **Coventry, Dutch railway strikes, London: Grove Lane/Champion Park, Lowestoft, Manchester, Oslo** and **Sheffield.**

- **Caveats and comments**

When considering the summary data given here, the reader is referred to the case study pages, and section 3.2, for a more detailed discussion of potential caveats and sources of bias that may have affected the results. Specific caveats or comments for the data in the table are as follows:

Bologna 1972-89 - over the 17-year period between 1972 to 1989, traffic reductions were becoming greater. From 1989 to 1992 this seemed to reverse, possibly due to weak enforcement of the traffic restrictions and a large number of exemption orders.

Cambridge 1997- In general, all counts support a city centre traffic reduction of about 10%. The traffic changes across Cambridge as a whole are less clear.

Freiburg 1996-97 - Data given relate to traffic flows on the ring-road, resulting from narrowing one section from four lanes to two as part of a longer term series of changes in which the ring road capacity first provided for traffic diverted by pedestrianisation of the town centre, and subsequently was itself partly reallocated from car traffic to buses and cycles. (Further reduction of capacity of the ring road is planned for the future). There have been traffic reductions of much greater magnitude in the centre of Freiburg, as the city has undertaken one of the most ambitious programmes of pedestrianisation in Europe.

Gothenburg 1970-84 - although the two statistics chosen are representative about changes in traffic flows entering the areas specified, it is notable that a survey of through traffic in Gothenburg showed an increase of 6% over a ten year period.

Hamm 1991 - traffic levels on different sections of the affected road have been added together and averaged. Local changes are of the same proportion as overall changes.

Hobart: Tasman Bridge collapse 1975 - the vehicle flows 14 months after the bridge collapse are quoted in the original source. Longer term change is inferred from the reduction in the number of person trips made. It is notable that five months after the bridge restoration constitutes 39 months after the bridge originally collapsed.

London: Hammersmith Bridge 1997 - At the time of writing, the data consistently suggest traffic reductions in the local area, as evident from the three bridges screenline data given here. Traffic increases have been reported on more distant streets and bridges. However, these increases add up to much more traffic than ever used Hammersmith, so they must be due, at least in part, to other factors. Some evidence suggesting longer-term reductions in traffic over a wider area is still being analysed. Both London Transport Buses and a monitoring group set up by the Traffic Director for London are looking more deeply into the survey results, to enable more robust, overall conclusions to be drawn.

London: Partingdale Lane 1997 - Data from three one-hour time periods have been added together to give a crude measure of the overall average traffic reduction in the local area. It was not possible to analyse changes in traffic over a wider area.

London: Tower Bridge closure 1993 - the traffic reduction quoted refers to traffic flows over the four Thames bridges leading to the City of London. Data for a broader area were unavailable.

London: Westminster Bridge 1994-1995 - data refer to a 3 bridges screenline. A 10 bridges screenline showed an increase of 8,170 vehicles, or 2% of the total screenline.

Los Angeles: Northridge earthquake 1994 - data from the four corridors have been summed together, to produce an 'average' value (weighted by the flows). For individual corridors, traffic reductions ranged from -4% to <-1% after the damaged highways were reopened.

Norway: Street Enhancement Programme 1991-5 - traffic counts given are the totals for the 4 towns - Rakkestad, Os, Stryn and Batnfjordsora, so that percentages quoted are equivalent to an average weighted by the flows. Hokkesund has been excluded, because of the complexity of its road structure. For the individual towns, changes in counted traffic ranged from -12% to +17%.

Nurnberg 1988-93 - data quoted here refer to the impacts of the closure of the last major traffic route through Nurnberg central area, following a phased implementation of very large scale pedestrianisation (one of the largest in Germany) over 20 years. They are based on a town centre cordon. Counts on a screenline of 12 bridges across the city region showed a decline in traffic of 4.8 % in the first year, and 6.2% over the first five years. At an outer cordon round the city, traffic fluctuated from year to year, with an average increase of about 4% per year from 1984 to 1988, whilst pedestrianisation was still being implemented. This growth reduced to an average of less than 2% per year from 1988 to 1993, when pedestrianisation was nearly complete. Car ownership continued to increase over the period. The figures quoted here are more narrowly defined than the very much larger reductions in town centre traffic that resulted from pedestrianisation as a whole, but are undoubtedly influenced by it.

San Francisco: Loma Prieta earthquake 1989 - the change in traffic flows has been inferred from a 'before' bridge count, and information about the number of BART passengers retained when full road capacity was restored. Actual 'after' traffic counts were not available.

Six Towns Bypass Project 1992-5 - traffic counts given are the combined totals for Whitchurch, Wadebridge, Berkhamstead and Dalton, making the quoted percentage changes equivalent to an average change weighted by the size of the flows. For the individual towns, changes in traffic ranged from -5% to +25%. The 'before' and 'after' surveys related to a period of capacity reductions on the old trunk roads through the town centres, which occurred after new bypasses had been constructed to relieve them. These bypasses had already resulted in induced traffic, and it seems that continuing induced traffic outweighed any traffic reduction in most cases.

York: Lendal Bridge closure 1978/9 - data on 'before' traffic flows has been combined with the reported percentage changes. 'After' traffic counts are not quoted in the original source.

3.2 Assessing the robustness of these results

The figures given in the table have usually been taken from reports written by local experts, who used their expertise to define the most appropriate routes and measurement techniques required to assess the impacts of each specific capacity reduction. They are therefore based on the general standard of professional practice on these matters. Careful consideration has been made as to which of the many statistics available for each case may be treated as the most representative at the level of an overview. Where possible, all of the case study summaries have been checked with those originally providing the information.

Nonetheless, as explained in Chapter One, there are caveats and problems in obtaining absolutely definitive results for practically every example. Problems arise because monitoring is usually done for a different purpose. Screenlines for traffic counts are rarely completely reliable, sometime cover a rather small area and often exclude minor rat-runs. Moreover, however large the area, there is always the possibility that some changes to even more distant routes are missed. Some counting methods are proportional to the number of trips, and others proportional to the mileage travelled, and these are not always reconciled. Surveys of behaviour often do not cover a long enough period of time, are not always carried out at the most appropriate intervals, and rarely use techniques which can identify the underlying changes in individual behaviour behind the net changes in aggregate quantities. Available reports, written for specific local purposes, often omit some pieces of information which would be relevant to this study, and require a certain amount of interpretation. In addition, in many cases, other transport changes have also been implemented in the same period as the capacity reduction, such as opening a new bypass, or improving public transport services. There is also a certain amount of 'natural' change in travel behaviour anyway.

In examination of the case studies, and discussion of their interpretation with collaborators and sponsors, four main relevant potential sources of error or systematic bias were identified, which are associated with particular methodologies. These are described below.

1. *'Natural' variability in traffic is not allowed for in one-day traffic counts.*

As discussed in more detail in Chapter Four, traffic flows can vary significantly from day-to-day in their aggregate magnitude, and even more in their components. Where traffic counts have been used which were not the average of numerous daily readings, both before and after counts are subject to random variation, and the changes recorded could be unrepresentatively high or low. Hence, studies which have relied on one day traffic counts are likely to produce a range of results which is wider than if many days' records had been available for the same locations. However, over-estimates and under-estimates of changes in traffic flows are equally likely, and so this source of bias does not, in itself, alter expected mean values of traffic changes. Therefore, the highest and lowest case study results reported in this study, based on one-day traffic counts, are statistically likely to be less reliable than those in the central range. (This is not a criticism of the competence of these studies. It arises inevitably from statistical variation that there will be such cases, and underlines the importance of reporting all results, not just the 'believed' ones).

2. *Longer distance detours may not always be sufficiently considered.*

Detours taken by some drivers may be of such long distance that they occur outside the area studied. Any omission of these detours would result in an overestimate of traffic reduction, and since any boundary, however large, always leaves open the logical possibility of even longer detours, it is never possible, using traffic counts, to take account of this effect completely. The important issue then becomes to assess whether the size of this effect is likely to be significant, and to gauge the propensity for effects to 'ripple outwards'. This will be influenced by the availability of alternative routes outside the studied area, the advantage to be gained from using them, and the proportion of trips whose origin or destination is sufficiently far away from the affected roads that longer-distance detours are realistically more attractive than any other behavioural response.

There does not appear to be a general literature on the prevalence of long-distance diversion.

Intuitively, the longest detours from the study area are likely to be those journeys whose origins and/or destinations are a long way outside the study area, such that the diversion is likely to be a 'wobble', which may not significantly add to the mileage of the overall trip, and indeed in some cases (eg where a rat-run was being used in preference to a main road for reasons of speed) the distance travelled might actually reduce

Some of the case studies, as reported below, did use survey methods in which people were asked how they changed their behaviour following capacity reductions. In these surveys, long-distance detours were reported, but were few in number.

In general, selection of counting locations in most studies was decided by local professionals, who considered that they had caught the routes and roads where the traffic impacts were likely to be significant.

Therefore, there has been no evidence to suggest that non-counted long distance detours are likely to account for a very substantial proportion of apparently 'disappeared' trips or mileage. However, to the extent that they do exist, there will be some tendency to overestimate the reduction in traffic.

A related question of journey distance applies to studies which rely solely on screen-line data. Screen-lines will count the number of vehicles passing, hence capturing, for example, changes in the number of trips or mode choice. But this does not necessarily equate to the mileage travelled, which could be increased by short distance detours within the neighbourhood of the change (or, as above, reduced in the case of fast but circuitous rat runs). Again, there does not appear to be any direct evidence on the size of this effect, but it is notable that the range and magnitude of traffic reductions found does not seem to be systematically greater for those studies using screen lines than those using traffic counts taken at points spread across a network (which produce results proportional to vehicle mileage travelled), which might be the case if this effect was large and one-directional. Also, some cases have used a number of different methodologies to provide different insights into the traffic impacts, with no obvious pattern of results relating to this issue.

In summary, there is a logical possibility that some longer-distance and shorter distance diversions have not been recorded appropriately in the traffic data given for many case studies. However, there is no evidence that omitting such diversions has had a large effect on the majority of the results or the median average, and there is some tentative evidence suggesting that the impact may have been small. Where such error exists, it seems, on balance, more likely to cause an overestimate of traffic reduction, though in some cases it might cause an underestimate.

3. *Traffic growth occurs due to other factors like increased income and car ownership.*

Most studies do not make any allowance for the 'natural' change in traffic that would usually be occurring over the period of the study, due to factors such as income, car ownership, changes in land use, demographic effects and so on. In current conditions, it is usually assumed that these factors almost invariably lead to traffic growth, rather than decline. Consequently, studies of capacity reductions should observe an increase due to these factors, offset by a decline, perhaps, due to the road capacity reduction. If the overall effect recorded is solely attributed to the capacity change, the figure recorded is an underestimate of the impact of the road reduction, since any recorded change in traffic should be compared to the traffic level that would have occurred if no change had been made to the network. The degree of underestimation increases as the period of the study lengthens.

In broad terms, it is possible to say more about the size of this effect than the effect of longer-distance detours discussed above, since the extent to which traffic reduction is underestimated depends on the magnitude of the traffic growth that would be expected without the network change. This is a very well-researched area. In many circumstances, traffic growth due to factors other than network changes is likely to be in the range of 1%-4% per year[2].

An adjustment could, if desired, be made to the 'after' figures to take account of this effect, reducing them by say 2% per year. This has not been done. However, it is notable that for changes over a five to ten year period this would double the estimated traffic reduction for some studies.

4. *Partial sampling via repeated panel surveys.*

A few studies are based on repeated panel surveys, where the sample has been selected from people who were using the road before the capacity reduction and those same individuals were then surveyed at a later date. Such surveys are particularly useful for discovering the real changes that people make in their own behaviour, as distinct from average changes in the population as a whole. However, there is a problem if *only* people who were users of the road before the change are interviewed, since the survey will identify people who reduce their use of the car, but will not observe offsetting changes by former non-users who may increase their car use. The problem here does not arise from the changes actually due to the capacity reduction (since changes to road conditions that deter existing drivers are unlikely to attract a substantial number of new ones). Rather there is a problem because some people will be changing their amount of car use in both directions due to other factors entirely, and these changes should not be attributed to the network change alone. Hence, relying solely on such information is likely to result in an overestimate of the reduction in travel, although this is complicated by the interaction between changes in behaviour whose timing is triggered by (for example) life-cycle effects, but whose content is then influenced by travelling conditions.

In general, such interactions are an important feature of the interpretation of the evidence, and are discussed further in Chapter Four.

Conclusions about the robustness of the results

The sources of bias described above need to be considered in conjunction with the summary results given in the table. Adjustments could have been made to compensate for some of their potential

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[2] If road capacity has also been increased elsewhere on the network, this will similarly tend to result in some induced traffic, masking the effects of the capacity reduction. SACTRA (1994) found that inclusion of income and other effects made a very substantial difference to calculation of the size of induced traffic (where, in that case, omission leads to an overestimate rather than an underestimate).

effects. However, this was considered undesirable as new sources of error would be introduced, particularly as not all adjustments could be made with the same degree of confidence. Instead, an overall judgement is suggested on the role of each source of bias separately, and together.

As explained above, source 1 ('natural' variability of traffic counts) will not have affected the likely mean values recorded, although it may be responsible for an exaggeration of the range of results. Source 4 (partial sampling via repeated panel surveys) is also likely to have relatively little effect on results, because it has been used as a measurement technique in very few of the cases, and in those cases, it has invariably been backed up with other data, which prevent any error dominating the overall results.

The second and third effects mentioned (long distance diversions and traffic growth) are those cited most frequently in discussions on interpretation, and can apply to many of the case studies. They pull in opposite directions, and the crucial question is the net balance between them. For any given relative magnitude of the two effects, the net effect will be progressively more influenced by general traffic growth as the time period of a study gets longer. There is therefore more potential danger of *over*estimating the traffic reduction effect in the short term studies, and *under*estimating it in the longer term studies. This interpretation is reinforced by substantial empirical evidence on aggregate demand elasticities, and is consistent with pervasive evidence on the importance of other behavioural responses in addition to route change. Moreover, it is judged that both effects are likely to be relatively small, by comparison with the size of 'disappearing traffic' that has been recorded in the central range of the case studies.

In conclusion, these caveats need to be taken seriously, but reinforce rather than overturn the initial important observation: the results of the studies, taken as a whole, do not simply show random variation and uncertainty, and central values are certainly not clustered randomly around zero, as might be expected given so many potential, and conflicting sources of bias. Instead, the majority show a reduction in counted traffic. Whilst each individual example falls short of being a 'perfect' case study, (and will inevitably always do so, given the complexity of other things that will be going on at the same time as any transport change), to find so many cases of reductions in traffic, at a time when increasing car ownership and general traffic growth create prevailing expectations of increases, shows a balance of evidence that a proportion of traffic can indeed 'disappear' when capacity is reduced.

The other key observation is that the calculated reductions in traffic vary over a remarkably wide range, even if the extreme values are discounted. Hence it would clearly be difficult to justify using a standard rule-of-thumb, for example, that 16%, or 25%, of traffic will disappear as a matter of course whenever road capacity is reallocated. It would be even more difficult to justify the assumption that *no* traffic will disappear, particularly in situations where this would imply significant changes to traffic speeds.

Given the range of results, it becomes important to try to assess what specific reasons underlie and explain them. The rest of this Chapter therefore considers the size of the change in capacity, the context in which the capacity reductions were implemented, and the prevailing conditions in the study area.

3.3 Relationships between the extent of capacity reduction and the effect on traffic

The most obvious first question to ask, when seeking to explain the variations found, is whether the capacity reduction was large or small. This can only be done in broad terms, since few of the case studies produced measurements of the amount by which capacity was reduced, in terms of pcu/hr or 'percentage reduction in road capacity', from which it would be possible to calculate elasticities. Provision of such quantities has not been a major part of the analytical tradition of network management.

A set of three hypotheses[3] was developed during the early stages of the project to address the issue. They appear robust following subsequent examination of the evidence.

Hypothesis 1: *No real reduction in effective capacity:*
No reduction in traffic.

In many cases, close examination shows that a reported 'reduction' in road capacity is an illusion, since it has been offset by an increase in available capacity elsewhere. Sometimes this is a deliberate part of the implementation strategy, notably with ring roads or improved network management, and sometimes it happens spontaneously as people adapt their driving styles in a way that increases the effective capacity of the network. A related case is the situation where there is a reduction in capacity, but traffic flows are not actually very close to the capacity level. In these cases, little or no reductions in overall traffic levels occur, or would be expected.

Hypothesis 2: *A reduction in capacity, but alternative capacity exists:*
Traffic re-routes or re-times.

There are also many cases where road space is reduced in a way which does bear on, say, peak period trips on major roads, but alternative routes are not so congested, and even if they are, reasonably acceptable alternative times of day are not. In this case, reductions in traffic are expected at those times and places where congestion is worst, but there is not an overall reduction in the 24-hour traffic levels.

Hypothesis 3: *A reduction in capacity, and no suitable alternative capacity available:*
Traffic 'disappears'.

There comes a point where traffic diverted from its initial choice of route and time of day cannot find an acceptable alternative route or time - either because of the general traffic levels, or because of the design and coverage of the measures. This is the major case where real reductions in overall traffic levels might be expected, although what people choose to do instead will depend on other factors, like the availability of public transport. These are the circumstances thought to be most relevant to future policy development in London, and to other congested urban areas, especially as there is interest in the effects of extensive programmes of road space reallocation.

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[3] The authors thought these hypotheses original. However, it emerged that the approach was very similar to that suggested by WS Atkins (1996) for a study in Cambridge, and by Berg & Bartsch (1995), following a study of capacity reductions in Switzerland. Berg & Bartsch argued that *'If there is a reduction of capacity the local efficiency of junctions is put to the test first. After that, when congestion frequently occurs then other routes are chosen until the capacity reserves of the network is exhausted. Only then, other types of behaviour are considered, such as different mode, time of day, other destination or another job'*. Their results are discussed further later, and in some of the case studies.

The case study evidence is now examined in the light of the above hypotheses.

- **Hypothesis 1:** ***No real reduction in effective capacity: No reduction in traffic.***

In a number of cases which have been publicly discussed as examples of highway capacity reduction, in reality, overall capacity has been maintained. Indeed, in many of these cases, sophisticated traffic management procedures have been specifically used to cushion or offset road closures.

In such cases, space may well have been reallocated to buses, or bikes, or pedestrians. Traffic may have been entirely excluded from some parts of the network, bringing numerous improvements in environmental and social conditions to those areas, and enhancing the 'people access' to a place. However, this can happen without any real effects on either traffic flows or speeds.

Examples of cases where road capacity has been reduced or reallocated without much effect on overall traffic flows include the Street Enhancement Programme in Norway, the Nottingham Zones-and-Collar experiment, the City of London's 'Ring of Steel', and Bern in Switzerland. These studies suggest that if there is still enough spare capacity left, there is no need for behavioural change.

More detailed consideration of the case studies enabled the identification of three general mechanisms by which reallocation has taken place in various locations with little loss of effective capacity for cars.

a) Driving behaviour may change and increase effective capacity

First, driving behaviour may alter, releasing some hidden 'reserve' capacity, since road capacity is not a strictly determined engineering characteristic, but arises from the interaction between drivers and roads. This was particularly apparent in the Nottingham Zones-and-Collar experiment, where Vincent and Layfield (1977) noted that "driver behaviour changed when faced with the imposed delays to the extent that, despite shorter green times, the traffic discharged over the stop line at a higher rate". A recent study by Machuca, Jeffrey, Avaria & Ingenieria (1996) on the interaction of buses and cars also found that car drivers can adopt more efficient driving styles to 'preserve' capacity. They studied the time gaps between vehicles on 34 roads in Santiago. Their results demonstrated that, whilst the expectation is that gaps between buses and other vehicles should be larger than the gaps between two cars, in reality, when buses form less than 15% of the vehicle flow, people adjusted their driving so that there was no statistically significant difference in the gaps between vehicles compared with the gaps in vehicle flows where there were no buses.

More negative changes in driving behaviour may also occur if road space is taken away from cars, especially in short term emergency situations, with cars driving closer together, straying onto hard shoulders and restricted lanes, and displaying standards of courtesy that would usually be unacceptable. Correspondence received from Newman (1997) describes a proposed road closure near Tunbridge Wells, where currently restricted space for cars is causing "speed, aggression, reckless driving and a total disregard for others". She also notes that the recent introduction of traffic calming "has, in fact, achieved the opposite effect of that desired, with traffic speeds increasing where drivers try to 'beat' the oncoming traffic across the restricted section".

b) Network efficiency can be improved by closing minor roads or separating vehicle flows

The closure of minor roads, particularly where they feed onto a bigger road, may actually improve the efficiency and capacity of a network, since the number of turning movements and delays at junctions are reduced. Perhaps this is best illustrated by some results from the London's Red Route network, where journey times fell by up to 36%, according to a study by TecnEcon in 1995 (TEC, 1997). (This result becomes more complex for later developments, as the Red Route strategy has placed less emphasis on speed than its original formulation).

The 'Ring of Steel' in London also demonstrates this, as the Embankment route through the Ring of Steel is now carrying 20% greater flows with shorter overall journey times, following the closure of 17 minor roads and 23 junctions, (Weiss, 1996). A similar principle has been used in Gothenburg, whose traffic calming policy used restrictions to reduce traffic in certain residential zones, and transfer it onto more efficient main routes.

In addition, when network capacity for cars is reduced by transferring the space to other modes like buses or bikes, it may sometimes be more efficient for all categories of vehicle. Cairns (1996) notes that for bus lanes in Bristol "the travel times of all vehicles, not just buses, can decrease", and the recorded changes in peak journey times for non-priority vehicles included reductions of 16%, 17% and 50%, on three stretches of road.

c) Associated policies may compensate for capacity reductions

In several cases, highway capacity reductions are associated with, or preceded by, opening a new ring road, expanding alternative routes, or more efficient traffic management procedures, like the removal of parked cars. Reports of such changes to offset specific capacity reductions are frequently referred to as commonplace, as mentioned for example, in the case of Manchester. Similarly, in Erlangen, the local highway authority stated (3.6.1997), *"Erlangen has reduced road capacity on several roads by introducing bus lanes but also by pedestrianising. Whenever this was planned, both the police and the ADAC [similar to RAC in Britain] forecast that there would be a traffic chaos. This has never been the case because we - [the Office of Traffic Engineering] - carry out an analysis of the traffic situation and provide extra road capacity if necessary".*

Specifically, building a ring road was often thought to be justified by, and a necessary condition for, taking traffic out of the town centre. However, building a new road may then induce extra traffic, as well as taking diverted traffic. The most obvious example of this situation is the Six Towns Bypass Project, where reductions in traffic resulting from capacity reductions of the old trunk routes through the town have been masked, and in several cases overwhelmed, by traffic generated by the bypasses[4].

Adjustments to signals are also common, and can increase traffic flows substantially. For example, in Coventry, Hunt and Holland (1985) describe how the use of SCOOT to reallocate green traffic light times between junctions was estimated to reduce queues from 200 to 25 vehicles in the off-peak, and 500 to 150 vehicles in the peak, during the temporary closure of the A4114 in 1983.

It should also be remembered that whilst measures to restrict speed may result in (usually rather

[4] The evolution of plans in Freiburg is a very instructive counter-example to the common assumption that expanded traffic capacity on ring roads is a necessary condition for traffic restrictions in town centres. The ring road there first provided capacity for traffic diverted by pedestrianisation of the town centre, but subsequently was itself partly reallocated from car traffic to buses and cycles, and further reduction of capacity of the ring road is planned for the future. Luneburg was also advised that expansion of ring road capacity was necessary in order to allow their planned pedestrianisation to go ahead: they declined to do so, and successfully proceeded without.

small) increases in journey time, they do not necessarily reduce capacity and may actually increase it, in effect because the space needed between vehicles is less. For example, in the Nottingham Zones-and-Collar experiment, Vincent and Layfield (1977) report that delays were not as great as expected because "a vehicle in a stationary queue normally takes up an average of 6m along the lane, but vehicles moving up in the queue will require about twice this space".

Conclusion

Although road space for cars may be reduced, highway *capacity* may not, as there are various mechanisms by which such reductions are counteracted, and the true maximum capacity of a network may often be underestimated. In these cases, predicted 'traffic chaos' from reallocations of highway capacity may not materialise, but the reason is nothing to do with disappearing traffic. The same amount of traffic can still flow through the system, at reasonably close to the same speeds, with little incentive for people to adapt their behaviour.

It is received wisdom that there is now little remaining opportunity for making significant capacity allocations to buses or pedestrians without reducing capacity for other traffic, but the results hint that such opportunities may still exist, even in such intensively used networks as the City of London.

- **Hypothesis 2: A reduction in capacity, but alternative capacity exists: Traffic re-routes or re-times.**

There is much evidence in the case studies that trip re-routing and re-timing occur substantially, so that congestion spreads out over time and space, rather than becoming significantly worse on the treated road itself. This can happen in a range of contexts. At one extreme, relatively minor adjustments in route and time may occur even in the 'Hypothesis 1' situation, and at the other extreme, route and time changes are invariably included in the responses discussed in Hypothesis 3.

Changes in routes are discussed in most of the case studies, and are evident, for example, in Edinburgh, Sheffield, Edmonton, Lucerne, Zurich and the Nottingham Zones-and-Collar experiment, where Vincent & Layfield report on "a redistribution of traffic between the main radial roads leading into the City" as drivers attempted to counteract any delays imposed by the system. Similarly, Berg and Bartsch (1995) studied eight Swiss examples of capacity reduction, and concluded that if there is a temporary capacity reduction, then *"the majority of car drivers accept the additional time delay and do not change their behaviour. A minority change the route and thereby reduce the capacity problem and also the time delays for others on the original route" (Berg, W. & Bärtsch, D. 1995, p. 28).* They report that more severe time delays are accepted for leisure and long distance driving, especially during holidays. (With the latter group of travellers it is difficult to establish their reaction and route choice mainly because their change of plan may have occurred a long distance away).

Changes in travel time are also commonly reported. Specifically measured changes in the time at which people make journeys are available for Edmonton, York and A104 Lea Bridge Road, whilst "changing journey time" was mentioned as part of a list of responses people had made to capacity reductions in cases like Hammersmith Bridge, Portsmouth and Frankfurt. In the studies of Edinburgh and Hobart, the time period during which 'peak' traffic flows were measured was extended, with the

AM peak recorded from an earlier start time[5].

Hence, overall, the two responses - changing route and changing journey time - seem to be the most universal, often accounting for the majority of changes people report. For example, Kuhn (1991) studied temporary road capacity reductions in Vienna, such as bottlenecks due to building works, and reported that 44% of drivers did not change their behaviour, 35% used a different route, 17% changed the time of day of their journey and 4% used public transport.

However, although it is clear that both changing route and changing time of journeys may occur substantially, it does not seem to be the case that one is always preferred to the other. Somebody making a local journey on a well-known network may prefer to change route rather than time, particularly if their trip has specific time constraints. Many also highlight the desire to 'keep moving'. This emerges in the case of Portsmouth, and in Sheffield, where a typical comment was *"rather than actually sit in the car and crawl, if we had to go in at peak periods then I would choose another route...It might take a bit longer...but at least I would be travelling"*. Some drivers are also reported as deriving a certain amount of satisfaction from being able to 'beat' the congestion by finding complex back routes. Moreover, discussions with a traffic engineer in Innsbruck revealed that, where journeys are very long distance, even minor 'wobbles' in route may take a driver completely outside the local traffic system studied. (He suggested that this may have occurred during the closure of the A12 Inntal motorway in Austria in 1990).

However, in other cases, changing the *time* of journey may be more popular than confronting a more complex, and less well known, set of alternative routes. During the closure of the Lendal Bridge in York, trip retiming emerged as an important alternative response to route changing. Moreover, survey work into the flexibility of journey times, which was carried out during the Lendal Bridge closure, showed that most *are* very flexible, except for school trips. Many studies of how drivers respond to motorway congestion also confirm that leaving at a different time (usually earlier) is a common solution. Black, Hyde & Towriss report that from a survey of approximately 300 motorway users, 44% make an early start to allow for traffic, and allocate 24% of their anticipated journey time as a cushion against uncertainty. In other circumstances, changing journey time may be the only option. Ramsey & Hayden (1995) investigated the impacts of congestion on travel behaviour over the River Tyne, where all alternative crossings are busy, and found "clear evidence" of peak spreading, with a significant increase in the proportion of traffic using the river crossings before 7am.

Conclusion

There is evidence supporting the hypothesis that in circumstances where capacity is reduced on one road, but there is still available capacity on other routes or at other times of the day, there are two major reactions to highway capacity reductions for cars. These are:

- diversion onto a close parallel route which still has available capacity
- a marginal change in the time of day at which the journey is made, to a time at which sufficient capacity is still available.

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[5] People altering the time period when they make journeys partly explains the differences in changes to traffic flows in different time periods. For example, about 3 months after the closure of Princes St in Edinburgh, overall traffic levels had reduced by about 3%, whilst traffic in the PM peak had declined by 22%.

As described here, neither response is likely to require major re-planning or drastic alteration to any chosen pattern of activity or travel. Both mean that total traffic patterns will be broadly preserved, despite capacity reduction on particular roads, since such adaptive changes in driver behaviour ensure that little or no change is noticed in the overall traffic flows over a larger area or longer time period.

Since reductions or reallocations of capacity are mainly controversial when it is thought that they are likely to significantly worsen congestion, it is relevant that these ways exist in which drivers can, by avoiding congestion, also avoid (to some extent) causing it. It is notable that so many opportunities still seem to exist for drivers to avoid the effects of capacity reduction by changing the route or time of their journey, and this highlights that congestion, even when very severe, is often quite localised in time and space.

However, making such adjustments becomes problematic as the alternative available route becomes less 'close', or the required time change less 'marginal'. There may then be more substantial implications for other activities and associated costs. At this point, other responses will come into play as discussed below. It is notable that there has been no evidence of a sharply defined threshold between acceptable and unacceptable degrees of change in route and journey time.

- **Hypothesis 3: A reduction in capacity& no suitable alternative capacity available: Traffic 'disappears'.**

It is evident that, in some cases, modest trip retiming or choice of obvious alternative routes may be unattractive because conditions are already congested there as well, or quickly become so if all of the traffic using the original route diverts. Yet in every case studied, even quite drastic reductions in road capacity have not been followed by prolonged gridlock, and major increases in existing levels of congestion are typically only temporary.

Instead, there is a fairly substantial body of evidence to suggest that some proportion of traffic effectively 'disappears' as a planning consideration for a particular route or a particular place. This conclusion is borne out in a number of studies for which reasonably comprehensive traffic counts were received, including examples like Cambridge, Cardiff, Hamm, Nurnberg and Wiesbaden. In addition, there were some studies which also collected other survey information that helped to explain what had caused that reduction. These studies included those for Hammersmith Bridge, the Hanshin Awaji earthquake, Hobart (Tasman Bridge collapse), Portsmouth and San Francisco (Loma Prieta earthquake).

'Disappearing traffic' clearly requires more explanation in behavioural terms. Available evidence suggests that:

- traffic seems to'disappear' because of a wide variety of travel adaptions that people make, going far beyond the three already cited (changes in driving style, change of route, change of time of journey)

- within this longer list of responses, the evidence does not show any clear or obvious hierarchy, such that, for example, changing destination choice or mode choice always dominates. Rather, the relative importance of the different responses seems to be influenced by specific personal or contextual factors.

Not all of the same responses are mentioned in each study. In some instances, this may be because such adaptations were not made. In others, it may be because the survey was simply not designed to record certain types of adjustment, and was only carried out over a certain time period. However, taken together, each of the following responses were identified in at least one study.

- more drastic changes of the time of the journey
- much longer diversions
- making a journey to a different destination,
- changing frequency of journeys
- changing mode of journey
- car sharing[6]
- consolidating trips so that several different purposes are fulfilled in the same round trip
- changing the allocation of different tasks within a household (errand-swopping)
- actual elimination / suppression of trips
- changes in job location
- changes in housing location
- changes in developer choices for locating new developments
- many combinations of these.

The diversity of these responses requires further consideration, as discussed in Chapter 4 below. However, it may be noted that they share one common feature with the route and time changes mentioned above: they enable a proportion of traffic to 'disappear' from those times and places where it would cause a planning problem. The activities which were served by the affected journeys may still be undertaken (by reorganisation of travel and activity patterns, or by another mode, or by incorporation into another trip, or to another place), such that there is not necessarily any diminishment in activity space or individual mobility, but they no longer appear when and where they would cause, or meet, unacceptable levels of traffic, long queues and delays.

Although the group of responses described are likely to be triggered by stronger stimuli than the earlier changes mentioned, such changes will not always be of net disadvantage to the individuals concerned. The relative costs and benefits of a capacity reduction will depend on the combined effects of the capacity reduction, the associated impacts on transport operation and the attractiveness of the area, and the other opportunities available. Transport changes may also (just) become a decisive factor in more complex decisions primarily being made for other reasons. For example, in the case of the Tasman Bridge collapse, Sharples (1997) (a resident on the eastern shore of Hobart at the time) reports that *"the collapse wasn't a major problem for me. It was, however, part of the reason for me going into a residential college in my first year at university"*. Meanwhile the relocation of services and industry to the eastern shore strengthened that area of Hobart in the long term. Similarly, the retention of 30,000 new underground train passengers, after the earthquake damage in San Francisco had been repaired, suggests that travellers considered that their journey was improved by changing mode. However, in other cases, there are obvious disadvantages. For example, one resident in Portsmouth comments that major changes in journey time *"leave us with precious little evening by the time we get home and have dinner"*. Hence, although 'disappearing traffic' may involve relatively substantial changes in behaviour, the implications on utility and disutility cannot be directly inferred. Considerations for evaluating schemes are discussed further in Chapter 5.

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[6] Car sharing, whilst sometimes mentioned, appears to be a relatively rare response, and often does not increase. Vehicle occupancy is recorded as static or declining in the cases of York, Toronto, Hobart and Hammersmith Bridge. With the Tasman Bridge collapse in Hobart, the decline in vehicle occupancy is attributed to the loss of trips in the category 'drove passenger', which may represent a reduction in discretionary travel due to the increases in journey times.

- **Summary of the three hypotheses**

Although there are caveats about the reliability and comprehensiveness of data, nevertheless cases exist which are consistent with the three main hypotheses mentioned. Traffic levels do appear to respond to changes in capacity when capacity is reduced, just as they do when capacity is increased. The nature of the responses is sensibly influenced by the intensity of pressure caused by the capacity reduction. The common pattern is that, when not to respond would cause levels of congestion that people find unacceptable, then some find ways of avoiding that congestion. Typically, they make minor changes if possible, and major ones if necessary.

Hence, all the experience gathered suggests that misleading expectations of 'traffic chaos' are produced by assumptions that the total amount of traffic is insensitive to changes in congestion.

However, it is also clear that there is still a wide range of differences between the places studied. This will now be considered further.

3.4 The influence of context and prevailing conditions

When road space is reallocated away from cars to other uses, different types of behavioural responses are prompted by the scale of reduction in capacity. There are three main scenarios, which may be described simply as:

- traffic intensifies
- traffic spreads out
- traffic disappears

There are a number of factors which appear to play an important role in determining which responses are triggered. Some of these are 'situational' characteristics that are difficult to change (although they may require consideration when planning capacity reductions). Others are policy related, and reflect the importance of the planning context in which capacity reductions are made.

Before describing these, it is important to identify some factors which have been suggested as determining the impacts of a capacity reduction, but which do *not* appear to be important, based on the evidence. Notably, at a workshop organised during the project, it was suggested that the structure of disappearing traffic might be locationally dependent, such that taking road space away from cars in small towns would cause people to go elsewhere, whilst taking road space away in large towns would cause people to change mode. There was no clear evidence along these lines. In the Six Towns Bypass Project, where towns were deliberately selected to be rather similar, the measures implemented produced as wide a variation of impacts as those that occur between towns of different sizes, both in terms of the traffic reductions produced, if any, and in the traffic increases that occurred prior to the reductions[7]. Similarly, following the Northridge earthquake in Los Angeles, changes made were markedly different on different corridors, depending on the specific opportunities for rerouting or changing mode open to drivers.

[7] As described in the summary of the Six Towns Bypass Project, this case study differs from many of the others in that capacity reductions were pre-dated by major capacity increases, and the purpose of the capacity reductions was largely to displace traffic to the new routes. Nonetheless, within the project, the selected towns were treated in broadly similar ways, and it *is* notable that this resulted in such a wide range of effects.

The factors listed below, however, do seem to be important in determining what happens.

- **The nature of the network, existing levels of congestion and tolerance to congestion**

As already highlighted, the nature of the network, the existing level of congestion and the existing tolerance to congestion affect the ability and desire of traffic to change route, vary journey time and make other responses. As long as there are relatively easy options for people to continue driving, it is unlikely that they will make more substantial changes to their behaviour. Where such changes are not possible, other factors become more important. The number and type of alternatives available, and the density and service characteristics of the network have an effect. Moreover, policies to change those network characteristics, like restricting turning movements or altering signal timing, can result in significant increases to the 'natural' capacity of the system.

- **The type of trip affected, with non-work traffic giving way to work traffic**

The type of trip affected is important, as different trips have different types and amounts of flexibility associated with them, and clearly the amount people change their behaviour is going to depend on how far they *can* do so. In general, it appears that peak travel and work trips have less flexibility than off-peak and non-work trips. Thus, more off-peak and non-work travel is likely to 'disappear', and, as a result, there are opportunities for other traffic to spread into the road space vacated. The differential impact on different types of trips has been shown during the Hammersmith Bridge closure, where surveys suggest that 5% of work trips are no longer made, compared with 20% of non-work trips (Accent Marketing & Research, 1997). Similar differences are also reported from the closure of the Lendal Bridge in York , the Hanshin-Awaji earthquake and the Tasman Bridge disaster in Hobart. Peak travel may also include school trips, which tend to have relatively inflexible timing.

- **The attractiveness and availability of other modes**

Another key determinant of whether people can reduce their car travel is the availability and attractiveness of alternative modes of travel. In Portsmouth, a substantial proportion of people said they would have travelled by a different mode, if it had been available locally (including 2% who were put off walking because of the unpleasantness of their route). Alternatively, in situations where road space is reallocated to other modes whose journey times and reliability improve as a result, a mode shift does seem to occur.

Luneburg provides interesting evidence. Increases in cycling (+58%) were far greater than increases in bus patronage, since the improvements to the conditions for cyclists were greater.

The difference between a real and perceived improvement in alternative modes may also be important. For example, in Toronto bus lanes resulted in increased patronage of about 25%. Shalaby and Solomon (1994) note that this is largely due to "the perception of an enhanced service", as buses now travel freely through sections of major congestion. However, bus journey times overall did not improve, mainly due to longer dwell times at bus stops that resulted from more people waiting to get on.

Mode shifts may not always be particularly painful, even as a result of major catastrophes. Webber (1992/3) notes that the loss of the Bay Bridge in San Francisco, which previously carried 400,000 people daily, added less than 15 minutes to the majority of commuter journeys because there were other modes of transport to which people had transferred. (Those who felt strongest that their journeys had become less pleasant were existing public transport users, who resented the influx of ex-car drivers).

However, although modal transfer does often occur as a result of capacity reduction, provided that the other modes are relatively attractive, the new users are not always former car-drivers. For example, in Toronto, it was suggested that some new bus passengers had been attracted from nearby competing subway lines.

It is also important to note that even if car drivers do transfer from a different mode, this effect may be masked by induced or 'replacement' traffic, so that modal shift is not directly translated into an effect on the amount and speeds of traffic. For example, in Oxford, there have been substantial increases in patronage of the Park-and-Ride service over the years, which now accounts for a far higher proportion of trips into the city centre, and has enabled a substantial increase in person trips into the centre overall. Meanwhile, traffic levels have also reduced at an inner cordon into the city. However, the timing of traffic reductions does not show any direct correlation with changes in bus service patronage, and the extent of traffic reduction has been significantly less than the dramatic increase in bus use. Hence, the two processes must be partially independent of each other, and reflect a complex set of behavioural changes at the individual level.

It follows that the success of bus priority measures or light rail systems in increasing public transport patronage, and their role in reducing traffic, have to be assessed, in part, as two separate impacts rather than a single transfer. Moreover, priority may not be sufficient, in isolation, to bring about modal change. During the Nottingham Zones and Collar experiment, bus fares increased by 20-25%, and petrol prices decreased by 20%. In this context it is perhaps unsurprising that "no significant changes were observed in the means of travel used by residents of Bilborough and Wollaton zones" (Vincent & Layfield, 1977).

- **Other factors influencing car use, particularly parking**

Parking policy will also affect how people react to reallocations of road capacity, as shown in the case of Oxford mentioned above. Interestingly, parking policy is often used to complement other policies in opposed ways. In some cases, car parks in restricted areas are carefully relocated on the edge of such areas, to ensure that any car-borne shoppers are not deterred. Nurnberg provides an interesting contrast, where car parking has been increasingly restricted and increased in price for non residents. It is notable that car traffic has declined, but without a decline in retail activity.

- **The relative attractiveness of alternative locations.**

The relative attractiveness of alternative locations also plays a vital role in how people alter their behaviour, affecting whether they go elsewhere, whether they are prepared to change mode, and so on. For example, the restrictions on traffic in Wolverhampton, coupled with a town centre promotion exercise, increased the number of visitors, and was described by the local Chamber of Commerce as "an unqualified success". On the other hand, roadworks in Portsmouth led several respondents to use more local shops and facilities, and these have proved popular, one respondent commenting *"[the roadworks] have made me realise what I have been missing...after roadworks, I will still avoid Portsmouth for leisure and shopping"*. It is notable that the attractiveness of shopping facilities is often not determined by their parking and car access, but by the quality of shopping environment that they provide, (Hass-Klau 1993, Carley & Donaldsons 1997).

- **Information, marketing and publicity**

Information will affect both how fast the evolution of responses occurs, and the ways in which travellers adapt their behaviour. Black, Hyde & Towriss explored this in relation to motorway travel, and found that 83% of those who consulted information sources were likely to make adaptions to their journey, compared with 50% of those who did not consult information. In Wolverhampton, advertising and marketing were considered particularly important for maintaining the town centre's retail trade, and a major campaign over Christmas helped to deter car-driving shoppers from going elsewhere. Read (1992) comments that "it was notable how the public responded to the radio broadcasts [about available car parking]". Advertising may also be important in reconciling people to changes. With Hammersmith Bridge, one of the strongest criticisms has been about the lack of warning, with 68% of respondents to a survey carried out by Accent Marketing & Research (1997) agreeing or agreeing strongly that "not enough warning was given of the bridge closure". The importance of proper consultation is also mentioned in the case of the Six Towns Bypass Project, the closure of Orpington High St. and Wolverhampton, although there is some concern that people find it difficult to relate to plans and drawings of proposed changes. In the case of Gothenburg, the authors note that "it would have been preferable to implement the scheme more rapidly, modifying it later as necessary in the light of experience", and this point is also made in relation to the original closure of Oxford Street.

- **The specific design details of the scheme**

Finally, it is perhaps worth noting that the design details of a scheme will make a substantial difference to the way people react to it. Some examples are:

Rat runs
In general, it seems that if rat runs are left open, people will use them, rather than making a more 'positive' response. This raises questions of equity and fairness between residents and drivers, and can be a source of tension. For example, following the introduction of bus lanes on the A104 Lea Bridge Road, further measures were needed to reduce the amount of rat running occurring to the north and south of the road, and 85% of residents were recorded as being in favour of further road closures in their area.

Enforcement
Enforcement - and the ease of evading it - are related important issues, as highlighted in the case of Orpington High St, where complaints about evasion have been one of the most widespread criticisms of the road closure. The Red Routes have proved a testing ground for new camera detection technology, (Evening Standard 24/4/95 & 18/12/95), and cameras on board buses have just been introduced. However, more low technology solutions may also be useful. The use of red surfacing material on bus lanes in Bristol has reduced infringement from 15.2% to 1.8% (Cairns, 1996), and Lothian regional council has recently been testing the efficacy of 3 different types of green surfacing materials for use in Edinburgh, (New Civil Engineer, 23/3/95).

Aesthetic qualities
Interestingly, the aesthetic qualities of a scheme also seem to have an important effect on its acceptability. In the case of Wolverhampton, Read (1992) notes that the colour of planters used to demarcate the scheme became an item of contention "and given the scale of the outcry...it was little consolation that this was the principal objection to a scheme which had changed traffic patterns and environmental conditions fundamentally". Similarly, in the Six Towns Bypass Project, the use of

gateways has helped to reduce traffic speeds, however Ross Silcock (1995) note that "debate which centres on the aesthetic aspects of a gateway, and its value for money as a piece of art, can overwhelm the safety issue which it seeks to address".

Integration with other types of vehicles on a regular basis
As priorities for road users change, different road users may be forced to interact in new ways. Planning for this may affect the success of a scheme, and the importance of an adjustment period has been highlighted, for example, in the context of the Manchester Metrolink. The evidence from Sheffield has also highlighted that some people had changed their driving styles to avoid driving on the Supertram tracks, and some had even changed route altogether to avoid them.

Provision for emergency vehicles
Again, altering the allocation of road space may create specific problems for the emergency services. There is already a body of literature devoted to this topic, which could be explored in more detail to establish best practice. In the case studies examined, there was reporting from Manchester that plastic bollards have been used which shear off when hit, so that extra space can be created for emergency vehicles when necessary (Robinson, 1996). In Cambridge, the first phase closure has been created using rising (and retracting) bollards.

3.5 The time scale of behavioural adjustment in the case studies

The case study evidence does not, in general, come from sources which have used longitudinal survey techniques, following individual choices over an extended time period, which could allow us to examine the time-scale of effects of highway capacity reductions on behaviour directly. However, the results do give some indirect evidence from which choices, and their time-scale, might be inferred. These are discussed below, and in conjunction with other evidence on behavioural change in the next chapter.

A number of points can be made relating to the nature and time scale of responses.

a) *Very short term: in the first few days*

Some cases are marked by an initial period of quite serious traffic disruption - qualitatively in line with 'traffic chaos' forecasts. For example, in Wolverhampton, 'severe queues' were reported initially, that subsequently dissipated (Read, 1992). However, it is notable that drivers may adapt their behaviour extremely quickly. For example, during the Dutch railway strikes, the number of people driving increased from Monday to Tuesday, but the amount of congestion halved because drivers altered the timing and routes of their trips. Similarly, during a sequence of closures of the A13 in the Netherlands, fewer trips were made on the second weekend. Presumably this was because drivers became more aware that roadworks would create congestion, and altered their behaviour accordingly.

In other cases, even on day one there is no substantial traffic chaos, and these are often greeted with bemusement by press and professionals. There are some indications that the extent of publicity and information before the change may itself influence the expectations and outcome, as in the cases of Munich and Hammersmith reported in Chapter 1. It is sensible that in the very early days of a new scheme people will rely on advance publicity (if they believe it) to determine their responses, though over time their own experience will become more influential.

b) *Short term - say the second week, for the rest of the year.*

There is the common experience that, after an adjustment period, traffic alters to take account of the new conditions. Reference to a 'settling down' period has been made, for example, in the context of Manchester and the closure of Oxford Street. Following the Kinnaird Bridge closure, flows were estimated to stabilise in about three weeks. Some of the big changes in behaviour reported already apply to this period. Less than a month after the closure of Hammersmith Bridge, nine respondents had already moved house, had considered moving house, or had moved house earlier than planned.

c) *Longer term - the years following implementation.*

Two different variants emerge for the third stage.

In some cases, there is a tendency for any traffic reductions to be eroded, as cars are reported to be 'gradually creeping back onto the network'. Such comments invariably do not distinguish between the same cars coming back, or new cars replacing them, or general traffic growth due to increasing car ownership. For example, traffic in Bologna fell by about 50%, following traffic restrictions in 1989, but Topp & Pharoah (1994) report that traffic later crept back to perhaps 90% of its original levels, due to weak enforcement and a large number of exemptions to the traffic orders. Similarly, in York, traffic levels across the four bridges were back to pre-closure levels before the Lendal bridge re-opened, (Dawson, 1979). Ironically, this traffic growth may even be caused by improvements to the attractiveness of the area brought about by the capacity reductions. The Street Enhancement Programme in Norway has encouraged more shoppers to visit the towns, and various developers are now interested in building houses there, as the redesign of the old trunk routes has made the towns safer and more attractive. Consequently, traffic subsequently increased in several cases. However, in other cases, traffic flows may take longer to be restored than expected. For example, 6 months after the Tasman Bridge re-opened, peak period cross river trips were 8% less than they had been, and the number of private vehicle trips was still 14% lower than previously. Slow rates of trip restoration are similarly quoted in the cases of the Tower Bridge closure and the Hanshin Awaji earthquake.

In other cases, there is a tendency for the initial small reductions in traffic levels to become larger, suggesting that there are some delayed responses which build up into, implicitly, the larger demand elasticities characteristic of longer term responses. For example, the closure of a highway in New York was followed by a traffic reduction of 6% in the first year, and 8% in the second year. Similar trends are evident in Gothenburg, the Westminster Bridge area and Nurnberg, where initial capacity reductions have often been reinforced by additional policies which impact further on traffic.

Thus, whilst the time profile of response emerges as important, there is not uniform experience. The two variants mentioned are not necessarily inconsistent with each other: all could be showing an increasing response to the capacity change itself over time, but in the first case this may be offset by larger changes due to other effects. Moreover, it becomes obvious that the 'Hypothesis 3' responses are not necessarily long-term changes, since they often happen, or start to happen, very swiftly.

Another issue which has emerged in the course of interpreting the results, is the large amount of underlying variability in general behaviour. In some cases, this variability may be partially attributable to the capacity reduction studied (or the cause of the capacity reduction). For example, a year and a half after the Loma Prieta earthquake in San Francisco, Deakin (1991) reports that "we could no longer locate over 40% of our sample at their previous phone number, and another 7% had changed job". In others, it may appear to be part of 'random variation' that occurs anyway. For example, during the Nottingham Zones & Collar experiment, a 7% change in the trip rates to different destinations was recorded. However, according to Vincent & Layfield (1977) "this was mainly due to the variation in the number of work trips [and] a result of people starting, stopping or changing jobs, and of the fluctuation in the destinations of mobile workers such as salesmen and labourers". Variation may also often underlie apparently stable statistics. For example, as shown in Table 7 of the Annex, during the Hanshin-Awaji earthquake, a before-and-after survey of 882 households who did not change their address showed that the number of respondents commuting by rail only reduced by 2%, from 537 to 525. However, during this period, 56 people changed to rail from other modes, and 68 people stopped using rail, a total of 124 people who made changes (which represents nearly a quarter of the rail market).

In most circumstances, the variation described above is treated as important only as a methodological problem of measuring statistically significant differences. However, it also has important implications for understanding how and why people make changes to their travel patterns. This issue is discussed in more detail in the next chapter.

3.6 Summary

In general, the most robust finding from the case studies appears to be that road capacity *can* be reallocated to other modes, or other uses, without prolonged gridlock or traffic chaos occurring. When real traffic problems do occur, (or rather traffic conditions which are significantly worse than they are already), they tend to be short-lived.

Thus, traffic definitely disappears from some particular routes or places where it would otherwise be a major planning problem. However, this is not to say that conditions for remaining traffic will necessarily improve. Congestion tends to spread out across space and time even in the absence of reductions in capacity, and this tendency is not necessarily offset by a mere capacity reduction. Moreover, this may occur *even if* some people have changed mode, as new cars can take the places of those who have left.

Therefore, capacity reductions or reallocations do not, on their own, improve general levels of congestion over the network as a whole. However, where congestion increases, such increases tend to be less than those predicted in forecasts of 'traffic chaos', since it is in precisely this situation that more complex behavioural adjustments occur.

The key phrase in the above paragraph is 'on their own'. Where alternative modes are introduced or made significantly more attractive, people do use them, and where changes occur within a generally favourable policy context and people can carry out their activities in other ways, traffic may further reduce over time, even in a general context of growing car ownership, and car use.

Chapter 4: How and Why People Change Their Travel Behaviour

4.1 Introduction

The case study evidence suggests that responses to capacity reductions are of far greater range and scale than has often been assumed when predicting the impacts of such schemes. Accounting for this discrepancy initially requires the status of the evidence to be considered very carefully. However, as always in such circumstances, potential known and unknown sources of bias and error remain in relation to every example of road capacity reduction, and differences of interpretation and judgement are always possible. Issues of this sort are rarely completely resolvable.

Therefore, in this chapter, the overall conclusions from the case studies are approached from a different direction. Are they credible when judged against wider knowledge about travel choices and sensitivities ? This discussion goes beyond that originally anticipated in the study brief, since it has involved rediscovering and linking evidence of a kind which has not previously been directed towards this sort of problem. This analysis forms an important part of the overall assessment of the evidence.

The foundation for this analysis is set by the discussion in Chapter 3, which identified the following behavioural responses in the case study reports:

- changes in driving style

- moderate changes in route
- moderate changes in time of journey

- more drastic changes of the time of the journey
- much longer diversions
- making a journey to a different destination,
- changing frequency of journeys
- changing mode of journey
- car sharing
- consolidating trips so that several different purposes are fulfilled in the same round trip
- changing the allocation of different tasks within a household (errand-swopping)
- actual elimination / suppression of trips
- changes in job location
- changes in housing location
- changes in developer choices for locating new developments
- many combinations of these.

By contrast, as explained previously, many assessments of local traffic schemes have usually assumed that there will be little or no effect on travel choices other than on choice of route.

A starting point for seeking to resolve this discrepancy is the observation that, in the absence of any change in road capacity, some of these changes of behaviour would certainly have happened anyway, to some extent.

To draw legitimate inferences from the evidence, the importance of variation in individual travel behaviour from one time period to another must therefore be considered.

Specifically, the empirical distinction between 'before' and 'after' conditions in the real world is not directly comparable to the modelled distinction between 'with' and 'without' in a forecast, since the former unavoidably always includes the combined effects of everything that has changed, and the latter always (by definition) keeps everything else constant. Therefore, reconciliation of the difference between common assessment practice and the *prima facie* results will partly involve understanding the role of 'natural variability' in travel behaviour.

As part of this process, the distinctions between short and long term responses, and between individual choices and aggregate traffic observations, are crucial. Such distinctions cannot be considered directly using the case studies, as explained in Chapter 3, because few of them used research methods which give such information. Therefore, the following sections consider relevant evidence from several other strands of research.

4.2 Variation in traffic conditions and travel behaviour

- **Variation in traffic conditions**

It is generally acknowledged that traffic levels will be expected to change year on year (due, especially, to a general increase in car ownership, modified by changing land-use patterns, and damped, to some extent, by increasing traffic congestion). There is also recognition of seasonal changes in traffic flow, cycles according to day of the week and season, and specific social patterns such as the heavy school traffic at the start of the school year in September.

The initial interest in day-to-day variation for this project related to aggregate traffic conditions, since 'natural' variation determines how easy it is to detect statistically significant changes in traffic flow.

The classic work on this subject is by Smeed and Jeffcote (1971). They reported on the variability of a car journey repeated 253 times between Bray and Central London, and found day-to-day variability in the overall average journey speed such that the standard deviation was between 20% and 33% of the mean. Mogridge and Fry (1984) repeated the experiment for 172 journeys between Clapham and Central London, finding a standard deviation of 15% to 20% of the mean. Mohammadi (1997) analysed data from three much larger experiments, totalling about 1300 journeys. Standard deviation for different subsets varied from 2% to 51% of the mean, the overall figures being 16%, 16% and 20% for the three experiments (and subject to influence from a variety of factors such as incidents, weather, etc). Each of these authors cites further references, with broadly similar results.

Thus, it is the experience of drivers using the same route at around the same time on successive days that a degree of day-to-day variation is part of their normal lives. For a hundred journeys to work, broadly between 10 and 20 will be travelled with an overall door-to-door time more than 20% faster than the average, and a similar proportion will travel more than 20% slower than the average.

Two consequences follow.

(a) Measures which change journey speed in the order of 5%, say - *though entirely real* - may not always be revealed statistically by comparison of one day 'before' and one day 'after' traffic observations of speeds or flows. Such considerations led, for example, to problems in detecting statistically significant changes in traffic flows resulting from the implementation of a number of traffic calming measures in Reading, because the natural variability of traffic counts was as much as 40%. (Ward, 1997). Most of the case-studies reported here have not provided information about day-to-day variation, and therefore any one result has to be read with caution. As discussed in section 3.2, the effect is to exaggerate the range of the highest and lowest results, but not to bias the mean.

(b) Drivers accustomed to variation in their own travel conditions are unlikely to all respond immediately to changes in speed, since such changes are not immediately obvious. Their ability to detect changes and respond to them will be influenced by how long it takes them to build up a 'true' (to themselves) picture of the average conditions, or the frequency of unacceptable journeys, depending on the criteria they use.

It follows that the drivers' own stability of behaviour, which will affect the time over which such a picture can be built up, then becomes important.

- **Variation in individual choices**

Bonsall, Jones & Montgomery (1983) comment critically on household interview surveys which imply that '98% of workers who drive on a given day will also drive on a second given day', and that '88% claim never to vary their route from work'. On closer examination this proves to be very misleading. They investigated the stability of traffic flows by matching number plates on successive days on a major commuting route in Leeds, seeking to explain the results by reference to a variety of other data sources and analyses. This survey suggested that "as much as 50% of the cars present on a given day will not be present on the following day", and that even this reappearance rate decays over time. Their results, given in Figure 4A, are summarised in the form of an estimate of the proportion of drivers observed on one day who will be doing something different one week later.

Figure 4A: Predicted behaviour of a sample of commuters one week later (Bonsall et al)

If we could trace 100 drivers, observed on a commuter radial between 08.15 and 08.30 on a given weekday, we would find that, a week later -

30 will drive past the same point between 0815 and 0830
15 will drive past.....................................0715 and 0815
15 ....0830 and 0945
7..before 0715 or after 0945
14 will drive to the same destination by a different route
8 will make the journey by another mode
5 will travel to a different destination
5 will stay at home
1 will have sold his car

It is notable that this very high degree of variability does not derive essentially from response to any particular stimulus. Instead, it is the typical rate of change due to all influences taken together, whether personal, policy, or random.

Atkins (1985) reports surveys of 111 households asked the same questions in March and June 1992, in a study aiming to match specific trips in order to assess the effects of a bridge toll in Southampton. Of the 111, 50 interviews did not proceed for a variety of reasons, including house empty (2), people moved away (3) now no car (1) and car off road (1). These orders of magnitude are not inconsistent with Bonsall *et al.* For the remaining interviews which were successfully carried out, Atkins recombines some categories and provides a comparison with the results of Bonsall *et al*, as shown in Figure 4B

Figure 4B: Travel behaviour variability

Location: Time Lag: Sample:	Leeds One Week Commuter Radial	Southampton Four Months "regular trips"
Same Behaviour	60%	49%
Different Time	7%	5%
Different Route	14%	7% (bridge)
Different Mode	8%	1%
Different Destination	5%	13%
No Journey / Different Journey	6%	25%

Despite the small sample size involved for the Southampton survey the correspondence between the sets of results appears plausible. The patterns are fairly similar, although with slight changes as expected. (ie. For regular trips, over a longer time period, there has been a smaller percentage making the same journey and more destination changes, but fewer mode changes. Less route switching has occurred, probably due to fewer alternatives in the Southampton location)

A more recent small-scale survey along similar lines, but using retrospective questioning to detect variations from a year ago, was carried out by Anable *et al* (1997) in Oxfordshire. A quarter of all respondents stated that their travel pattern (all methods) was different in 1996 from 1995. For these twenty-nine, the changes fell into several main groups:

- those who had changed job (including leaving or becoming students) or retired;
- those who had stayed in the same job but had either moved house, which meant that they needed to drive further to work, or were required to drive more at work;
- factors independent of work, such as buying a car, increasing or decreasing their mileage (using the train instead), or no longer 'having to walk 4 miles a day to take the children to playschool';
- changes to air travel patterns, one travelling more, one less.

The majority of respondents (78) did not consider their travel pattern had changed over the previous year.

A much bigger study was carried out by the Department of Transport (1978) for a half-year period, based on two waves of a panel survey carried out in Spring and Autumn 1976 (in connection with a fare increase). The survey used a full week diary, hence taking out much of the day-to-day variability, and the results showed the degree of variation in individual travel over the half-year. Two results are indicative, both relating to quantities normally thought of as rather stable, namely the total number of journeys made (only using respondents for whom records were complete), and the main mode used for journeys to work (only using respondents whose records were complete and who had not changed their economic activity or their level of car availability).

Figure 4C: Individuals' change in journey frequency, Spring to Autumn 1976

Journeys Per Week in Spring	Journeys Per Week in Autumn				
	0-4	5-12	13-20	Over 20	Individuals, Spring
0-4	274	185	92	22	573
5-12	189	742	408	103	1442
13-20	101	506	1011	320	1992
Over 20	47	129	459	701	1336
Individuals, Autumn	611	1616	1970	1146	5343

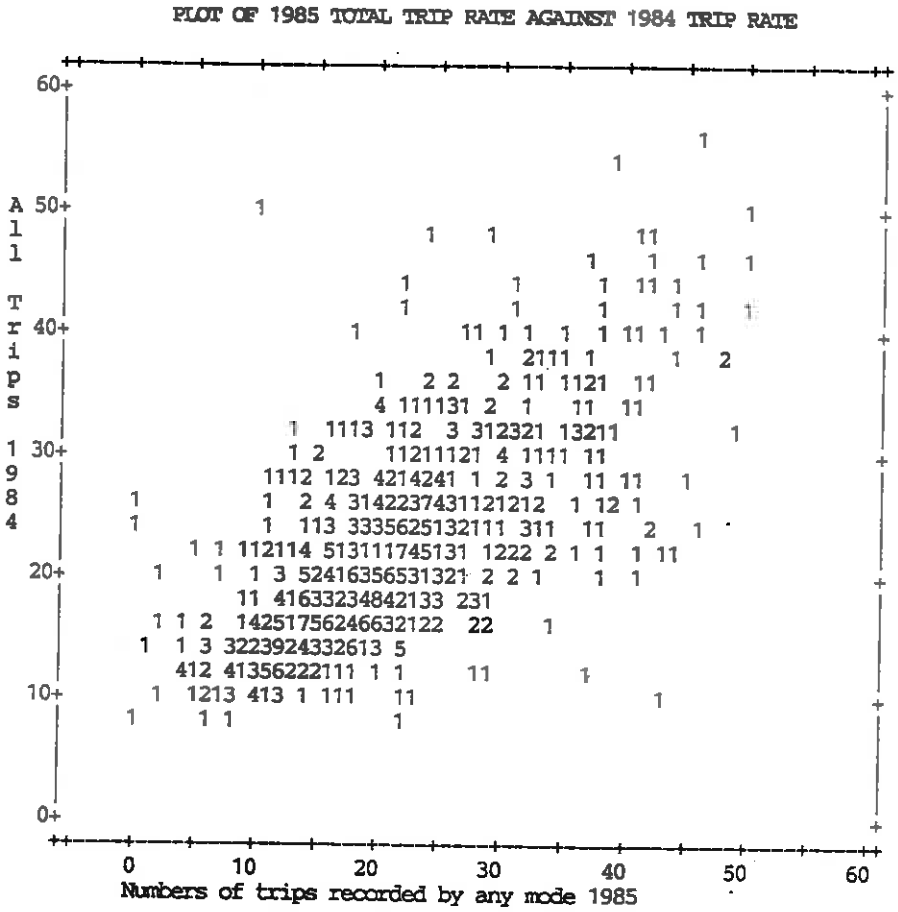
Figure 4D: Linked journeys to and from work per week in Spring and Autumn 1976

Mode of Travel in Spring	Mode of Travel in Autumn								
	Car/Van Driver	Car/Van Passenger	Red Bus	Underground	British Rail	Walk	Motorcycle/ Bicycle	Other	Total
Car/ Van Driver	3882	121	33	44	58	36	54	72	4300
Car/ Van Passenger	149	633	144	20	52	69	7	4	1078
Red Bus	106	203	2083	108	102	140	28	10	2780
Underground	99	43	123	1018	81	3	12	13	1392
British Rail	42	23	31	91	1201	14	22	0	1424
Walk	100	66	97	14	19	1251	8	12	1567
Motorcycle/ Bicycle	101	25	57	3	11	29	503	1	730
Other	92	14	42	0	2	1	9	81	241
Total	4571	1128	2610	1298	1526	1543	643	193	13512

The results show that, during the period, nearly half of the sample had changed the number of trips they made in a week by enough to take them into a different, very broad, category of trip-frequency. Nearly 10% had changed trip frequency so much that they were not even in the neighbouring category. Over 20% of the sample of the most stable category of employees had changed their main mode of journey to work from Spring to Autumn, including 10% of car drivers and nearly 40% of car passengers who had chosen a different mode half a year later.

Further evidence on such changes is recorded in Stokes and Goodwin (1989). Using one-week panel data from later surveys in London from 1982 to 1985, they found that around 10% of the sample changed from being non-public transport users to users from one year to the next, with a similar proportion transferring the other way. Figure 4E shows the relationship between the number of trips made by each of 696 individuals, by all modes, in a week in Autumn 1984, compared to the trips made by the same individuals in Autumn 1995. The numbers indicate the number of individuals in that location on the graph.

Figure 4E: Variability in individual weekly trip rate from 1984 to 1985.



About 20% of the sample had increased or reduced the number of trips they made by more than 10 trips per week, compared with a mean recorded trip rate of around 25 trips. Around half of the sample stayed within +/- 4 trips of their previous year's value. About 25% of 'frequent' car drivers in each year (those making more than 10 car trips per week) were making less than 5 trips per week by car in the following year (offset by more car use from previously frequent users of other modes).

A particularly interesting result is that over 10% of the market for public transport in one year was made up of people who, the previous year, were making more than 10 trips per week by car.

The results of this analysis of changes from 1984 to 1985 were broadly similar to those found when comparing 1982 with 1983, and 1983 with 1984. The degree of year to year variation was rather stable.

Next, it is interesting to look at the degree of variation in car ownership, since this is often assumed to be the travel choice least subject to variation. Conventional analyses almost invariably show car ownership as monotonically increasing, with temporary pauses only at times of the most exceptional economic hardship. This has undoubtedly been true at the aggregate level, but at the individual level, no such monotonic effect is found. Data from South Yorkshire panel surveys show that the net increase is made up of the difference between quite large numbers of people changing in opposite directions. It is true that a majority of the population during successive two or three year periods have not changed their level of car ownership, but the fact that the net changes are increases of 2%-6% does not imply that the unchanging majority is 94% to 98%. Rather, something like a quarter of the population are in households which change their car ownership level, with around 10% of the population involved in reductions. This is shown in Figure 4F.

Figure 4F: Proportion of individuals living in households whose car ownership increased or reduced. South Yorkshire, 1981-1991.

	1981-84 %	1984-86 %	1986-88 %	1989-91 %	1981-91 %
Cars reduced	10.5	8.6	7.2	11.6	14.8
No change	76.4	78.5	79.1	73.7	64.1
Cars increased	12.8	12.9	13.6	14.6	21.1
Net difference	+2.3	+4.3	+6.4	+3.0	+6.3
Sample	3221	2445	1565	2090	660

It is notable that the period when the net difference between increasers and reducers was smallest, 1981-84, represents the end stages of a long period of reducing bus fares, and the period when the net difference was greatest, 1986-88, bridges the disruption to public transport services which was caused by deregulation and reduced support. This suggests that, for those interested in the mechanisms by which public transport quality might influence car ownership, it is necessary to distinguish the evidently distinct processes of influences on decisions to reduce car ownership by those who already have cars, or to obtain cars by those who do not.

Data from three panels show that the probability of two-car households reducing to one is much greater than the probability of one-car households reducing to zero. The main influence on this is household structure, but about a quarter of people in households going from two cars to one in one period, reverse that decision in the following period, suggesting that decisions about a second car in a household may be generally more volatile than about the first car, and hence, subject to a degree of influence from prevailing travel conditions. This is illustrated in Figure 4G.

Figure 4G: Reduction in car ownership related to base level

	Greater Manchester 1986-1987	Netherlands 1984-1987	South Yorkshire 1981-1986
% of one car owners reducing to zero cars.	8.3	5.5	13.2
% of two car owners reducing to one car.	23.7	44.3	43.5
Total sample	653	1460	1808

All of the results reported above relate to specific choices such as method of transport used, numbers of trips and levels of car ownership. The next step, therefore, is to consider how they come together to determine mileage travelled, since this represents the bridge into observed traffic levels on the network, and resulting speeds. Information on the variation in mileage travelled is plentiful in relation to variation from one individual to another, but sparse in relation to the variation for one individual from time to time. Two indicative results are those by Goodwin (1978) and Gray (1969).

Goodwin (1978) analysed the weekly use made of 331 cars in Oxford, and found that the variation in mileage between the cars was systematically reduced when taking one day's data (coefficient of variation 1.14), two days (0.92), three days (0.82) and so on, up to seven days (0.64). This implies that some of the apparent variation between cars is actually variation between days, as was confirmed by analysis of variance. Gray (1969) provided data from which it can be calculated that the coefficient of variation between cars for a year is between 15% and 25% less than the variation for one week. Using this result to extrapolate Goodwin's results, a one year analysis would have shown a variation in mileage between cars of 0.48 to 0.54, or around half the one day figure. (Logically, there must be some further effect if five years, or ten years were taken, though such information is not available).

Thus on any one day, it might be observed that approaching a third of all cars are being used to travel more than twice the average mileage. But to a first approximation, about half of this variation in mileage travelled is not due to stable differences between the travel patterns of the drivers, but due to each of them behaving differently from one day to the next, one week to the next, one year to the next, etc.

These different results, from changes taking place from one day to the next, to those taking place over several years, come together into a picture of *aggregate stability* and *individual variability.*

Stokes (1994) analysed national survey data about the travel of (different) individuals in successive National Travel Surveys (plus supporting information) from 1952 to 1992, and also data from five waves of a panel survey of the travel of (the same) individuals in South Yorkshire from 1981 to 1993. The national figures show that the average amount of time spent on travel as a whole is rather stable, having only increased by about 10 minutes over a period in which the mileage travelled has increased by much more. (Such findings have led to suggestions that travel time is a good control variable which may be assumed to be rather stable).

However, the stability is only really noticeable when many people are averaged together.

This may be shown in Stokes' analysis of the degree of similarity between the amounts of travel time spent by individuals in total, and for each mode, from one survey to the following one. All the correlations are positive, implying that, *to some extent*, people who travel more one year are likely also to travel more in later years. But the similarity is very weak. For car travel, only around 12% of the variation in trips made between individuals in one survey is associated with the variation in the previous one, and even for car travel time (the highest correlation) only 26% of the variation is explained. These results are given in Figure 4H.

Figure 4H: Correlations (R) between surveys for individuals' travel times and trips.

	Total	Car driver	Car passenger	Bus	Walk	Trips/ person
1981 to 1984	0.19	0.43	0.09	0.20	0.21	0.21
1984 to 1986	0.21	0.46	0.10	0.27	0.19	0.31
1986 to 1988	0.28	0.51	0.04	0.32	0.26	0.35
1988 to 1991	0.17	0.40	0.12	0.17	0.13	0.27
1991 to 1993	0.15	0.38	0.11	0.27	0.20	0.23

4.3 Distinguishing the causes of variability, in the short to long run

The discussion above has established that, both in the short run (day-to-day) and in the longer run (year-to-year, and longer), individual choices show a very high degree of variation, which clearly provides a different starting point to understanding individual choices than that suggested by the observation of stability in some aggregate average quantities.

The next issue to consider is the extent to which this variation should be considered as composed of entirely random processes, or due to definite causes such as changes in travelling conditions or personal circumstances. The empirical evidence on such change over time must be based mainly on time-series analysis, using statistical methods which distinguish the relative importance of different causal factors. Two main literatures exist, based on aggregate and disaggregate methods. Taken together, they are able to offer insight into the relative strength of different influences on individual choices, as well as the larger spread of those choices themselves.

- **Aggregate analyses**

There is a well established literature, comprising well over 100 separate studies, calculating demand elasticities from time series data, which are analysed with dynamic models incorporating an explicit lag structure. Goodwin (1992) cited 13 studies in which the effect of fuel price on fuel consumption had been calculated, (giving a short-term elasticity of around -0.25 to -0.3 and a long-term elasticity of -0.7 to -0.8). He also quotes 11 studies in which the effect of fuel price on traffic-levels have been calculated (with results of -0.16 for a short-term effect and about -0.3 for a long-term effect). Sterner *et al* (1992) estimated gasoline demand elasticities for 21 countries separately. The mean result for the preferred model form gave a short-run elasticity of -0.24 and a long-run elasticity of -0.79. A review of Australian evidence by Luk and Hepburn (1993) cited 28 studies, and came to the conclusion that the long term elasticity of traffic levels with respect to fuel costs was -0.1 in the short run and -0.26 in the long run. Such findings are mirrored in similar studies of public transport fares elasticities, which, on average, are estimated as about -0.3 in the short run, and -0.6 or more in the longer run.

At the level of UK national analysis, Tanner (1974) gave elasticities of car use with respect to generalised cost in the range -0.9 to -1.3. He took -1.1 as a preferred value and corresponding elasticities with respect to total motoring costs of -0.67, and with respect to fuel price alone of -0.17. At that time the distinction between short and long run effects was not made. Later (Tanner, 1977), he confronted the very important problem of interaction between income elasticities and price elasticities, such that, if too much of the growth in car ownership and use were attributed to income growth, one would inevitably underestimate the effect of price or generalised cost effects. After considering alternative ways of assessing the balance between these effects, he suggested a 'middle value' of -0.6 (range -0.4 to -0.8) for the elasticity of car ownership with respect to money cost (the report is not quite clear, but it seems to relate to total motoring cost). Tanner (1981) then estimated a car ownership elasticity with respect to car purchase cost of -0.87, and with respect to fuel price of -0.31; also an elasticity of kilometres per car with respect to fuel price of -0.26. He interpreted these as long-term elasticities, and used other evidence to suggest a *short* term elasticity of around -0.15. He proposed a dynamic adjustment process such that the long-term effect on car use is achieved over about 4 years (with the first year effect being about 40% of the total), and about ten years for car ownership (first year less than 20% of the total).

Using rather similar methods, Virley (1993) gave a short run elasticity of fuel consumption with respect to fuel price of -0.09, and a long run elasticity of -0.46. The estimated coefficients imply that the first year adjustment to a price change is only 20% of the long run adjustment. These results were reported as in line with those reported in other surveys, specifically those by Goodwin, 1992, Oum *et al* 1992 and Sterner ***et al*** 1992. Further work along similar lines is currently under way in the DETR.

Using an entirely different method, analysing cohorts as if they were members of a panel (of interest because it takes into account the separate effects of changes in travel behaviour related to age and generation), Dargay (1997) found long term elasticities of demand for car *ownership* with respect to the total purchase costs of cars of -0.35 for France, and -0.33 for the UK, and elasticities with respect to running costs of -0.22 for France, and -0.51 for the UK. The results, combined with separate estimates for the elasticity of mileage per car in relation to the same factors, are consistent with a long term elasticity of traffic levels with respect to fuel price of about -0.3, as above. The estimated speed of response was such that just over a third of the full long-term response was estimated to take place in the first year, the full response being (nearly) completed in about ten years.

The salient conclusions from this body of empirical analysis are as follows:

- Price changes certainly influence the volume of traffic. By use of standard generalised cost arguments, it can be inferred that travel time changes must also influence the total volume of traffic, with elasticities that (using conventional values of time) will generally be substantially larger than price elasticities. A number of studies suggest that this influence acts on car ownership, as well as on the use made of each car.

- Nearly all published studies using methods allowing them to distinguish between short and long run effects find that long term transport demand elasticities are different, and usually bigger, than short term elasticities.

- The pace of behavioural adjustment is such that it takes several years to approach a notional equilibrium, typically with around 50% of the adjustment in 1-3 years, and 90% in 5-10 years.

If these findings are valid at aggregate level, they suggest that this level of change at the individual level is not random, but systematically associated with influences on travel costs.

- **Disaggregate Analyses**

Work along these lines at the disaggregate level has also been longstanding. Fried, Havens and Thall (1977), proposed a process of adaptation as follows:

"A process of adaptation, involving changes in activity and travel patterns and adjustments over time, provides a useful theoretical framework for understanding the travel behaviour of individuals and populations: the motivating force behind these behaviours is the effort to reduce imbalances that exist or develop between personal needs and environmental structures..."

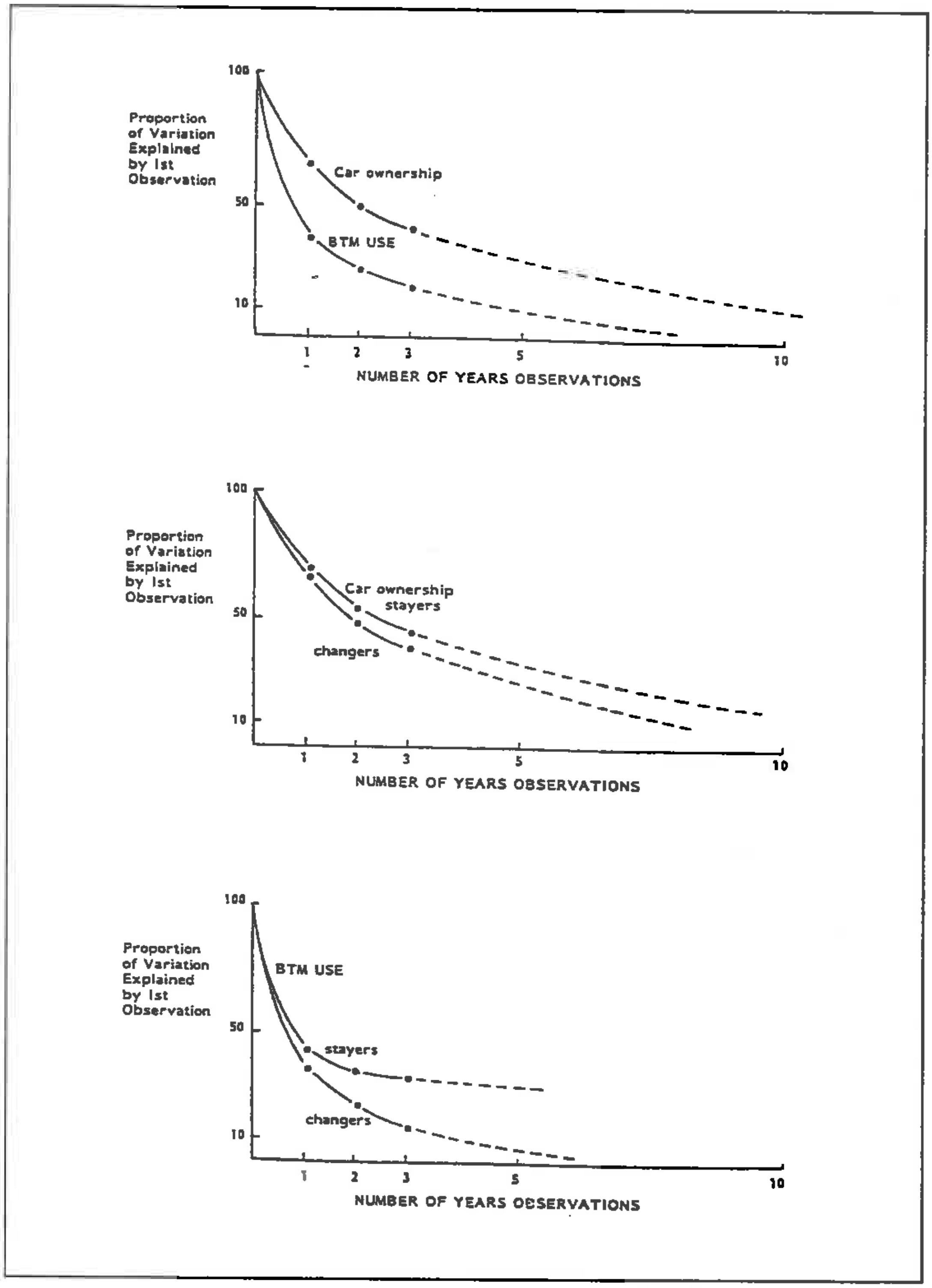
"Discrepancies in person-environment fit invoke the adaptional process consisting of informed trial-and-error sequences that continue until the discrepancies are resolved."

This approach suggests that changes are motivated by a discrepancy in 'person-environment fit', and this, logically, must be due to two different causes - changes in the conditions of the person, or changes in the condition of the environment in which the person operates (including travel costs and conditions). A logical hypothesis is that people whose conditions have changed will show greater (or faster) changes than those whose conditions have stayed the same.

This was tested by Goodwin (1989) on Dutch one-week panel data covering the period 1984 to 1987. The results are summarised in Figure 4I for car ownership and for bus, train and metro (BTM) use, separating out those people whose life-cycle stage, employment status and income had stayed the same ('stayers') and those for whom one or more of these had changed ('changers').

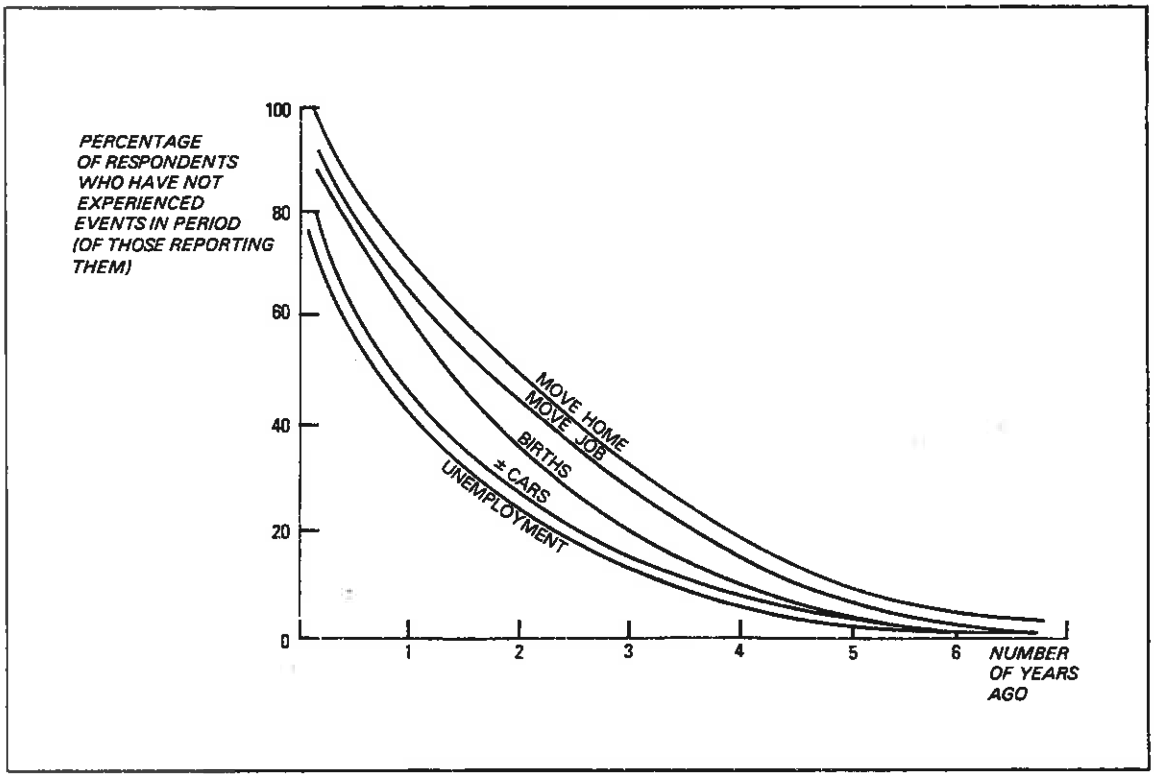
It may be seen that public transport use changes more quickly than car ownership, but that both change more swiftly for those whose personal circumstances change in some way. Extrapolation of the three years data suggests that the time scale over which car ownership becomes dissociated from its starting level (ie becomes influenced entirely by whatever combination of personal and external changes has happened since then) might be around ten years, and for public transport use, it might be about 5 years.

Figure 4I: Pace of change of car ownership and public transport use, for changers and stayers



Given that (a) econometric estimation of elasticities, and empirical observation of declining similarity to base levels over time both suggest time scales of behavioural responses in the order of five to ten years, and (b) that behaviour changes more swiftly for those whose lives change in some important way, it is of interest to consider the natural incidence of underlying demographic, economic or social processes. For the South Yorkshire panel sample, Goodwin (1984) summarises the time profile of events from those reporting experiences, in the previous ten years, of moving home (47% of respondents), moving job (38%), birth of a new child into the household (21%), changes in the level of car ownership (23%), and a period of unemployment (22%).

Figure 4J: Time scale of important life-events



4.4 Discussion and reinterpretation of the case study findings

The findings about the innate natural variability in travel behaviour provide the necessary context for understanding the behavioural responses implied by the case studies. When judged against this 'background' of change, the proportions of people in the case studies who cite a wide range of changes in their behaviour following a change to travel conditions become comprehensible.

The findings also imply that a proportion of people who accurately report that their behaviour has changed, will be *in*correctly attributing this change to the transport scheme under consideration. In other words, they would have changed their behaviour anyway. This is where the aggregate results become crucial: the case-study traffic counts indicate that more people must have changed their behaviour in one direction rather than in the opposite direction, and the econometric results establish that significant changes in long-term behaviour can result from changes in travel costs.

The incidence and pace of general changes in lifestyle are also important for the following reason. The idea that someone might make such a big decision as moving house, or changing job, simply as a result of a bus lane, does not seem intuitively acceptable. But when such major changes are happening all the time - mostly, of course, for other reasons - it is quite reasonable to suppose that the prevailing transport conditions should tip the balance, and should also influence the specific nature of the new travel patterns which are subsequently formed.

Therefore, the finding in the case studies that an 'unexpectedly' large proportion of people appear to vary their travel choices following a change in road conditions, makes much more sense if it is recognised that these choices themselves are continually being made and remade. Moreover, transport changes, though only one factor in the decision making process, are provided with a ready mechanism to influence the outcome.

This view of individual choices underpinning aggregate traffic flows leads to the following description. The response to changes in travelling conditions will be composed of at least two quite different processes. First, there are responses by specific individuals, limited by habit, the desire to experiment (or not to), ignorance, preferences, and by binding - but not permanent - domestic and economic constraints. For these people, minor adjustments may be quite swift, but bigger changes proceed at the pace of change in their own lives, and the pace of evolution of their attitudes and tastes. Second, each day or year, some individuals simply leave the system, and are replaced by different people making a new set of trips. These, being new, can react to whatever prevailing conditions they find, sometimes bringing a more open mind to the new situation.

Thus observation of a bus priority scheme in which bus use has gone up and traffic has been reduced, can only be *fully* understood if it is recognised that even without the scheme there would have been at least seven groups of people: those who would have transferred from car to bus, those who would have transferred from bus to car, those who would have made more journeys by bus, those who would have made fewer journeys by bus, those who would have made more journeys by car, those who would have made fewer journeys by car, and those who would not have changed their numbers of journeys by bus and car. Implementation of the scheme could be expected to affect each of these seven groups, but by distinctly different mechanisms - slowing down the loss of existing passengers, for example, is distinct from gaining new ones.

It is unlikely that, in practice, such calculations would often be done. The data requirements would be substantial, and in many cases, the difference to a policy decision would not be significant (although the focus of marketing initiatives might be redirected, and assessment of the different losers and gainers would be clearer). The distinction is, however, important for this project, since it helps to resolve the 'credibility gap' which might otherwise be implied by the discrepancy between the case study results and prior expectations.

4.5 Conclusions

The case studies suggest a range and scale of behavioural responses to changes in capacity which are greater than have often been assumed when assessing such schemes. The significance of this discrepancy has been considered in relation to evidence on the variability of traffic flows and travel behaviour.

Experiments show that for a hundred journeys to work, between 10 and 20 will be travelled with an overall door-to-door time more than 20% faster than the average, and a similar proportion will be more than 20% slower than the average. Survey evidence indicates that the vehicles making up the traffic stream are not, in general, the same set of cars from day to day. Similar instability is found in individual trip rates, choice between car use and public transport, car ownership and other measures of behaviour. This volatility provides the context within which changes in transport costs or travelling conditions can influence a wide range of choice and behaviour, building up cumulatively over several years.

Interpreting the case studies in the light of these findings suggests that: (a) there is no reason in terms of behavioural plausibility to reject the wide range of behavioural responses cited in personal surveys, or the scale and suggested structure of 'disappearing traffic' found in the traffic counts; (b) the process of adaptation to a new policy starts on day one, but may take between five and ten years before it is complete. The 'surprising' range of behavioural responses indicated in the case study literature is only surprising when considered against expectations of stable behaviour, repeated day after day, which is not the case.

These considerations strengthen the conclusion that, when there are circumstances in which an accurate assessment of 'disappearing traffic' would make a difference to the decision about whether to implement a capacity reallocation or not, it will be necessary to accept the existence of broader and longer-term behavioural responses than has been the case in the past.

Chapter 5: Summary and Conclusions

5.1 Background to the study

It is generally accepted that in most locations road capacity will not be increased sufficiently to provide for unrestrained growth in car use. For this reason, there will be increasing pressure to ensure that the best possible use is made of existing road capacity. In addition, greater attention is being focused on the role of road capacity in policies intended to reduce traffic growth, and, in some locations, to reduce the present amount of traffic.

Reallocation of a proportion of road capacity - either selectively to favoured classes of vehicle traffic, or to non-vehicle use, is of major policy interest. Measures like bus priority schemes, street-running rail systems, cycle lanes, wider footpaths and pedestrian areas, where well-designed and appropriate for their context, can help to achieve a more efficient use of road space, improve the attractiveness of non-motorised modes, increase accessibility to specific locations, bring about environmental improvements, enhance street attractiveness and improve safety.

Such measures raise public relations, political and practical considerations, in which the technical feasibility of measures to reduce capacity is a key relevant issue. Feasibility is sometimes calculated on *the assumption that all traffic displaced from one street will simply divert to another*. Since those other streets may also be suffering from congestion, calculations which use this assumption, whether carried out manually or via a computerised traffic model, have sometimes produced forecasts of such unacceptable congestion that they have been caricatured as 'traffic chaos'. On occasion, concern that this 'traffic chaos' will happen has been so strong that it has led to measures being rejected, or implemented in a reduced form.

But there have been increasing suggestions that such forecasts may not be well-founded, particularly since (a) there is now practical experience that many cities have implemented policies to reallocate road space successfully, and (b) SACTRA (1994) concluded that increases in road capacity in congested conditions were likely to *induce* additional traffic. Therefore, by symmetry, it might be expected that a reduction in capacity would lead to some overall *reduction* in traffic volume, in which case the displaced traffic would cause less severe congestion than expected.

5.2 Theoretical evidence

Theoretical approaches, and their development in wider practice, give some guidance on these questions, as follows.

- The theory of traffic flow and assignment reveals circumstances in which the reallocation of road space to higher capacity vehicles might give overall improvements in speed and mobility. This is because, whilst capacity for private vehicle movements might decline, overall capacity for *people* movements can be increased.

- Considerations of previous appraisal methodologies, network topology, market distortion, feedback effects, and the non-transport functions of streets also identify particular conditions where there may be greater provision of road capacity in some locations than is economically optimal, even in the presence of congestion.

- Emerging theories of travel choice and behavioural response reveal that people's reactions to changes in travel conditions may be complex and wide-ranging, especially in comparison to the assumption that a change of route may be the only response made by drivers as a result of reductions in capacity on the route they currently use.

However, theoretical arguments relating to the reversibility of behaviour suggest that it should not be taken for granted that simply reversing SACTRA's 'induced traffic' results will produce the correct estimate of suppressed traffic, especially in the short run.

5.3 Empirical evidence

Many cities, either not provided with dissuasive modelling forecasts, or disbelieving them, have introduced measures to reallocate road space away from cars. In general, they report that there has often (but not always) been a fairly short period of traffic disruption, but that 'gridlock' or 'traffic chaos' are rare, and never last longer than a few days, as traffic adjusts relatively quickly to new conditions. Sometimes there has not even been a short term problem. Two characteristic comments from local transport planners are: *"it'll be all right by Friday"*, and the ubiquitous *"the traffic has disappeared and we simply don't know where it has gone to"*.

This research has assessed the empirical evidence that bears on these claims. Experience is reported from:

- situations where capacity allocation has changed as a result of direct policies like bus lanes or pedestrianisation;

- situations where capacity has been reduced as a side-effect of maintenance or structural repairs; and

- situations where capacity has been reduced as a result of natural disasters such as earthquakes.

Clearly, the political and public relations aspects, and associated other changes in the location, are quite different in the case of an unexpected emergency and a carefully planned policy. But the range of behavioural responses open to people may be rather similar, and therefore evidence from all these situations helps in understanding the nature of such responses.

Altogether, evidence from over 100 places has been studied. Over 60 are primary case studies from locations in the UK, Germany, Austria, Switzerland, Italy, The Netherlands, Sweden, Norway, the USA, Canada, Tasmania, and Japan. These have been reported together with supporting evidence from related surveys in many other locations. The UK studies include major town centre traffic schemes (eg. Cambridge, Edinburgh, Wolverhampton, City of London); bus priority measures (eg Belfast, Bristol, Cardiff, Oxford, London); and bridge closures (eg London Tower Bridge, Westminster Bridge, Hammersmith Bridge; York Lendal Bridge). The studies have been based on a range of methods, including road-based and cordon-based traffic counts, roadside interviews, repeated cross-sectional travel surveys, and panel surveys.

Available evidence shows a very wide range of results. The sample of case studies for which complete traffic information could be calculated shows an unweighted average reduction in traffic on the treated road or area of 41%. Less than half of this reappears as increased traffic on alternative roads, at the same or different times of the day. Thus the average overall reduction in traffic was 25% of that which used to use the affected road or area. These averages are influenced by a few extreme results - in two cases the overall reduction in traffic was greater than all of the traffic originally travelling on the treated roads, and in seven cases there was an overall traffic increase. The median average, which is less affected by outlying results, indicates that 50% of cases showed overall traffic reductions, taking affected and alternative roads altogether, which were greater than 14% of the traffic which originally used the affected road. If the 9 exceptional cases mentioned are excluded, 50% of the remaining locations showed overall reductions of more than 16 % of the original traffic on the affected roads.

Taking each of the studies separately, detailed examination shows that in every case there are caveats and problems in obtaining absolutely definitive results. Problems arise because monitoring is usually done for a different purpose. Screenlines for traffic counts are rarely completely reliable and often cover a rather small area, but however large the area, there is always the possibility that some changes to even more distant routes are missed. Some counting methods are proportional to the number of trips, and others proportional to the mileage travelled, and these are not always reconciled. Surveys of behaviour usually do not cover a long enough period of time, are not always carried out at the most appropriate intervals, and rarely use techniques which can identify the underlying changes in individual behaviour behind the net changes in aggregate quantities. Available reports, written for specific local purposes, often omit some pieces of information which would be relevant to this study, and require some interpretation. In addition, in many cases, other transport changes have also been implemented in the same period, such as opening a new bypass, or improving public transport services. Four main potential sources of systematic bias were identified. These were:

- *Day-to-day variability in traffic not allowed for in one-day traffic counts.* This is almost certain to result in an overestimate of the range of results from lowest to highest, but does not, by itself, cause bias to expected mean values.

- *Journey detours may be longer-distance than captured in cordon counts.* Logically, such detours are always possible, and would result in some increase in traffic outside the studied area, and hence, an overestimate of the measured reductions in traffic. The likely size of this effect will be influenced by the availability of alternative routes outside the studied area, and the proportion of trips whose origin or destination is sufficiently far away from the affected roads that longer-distance detours are realistically more attractive than any other behavioural response. Selection of counting locations in most studies was decided by local professionals, who considered that they had caught the routes and roads for which traffic effects were likely to be important. For the few examples with surveys where individuals were asked to report on their responses, long distance detours were not recorded as a very common phenomenon.

- *Traffic growth occurs due to other factors like increased income and car ownership.* If this is not allowed for in before-and-after studies, it will lead to an underestimate of the decrease in traffic due to capacity reduction, and this underestimation increases as the period of the study lengthens. The extent to which traffic reduction is underestimated relates to the magnitude of the traffic growth that would be expected as a result of increases in income, car ownership and similar factors, assuming road capacity remained constant. In many circumstances, it is therefore estimated to be in the range of 1%-4% per year. If road capacity itself has increased elsewhere on the network, this will similarly tend to result in an increase in traffic masking the effect where capacity has been reduced.

- *Partial sampling*. If a survey-based study is confined exclusively to the users of the road before the capacity reduction, it can observe people who reduce their use but will not observe offsetting former non-users who increase their use, resulting in an overestimate of the estimated reduction in travel.

Where these potential sources of bias apply, the analysis has not made adjustments to compensate for these effects, but has drawn attention to the issues in relation to the particular case studies. The second and third effects mentioned are those cited most frequently in discussions on interpretation, and can apply to many of the case studies. They pull in opposite directions, and the crucial question is the net balance between them. For any given relative magnitude of the two effects, the net effect will logically be progressively more influenced by considerations of general traffic growth, the longer the time period of a study. The reader should therefore be (relatively) more alert to the possibility of overestimating the traffic reduction effect in the short term studies, and underestimating it in the longer term studies. This interpretation is reinforced by substantial empirical evidence on aggregate demand elasticities, and is consistent with pervasive evidence on the importance of other behavioural responses in addition to route change.

Given all these caveats, it is notable that the results of the studies taken as a whole do not simply show random variation and uncertainty, and central values are certainly not clustered randomly around the 'zero' mark, as might be expected given so many potential, and conflicting sources of bias. Instead, the majority show a reduction in counted traffic. Hence, whilst each individual example may fall short of being a 'perfect' case study, to find so many cases of reductions in traffic, at a time when increasing car ownership and general traffic growth create prevailing expectations of increases, shows a balance of evidence that a proportion of traffic can indeed 'disappear' when capacity is reduced.

These figures relate in most cases to relatively well-defined schemes or events on specific roads. Rather different considerations apply to the scale of effects where there have been much more ambitious reallocations of capacity, notably in some German cities, with pedestrian areas covering most or all of the traditional town centre, bus priority, cycle lanes, and traffic calming, all constituting long-term strategies rather than specific schemes. In particular, Freiburg, Luneburg, Munich, and Nurnberg are known internationally for highly successful policies carried out over more than two decades, which have transformed the town centres, increased public transport use, and are very popular in the cities. The results of specific closures in these circumstances have been influenced by the prevailing trends in the city as a whole. At the other extreme, the bypasses constructed in towns covered in the British 'Six Towns Bypass Project' seem to have induced more extra traffic than any reductions brought about in most of the town centres that they relieved.

5.4 Understanding the results

It would be wrong to use as a universal rule-of-thumb a presumption that 16%, or 25%, (or any other standard percentage) of traffic will conveniently disappear as a matter of course whenever road capacity is reallocated. It would also be wrong to assume that *no* traffic will disappear, particularly in situations where continuance of existing traffic levels would imply significant changes to traffic speeds. The effects of a particular capacity reduction will be substantially influenced by the circumstances of the case.

- **Reductions in traffic only occur given certain network conditions**

It is apparent that the size of the change in traffic flows, and individual choices in response to a capacity reduction, can vary considerably. Analysis of the evidence suggests that three different situations can be broadly defined, with correspondingly different responses to each.

- In some cases, in spite of a strong local perception that capacity for cars has been reduced, closer examination shows that this is an illusion: there has been no real reduction at all in effective capacity, because any reductions on the treated road are offset (and sometimes more than offset) by capacity increases on other routes, or by changes in traffic management, or by spontaneous changes in driving styles which pack more vehicles into the same space. *In these situations, there is little or no change in overall traffic levels, congestion or traveller choices.*

- In a second group of cases, there is a real reduction in capacity on the treated route or area, but it does not 'bite' because there is still adequate spare capacity on alternative routes, or at other times of day, and there are no measures to discourage people using this. *In these situations, traffic does decrease in the place or at the time when it would experience (and cause) an unacceptable level of congestion, but it reappears on some other road or at some other time*, as people change the route they take or adjust their journey time. Hence, congestion spreads out over time and space, but the overall number or pattern of trips, and vehicle mileage, are less affected.

- The third group of cases, which would be of greatest importance if there were to be a substantial expansion of measures reallocating road capacity, are situations where capacity is significantly reduced, and there is not adequate spare capacity on alternative routes or at acceptable other times, due either to the nature of the network, the prevailing level of congestion or the comprehensiveness of the scheme. *In these situations, traffic counts and surveys suggest on balance that - as well as rerouting and retiming - a proportion of traffic does 'disappear', due to a very extensive set of behavioural responses.* These include, but are not confined to, changes in choice of mode, destination and trip frequency. These responses differ from individual to individual, and from place to place.

The available evidence is consistent with the following suggestion on the combined effect of these three situations: *traffic does 'disappear' in response to reductions in road capacity, but only to the extent that it needs to do so.* This occurs due to responses by a proportion of drivers who take action to avoid what they consider, in relation to their prevailing experience, to be unacceptable conditions. It should be noted that responses by some drivers to improve their own travel conditions may put greater stress on other roads. The added congestion will not be as much as would be produced if the total journey pattern remained unchanged. It is rarely significantly more intense than the already endemically bad levels of congestion that many towns experience. However, extra congestion can take the form of an extension in both space and time, unless other measures are taken to discourage this. These are broadly the same measures which may be required at a later date in any case, if traffic growth is expected to continue for other reasons.

- **Behavioural responses partly depend on 'natural' variability in behaviour**

The nature of the responses made by drivers has been a subject of close attention in the research. The traffic counts and survey analyses indicate a wider range of behavioural change than is often assumed.

Responses which have been identified in the case studies are given in Figure 5A.

Figure 5A: Changes in behaviour as a result of capacity reductions

- changes in driving style;

- moderate and more extreme changes in route;
- moderate and more extreme changes in the time at which the journey is made;

- making a journey to a different destination;
- changing frequency of journeys;
- changing mode of transport;
- differential responses by journey purpose (non-work trips giving way to work trips);
- car sharing:
- consolidating trips to carry out several different purposes in the same round trip;
- changing the allocation of different tasks within a household (errand-swopping);
- elimination or suppression of trips;
- changes in job location;
- changes in housing location; and
- changes in developer choices for locating new developments.

Most studies which looked at responses have found some combination of some of these changes, although the combination varied, and no single study identified them all.

Given that this range of responses is wider than would usually be allowed for in planning traffic schemes, the credibility of the findings has to be judged by reference to other associated evidence, particularly in relation to the degree and type of variation in behaviour that might be expected even if the scheme had not been implemented.

Analysis gathered from a wide range of sources reveals that apparently stable traffic flows at the aggregate level consist of a very large period-to-period variation in behaviour by the individuals making those journeys. As a result, a substantial proportion (usually more than 30%, and anything up to 80% for a longer period or for more tightly defined trips) of *the traffic observed in an 'after' survey usually consists of **different people** from those observed in a 'before' survey.*

One reason for this is random variation, which is often at a level where it may be difficult to detect, or dismiss, significant changes in traffic from one-day traffic counts alone. But it also occurs because, even within a year, a significant proportion of people change their house or job location, car ownership level, household structure, income and other factors. Each of these changes requires or enables them to change their travel patterns.

As a result, the behavioural responses to changes in road capacity or other conditions of travel are composed of at least two distinctly different processes, as follows.

- Responses by a stable population of individuals, limited by habit, preferences, and constraints on their choices. For these people, minor time-of-day and route changes may be made within their current circumstances, but other responses are likely to proceed at the pace of other changes in their lives - very quickly for a small proportion, but slowly and cumulatively for the group as a whole.

- Responses due to the departure of some individuals from the population making use of a particular road, and their replacement by new people making a new set of trips. These people are swiftly able to take account of the new network conditions.

The balance between the two processes is determined, in part, by demographic and socio-economic developments. Taken together, the two processes explain why the full effect of a change in conditions may take a long time to be complete, but some changes (even affecting 'big' decisions like choice of location or trip frequency) can start very soon.

- **Behavioural changes vary over time**

The research has considered evidence on the speed of change drawn from: (a) the natural demographic pace of events; (b) empirical analysis of the changeability of individual travel behaviour shown in panel surveys of the same individuals over time; (c) aggregate econometric analysis of the size and speed of responses to transport changes such as travel costs; and (d) the period of observation of the case studies.

The first three sources of evidence all indicate that a full response to a particular transport change may take between five and ten years to complete, although the largest impacts are usually in the first one to three years.

The case study evidence also contains strong indications that the measured response to capacity reductions is different in the short, medium and long term. However, the time profile does not seem to follow the same path in all locations.

In the first few days, there is a volatile and uncertain range of experience. In some cases, there are longer queues and worse congestion than usual. In other cases there is no problem even from the first day, often to the surprise of local press and residents. The most likely explanation for these differences is the extent of (convincing) advance publicity and information, compared to a learning period based on experience, and the successive responses each day to the changing experience of the previous day.

During the first year, after the first adjustments, there tends to be a more settled period, as traffic adjusts to new conditions. Aggregate flows will tend to be variable from day to day, and subject to seasonal and trend effects, but not obviously more so than was previously the case.

In the longer run, different case studies have revealed two different patterns, as follows.

- In some cases there is a tendency for an initial traffic reduction to be offset by subsequent re-growth. Local reports often describe this with comments like "*the displaced cars gradually creep back onto the roads*", implying that behavioural responses are short-lived. Strictly, this interpretation can only be made if it is possible to distinguish between traffic growth due to a return of the same displaced drivers, and traffic growth due to latent demand, increases in car ownership, income etc. This distinction is rarely made, but considerations of variability discussed above suggest that a relatively small proportion of the subsequent growth in traffic is likely to unambiguously be a re-appearance of the originally displaced traffic.

- There are other cases where the longer run effect is not an erosion of the traffic reduction, but a build-up, *ie* the longer-run reductions in traffic are greater than those which occur at first. This may be seen as analogous to the tendency for longer-term elasticities to be larger than short-term elasticities. Even in this case, other traffic trends may be masking the *size* of such a build-up of effect, but they do not obscure its existence.

In principle, both scenarios can be consistent with an increase over time in the reduction in traffic due to the capacity reduction, offset by growing traffic levels for other reasons, and the different experience may be due to the relative size of the two effects. The distinction between the two outcomes partly seems to arise from the other policies which are in operation at the same time, in the area and in the town as a whole, and by the degree, type and credibility of publicity and marketing.

5.5 Implications

- **Assessing the effects of schemes in advance**

The results have complex implications for those who wish to forecast the effects of a reduction in road capacity in advance. A first useful step may be to estimate what would happen with no allowance for any reduction in traffic. If the traffic can still fit comfortably into existing road capacity (perhaps assisted by changes in driving styles or some additional traffic management), then no further complications are likely to arise. However, if such changes would cause significant traffic problems, simple adaptations in behaviour should be expected, especially diversions in routes and changes to the time at which people travel. If opportunities to make these changes are restricted, or if significant traffic problems would still remain, then some or all of the very many other responses are likely. Together, these are likely to give the effect that a proportion of the traffic disappears from the area under consideration. If a forecast suggests prolonged congestion of an intensity which is substantially greater than the prevailing traffic conditions of the town, then it is *prima facie* likely that it has underestimated the scale of behavioural response. This suggests a hierarchical modelling approach, in which complex effects only need to be modelled if simpler assumptions suggest traffic conditions which are noticeably worse for a proportion of drivers, and if assessment of the scheme is dependent upon these traffic conditions.

A separate report, by MVA (1998), considers the modelling implications of capacity reductions more fully, exploring the nature of the hierarchical approach that would be needed, and the further research which is required to enable comprehensive modelling of the changes in traffic following a highway capacity reduction. As explained in their report, initial assignment procedures (either manual or computer-based) can provide a useful starting point to assess worst-case traffic diversion, to identify likely traffic blackspots which would require further traffic management measures, and to calculate related cost changes. When the cost changes implied are significant, progressively more complex demand responses will need to be modelled.

Notably, comments about forecasting procedures have been received from many cities with practical experience of successfully implementing major reductions or reallocations of capacity. Many argue that they do not want to rely too much on simple traffic models (which they consider would be misleading) or on complex models (whose development they perceive to be out of proportion to the scale of the schemes involved), preferring to depend more upon local knowledge, professional judgement and policy insight. Many state that this does not necessarily reduce the quality of design of schemes, and that if there are real doubts, it can be preferable to go ahead with schemes on a trial basis so that they can be modified, after a reasonable period, if problems arise. These comments serve as an important reminder that the decision how - and whether - to use transport modelling is a positive decision to be taken on its merits in the specific circumstances, not a text-book procedure which should always be followed.

- **Policy and implementation**

There are cases where capacity has been reallocated with little or no resulting reduction in traffic, but also without making congestion substantially worse. These cases suggest that there may still be some opportunities for reallocating or reducing road capacity (and bringing about associated benefits), without causing much change in travel patterns or traffic levels.

In other cases, scheme appraisal would usually include an assessment of the relative scale of the **disbenefits** suffered by people whose travel conditions or opportunities are worse than they would otherwise be (for example, because they are forced to travel by a less preferred route, time, or mode), and the **benefits** enjoyed by those whose circumstances are improved (eg by better bus services, improved conditions for walking and cycling, and better air quality). The results of this study are significant for the calculation of this balance. They suggest that for schemes whose initial effects on traffic are substantial, the responses that are likely to occur are generally of a form which would reduce the estimated amount of congestion and traffic-related environmental damage (or slow down its rate of increase), and hence the overall social benefits of the scheme are increased, *compared with* the serious impacts there would be if all traffic simply reappeared on another route. Thus, the net benefits taking account of traffic reduction will be greater than the benefits if there is no traffic reduction. Some disbenefits will, however, normally still exist. These arguments are identical (in reverse) with the SACTRA analysis of the effects of increasing capacity, namely that the extra costs of congestion caused by induced traffic in congested conditions are likely to be greater than the extra benefits to the induced traffic itself, and therefore, in these circumstances, even though the scheme may still have a positive net benefit, this will be smaller.

There is evidence that responses differ according to local conditions, and local policies. In particular, the way in which people respond to a capacity reduction, and the types of changes that they make will be determined by:

- the nature of the network and existing levels of congestion;
- the type of trip affected;
- the relative attractiveness of alternative locations;
- other factors influencing car use, particularly parking controls;
- the real or perceived attractiveness and availability of other modes;
- the specific design details of the scheme; and
- information and marketing.

Hence, the general policy framework in which changes are made, the specific ways in which a capacity reduction is implemented, and the various other policies or road alterations occurring in the study area at the time, will all significantly affect how traffic reacts, and can be used to determine whether the net result of the capacity reduction is perceived to be positive or negative.

In this policy area, as in others, when evaluating schemes, it will obviously be necessary to consider wider possible effects than the traffic impacts investigated in this project, including safety, accessibility, environmental impact, and the social and economic consequences. All of these issues will be vitally important in determining the overall desirability and success of changes to a particular road network, though it was beyond the scope of this report to consider them. A full treatment of these issues would require further investigations.

In terms of the issue addressed here, the balance of evidence is that measures which reduce or reallocate road capacity, when well-designed and favoured by strong reasons of policy, need not automatically be rejected for fear that they must inevitably cause unacceptable congestion. The effects of particular schemes will be reinforced or undermined by network conditions, and by the sticks and carrots of other policies, in a time-scale which is continually determined by wider choices about home, work and social activities. Specifically, the most important responses to a scheme may be governed by the extent to which the scheme tilts the balance in decisions that many people will be making anyway, during the natural development of their lives. Hence, the research reinforces the need for an integrated transport policy which takes account of the interaction between transport and other activities, as well as the interaction between different elements of the transport system itself.

CASE STUDIES OF CAPACITY REDUCTIONS

1 Aarau 1983-1994 (Switzerland)
2 A13 closure 1996 (Netherlands)
3 Belfast - bus lanes on Ormeau Road 1992-95
4 Bern 1980-81 (Switzerland)
5 Bologna 1972-1993 (Italy)
6 Bristol - bus lanes 1991-94
7 Cambridge Core Scheme phase 1, 1997
8 Cardiff - bus lanes 1994-96
9 Coventry - closure of A4114, 1983
10 Dutch Railway Company strikes 1992 (Netherlands)
11 Edinburgh - Princes St. closure 1996
12 Edmonton - Kinnaird Bridge closure 1979 (Canada)
13 Frankfurt am Main 1988 (Germany)
14 Freiburg 1960-1997 (Germany)
15 Gothenburg 1970-1984 (Sweden)
16 Greater Manchester - general
17 Hamm 1992 (Germany)
18 Hanshin-Awaji or 'Kobe' earthquake 1995 (Japan)
19 Hobart - Tasman Bridge collapse 1975 (Tasmania)
London:
20 A104 Lea Bridge Road - bus lanes 1994
21 Grove Lane/Champion Park closure
22 Hammersmith Bridge closure1997
23 Orpington High Street closure 1996
24 Oxford Street closure phase 1 1972
25 Partingdale lane closure 1997
26 Ring of Steel 1993
27 Tower Bridge closure 1993
28 Westminster Bridge 1992-97
29 Los Angeles - Northridge earthquake 1994 (USA)
30 Lowestoft 1997
31 Lucerne 1993-94 (Switzerland)
32 Lüneburg 1991-94(Germany)
33 Munich 1970-1995 (Germany)
34 New York 1973 (USA)
35 Norway - Street Enhancement Programme 1991-95; Oslo 1997
36 Nottingham Zones-&-Collar 1975-76
37 Nürnberg 1988-1994 (Germany)
38 Oxford - road closures and bus lanes 1974
39 Portsmouth - road works 1995
40 San Francisco - Loma Prieta earthquake 1989 (USA)
41 Sheffield - Supertram 1994-1995
42 Six Towns Bypass Project - phase 2 1992-95
43 Toronto - bus lanes 1990 (Canada)
44 Wiesbaden 1991 (Germany)
45 Wolverhampton 1987-1991
46 York - Lendal Bridge closure 1978-79
47 Zurich 1980-1992 (Switzerland)

CASE STUDIES BY COUNTRY

UK

Belfast - bus lanes on Ormeau Road 1992-95
Bristol - bus lanes 1991-94
Cambridge Core Scheme phase 1, 1997
Cardiff - bus lanes 1994-96
Coventry - closure of A4114, 1983
Edinburgh - Princes St. closure 1996
Greater Manchester -general
London:
- A104 Lea Bridge Road - bus lanes 1994
- Grove Lane/Champion Park closure
- Hammersmith Bridge closure1997
- Orpington High Street closure 1996
- Oxford Street closure phase 1 1972
- Partingdale Lane closure 1997
- Ring of Steel 1993
- Tower Bridge closure 1993
- Westminster Bridge 1992-97

Lowestoft (Suffolk) 1997
Nottingham Zones-&-Collar 1975-76
Oxford - road closures and bus lanes 1974
Portsmouth - road works 1995
Sheffield - Supertram 1994-1995
Six Towns Bypass Project - phase 2 1992-95
inc. Berkhamstead (Hampshire), Dalton (Cumbria), Wadebridge (Cornwall) and Whitchurch (Shropshire).
Wolverhampton 1987-1991
York - Lendal Bridge closure 1978-79

Europe

Germany
Frankfurt am Main 1988
Freiburg 1960-1997
Hamm 1992
Lüneburg 1991-94
Munich 1970-1995
Nürnberg 1988-1994
Wiesbaden 1991

Switzerland
Aarau 1983-1994
Bern 1980-81
Lucerne 1993-94
Zurich 1980-1992

Italy
Bologna 1972-1993

The Netherlands
Dutch Railway Company strikes 1992
A13 closure 1996

Norway
Oslo 1997
Street enhancement programme 1991-95
inc. Batnfjordsøra (Møre og Romsdal), Os (Hedmark), Rakkestad (Østfold) and Stryn (Sogn og Fjordane)

Sweden
Gothenburg 1970-1984

Rest of the world

Canada
Edmonton - Kinnaird Bridge closure 1979
Toronto - bus lanes 1990

USA
Los Angeles - Northridge earthquake 1994
New York 1973
San Francisco - Loma Prieta earthquake 1989

Japan
Hanshin-Awaji or 'Kobe' earthquake 1995

Tasmania
Hobart - Tasman Bridge collapse 1975

CASE STUDIES BY STIMULUS FOR ROAD CAPACITY REDUCTION

Changes to city centre area/ major central street
Bern 1980-81
Bologna 1972-1993
Cambridge Core Scheme phase 1, 1997
Edinburgh - Princes St. closure 1996
Freiburg 1960-1997
Gothenburg 1970-1984
Hamm - Wilhelmstrasse narrowing 1992
London: Orpington High Street closure 1996
London: Oxford Street closure phase 1 1972
London: Ring of Steel 1993
Lüneburg 1991-94
Munich 1970-1995
Nürnberg 1988-1994
Oxford - road closures and bus lanes 1974
Wiesbaden 1991
Wolverhampton 1987-1991
Zurich 1980-1992

Introduction/extension of bus priority measures
Belfast - bus lanes on Ormeau Road 1992-95
Bristol - bus lanes 1991-94
Cardiff - bus lanes 1994-96
London: A104 Lea Bridge Road - bus lanes 1994
Oxford - road closures and bus lanes 1974
Toronto - bus lanes 1990

Closure of a particular street
Aarau 1983-1994
London: Grove Lane/Champion Park closure
London: Partingdale Lane closure 1997
London: Westminster Bridge 1992-97
New York 1973
Norway - Oslo 1997

Medium-term road or bridge closure for repairs
Edmonton - Kinnaird Bridge closure 1979
Frankfurt am Main - bridge closure 1988
Hobart - Tasman Bridge collapse 1975
London: Hammersmith Bridge closure1997
London: Tower Bridge closure 1993
Munich bridge closure 1988
Portsmouth - road works 1995
York - Lendal Bridge closure 1978-79
Zurich - Europa Bridge closure 1991-92

Short-term closure due to maintenance work, strikes, etc.
A13 closure in Netherlands 1996
Coventry - closure of A4114, 1983
Dutch Railway Company strikes 1992
Lowestoft Harbour Bridge closure 1997
Lucerne 1993/4

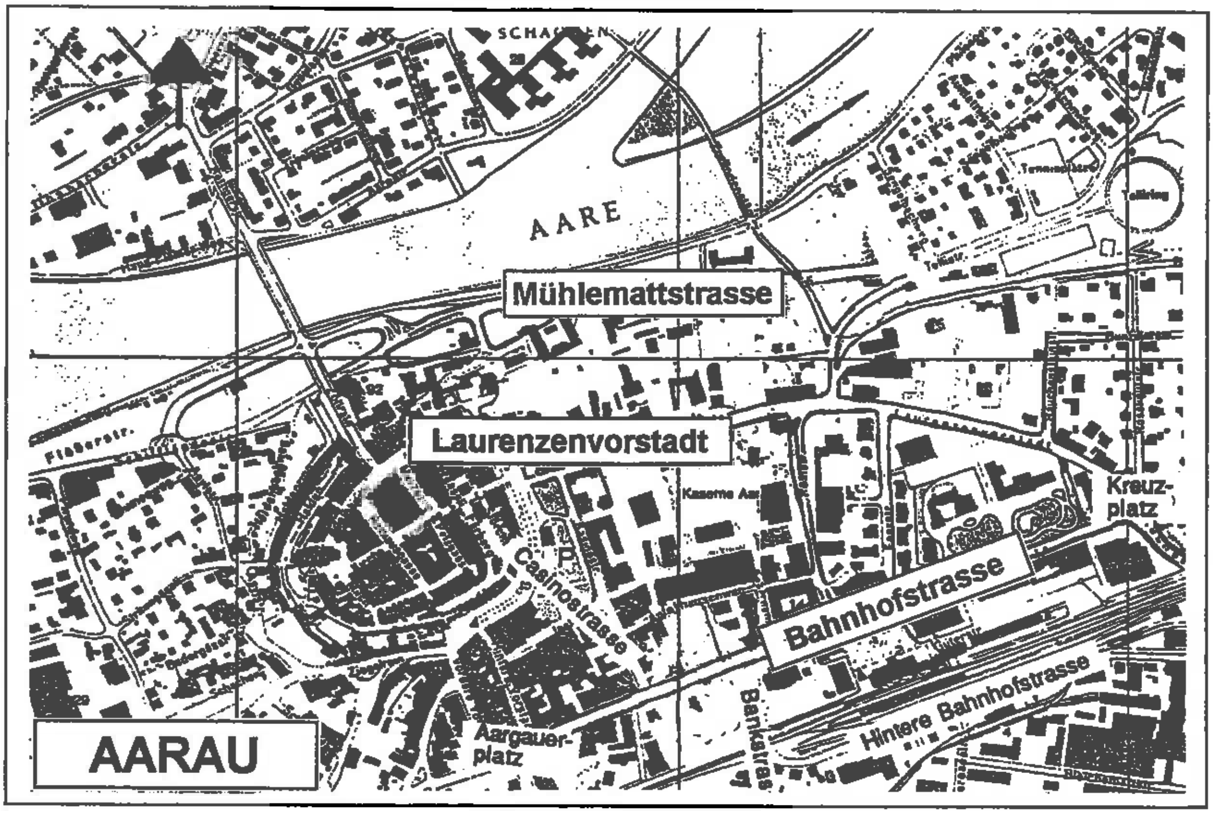
Earthquake disruption
Hanshin-Awaji or 'Kobe' earthquake 1995
Los Angeles - Northridge earthquake 1994
San Francisco - Loma Prieta earthquake 1989

Other
Greater Manchester -general
Nottingham Zones-&-Collar 1975-76
Sheffield Supertram 1994-1995
Norway Street Enhancement Programme 1991-95
Six Towns Bypass Project - phase 2 1992-95

** Some locations are mentioned twice, as they fall into several categories. Notably, most of those classified as 'changes to city centre area/major central street', have usually involved some introduction or extension of priority measures for buses, cyclists and pedestrians, as well as reductions in road capacity for private motorised traffic.*

1. Aarau 1983-1994

Sources: Berg, W. & Bärtsch, D. 1995, Aarau Stadt, Internet Information



Aarau is a small town of 16,000 inhabitants, not far from Zürich, with a population of about 74,000 living in the region.

The focus of this study was the long-term effects of road capacity changes on three roads. All three were leading to and passing the city centre between east and west.

Over 1983-1988, traffic flows increased on all three roads. According to the sources, traffic flows were constant on two roads during the evening rush hours whereas they increased on the third road (no separate figures are given for the rush hours). In this period drivers were able to find an alternative route - the third road (Mühlemattstrasse).

Traffic Flows between 1983-1988/24 hours for weekdays			
Street	1983	1988	Difference in %
Bahnhofstrasse	18,600	19,000	2
Mühlemattstrasse	12,000	15,600	30
Laurenzenvorstadt	12,300	13,000	6
Total	42,900	47,600	11

Between 1988 and 1994 a small side street off a major road (Bahnhofstrasse) was closed, which had the effect that some of the traffic could not divert and all traffic was squeezed into Bahnhofsstrasse or the other two roads. According to the authors, in 1994 all three roads were at their capacity limits so that during the evening rush hour drivers could not change their route, though the time of day of their trips may have been changed.

Average daily Traffic Flows over 7 days between 1988-1994/24 hours				
Street	1988	1994	Difference	in %
Bahnhofstrasse	18,292	17,244	-1,048	-5.7
Mühlemattstrasse	14,611	16,921	2,310	15.8
Laurenzenvorstadt	11,901	13,172	1,271	10.7
(Kaserne)				
Total	44,804	47,337	2,533	5.7

Traffic Flows during the evening rush hours									
	1988				1994				Change
Hours	'B'	'M'	'L'	Total	'B'	'M'	'L'	Total	in %
1500-1600	1,061	962	830	2,853	1,054	1,130	833	3,017	5.8
1600-1700	1,173	1,001	806	2,980	1,095	1,158	838	3,091	3.7
1700-1800	1,444	1,379	896	3,719	1,132	1,389	935	3,433	-7.7
1800-1900	1,275	1,187	887	3,349	1,177	1,347	912	3,459	3.3
Total Evening	6,194	5,593	4,186	15,973	5,550	6,275	4,330	16,155	1.1

'B' = Bahnhofstrasse, 'M' = Mühlemattstrasse, 'L' = Laurenzenvorstadt

Inspection of the figures suggests that during the height of the peak, 17.00-18.00, it is reasonable to suggest that all three roads were at their capacity limit. During this hour Bahnhofsstrasse declined by 21.6%, Mühlemattstrasse increased by 0.7% and the last road by 1.8%, so taken together traffic on the three roads declined by about 20% during this hour. This pattern is not valid for all the other evening hours, as there is still an increase. Between 15.00 - 19.00, Bahnhofstrasse declined by -10.4%, Mühlemattstrasse increased by 12.2% and Laurenzenvorstadt by 3.4%.

Comment:

Over a six year period, overall traffic flows on the three roads taken together increased, in spite of a reduction in capacity on one of the roads, at times where there was still available capacity on the other two roads. In drawing conclusions, traffic growth that might have been expected for other reasons, like increasing car ownership, has to be taken into account.

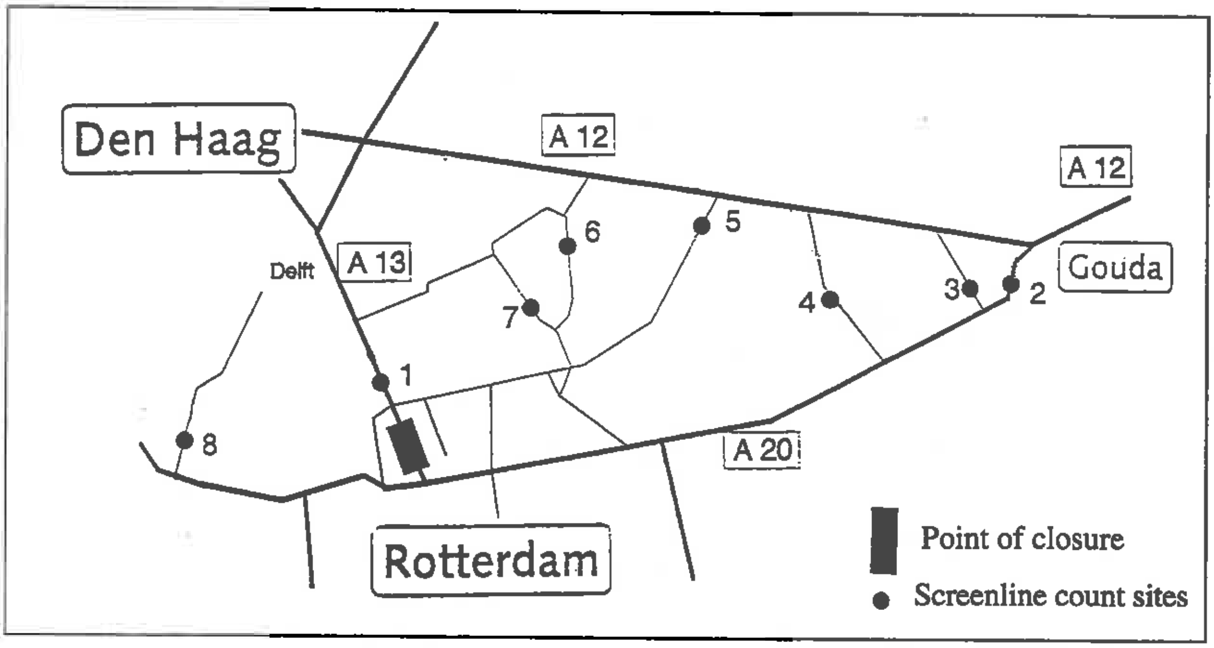
Car ownership in the district and in the town of Aarau				
	1988	**1994**	**Difference**	**in %**
District	25,461	28,216	2,755	10.8
Town	6,634	7,138	504	7.6

Source: Aarau Stadt Internet Information

During the time period in question (1988-1994) car ownership growth was nearly twice as high in the District (which would affect commuters) than in the town, and even in the town, the growth in car ownership was somewhat higher than the increase in traffic flows.

2. A13 closure 1996 (Netherlands)

Source: Horst & Egeraat (1996) - translation of key points by Henk van Mourik (1997)



During three weekends in June, the A13, a major route between Rotterdam and the Hague was closed for maintenance. It was shut in the southbound direction on June 1st and June 8th, and in the northbound direction on June 15th.

Traffic counts were carried out at eight locations, on the three relevant Saturdays, plus the Saturday before, and the Saturday afterwards for reference.

Vehicles on...	Reference	June 1st	Total
A13 southbound (1)	56,000	19,722	-36,278
Alternative routes southbound (2-8)	50,800	71,463	+20,663
Total	106,800	91,158	-15,615 (-11%)

Vehicles on...	Reference	June 8th	Total
A13 southbound	56,000	22,800	-33,200
Alternative routes southbound (2-8)	50,800	65,513	+14,713
Total	106,800	88,313	-18,487 (-17%)

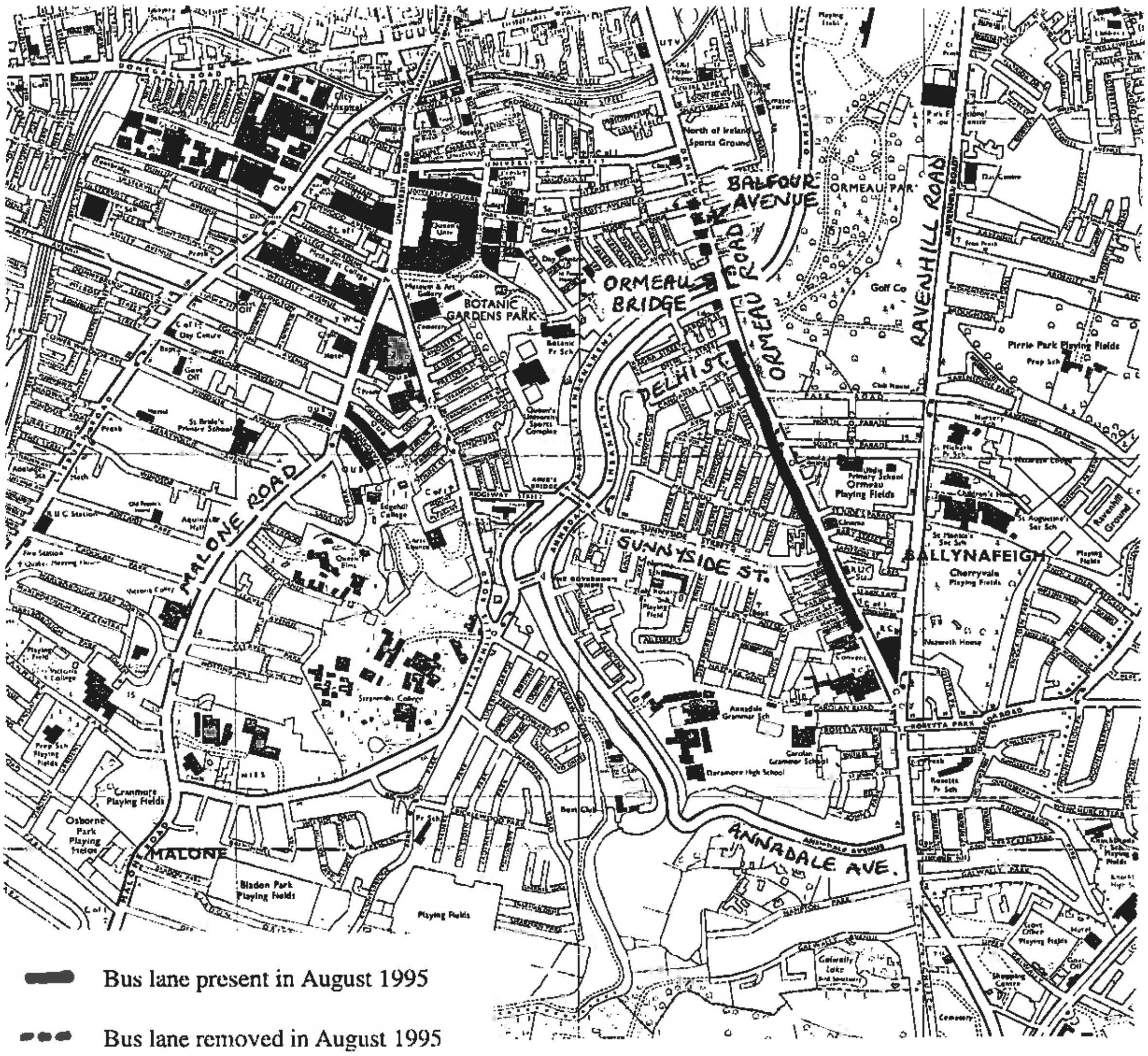
Vehicles on...	Reference	June 15th	Total
A13 northbound	54,200	26,804	-27,396
Alternative routes northbound(2-8)	52,200	67,347	+15,147
Total	106,400	94,153	-12,249 (-15%)

Comments: It is notable that traffic reductions were greater on the second weekend of roadworks. Untranslated graphs in the report suggest that there may also have been traffic reduction in the intervening weekdays. This might be interesting to pursue.

3. Belfast - bus lane on Ormeau Road 1992-5

Source: D O'Hagan 1997 (personal correspondence)

BELFAST



Between 1992 and 1995, a bus lane operating betweeen 8 and 9.30 am w as introduced and extended along Ormeau Road, one of the main routes into Belfast from the south. Two lanes of traffic were also narrowed to one at one point (near Balfour Avenue), by introducing a pelican crossing on the road. In August 1995, a section of the bus lane was removed because "capacity was being lost at Ormeau Bridge, as motorists would not use the left hand lane faced with the immediate prospect of the bus lane having crossed the bridge".

The overall effects of the bus lane were monitored before and after its implementation.

Vehicles per hour (8am-9am, citybound)	Before	After	Total
Flows on Ormeau Road (near Delhi St)	1400	1000	-400 (-29%)
Flows on Ormeau Road (near Balfour Avenue)	1700	1540	-160 (-9%)
Flows on possible diversion routes (Ravenhill Road, Annadale Avenue, Sunnyside St & Malone Rd)	"It is believed that traffic [simply] diverted", although "traffic counts proved to be inconclusive [as] there were fluctuating results"		

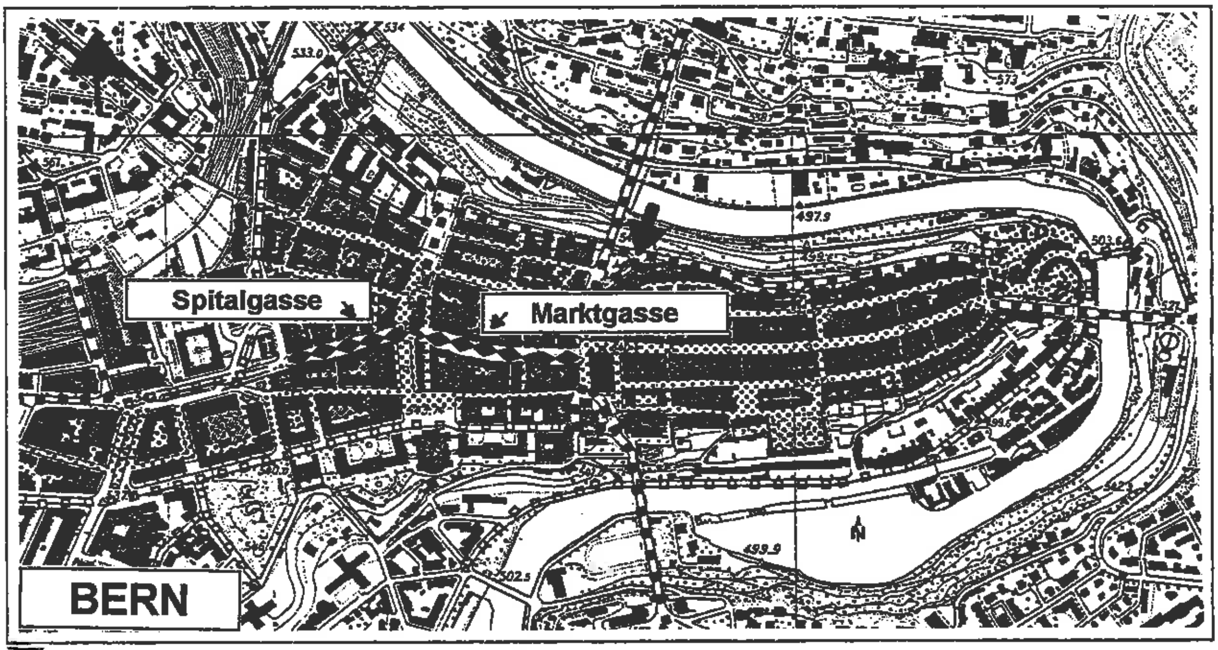
Journey times for all traffic on Ormeau Road (between Annadale Avenue & Rugby Avenue) increased by between 0 and 14 minutes, with an average increase of 2-3mins. Journey times are also "thought to have increased" on the southern end of Annadale Avenue, due to traffic diversions.

Bus times remained largely the same, with CityBuses improving by 20-30 secs, whilst Ulster buses took slightly longer. (This is because Ulster buses only set down passengers in the vicinity of the bus lanes, whilst City Buses also collect them).

O'Hagan, whose work we acknowledge in this area, notes how the particular road configuration has had locally-specific impacts on traffic. He also highlights that, generally, impacts range "from zero at the beginning of the peak period, to close to zero at the end of the peak period, rising to a maximum in the middle of the peak period".

4. Bern 1980-81

Sources: Berg, W. & Bärtsch, D. 1995, Aerni, K. *et al*



Bern is the capital of Switzerland. It has a population of 135,000 and a million people live in the region. At the end of the 1960s, some city centre streets, including the main axis (Marktgasse - Spitalgasse) and some squares and side streets, were pedestrianised. Both streets still allowed bus access, deliveries and traffic in search of car parking spaces.

In 1980, the city centre was divided into three cells in order to close the town centre to through traffic (Aerni, K. et al 1993, p.3). A study was carried out to research the effect of the 3 cell scheme on the north-south traffic. Before and after studies were carried out in June 1980 and June 1981.

Impacts on traffic

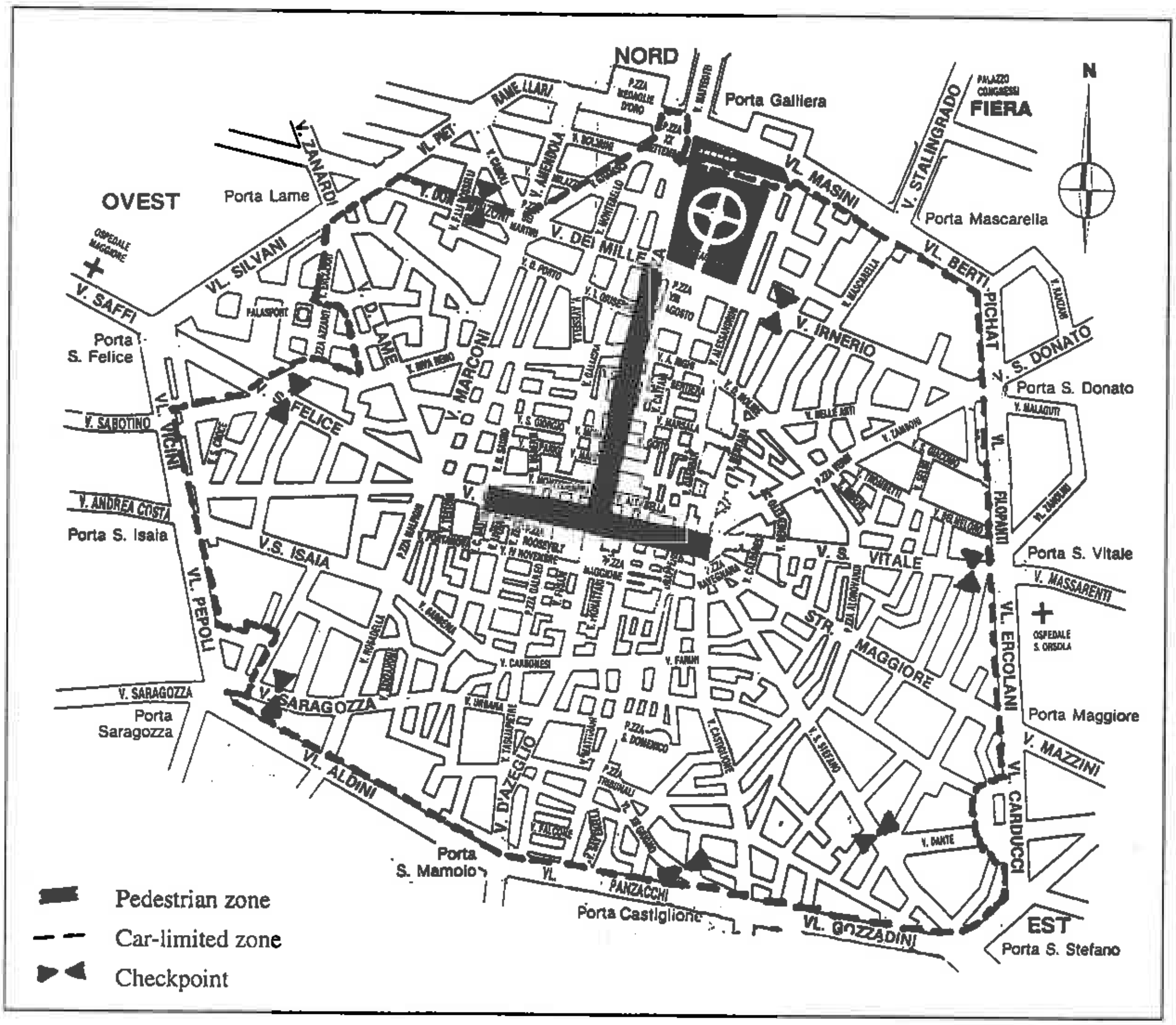
The main road leading into the town centre showed a reduction of 316 vehicles going into town during the morning rush hour and a reduction of 290 vehicles during the evening rush hour. The parallel routes, of which there were four, absorbed the traffic. There was no evidence that traffic was using a different time period or that the rush hours were lengthened or any other reaction. In the opinion of the authors this showed that there was still sufficient road capacity.

The travel time for trams on this main road leading into the city centre was reduced on average from 118 to 44 seconds. (ibid, Anhang 4).

Hence, initial data from the scheme suggests it did not result in any traffic reduction in the short term.The longer term impacts of the scheme could constitute an interesting study.

5. Bologna 1972-1993

Sources: Topp & Pharoah 1994, Donati 1994, ECOPLAN 1994, Pharoah 1992, CILT & TEST 1985



Bologna is the capital of the Emilia-Romagna province. It has a large historic centre of about 3 square kilometres, which is divided into 4 quadrants by two broad streets which meet in the centre. In 1994, there were about 54,000 people living and 80,000 people working in the old town, with approximately 400,000 inhabitants in the surrounding region. The old town is encircled by a large, four lane ring-road. Most of the regional traffic is carried by a motorway 3-4 kilometres to the north of the city.

Changes to traffic conditions in the old town have been introduced in various phases.

Attempts at traffic limitation began in 1972, including the introduction of a pedestrian area and bus lanes, and restrictions on private vehicle movements. Improvements were also made to public transport.

In 1984, a referendum on transport led to further measures, including greater access controls, parking management and extension of the pedestrian zone. In 1989, the entire old town was classified as a "zona a traffico limitato" (traffic-limited zone). Entry by motor vehicle was restricted between 7am and 8pm, although exemption permits were given for certain categories of vehicle, including residents cars, delivery vehicles and those from outside the Bologna region. The access controls were supplemented by other measures including parking restrictions. Meanwhile, approximately 7,000 park-and-ride spaces were built outside the ring road, together with additional free parking. Public transport was improved throughout the city.

In 1993, another, comprehensive plan was being developed to "guarantee the citizen and efficient and environmentally-friendly transport system that will increase communication between different parts of the city". Measures to be implemented included reductions to the number of access permits, more pedestrianisation, parking controls in the surrounding area, more bicycle routes etc.

Impacts on traffic

24 traffic entering and leaving the old town	1972	1974	1981	1989	1992
Number of vehicles	213,200*	185,500*	177,000	87,000	159,300 / 191,900*
% change since 1972		-13%	-17%	-59%	-10 / -25%

The 1981 and 1989 vehicle figures are quoted directly in the literature. The others were inferred from the % changes mentioned. The range given for 1992 is due to a lack of clarity in the sources used. Topp & Pharoah state that the reductions in car traffic were even greater than the reductions to all classes of vehicle (which have been quoted here).

Topp & Pharoah (1994) note that the traffic reductions after 1989 were "achieved without major traffic increases on the ringroad", and that "traffic flow and safety were improved". However, they note that "more recent experience is that the concept of car limitation has been eroded. The large number of permits and weak enforcement has led to increases in traffic".

Similarly, Donati (1994) quotes problems with enforcement of entry and parking controls. She highlights that some of the more ambitious plans to expand public transport in the 1980s met a number of problems, and that development of land uses in peripheral areas poorly serviced by public transport have undermined attempts to reduce traffic. Furthermore, there has been an increase in people living outside the main city, and a general growth in mobility.

Impacts on public transport / modal split

According to CILT & TEST (1989): "Between January 1972 and May 1974, bus patronage increased by 38-66% according to route, and average bus speeds increased by about 15-20%."
Topp & Pharoah (1994) comment that the changes in the 1980s meant that "public transport achieved shorter journey times because of less traffic on the bus routes, and in 1989 the trend of decreasing patronage was broken for the first time".
(The trend Topp & Pharoah refer to probably dates from post-1974, and therefore the two comments are not necessarily incompatible).

In 1990, the modal split for those visting the old town was approximately 78% bus, 11% car and 8% by bike or motorbike. The modal split for trips being carried out within Bologna is quoted as 31% walking, 2% cycling, 33% by public transport and 34% by private motor vehicle.

Perceptions of the scheme

In the 1984 referendum, at least 75% of Bologna residents supported measures to close the city to private traffic.

Topp & Pharoah (1994) report that, post 1989, "the restrictions on traffic within the old town received support from the population and - despite initial opposition - from much of the business community...A point of criticism...is the compromise for tourism, that cars from outside the Bologna region are allowed to enter".

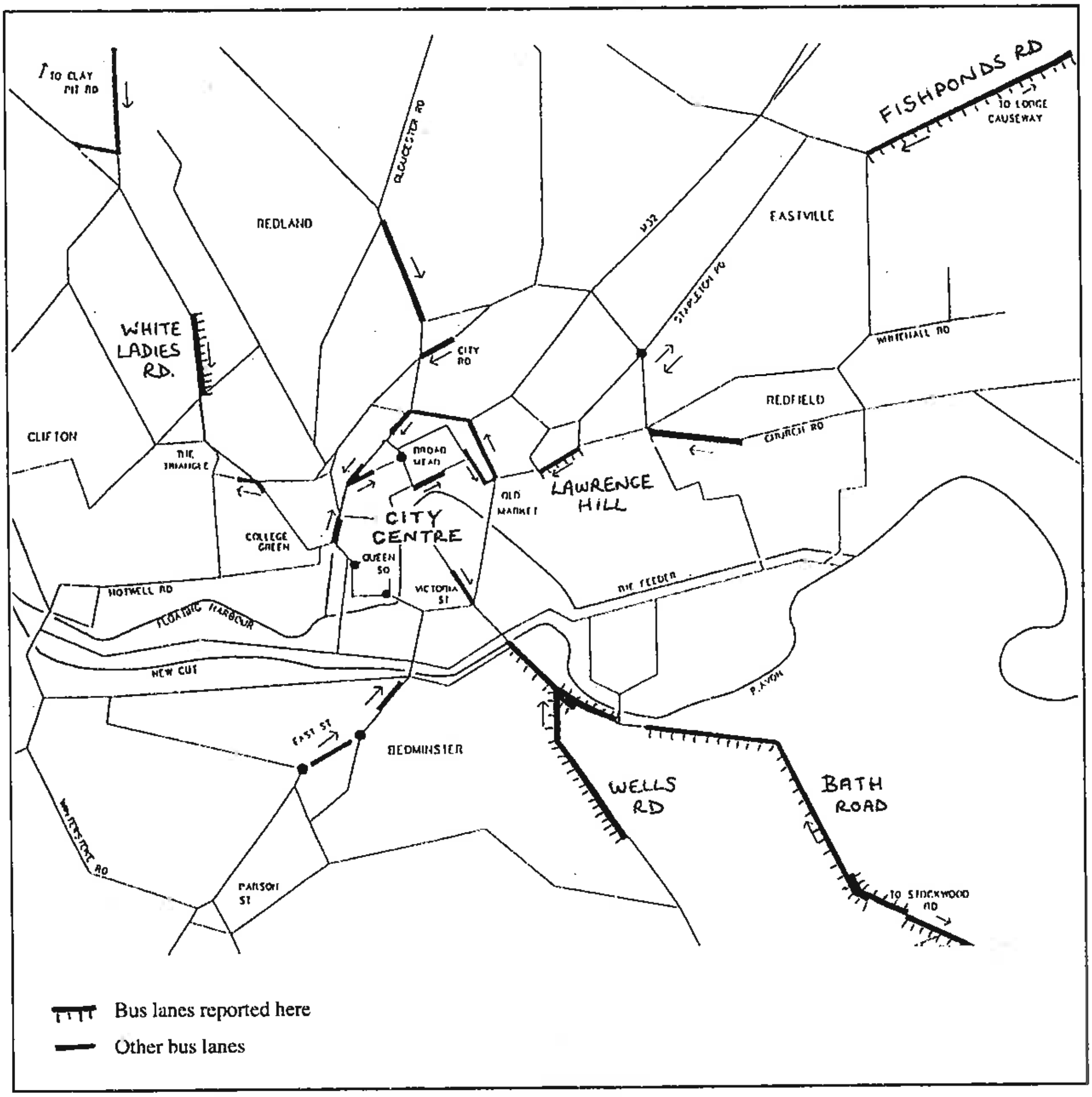
Caveats:

The information is taken entirely from secondary data sources, some of which seem to be relying on secondary source data as well. Moreover, there are some minor inconsistencies, as highlighted in the text.

The changes in traffic levels will only partially be due to the restrictions on car traffic using certain roads. They will also have been influenced by associated changes to parking, public transport etc.

6. Bristol - bus lanes 1991-1994

Source: Cairns 1996



Between 1991 and 1994, a series of bus priority measures were introduced along 5 corridors in the Bristol and Bath area. These were introduced by experimental traffic regulation orders, and monitored closely to enable a decision to be made within 18 months about whether to withdraw them, or make them permanent. Details of the five corridors are given below:

Bus lane	Length	Date of introduction	Times of operation
Wells Road	330m	Mar 1991/Nov 1992	mix of AM peak and 24 hr
Bath Road	3140m	Jun / Oct 1993	mix of AM peak (citybound), PM peak (from city), and 24 hr
Lawrence Hill	250m	Mar 1991	AM peak
Whiteladies Road	270m	Mar 1994	AM peak
Fishponds Road	1000m	Feb 1993	AM peak

AM peak = 7-10am, PM peak = 4-6.30pm, Monday to Friday

To assess the effects of the bus lanes, various data were available

- For 'before' data, "floating car" journey time surveys were undertaken on all of Bristol's radial routes in 1989. These were supplemented by static surveys of all buses travelling on corresponding links (including all surveyed bus lanes), carried out 3-6 months before the bus lanes were introduced.
- For 'after' data, comparable surveys were carried out 3-12 months after the bus lanes were completed
- Bus service patronage figures were supplied by bus companies from their regular monitoring of electronic ticket machine outputs.

Effects:

In general, Cairns (1996) notes that the bus priority measures "have reduced bus journey times by up to two-thirds and decreased the variability of journey times by as much as 89%. Monitoring of journey times for non-priority vehicles has shown that where a bus lane is introduced by narrowing existing traffic lanes to provide an additional lane for buses... the travel times of all vehicles, not just buses, can decrease".

Also, whilst "establishing the effect of introducing bus priorities on modal split is problematic...initial analysis of available traffic and bus patronage data indicates that patronage of bus services on corridors where bus lanes have been introduced has increased faster than traffic growth."

Specifically monitored changes are as follows:

		Before	After	Change
Wells Road	Average bus journey time, am peak	16.32	12.08	-26%
	Patronage of citybound buses in the am peak			+4%
	Traffic levels			"static"
	Journey times of non-priority vehicles, off-peak	3.75	4.07	+8.5%
	Journey times of non-priority vehicles, pm peak	3.33	2.75	-17%
Bath Road	Average bus journey time, am peak	21.07	12.1	-43%
	Standard deviation of bus journey time, am peak	5.08	1.63	-68%
	Average bus journey time, pm peak	13.43	11.4	-15%
	Standard deviation of bus journey time, pm peak	3.83	2.78	-27%
	Traffic levels			+2.4% "only"
Lawrence Hill	Average bus journey time, am peak	5.28	2.64	-50%
Whiteladies Road	Average bus journey time, am peak	3.85	3.15	-18%
	Standard deviation of bus journey times, am peak	3.22	0.7	-78%
	Non-priority vehicle journey times, am peak	1.88	1.57	-16%

		Before	After	Change
Fishponds Road	Average bus journey times, am peak	12.83	4.33	-66%
	Standard deviation of bus journey times, am peak	9.65	1.08	-89%
	Patronage of citybound buses in the am peak			+9%
	Journey times of non-priority vehicles , am peak	8.27	4.15	-50%

All journey times are in minutes.
Standard deviations provide a measure of the difference between the fastest and slowest buses. Therefore, as they decrease, buses are effectively becoming more reliable.

Design considerations:

Along the Wells Road corridor, traffic management measures were also used to reduce rat running traffic, which was delaying buses entering the bus lanes. Elsewhere, traffic management measures on parallel routes were considered unnecessary, as "it is not believed that the provision of the bus lanes has resulted in any significant diversion of traffic".

15.2% of non-priority vehicles were violating the Westbury road bus lanes in the morning peak. The application of a red surface coating reduced this violation to 1.8%.

Comparison of costs:

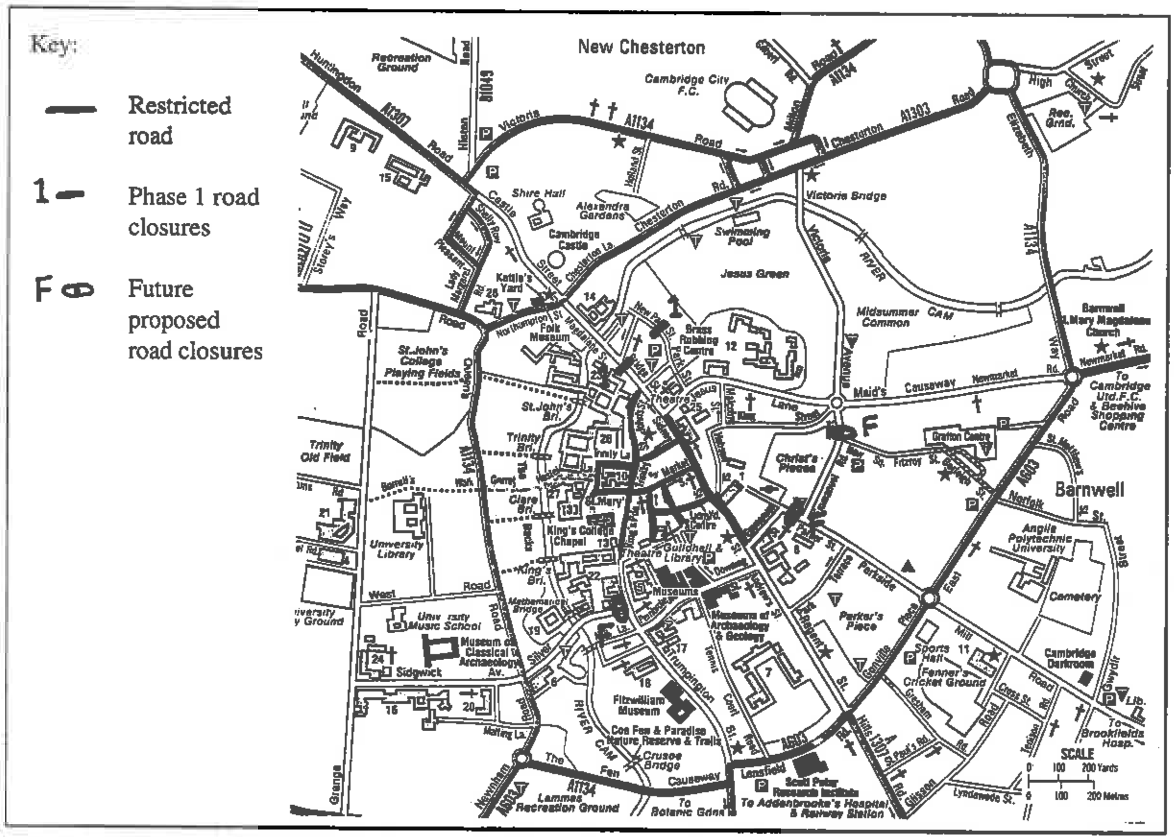
Greater promotion of public transport followed a congestion survey in the Bristol built-up area in 1989/90, which showed that the value of time lost due to delays was approximately £37 million per annum. Bus lanes costs are estimated at £10,000 per km for signing, white lining and the relocation of traffic islands, plus £30,000 per km for the application of red surfacing material.

Caveats:

Only certain parameters are reported for each of the five corridors in the original source.
There may be further information on changes to central roads in 1995, (including the closure of the A4 Cathedral Road, the road through Queen Square, and the introduction of a cycle lane at the foot of Park St).

7. Cambridge Core Scheme 1997 - phase 1

Source: WS Atkins (4 reports), correspondence from Jo French, Richard Preston & James Lindsay, and Cambridge County Council leaflet



Following on from the successful closure of several central Cambridge streets to private traffic in 1992, the 'Cambridge Core Traffic Scheme' is being implemented. It is planned that this will involve the closure of three through routes in the city centre which are used to short circuit the inner ring road. Access through the closure points will be permitted for cycles, buses and taxis. The first route (Magdalene St/Bridge St./Jesus lane was closed on an experimental basis (as shown above) on 22nd January 1997.

Various monitoring exercises have been undertaken:
a) The County Council records a River Cam screenline annually anyway.
b) WS Atkins were commissioned to:
- use models to predict what would happen
- carry out before and after surveys of traffic counts, journey speeds and journey times in June/July 1996 & 1997 (with minor adjustments to survey timings to avoid roadworks)
- carry out before and after surveys of journey times, traffic counts and pedestrian flows in October/November 1996 & 1997, (after phase not yet available)
c) The City & County Councils are monitoring air quality (results not yet available)
d) Local traders, bus companies and the University and colleges have been encouraged to monitor the impacts on shopping activity, deliveries and bus journey times (any results not yet available).

Available evidence on the impacts

A selection of before-and-after information has been extracted from the WS Atkins survey results to try and get an initial measure of the impacts of the road closure (prior to their analysis of the results, which is not due out for a few months, unfortunately).

Reference diagrams showing the locations of the traffic counters on which data are based, are given at the end of this section. Results from specified counters have simply been added together to give a crude measure of the overall impacts of the scheme (apart from speeds, where the total figure has then been averaged). Journey times have been converted from minutes and seconds, into minutes, to facilitate calculation. Traffic counts refer to all motorised traffic (and therefore exclude cyclists). Site numbers given relate to those used in the WS Atkins report.

Data from the River Cam screenline counts:

The River Cam screenline provides a measure of the relatively short-term impacts, having been undertaken in March of each year. Counters have been divided into those on the ring road, and those within the city (since the aim was partly to transfer through traffic onto the ring road).

12 hour flows:		March 1996	March 1997	Change:	
Within the city (sites 3,4,5)	All motorised traffic	31,869	28,781	-3088	-10%
	Cycles	6,845	7,303	+458	+7%
On the ring road (sites 2,6)	All motorised traffic	44,286	48,338	+4052	+9%
	Cycles	1,239	877	-362	-29%

* only cyclists on the carriageway have been recorded (excluding cyclists on the footway).

Data from the WS Atkins surveys

The June/July surveys contained a wealth of information, which attempted to measure the impacts on traffic in different ways. A selection of this information has been grouped by area:

Impacts on Cambridge as a whole

		June/July 1996	June/July 1997	Change:	
12 hour manual link counts of traffic (sites 1-15)	weekday	112,852	102,080	-10,772	-9.5%
	Saturday	108,562	96,655	-11,907	-11%

Impacts on the affected route:

		June/July 1996	June/July 1997	Change:	
12 hour manual link counts of traffic (sites 8-12)	weekday	26,101	13,476	-12,625	-48%
	Saturday	28,635	16,059	-12,576	-44%
Average speed mph (from radar speed surveys) (sites 29-34)		19.42	18.6	-0.82	-4%

Impacts on the rest of the central area:

		June/July 1996	June/July 1997	Change:	
12 hour manual link counts of traffic (sites 13-15)	weekday	23,411	20,937	-2,474	-10%
	Saturday	25,532	20,276	-5,256	-21%
24 hr daily flow recorded by automatic traffic counters (sites 29, 31)		22,200	20,500	-1,700	-8%

Impacts on the Ring Road:

		June/July 1996	June/July 1997	Change:	
12 hour manual link counts of traffic, north side (sites 4,6)	weekday	29,116	30,320	+1,204	+4%
	Saturday	24,972	26,132	+1,160	+5%
24 hr daily flow recorded by automatic traffic counters, south side (sites 27 & 32)		21,500	21,000	-500	-2%
Average journey time around ring road *	am peak	15.45	16.78	+1.33	+9%
	off-peak	14.2	15.99	+1.79	+13%
	pm-peak	25.59	23.79	-1.8	-7%
Minimum journey time around ring road *		13.72	13.09	-0.63	-4%
Approximate measure of congestion (difference between fastest and slowest journey time recorded)	clockwise	19.83	25.67	+5.84	+29%
	anti-clockwise	10.03	10.52	+0.49	+5%

*Clockwise, and anti-clockwise added and averaged, since the direction and magnitude of change was similar for both.

Impacts on the NW quadrant:

		June/July 1996	June/July 1997	Change:	
12 hour manual link counts of traffic, weekday (sites 1,2,3,5)	weekday	29,537	32,525	+2988	+10%
	Saturday	25,728	30,246	+4518	+17%
2 hour manual link counts, weekday (sites 20-27)	am peak	3,192	3,906	+714	+22%
	pm peak	3,736	3,779	+43	+1%
Average speed mph (from radar speed surveys) (sites A, C-I)		21.0	22.8	+1.8	+9%

Summary:

Because of the way the traffic counters have been aggregated for this synopsis, there are few numerical statements that can be robustly made, however some general comments do appear to be true.

In general, traffic on the treated road has fallen substantially, and daily traffic over the whole of the central area seems to have fallen by about 10% (a figure that reoocurs in the River Cam screenline, the 12 hour manual counts, and 24 hr automatic traffic counters). Reductions seem to have been greater at the weekend. There is also some evidence that cycling in the central area may have increased.

On the ring road, traffic has increased, particularly in the north near to the junction of the treated road, although in the south, it has apparently decreased. Journey times have reduced in the pm peak, although increased slightly in the am peak and the off-peak. Congestion seems to have become worse in the clockwise direction.

Traffic to the north west of the city (which was presumably the main origin for many of the trips made along the treated road) has increased (suggesting that it has been relatively unaffected by the road closure). Speeds have also increased slightly.

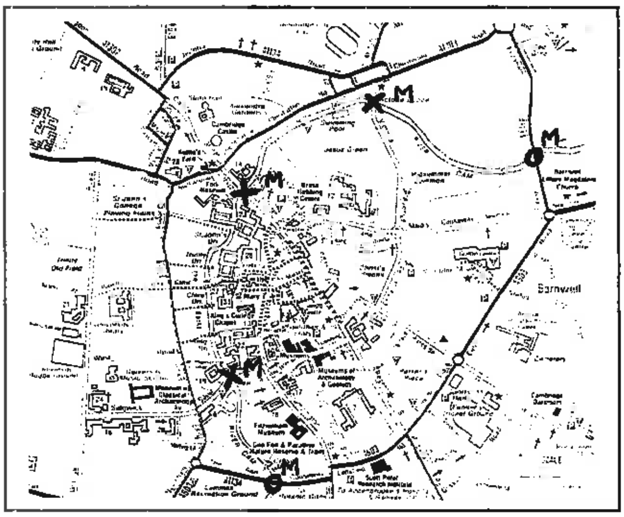
Traffic over the whole of the city may have decreased.

The impacts on specific, individual roads have not been considered at all here, although the very local nature of impacts may obviously be politically important

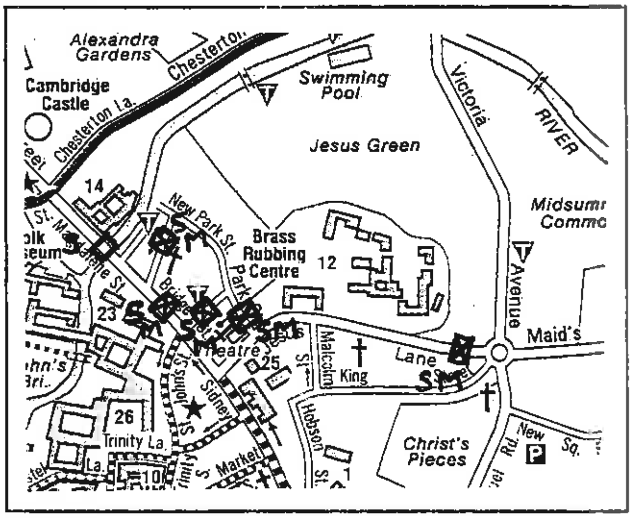
Location of traffic counters:

Key:
- M 12 hour manual link count site
- A 24 hour automatic traffic count site
- S speed check sites
- P 2 hour (peak) manual link count site

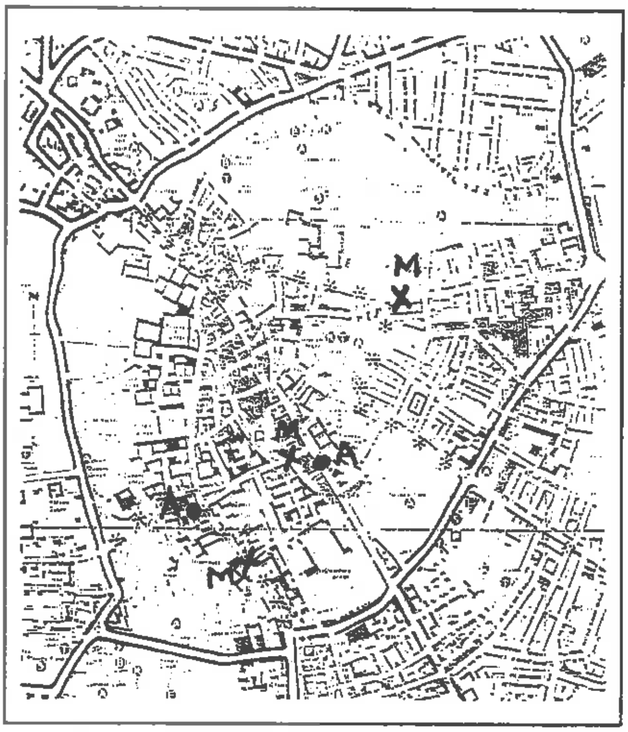
River Cam screenline



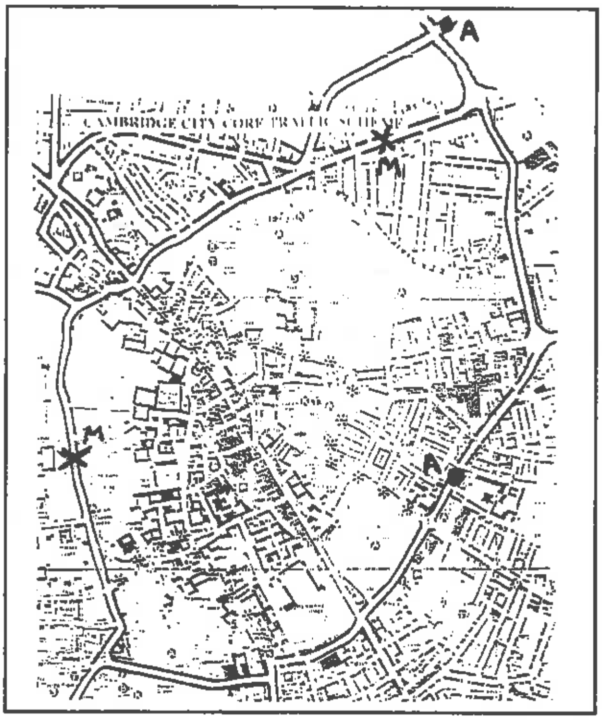
Affected road



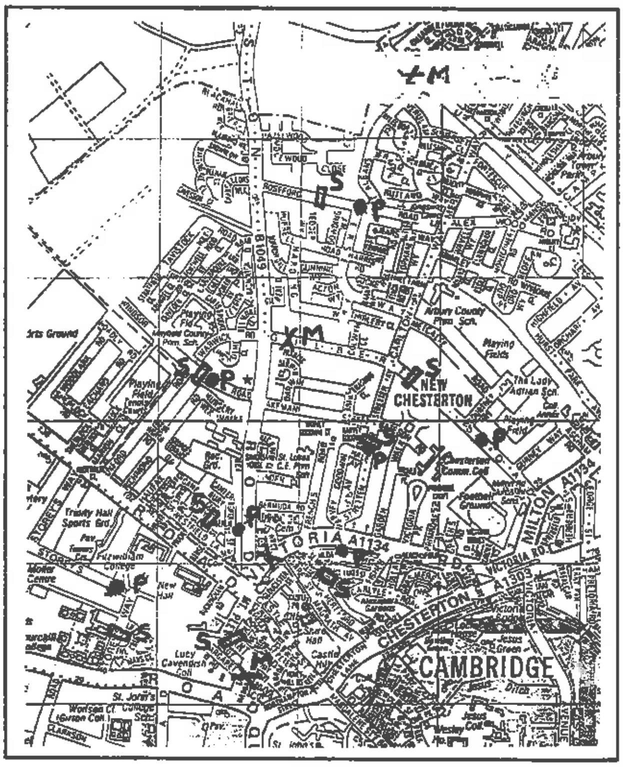
City centre



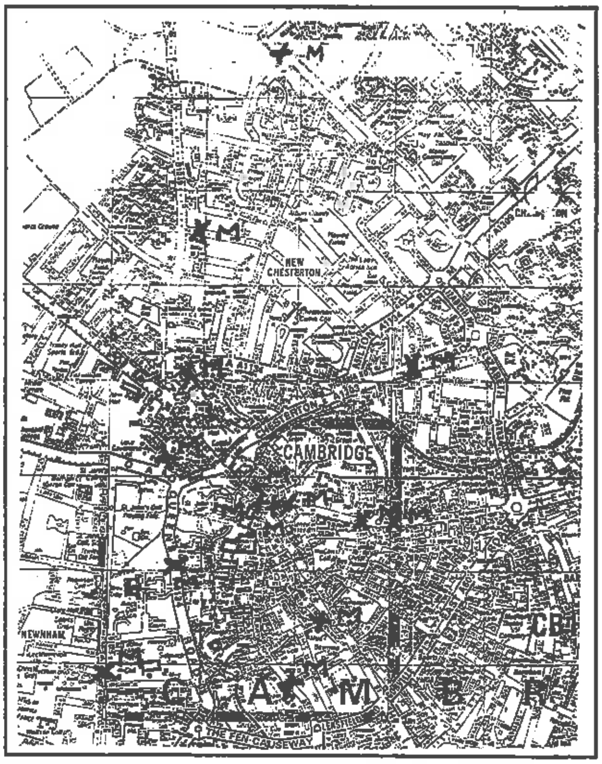
Ring road



NW Quadrant



Overall map of Cambridge



The modelling strategy adopted:

The modelling approach used to forecast the impacts of the scheme was based on the SATURN suite, and "gave trip makers three basic options:

- to change route to avoid closure
- to change time period to travel by car at non-peak times
- to no longer contribute to the vehicle trip matrix (transfer to public transport mode, cycle, walk, or trip suppressed)"

To operate the model, it was assumed that when speeds fell below 10km/hr for the entire trip, then 50% cars would transfer to off-peak, 18% would transfer to public transport, and 32% would cycle, walk or be suppressed.

10km was chosen as the threshold because at this speed, cycling becomes an alternative, and also, iterations based on data before the scheme was introduced, suggested that when speeds are >10km, less than 4% of trips transfer, which "is considered to be within the inherent errors associated with the Traffic Model."

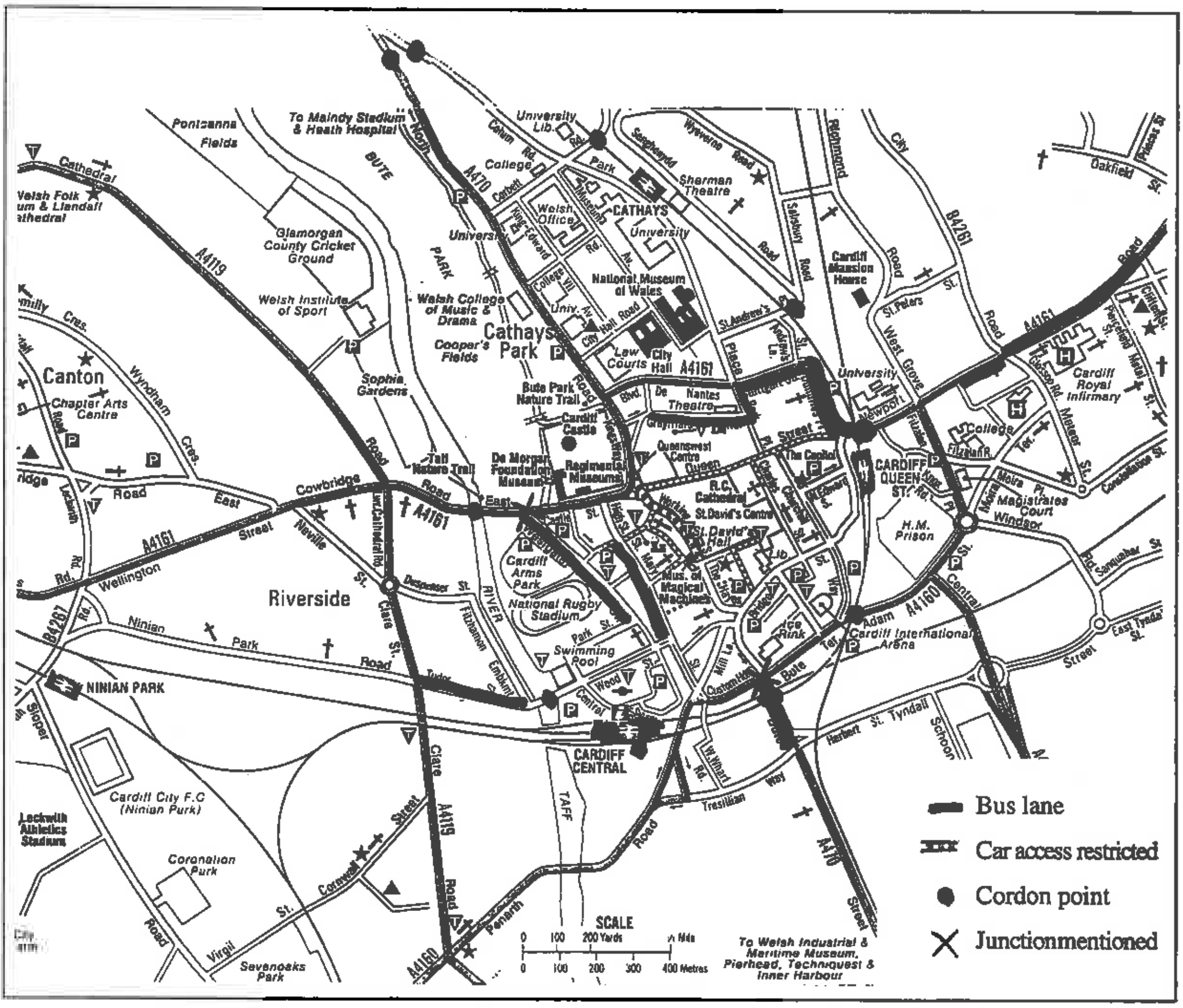
The predicted impacts for the Bridge St. closure included "a 3% reduction in traffic through the central area [over 16 hours]...in the peak hours this figure would rise to about 10%". Vehicle time spent on the ring road was predicted to rise by about 10% and vehicle delays were predicted to rise by about 14%.

Caveats:

Further reports evaluating the scheme in more detail, and on the basis of specialised local knowledge, are due out over the next few months. There should also be more forthcoming data, and an evaluation statement by the County Council. These should all help to clarify further what has happened.

8. Cardiff - bus lanes 1994/5

Source: John Gibson, Paul Byers & Frank Zip, Cardiff County Council, 1997.



Between 1994 and the beginning of 1996, a series of bus lanes were put in along several major routes in Cardiff, as shown above. These could potentially have affected most of the traffic accessing the central area.

Aggregate impacts on traffic

All vehicles entering the central area cordon	1993	1996	Change
12 hour flows	156,299	149,596	-6703 (-4.2%)
AM 2hr peak	18,462	17,120	-1342 (-7.3%)
PM 2hr peak	19,353	19,019	-334 (-1.7%)

All cars entering the central area cordon	1993	1996	Change
12 hour flows	130,892	125,224	-5668 (-4.3%)
AM 2hr peak	15,462	14,765	-697 (-4.5%)
PM 2hr peak	17, 156	17,326	+170 (+1.0%)

There was also some (patchy) data on the impacts of the bus lanes at specific junctions. Two examples are given below:

Bute St. bus lane (introduced 1994)

Traffic flows 8-9am	11/88	12/89	9/91	9/95
Nprthbound flows on Bute St, at junction with Custom House & Bute Terrace	383	317	321	339

Westgate St. bus lane (introduced February 1995)

Traffic flows 8-9am	12/91	7/92	9/94	11/95
Northbound flows on Westgate St, at junction with Cowbridge Rd East & Castle St.	336	381	450	303

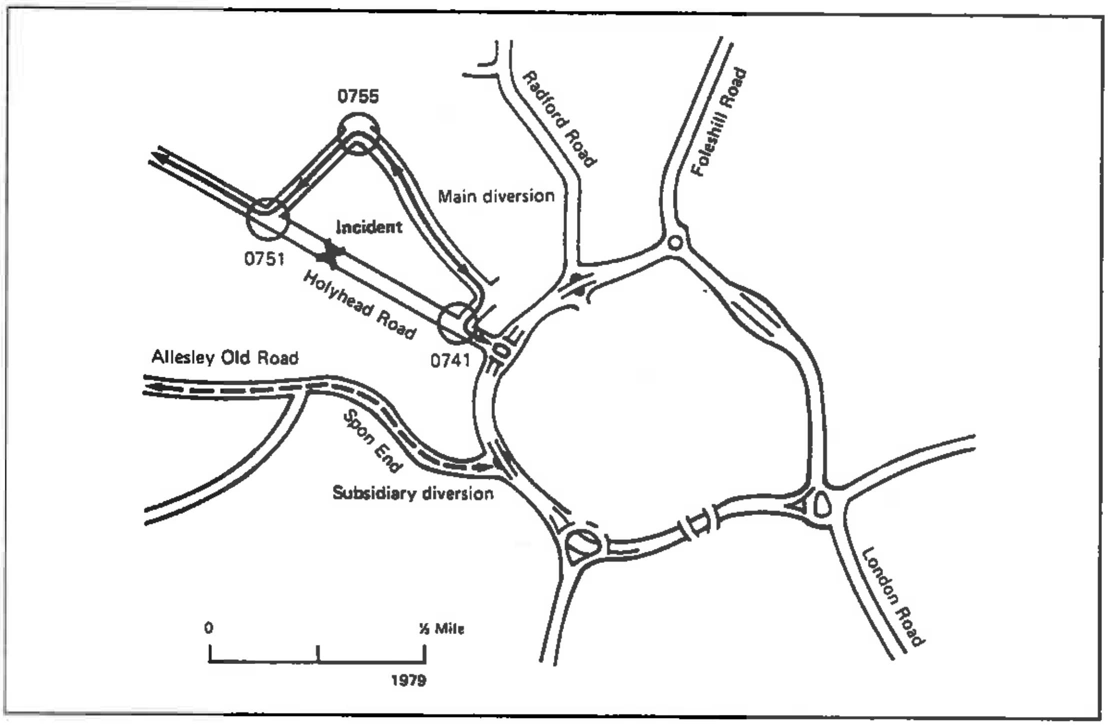
Summary:

In general, the results suggest that the bus lanes have reduced traffic flows into Cardiff over both a 12 hour period, and in the morning peak, although there has been negligible change in the PM peak. Similar changes in flows have been recorded specifically for cars, although they have become a slightly larger proportion of the vehicles in the evening peak, suggesting that other classes of vehicles (like light goods vehicles) may have transferred to less busy times of the day.

The junction counts suggest that the local impacts of the bus lanes have been less consistent. The one on Westgate street does appear to have reduced flows significantly. However, the bus lane on Bute St appears to have had little impact. The lack of change on Bute St. is largely due to improvements in a major distributor road south of Cardiff, which reduced the need for traffic to use Bute St prior to the introduction of the bus lane. According to Paul Byers, of Cardiff County Council, part of the rationale for creating the bus lane was therefore partly to make use of the vacated capacity, before it filled up again due to general traffic growth, and (potentially) induced trips.

9. Coventry - closure of A4114

Source: Hunt & Holland 1985



On 24th February 1983, half a mile of the A4114 (Holyhead Road) was closed, due to a lorry spillage of hydrofluoric acid. Holyhead Road is one of the major feeder roads (and off) Coventry ring road. The road was closed between 3.15pm and 6.30pm. The traffic light control system 'SCOOT' was used to regulate diverted traffic at junctions 741, 751 and 755. During the peak, police also forced some southbound vehicles to divert onto a subsidiary route, as queues were building up from junction 741 and beginning to block the Inner Ring Road.

Hunt and Holland highlight that:
"SCOOT reorganised the green splits to suite the new flow patterns",
and that, whilst it was not possible to eliminate the queues (particularly during peak traffic flows), "The SCOOT system showed large benefits over a Fixed-Time system."

Specifically, they produced the following table of comparison:

	Average sum of queuing vehicles at junctions 0751 and 0755	
	Off-peak	Evening peak
Normal	12	33
Diverted: Fixed-Time	200	500
Diverted: SCOOT	25	150

Caveats: This example only refers to a very short term reduction of highway capacity. However, it has some useful insights about the role that traffic signals can play in diverting flows.

10. Dutch Railway Company strikes 1992 (Netherlands)

Source: Directoraat-Generaal Rijkswaterstaat - translation of key points by Henk van Mourik

On Monday 6th and Tuesday 7th April 1992, the Dutch Railway Company went on strike.

A variety of studies was carried out, including a telephone poll of 700 people, a written poll of 850 students with free public transport cards, and before and after traffic counts and observations.

275,000 train passengers were disrupted.

On Monday, traffic flows increased by 4% overall (an extra 60,000 cars) with maximum increases of 20% near train corridors, and during the morning peak. Congestion was reported on 30% more sections of trunk road.

On Tuesday, traffic flows increased by 5% overall (an extra 80,000 cars), however it was better spread throughout the day. The congestion index (congested road length * duration) was half the magnitude of Monday, and equally bad levels are recorded on days when the weather is bad.

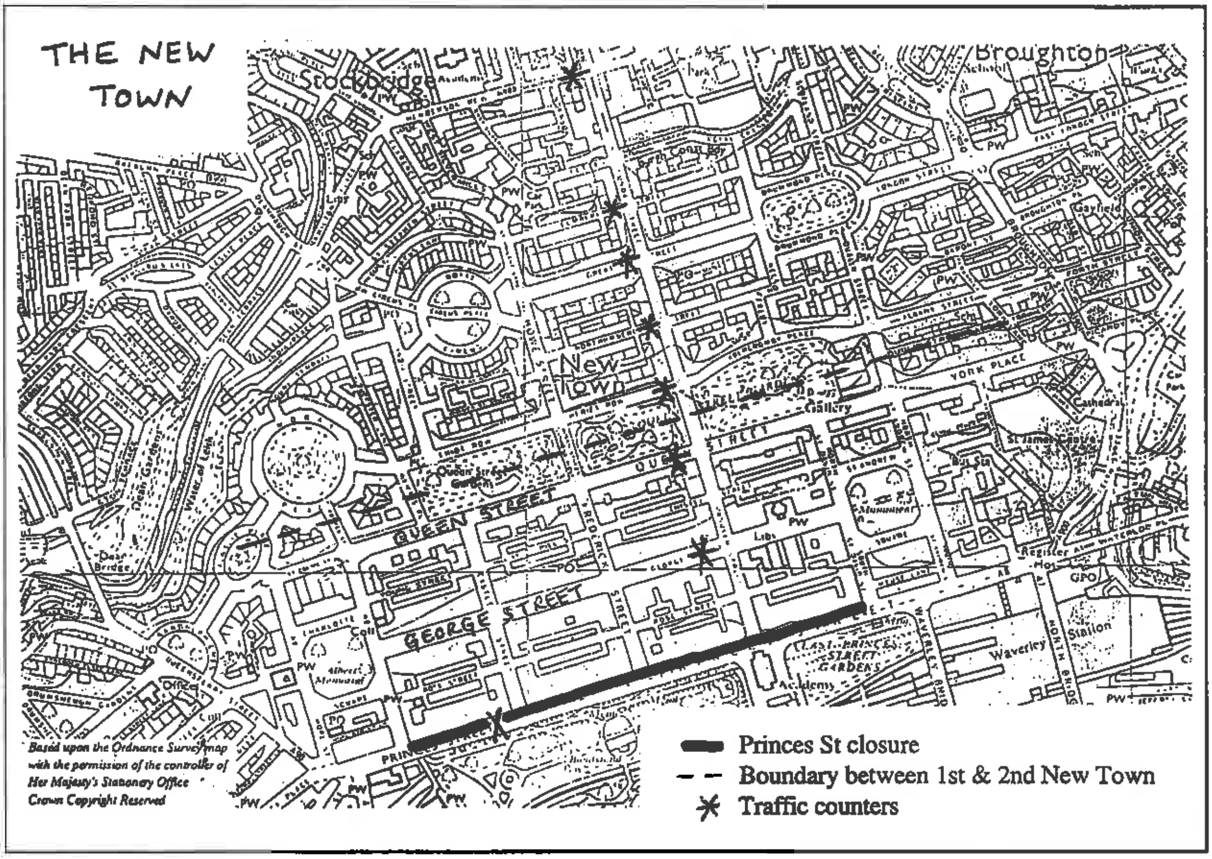
In addition, vehicle occupancy increased, as 50,000 train passengers were estimated to travel as car *passengers*. Supporting this, 25% more car passengers were recorded on one of the major routes (the A16 between Rotterdam and Belgium)

		Monday		Tuesday	
		All workers	Train commuters	All workers	Train commuters
Commuters who stayed at home		74,000	25%	49,000	17%
		Half worked from home and half took a holiday			
% who cancelled business meetings		10%	60%	--	
% who cancelled private meetings		10%	75%		
Of those who changed mode (who were mainly train passengers)	% who became a car driver	26%		33%	
	% who became car passenger or 'autobestuurder + meerijders'	37%		32%	
	% who swapped to bus, tram or metro	25%		21%	
	% 'other'	12%		14%	

*Caveats:*This is clearly not an example of road space capacity reduction. Nonetheless, it is interesting to show the mechanisms by which people adapted, the differences in adaption by different groups, and the way reactions changed between Monday and Tuesday. There could be other useful untranslated information

11. Edinburgh - Princes St closure 1997

Source: key references - Oscar Faber 1997d, Local Transport Today 9/10/97. Other references - Oscar Faber 1996+1997abc, D Begg 1997a,b,c, G Hazel (1997), the Scotsman 1997.



Edinburgh is the capital of Scotland, with a population of about 450,000. In July/August 1996, an Experimental Traffic Regulation Order was used to restrict eastbound traffic on a section of Princes St to buses, taxis and cycles only. Princes St. is the main shopping street in the city centre.

To assess the impacts of these traffic restrictions, Oscar Faber were commissioned to undertake a variety of surveys, before the closure in October 1995, and after the closure in November 1996, with a smaller follow-up survey of traffic counts in early June 1997. Specific details of surveys are given in the text, where available. Only the sites of traffic counters reported here are shown on the map above. There were too many different sites specified for all the other attributes measured to be included in this summary.

At some points, a distinction is made between the 1st New Town (the commercial area which includes Princes St, Georges St and Queens St), and the 2nd New Town (the residential area to the north of this). Where it was only relevant to measure a feature in one or the other, this distinction has been used.

Aggregate impacts on traffic:

16hr traffic counts were carried out at 51 junction and on 19 links throughout the city centre. Peak hour traffic counts were carried out at 13 locations. Weather conditions were wet and windy during the first survey, cold and wintery during the second, and dry and bright during the third.

16hr weekday average traffic flows	Before (Oct 1995)	After (Nov 1996)	After (June 1997)
Two way trips passing through a cordon around the New Town	221,953	215,011	221,834
Eastbound traffic on Princes St.	11638	2840	5282
Eastbound traffic on George St	6976	7271	7145
Eastbound traffic on Queens St.	10208	18266	17603
Eastbound traffic through the rest of the New Town	9987	9794	10658
Total change in eastbound traffic flows through the New Town	38809	38171	40688

AM peak hour weekday average traffic flows*	Before (Oct 1995)	After (Nov 1996)	After (June 1997)
Eastbound traffic on Princes St.	816	243	540
Eastbound traffic on Georges St	553	610	484
Eastbound traffic on Queens St.	821	1635	1357
Eastbound traffic through the rest of the New Town	793	989	990
Total change in eastbound traffic flows through the New Town	2983	3477	3371

* Peak defined as 7.30-9.30 for the 'before' surveys, and 7-9.30 afterwards

PM peak hour weekday average traffic flows	Before (Oct 1995)	After (Nov 1996)	After (June 1997)
Eastbound traffic on Princes St.	1467	216	482
Eastbound traffic on Georges St	494	290	638
Eastbound traffic on Queens St.	839	1504	1423
Eastbound traffic through the rest of the New Town	1144	1050	1105
Total change in eastbound traffic flows through the New Town	3944	3060	3648

* Peak defined as 4-6pm for the before surveys, and 4-6.30pm afterwards

Summary and interpretation

Data from 3 months after the closure of Princes St suggests that traffic has reduced by 3% compared to the previous year, although traffic in the morning peak appears to have increased by 17%, (which might be explained by traffic growth), whilst traffic in the evening peak has shown a decrease of 22%, (which might be explained by greater opportunities for peak spreading).

Data from June 1997 (nearly a year after the scheme), suggests that any changes are relatively marginal, with traffic flows approximately what they were before the scheme. This could either be because steady traffic growth has cancelled out any reduction, or simply due to seasonal variation from October to June, as much of the traffic in June may be related to the holiday season. The AM peak has declined slightly, whilst the PM peak has risen, which reinforces this theory, as the AM reduction may reflect regular commuters who are absent from the morning flows into work, whilst tourists may be reinforcing the PM peak.It is also notable that weather conditions were very different between the surveys which will have introduced an element of variation.

There were also significant increases in westbound flows recorded on certain streets, including Princes St, which may reflect complicated routing strategies by drivers. This has obviously been picked up in the cordon, although not in the measurement of eastbound flows.

Other impacts:

- **Speeds**

"Improving the pedestrian environment by reducing vehicle speeds is part of the philosophy behind the traffic management proposals for Central Edinburgh". Thirteen locations across the New Town were monitored, with 100 measurements taken. (Eastbound speeds on Princes St were discounted due to the new 20mph restriction). "In the majority of cases, the speed of traffic has reduced by, on average, 2 to 3 mph, and the perception that traffic on Queen St. travels at excessive speed is not supported".

- **Pedestrian Activity**

Pedestrian flows were measured at 7 key locations across the New Town and "indicate a slight reduction in pedestrian activity over 1995, although this may mainly be due to the wintery weather that prevailed during the course of the second survey".

- **Bus journey time surveys**

Journey time surveys were undertaken on 5 major bus routes which pass through the New Towns in both peak and off-peak periods. "In general, journey times have reduced. The combined journey time saving over the five routes during the peak hour totalled around ten and a half minutes. The off-peak saving was around nine and three-quarter minutes". However, the savings were not uniform across all 5 routes, and "the benefits brought about by the restrictions to general traffic were offset in part by the increase in traffic levels elsewhere on the network".

- **Hotel, coach and taxi surveys**

All day before-and-after surveys of the taxi, coach and person movements associated with the Royal Overseas League and 5 hotels on Princes St were undertaken. "The results...suggest a slight reduction in the number of two-way person movements over a 16hour period compared with 1995".

- **Accidents**

By September 1997, accident rates on Princes St. were down 34% overall. For example, personal injury accidents had fallen from 108 to 60, in the year following the scheme.

- **Noise**

Before and after studies of noise at 15 locations throughout the New Town suggested that "at the majority of locations, the change in traffic level is of marginal significance and would be unlikely to be detected as an audible increase". "Benefits in noise reduction in Princes St, though tangible, are unlikely to be noticed subjectively above the general noise climate produced by both traffic and the hustle and bustle of general pedestrian activities within a high density, busy shopping area". "It should be remembered, however, that changes in noise do not necessarily correlate with subjective impressions of disturbance".

- **Pollution**

By September 1997, nitrogen dioxide levels had fallen on Princes St by 40%, and all 20 sites monitored for air pollution, including those in residential streets in the 2nd New Town, showed the same, or lower levels of pollutants than prior to the scheme. Nitrogen dioxide levels on Queen St remained unchanged.

- **Vibration**

Before-&-after studies of vibration impact were carried out on selected buildings at 7 locations in the New Town where traffic was expected to increase. These "indicate that there is no material impact from traffic vibration on the properties surveyed....both surveys confirm that vibration from road traffic is currently below the level of human perception [and] that there has been no change in vibration following the implementation of the traffic proposals".

- **Commercial profitability**

Princes St remains the strongest local shopping street, and investor and occupier interest and confidence in the 1st New Town is recorded as growing

- **Public attitudes**

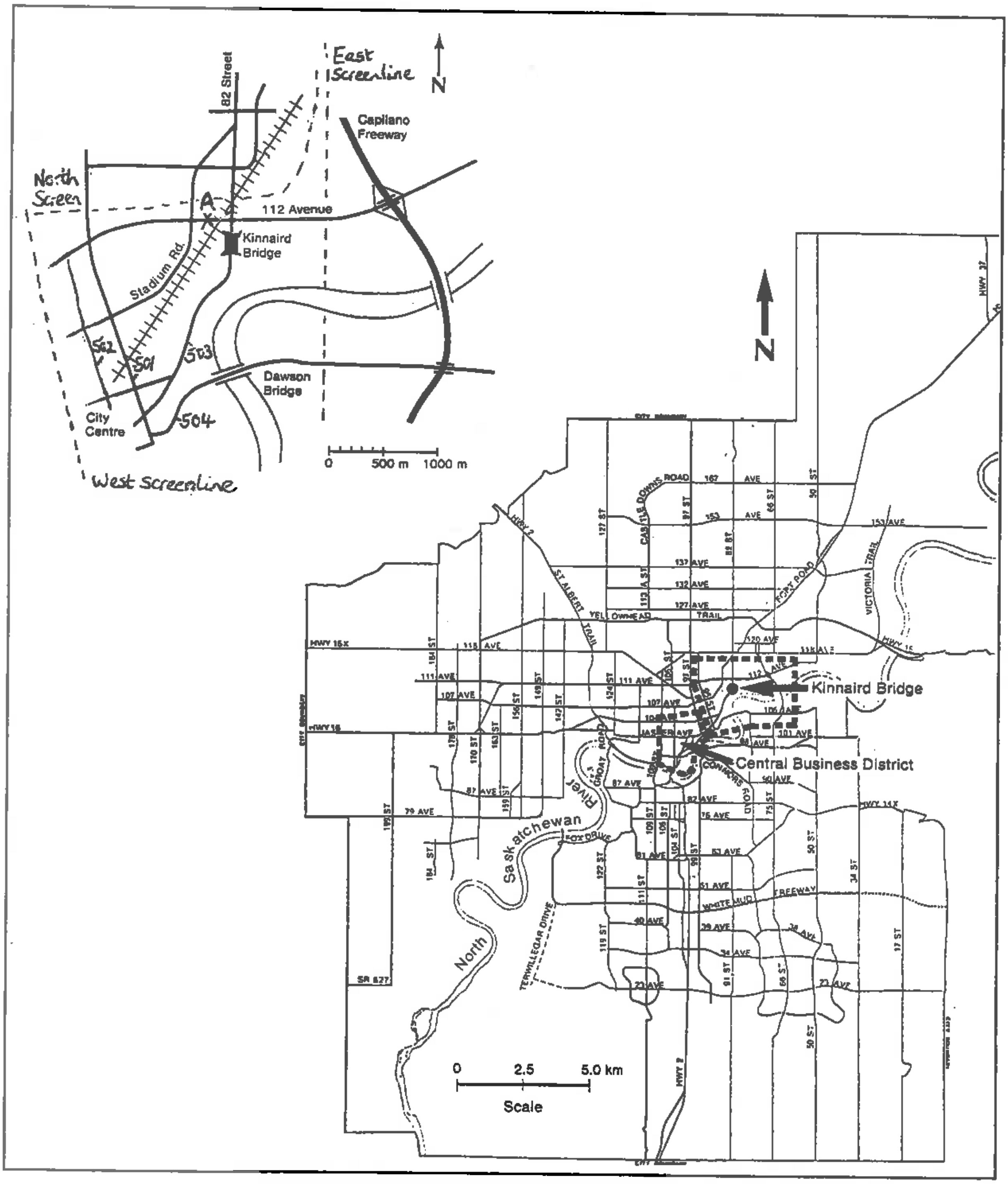
A public attitude survey in June 1997, based on 990 interviews on 5 streets in the New Town showed that three-quarters of respondents said they wished the changes to be made permanent, compared with two-thirds in 1996. 70% thought Princes St was easier to cross and 65% said that Princes St was generally pleasanter as a result. However, some objections to the scheme have been received by the Council, mainly relating to the increased traffic on Queen St., which has doubled.

Caveats:

The data on accidents, pollution, commercial profitability and public attitudes, is reported from Local Transport Today, so there may be some inaccuracies due to third hand reporting.
It has not been possible to go into all the details of all the Oscar Faber surveys, and for more information, readers are referred to the original reports.
The local effects on specific junctions and sections of road have not been reported, although there has been some variation which has been important for the immediate locality.
The Commonwealth Event held in October 1997, during which Edinburgh centre was entirely closed to cars, could provide additional useful information.

12. Edmonton (Canada) - Kinnaird Bridge closure 1979

Source: Stephenson & Teply 1984



In the late spring of 1979, Kinnaird Bridge was closed. The bridge forms part of a major commuting route between the NE urban area and the Central Business District in Edmonton

Traffic monitoring and before-and-after licence plate surveys were carried out daily, until 3 weeks after the bridge closure, when 'flows had stabilised'. Specifically, over 7,000 vehicles at 16 locations on arterial approaches were monitored during the 2 hour morning peak.

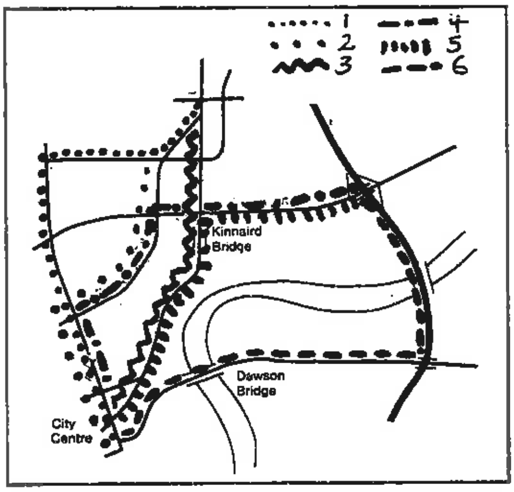
Aggregate effects on traffic and travel times:

Vehicles/hour (inbound) on...	Before	After	Total
Kinnaird Bridge (link 503)	1300	0	-1,300
Alternative routes (links 501, 502 & 504)	2130	2885	+755
Total	3430	2885	-545 (-16%)

Traffic fell by 17% at the Eastern screenline, 5% at the Northern screenline, and 10% at the Western screenline.

Initially, travel times increased substantially on some routes, however drivers quickly adjusted their behaviour. Data for six selected routes are given below.

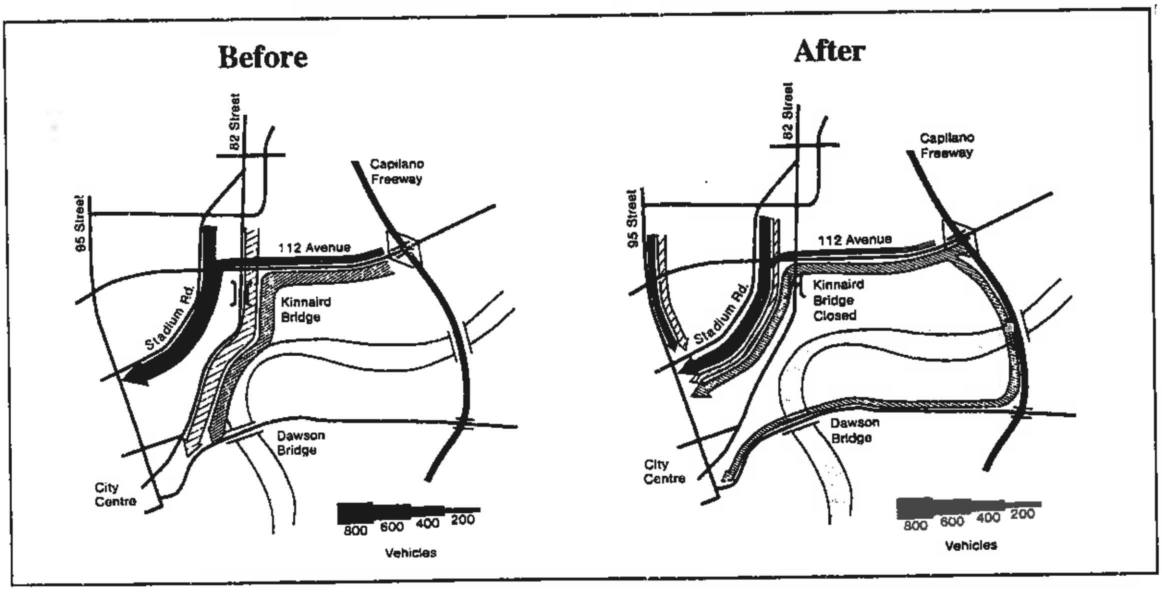
	Approximate travel time (in mins)		
Route..	Before	Day 1 (after)	Day 7 (after)
1	7.5	7.5	7.5
2	5.5	10.5	7
3	6	n/a	n/a
4	6.5	14.5	11
5	5.5	n/a	n/a
6	6.5	6.5	6.5



Stephenson & Teply report on various ways in which drivers responded to congestion, and reduced travel times "over a period of two weeks". These included:

- use of less direct routes

They observed "shifts in route choice... to less direct routes". Changes are illustrated below.

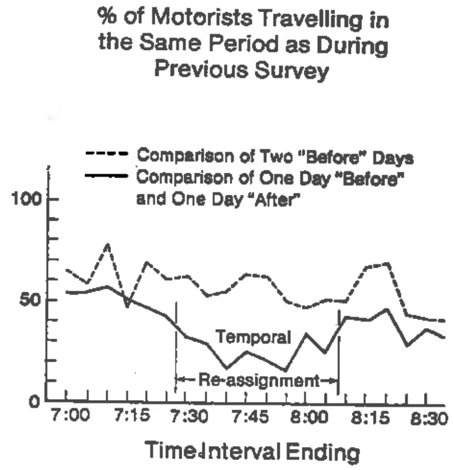


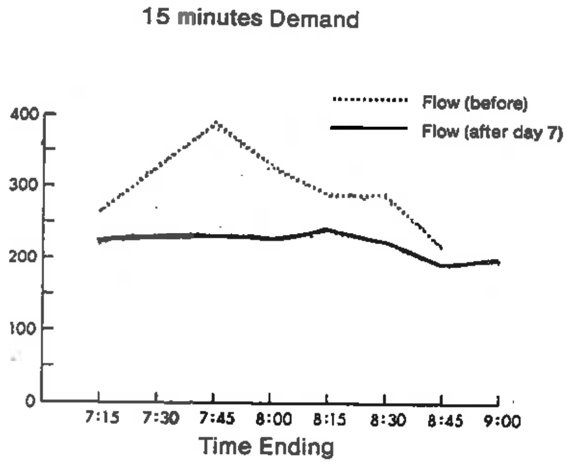
- rat-running

"Flows on residential streets increased adjacent to congested arterial intersections"

- changes in travel times

A comparison of times when drivers travelled before and after the Kinnaird Bridge closure (at location A) revealed that while about 60% of drivers travelled at the same time (+/- 5 mins) every day before the bridge closure, this percentage was reduced to 20% during congested peak periods after the closure. There was also clear evidence of peak spreading (at location A).The data for these two statements is shown below.





Modelling considerations:

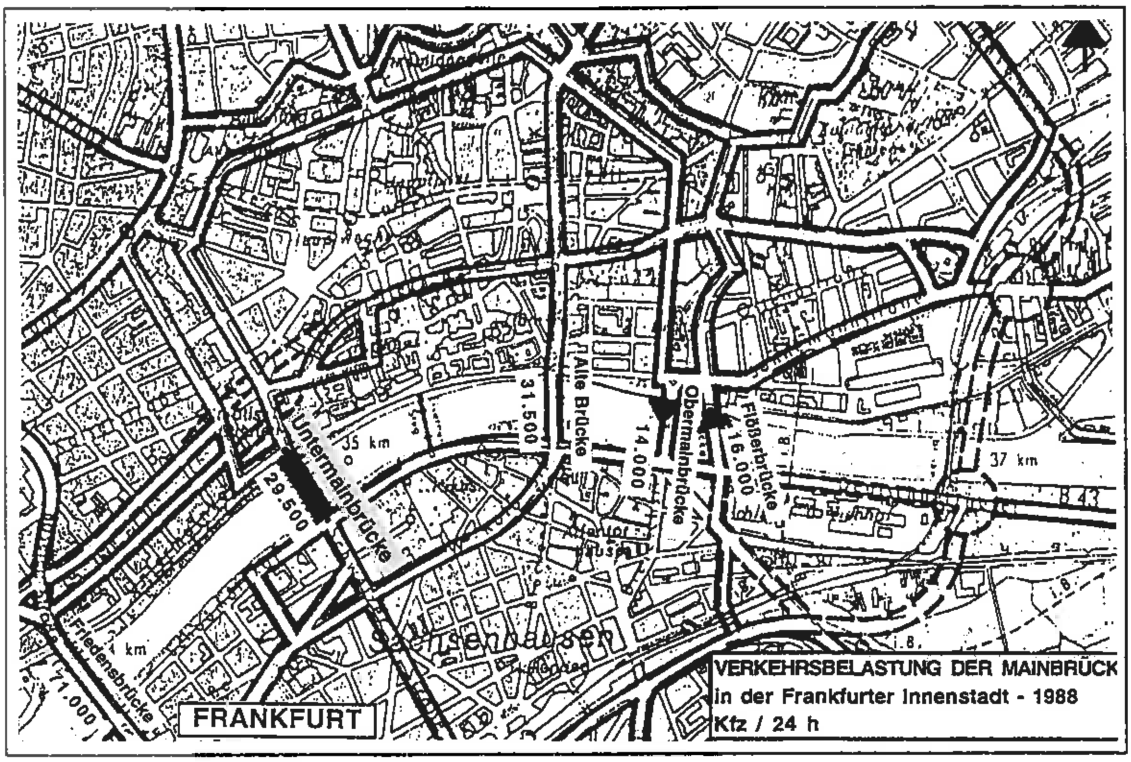
Data from Kinnaird Bridge closure was used to assess the value of the CONTRAM traffic assignment model. In general, the researchers describe the fit between actual data and model outputs as "excellent". Interestingly, they note that, in calibrating the model, "network adjustments were considered less desirable...Nevertheless corrections were required, involving capacity revisions and 'artificial' turn bans to prevent movements which can only occur with difficulty in the real network because of capacity problems".

It was also noted that the model was unable to cope with the flattening of the peak, or 'other levels of choice' potentially triggered by 'extreme congestion'.

Caveats: All data is drawn from one article, and dates are not always clear.

13. Frankfurt am Main 1988

Sources: Hupfer 1991, City of Frankfurt, VÖV 1987 & 1989



The city of Frankfurt am Main has 630,000 inhabitants, and is part of the polycentric Rhine Main region in which 2.4 million people live. A main bridge (Untermainbrücke)was closed near the city centre in 1988. It had been carrying 29,500 vehicles /24 hours. The total traffic flow over the river in both directions was 192,000 motor vehicles (24 hours).

Impacts on traffic

There are two sources which refer to this case, and the figures of the increase on the affected bridges do not correspond. There are significant differences between data from Hupfer 1991 (Report of the University of Kaiserslautern) and data from the city of Frankfurt, even taking into account that one is a 14 hour count (possibly 6.00-20.00) and the other the full 24 hours.

Data from the City of Frankfurt (June 1997) is given below:

Additional Traffic Flows at the other River Bridges

Bridges	Increase (24 hours)
Flösserbrücke	11,000
Obermainbrücke	9,500
Alte Brücke	8,500
Untermainbrücke	closed
Friedensbrücke	1,000
Difference	30,000

The city data shows that the four other available bridges were able to carry the additional traffic flows, although one of these already carried 71,000 vehicles and could only cope with another 1,000 vehicles. The two bridges with the lowest flows had spare capacity. This information can be summarised as follows:

24 hour vehicle flows	Before	After	Change
Untermainbrücke	29,500	0	-29,500
Other bridges	162,500	192,500	+30,000
Totals	192,000	192,500	+500 (+0.3%)

In contrast to the city data, Hupfer refers to an increase *on the Alte Brücke of more than 3,800 motor vehicles/14 hours going south (44%), (outbound) 32% on Friedensbrücke and 24% at the Obermainbrücke.* Flösserbrücke is not included because it is a one way street. In total 8759 motor vehicles were counted southbound. *In the opposite direction 8,100 motor vehicles /14hours were counted on the Alte Brücke,*(which was already much more than the city was counting for 24 hours). *On the Friedensbrücke 5,300 motor vehicles/14 hours (29%) and on the Flösserbrücke 5,000 motor vehicles/14 hours (27%).* Obermainbrücke is not included because it is a one way street (Hupfer 1991, pp. 11-12).

The reasons for the discrepancies are not clear, but the two sources are broadly consistent on the total increase. Over 14 hours, Hupfer counts 27,337 vehicles on all the open bridges, whilst the City of Frankfurt counts 30,000 motor vehicles over 24 hours. However according to Hupfer *8,759 motor vehicles/14 hours are going south* (outbound) and *18,578 motor vehicles/14 going in the opposite direction (ibid, p.12* inbound), which seems strange as roughly similar flows are expected during morning and evening rush hours.

In general the City figures appear more reliable than the data provided by Hupfer, but some of the observations and interpretations he makes are worth considering.

There was an increase in the duration of congestion during the morning rush hours (6.00-9.00) along the main streets leading to and from the Friedensbrücke (the area around the main railway station) and around the Alte Brücke (ibid. pp.35-41 and Anlagen). The traffic congestion at the first location was more severe and affected a larger part of the road network. Congestion during the evening rush hour was also widespread, but did not affect such large parts of the road network. Congestion was particularly bad around the main railway station during the evening peak.

After the closure there was a spread of the morning rush hour time in comparison to the main rush hour before the closure. This was not the case in the evening rush hour (ibid. p.41). On average the travel time increased by 10 minutes (ibid, p.23).

Impacts on public transport patronage

In addition to the traffic counts there was also a questionnaire survey. 6500 people were targeted of which 379 questionnaires were usable. In total, 344 people who answered used motor vehicles.

Thirty were cyclists and 5 pedestrians According toHupfer *"Eight percent of them said they had changed to public transport"* (ibid, p.22), though there is some confusion in the definitions as between motor-vehicle users and car users, and elsewhere (p. 29) Hupfer refers to 13% of people having changed to public transport. Apart from these inconsistencies, the sample size is too small to give a valid insight into these changes.

The report claims further that '*according the observations of the public transport operator there was a significant increase in the number of public transport passengers. During the morning rush hour between 7.00-8.30, an increase of 30% more passengers (about 2,500) on 2 suburban lines and nearly 50% more passengers on 2 underground lines (about 2,500) was reported. This increase is measured in comparison to the year before* '(ibid, p.39).

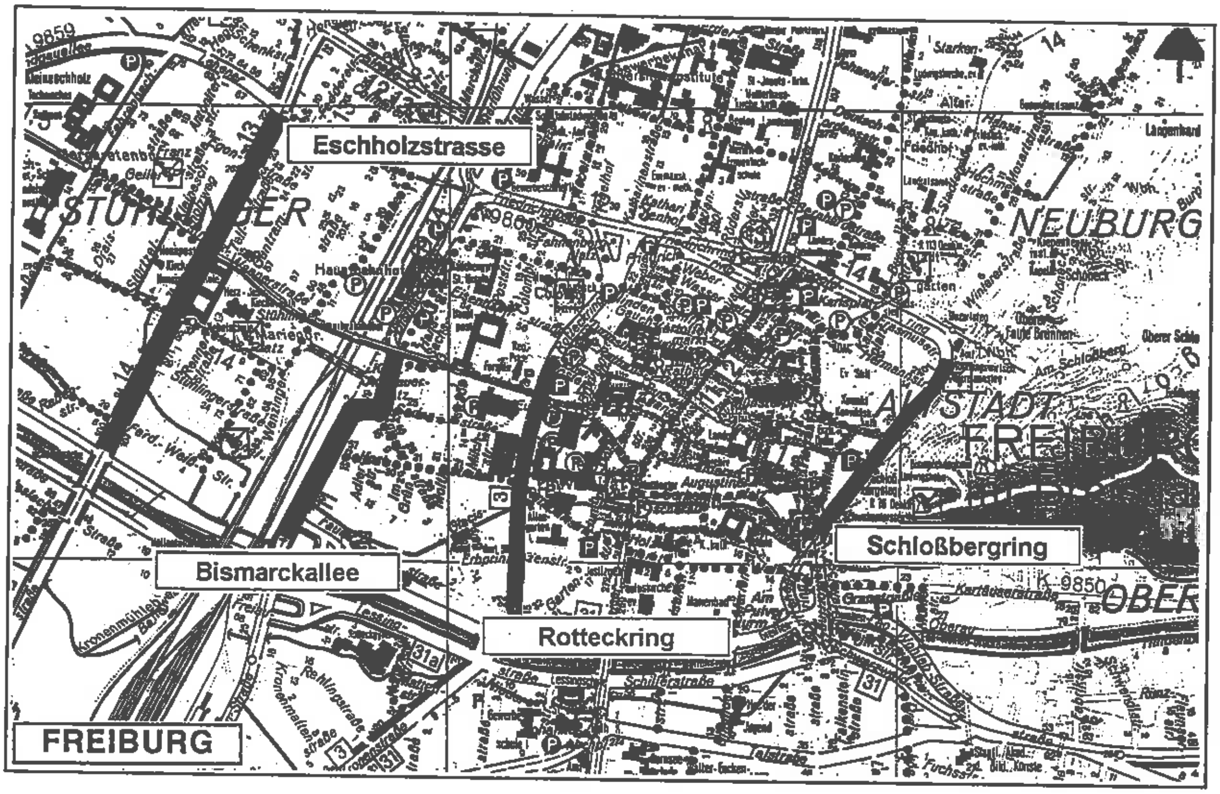
It seems possible that this figure should not be taken at face value, since it may include railway passengers on two suburban railway lines which are very distant from the area in question, in one case not even being located in Frankfurt. Therefore, there do not seem to be obvious direct connections between the increase in public transport passengers and the closure of the bridge. Enquiries made to the public transport operator confirmed this view: there was a significant increase in the number of public transport passengers between 1987 and 1989 of about 20%, which was far higher than the national growth but this seemed to have had nothing to do with the closure of the Untermainbrücke. (VÖV 1987 and 1989).

Summary

Overall, the bridge closure took place in the context of readily available alternative capacity, and the more reliable figures from the City indicate that there was a small increase in total crossings in the interval between the before and after surveys. The fact that public transport use during this period was obviously very bouyant (for reasons which had little if anything to do with the bridge closure), suggests that the period was one of general increase in movement, and the slight growth in river crossings reflected this.

14. Freiburg 1960-1997

Sources: Freiburg im Breisgau Stadt 1980, Freiburg Stadt 1997, Hass-Klau 1997a



Freiburg is a city of about 200,000 population located at the southern edge of the Black Forest.The city is internationally well-known as one of the leading examples of far-reaching environmentally-friendly transport policies, where extensive changes have been made to the amount and location of road capacity for motor vehicles over a period of more than 30 years. Its town centre is often cited as a model for large-scale pedestrianisation combined with public transport improvements.

By the end of 1970s most of the city centre was closed to motor vehicle traffic. This policy was originally developed following substantial road-building during the 1960s, when parts of the major ring road around the city centre were widened from 2 to 4 lanes (Rotteckring-Werderring-Friedrichring). In 1970 the last section of the ring road had been modified. Thus the city centre had a complete four lane ring road to take the city centre traffic. The main city centre road - Kaiser-Joseph-Strasse- was carrying about 23,000 motor vehicles/24 hours before 1973. This road was closed in November of that year (Stadt Freiburg 1980). Trams and buses were allowed to enter the city centre. Because of a very successful public transport policy, demand for public transport increased and new tram line extensions were built (Hass-Klau 1997).

During the late 80s, there was interest in reallocating some of the capacity on the ring road itself, and cycle lanes and cycle paths were installed. For these cycle lanes the width of the car lanes had to be reduced by 1-1.5 metres. No problems were experienced and in 1996, about 10,000 cyclists were using the ring road daily.

By the beginning of the 90s, demand for public transport had increased so much that the city centre interchange stations for trams and buses, which were located in the middle of the pedestrianised area, became so busy that they were a slight nuisance for the heavy flow of pedestrians. It was therefore suggested that three bus routes should be moved away from the city centre. Following protests by residents, it was agreed to put one bus route back into the pedestrianised area.

Plans were developed to provide bus lanes of 3 metres width along some parts of the ring road (Rotteck/Werderring)[1]. A parallel road (Bismarckallee/ Schnewlinstrasse) was widened to allow for extra traffic, with restrictions to ensure that traffic could not use other roads.

In March 1996 the Bismarckallee/Schnewlinstrasse was opened to 4 lanes and the Rotteck/ Werderring was reduced from 4 lanes to 2 lanes, and 2 lanes were changed into two way bus lanes. In addition the cycle lane was also still functioning[2]. A probationary period of one year until Spring 1997 was agreed for this arrangement. This has now been made permanent.

Impacts on traffic on the ring road

Changes to 24 hour traffic flows on major city centre ring roads in 1000 motor vehicles								
	Nov 87	Nov 95*	Feb 96**	Apr. 96***	May 96	Nov 96	Feb 97	Jun 97
Eschholzstr.	23.0	22.9	21.1	22.0	21.8	22.5	20.6	20.8
Bismarckallee	24.8	0.4	15.3	23.0	23.7	30.7	25.3	26.0
Rotteckring	33.5	41.1	34.2	27.2	27.0	28.2	22.6	23.2
Schlossbergring	31.5	29.3	28.0	30.3	30.5	33.5	27.9	29.6
Total	**112.8**	**93.7**	**98.7**	**102.6**	**103.0**	**115.1**	**96.3**	**99.6**

* In Nov 1995 Bismarckallee and Schnewlingstr. were closed.
** Febr. 1996 Bismarckallee was opened with 2 lanes.
*** 29.3 1996 opening of 4 lanes in Bismarckallee and reduction of Rotteckring to two lanes.

The table above shows a 12% decline of traffic flows on the major city centre ring roads in 10 years, despite a significant growth in the number of motor vehicles in Freiburg from 350 per 1000 population to 487 per 1000 in 1996, an increase of nearly 40% in 20 years, and despite a policy that (overall) road capacity stayed about the same.

In 1995, 26% of all trips into the city were made by public transport, 28% by bicycle and walking, 46% by motor vehicle. This success has to be compared with 1976, where only 22% used public transport, 18% bike and walking and 60% motor vehicle (Stadt Freiburg 1997).

The general context provides an important background for interpreting the particular effects of specific reductions in capacity, like the reallocations on the ring road in 1996. These changes resulted in a reduction in traffic on the treated road of 34%, of which a large proportion (but not all) was observed on the alternative routes provided. The overall effect was a reduction in traffic of about 7% of the traffic formerly using the treated section.

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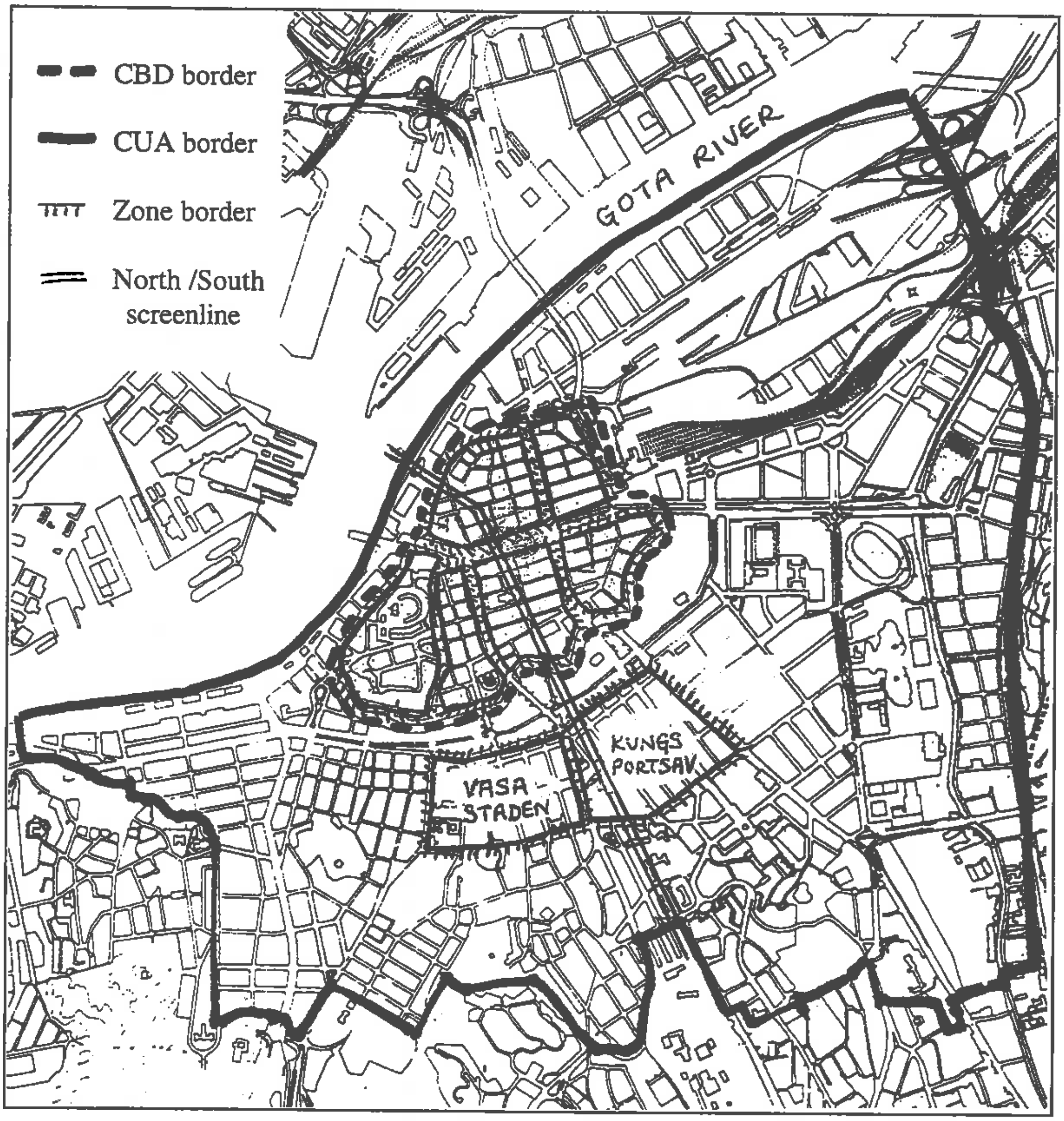
[1] It is interesting to note that future plans involve further reallocations of road capacity. Some of the tram lines may be able to use the route, and there are new plans to close one part of the inner ring road (Rotteck-Werderring) in order to reduce the barrier effect this ring road is causing between the city centre and the residential area to the west, which includes the university, the theatre and the station. This evolution of plans in Freiburg is an instructive counter-example to the common assumption that expanded traffic capacity on ring roads is a necessary condition for traffic restrictions in town centres.

[2] In contrast to Britain, cyclists are not allowed to use bus lanes in most cities in Germany. In Freiburg, the number of cyclists would have been so high as to be a hindrance for the buses. The cycle lane is between the pavement and bus lane.

15. Gothenburg 1970-1984

Source: OECD Environment Committee report 1984, CILT & TEST 1985, ECOPLAN 1994.



Gothenburg is the second largest city in Sweden. It has a population of 430,000, and in the Gothenburg region, there are 700,000 inhabitants. It is bisected by the Gota river, and has the remnants of an old canal system.

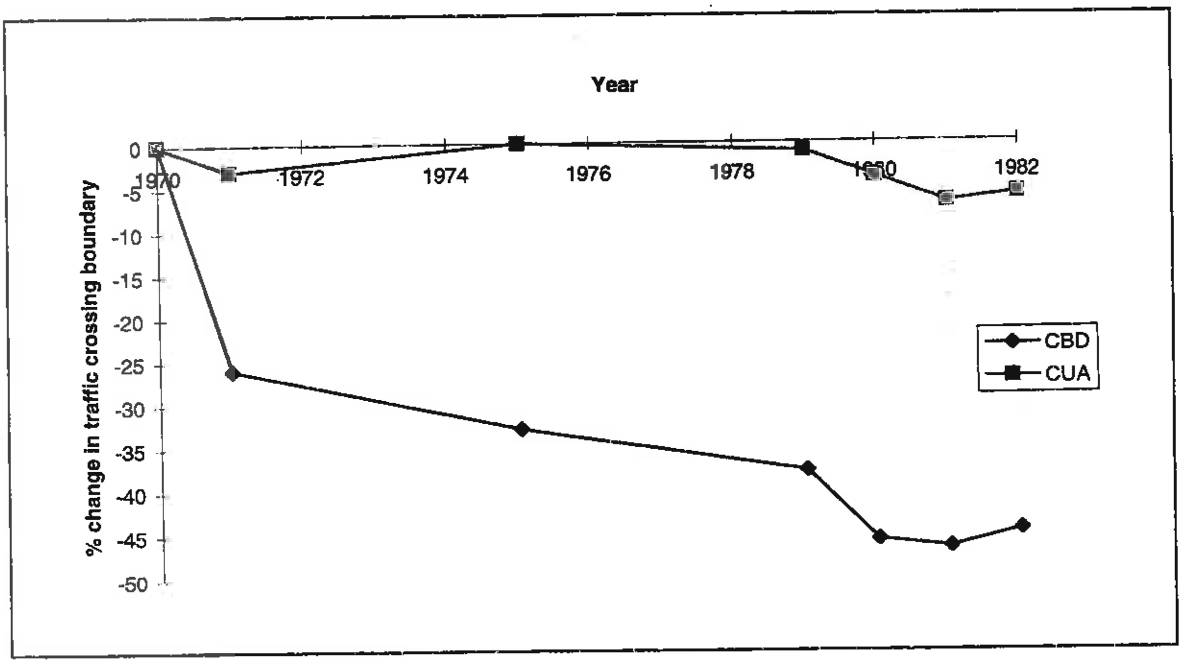
"By 1970, severe traffic and environmental problems became apparent" and this led to the closure of the CBD to unauthorised vehicles at weekends. Subsequently, in 1970-72, the Central Business District (CBD) was divided into six zones, whose boundaries could not be crossed by private traffic. The zones were surrounded by an inner ring road, which acted as a bypass for through traffic, and allowed entry and exit to and from the sectors. Between 1970 and 1980, a number of other policies were also put in place.Three major central streets were pedestrianised, many streets were made one-way, parking charges were increased, and the number of spaces were reduced. The proportion of the tram network running on reserved tracks was increased from 65 to 90%, and other public transport was given some priorities on street and at signals.

In 1973-74, it was planned to extend the zoning concept to the whole of the Central Urban Area (CUA), and in 1978-80, the Vasastaden and Kungsportsav zones were introduced. In 1979, a comprehensive traffic policy was put into place, to manage traffic, to improve the attractiveness of other modes, to complement the existing cells, and to try and reduce vehicle flows, partly to facilitate implementing further cells. Parking was seen as particularly important, and by 1988, the number of parking spaces in the CBD had been cut from 21,000 to 14,000, and parking charges were increased by up to 100% (to about 1ECU/hour)

Aggregate traffic impacts:

24hr car traffic	1970	1971	1975	1979	1980	1981	1982
Across CBD boundary	150,000	111,000	100,500	93,000	81,000	79,500	82,500
Across CUA boundary	320,000	310,400	320,000	316,800	307,200	297,600	300,800
Around the 2 CUA cells*	194,500	--	191,500	179,100	--	178,800	--

*Traffic counts made at 8 selected locations on the cell boundaries, and aggregated to get an estimate of the change of flow.



A North-South screenline across the CUA recorded 25,265 vehicles in 1971, and 26,690 vehicles in 1983, an increase of 5.6%, with a marked shift of traffic towards the reently completed southern riverside route (to the north of the CBD).

These changes have occurred in the context of a 45% rise in cars crossing the regional community border, and an increase of 29% of car traffic in Gothenburg generally (as measured at 28 strategic locations) between 1970 and 1982.

Summary of aggregate traffic impacts:

There has obviously been a substantial decrease in traffic entering the CBD (-47% in 10 years), and the CUA (-4% in 1 year), and even some decrease in traffic around the boundaries of the two CUA cells created. However, through traffic has actually increased (+6% in 10 years), transferring onto the remaining available routes, particularly the southern riverside route. Nonetheless, the increase in through traffic is much less than traffic increases in the rest of Gothenburg, suggesting that the cells have both suppressed car trips for which they were the destination, and suppressed traffic growth in the area generally.

Other impacts of the CBD zones:

- Between 1970 and 1982, traffic casualties fell by 45% within the zones, and 40% overall (ie. both within the zones and on the zone boundaries). The material damage due to accidents fell by 55% within the zones, and 50% overall.
- Vehicle kilometres for private traffic increased by about 7%, but with no increase in vehicle hours, as changes to junctions made flows more efficient.
- 1981-1983, the number of bikes in the city increased by 200%.
- Noise and air pollution have declined
- "The CBD zones, which were initially opposed by traders, are nowadays accepted by everyone in the city."

Other impacts of the two CUA zones

- Time taken for trams and buses to pass through the area has reduced by 45 seconds per trip.
- In two years, accidents within the cells fell by 27%, and on roads surrounding the cells, fell by 9%, giving a total decrease of 14%. ('Before' accidents were recorded 1/9/77-31/8/79, and 'after' accidents were recorded 1/9/80-31/8/82). The authors comment that substantially greater accident reductions are expected, as it took two years before major reductions occurred in the CBD
- Approximately a third of residents enjoyed a decrease in noise of up to 8dBA, one third were not affected, and one third experienced an increase in noise of up to 4dBA, although largely only of 1-2dB. Overall, there was a decrease in the amount of noise experienced by residents.
- "It seems likely that reductions in air pollution will also have occurred"
- The new cells and associated measures cost 5.8million SEK. Set against these are accident reductions (2.2m), public transport time savings (estimated 2m), private transport time losses (estimated 0m), extra vehicle kilometres (estimated 0.5m) and 'unquantifiable environmental benefits'. "This suggests a first year rate of return in excess of 60%, which is impressive by any standards".

General

- 1967-1982, total delay for all trams in the peak hour reduced from 7 hours to 1 hour

Motives:

Falk, May and Bendixson argue that the zoning scheme was largely introduced to *reroute* traffic, and that any traffic restraint is largely "a by-product". They note the importance of spatial scale, and that "what may look like traffic restraint for a small area may be traffic rerouting in a large one". They also argue that any zoning plan needs 'alternative capacity' available nearby (for rerouting), and that road improvements on the southern river route were vital to the successful introduction of the cells. They do highlight that 'alternative capacity' can partly be created by other traffic restraint policies like parking restrictions, that rerouting "implies a resdistribution from private to public transport", and that the 1979 traffic plan may create new opportunities. Interestingly, the traffic restraint evident from the zoning policy itself is largely ignored as a self-regulatory mechanism.

Design:

The CBD cells were initially introduced as "an overnight operation using temporary concrete barriers which were gradually made permanent once the system was seen to be working". With the smaller cells, parly because of the CBD experience "it was possible to go at once to permanency".
Moreover "experience of the CBD cells led to decisions to rebuild the footways along the boundary streets so that they act as thresholds, and signal to drivers that they are entering protected areas where they should be especially careful about pedestrians".
Since the traffic cells result in a lot of traffic rerouting, "it is notable that the city intends to encourage a change of land use in those places [with traffic gains] to make them less sensitive. Specifically, "the land use plan therefore prescribes that apartments on the lowest floors of buildings along those streets will be turned into offices".

Public consultation:

An extensive public consultation exercise was undertaken before introducing the two CUA cells, however received a poor response. The authors note "with hindsight, it appears that the need for consultation was exaggerated...it would have been preferable to implement the scheme more rapidly, modifying it later as necessary in the light of experience"

Caveats:

It is not clear whether the zoning policy for the city represents true 'capacity' reduction, in that access across particular roads has been restricted, rather than road space reduced, (although in the CBD, the associated pedestrianisation *has* clearly reduced the space available to motorised traffic). Nonetheless, traffic reduction has occurred, and traffic growth has been suppressed, and so this example partly serves to highlight that traffic flows (and capacity for particular movements) are a product of network configurations, not merely road space.

The other 'problem' with this case study, is that a number of associated policies were put into practise at the same time. The authors themselves note "it is difficult to isolate the effects of different measures, although it is clear that the main cause of the changes described in this study have been the cells and associated road improvements". This case study perhaps shows how effective capacity reductions can be when they form part of a complete package of measures.

16. Greater Manchester - general

Sources: Rogers 1997, Rogers 1991, Robinson 1996

Although no details were available about particular schemes in Greater Manchester, a number of responses were received relating to policies implemented there, which have relevance for the issue of capacity reduction.

Keith Rogers, Greater Manchester Transportation Unit, writes generally about schemes involving capacity reduction, and states:

"Such schemes often work well from a traffic viewpoint, especially after a settling down period, because:

- their design is often the result of consultation, evaluation of options and fine tuning
- traffic (ie. the trip matrix) changes to suit the new network.

There are also cases where the road closure may improve some features of a road network, even for vehicular traffic, eg. by reducing conflicting turning movements or eliminating some junctions altogether".

"In the last two decades, the main town centres of Greater Manchester have been treated with a range of measures, which include complete or partial ring roads and, within the ring roads, full or partial pedestrianisation, bus priorities and new or refurbished bus stations. The objectives of these town centre packages have been to enhance their attractiveness to pedestrians and to public transport users, to provide a framework for development and an attractive setting for important buildings and townscape. The ring roads...remove through traffic from the centre, and provide access for servicing and car park traffic. They were not planned either to increase or decrease highway capacity".

However, he argues that "if the effect of a town centre package *is* to reduce capacity, either overall or for particular movements, traffic forecasts made with a fixed, current (ie. pre-scheme) trip matrix may exaggerate the problems likely to result from a scheme".

Consequently, he describes an approach developed by GMTU to model traffic reductions and "simulate drivers' reactions to network changes", which is known as "matrix capping". Specifically, "ME2 is used with link flow targets based on link capacities to reduce individual matrix cell values to levels which the network can accommodate in the modelled hour". The modelling starts with a baseline matrix for a particular year. This matrix is then assigned to the network which will be operating at that time. "Traffic in excess of capacity... is removed, so that the traffic remaining in the matrix is realistic in relation to capacity. However, any assumed growth within capacity...is left unchanged".

He notes "the main alternatives to matrix capping for forecasting the effects of highway network capacity reductions are currently elasticity-based approaches. In the context of pedestrianisation schemes, however, matrix capping would appear to be a [more] suitable forecasting method because it operates directly from the features of the network, rather than indirectly through changes in generalised cost, [and schemes like pedestrianisation] typically reduce capacity for certain movements or prohibit certain movements altogether".

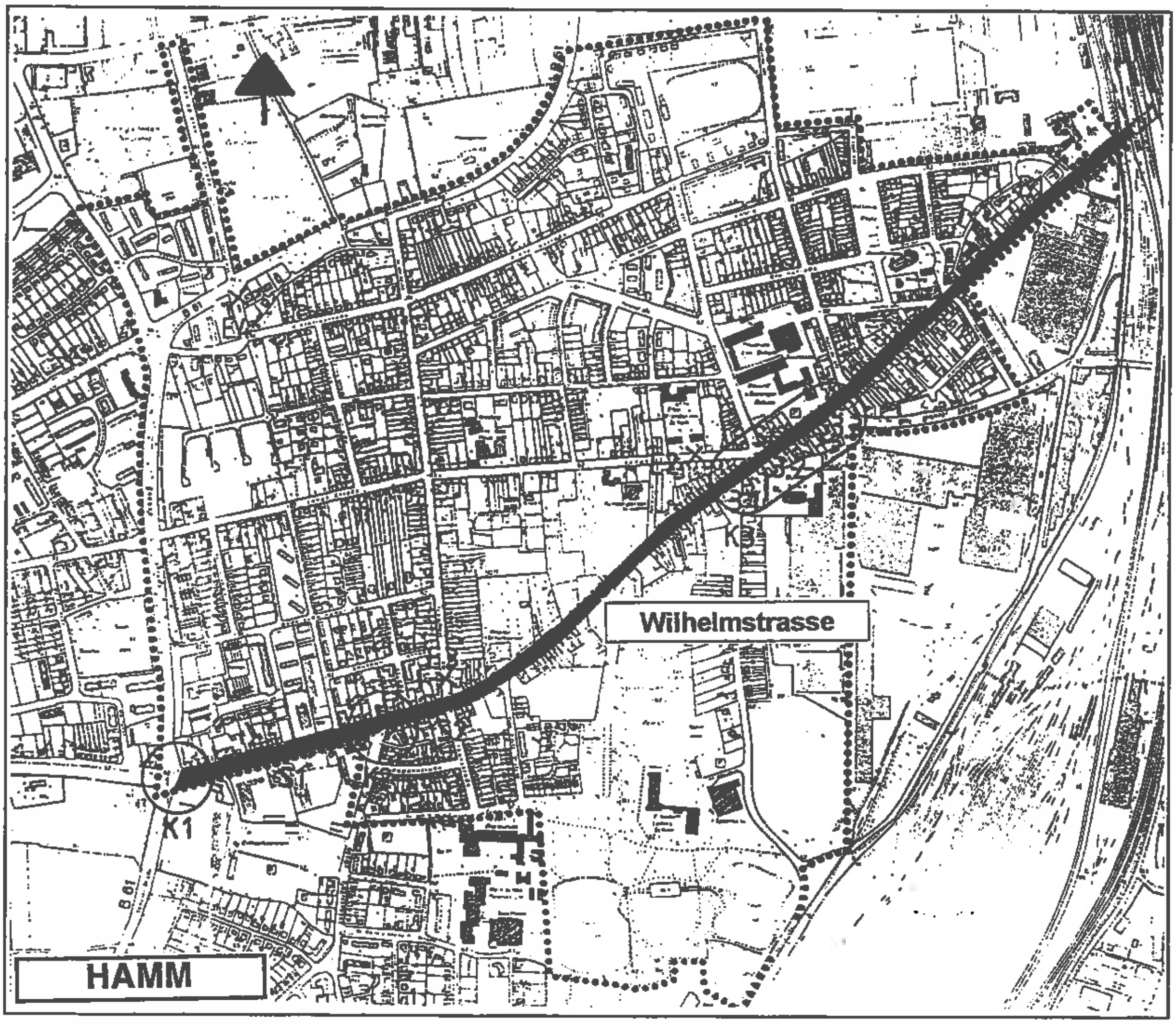
Derek Robinson, Acting City Engineer for Manchester City Council provides general information on the design of capacity reduction schemes. He writes:

"A number of traffic calming schemes have been implemented in recent years in Manchester, many with the objective of reducing or eliminating through traffic on unsuitable roads (rat running). Self enforcing measures such as road closures, priority chicanes and road humps are preferred over simply designating roads "access only"."

He also refers specifically to the recently successful closure of Spath Road, a residential road in South Manchester linking two radials. This road used to carry about 600-700 vehicles in the peak hour, and is now shut to all vehicles except cycles. "Access for the emergency services was accommodated through the use of plastic bollards that shear off when hit".

17. Hamm 1992

Source: Hatzfeld-Junker 1993



Hamm is a town of 183,000 population located in North-Rhine-Westphalia. It has implemented traffic calming and pedestrianisation in the town centre and inner city areas since 1986.

Wilhelmstrasse is a major road approaching the town centre in the westerly direction. In 1987, it had a daily capacity of 20,000 motor vehicles. The streets can be divided into the eastern part with 15,000 motor vehicles on average and the western part with 18,500 to 24,000 motor vehicles.

In 1992, the western part was reduced from 4 to 2 lanes, and at the same time left turning lanes were introduced at junctions.The eastern part had already been traffic calmed.

Before counts took place during November/December 1991, and after counts in May/June 1992 and again in Nov/December 1992.

Impacts on traffic

	Before	After	Change
Wilhelmstrasse (western part)	24,000	20,000	-4,000 (-17%)
Wilhelmstrasse (eastern part)	19,000	16,000	-3,000 (-16%)
Parallel roads	--	--	"Reductions"

The after survey showed that there was a reduction of motor vehicle traffic along most of the road of 16%. The decline was from 24,000 motor vehicles to 20,000 motor vehicles and on some stretches of the road from 19,000 to 16,000 motor vehicles. Yet, on one short stretch the reduction was no more than 4% (Hatzfeld-Junker 1993, p.7).

There was a stronger reduction in traffic entering the town centre in one direction. There has been no increase in traffic on parallel roads. Instead, there was also a reduction in motor vehicle traffic in these roads, though figures were not given.

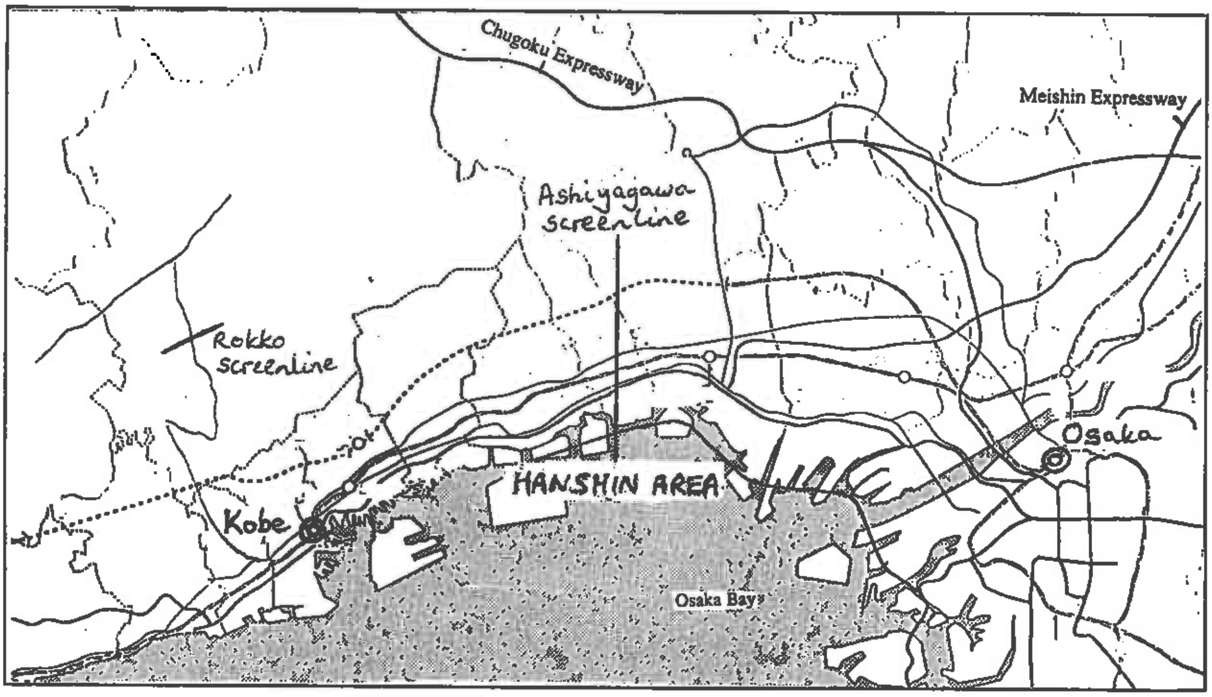
There was also no additional increase in waiting times for motor vehicles at traffic lights, with a few exceptions.

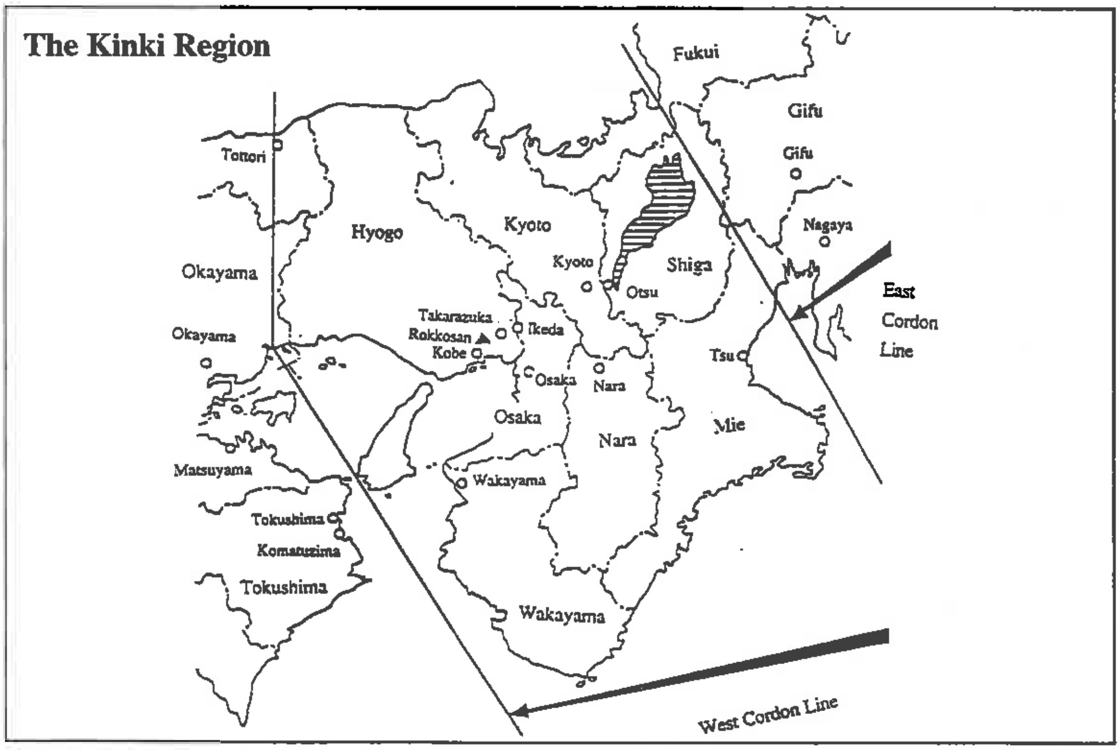
Impacts on accidents

The traffic flow reduction also had a positive effect on accidents. The number of accidents was reduced by 54% during the same time period, probably because of the reduced vehicles speeds after the modifications (ibid, p.10).

18. Hanshin-Awaji earthquake (Japan) 1995

Source: research for this project by Kitamura, Yamamoto & Fujii, reported in full in attached Annex.





On 17th January 1995, the Hanshin-Awaji earthquake devastated the densely populated Hanshin metropolitan area which stretches between Kobe and Osaka, killing 5,300 people. All of the major highways and rail lines running East-West between Kobe and Osaka were affected.

The Hanshin Expressway network (ie. the roads running between the two cities) was mostly restored by April 1995, and fully restored by July 1st, although there were still traffic restrictions on certain sections between certain hours, which lasted into 1996. The Meishin Expressway and Chugoku Expressway (roads further north, leading to other parts of Japan) were fully restored by the end of July. The rail lines were also restored gradually, becoming full operational by the end of June.

Traffic count data was available before and after the earthquake at selected locations on major highways, and a number of small scale surveys were also carried out.

Traffic counts at the cordons across the Kinki region as a whole showed a dramatic decline in vehicle traffic immediately after the earthquake, which resumed pre-quake levels in about a month.

However, traffic in the Osaka-Kobe area seems to have declined dramatically.

Daily traffic volumes for...	Pre-quake*	15th February	19th April
Ashiyagawa screenline	252,900	74,400	103,300
Rokko screenline	57100	75700	72400
Highway 4	54200	55600	56800
Maizuru Expressway	15300	13400	11200
Chugoku Expressway	79300	85600	93200
Totals	458,800	304,700	336,900
Change from pre-quake		-154,100 (-36%)	-121,900 (-27%)

* October 1994 for the two screenlines and 12th January for the 3 main roads

N.B. The Rokko screenline measures traffic on the major route for traffic wanting to divert north and avoid the Kobe-Osaka corridor. Highway 9, the Maizuru Expressway and the Chugoku Expressway routes are routes further north that traffic could have taken to avoid the Hanshin corridor altogether.

Peak-period mean highway travel speeds between Osaka and Kobe were about 22km/hr in October 1994, 11km/hr on 15th February and 14km/hr on 19th April.

Other evidence about the impacts of the earthquake was available from a range of small scale surveys. These surveys suggested:

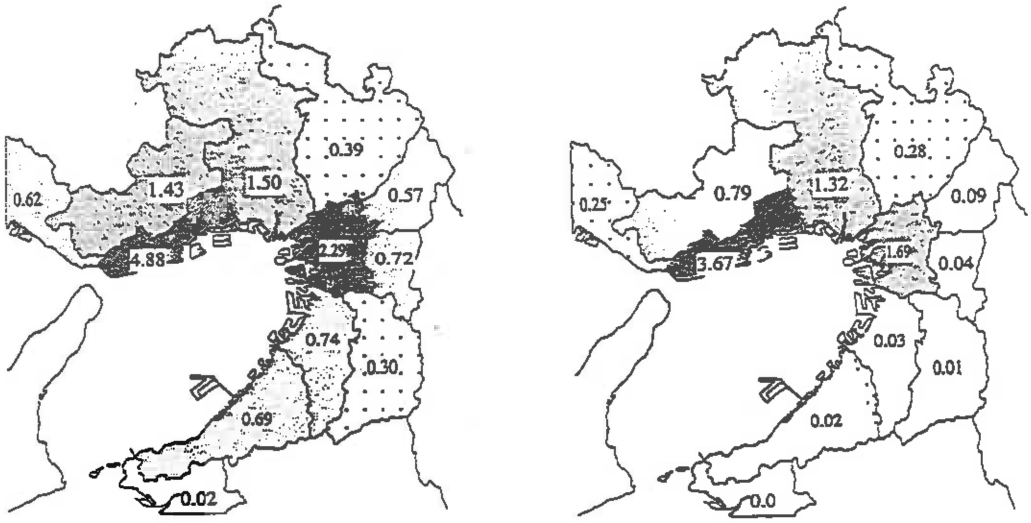
- a major decline in travel for non-work purposes

Kyoto University carried out 2 waves of a panel study of over 800 residents in the Hanshin area in November 1994, and June 1995. Respondents were asked about how often they visited 13 sub-areas of the Osaka-Kobe region for non-work purposes during the one month period preceding the survey. Dramatic reductions in trip frequency were recorded, particularly to the more distant southern areas, suggesting that respondents action spaces "have contracted substantially". This is shown below.

Frequency of trips made for non-work activities by respondents from the coastal sub-area of Kobe city.

Before - November 1994
(sample size - 116 people)

After - June 1995
(Sample size - 136 people)



Data were also collected about average travel distances of these trips. In general these had also reduced. Using the two measures together, it was possible to calculate that total travel distance (in person-km/month) had declined from 508.9 to 339.4 for all respondents, and from 646.4 to 213.4 for respondents from the hard hit coastal Kobe sub-area, a decline of over two thirds.

- a general decline in trip frequency of those within the impacted area

The Kyoto panel survey also collected two waves of data on all trips made in a one day survey period by over 200 residents in the earthquake-impacted area, and in a non-impacted area. There was a significant difference between the way the travel behaviour of the two groups changed. Residents in the non-impacted area showed no significant change in trip frequency, whilst mean trip duration fell by nearly 7 mins (which may have been due to a contraction in the area they were travelling to). Residents in the impacted area significantly reduced their trip frequency by an average of 0.5 trips a day, whilst trip duration increased by over 8 mins. Overall, there was a reduction in the total travel time (-20 mins) of respondents from the non-impacted area, whilst it has increased (+4 mins) for those in the impacted area, despite the fact that they now make less trips.

Surveys of residents and firms in and around the City of Kobe in July/August, 1995 by Kishino *et al* (1996), provides supportive evidence for the decline in trip frequency . Their results showed that the frequency of leaving home declined to 47% one week after the earthquake, and then gradually increased to 67% by 10 weeks (March 31st), 75% by 15 weeks (April 30) and was still at only 86% by about 28 weeks (July 31st).

- no major change in mode use

Matsumura et al carried out a number of surveys into mode use.

In October 1995, 386 residents around a major rail station in the Hanshin corridor were surveyed. The results showed that immediately after the earthquake, nearly 70% of respondents were working from home, however by April/May, only 8% were, and patterns of mode use were basically re-established. By October 1995, "the distribution of primary commute modes had more or less reverted to the pre-quake distribution", as shown below. Analysis of 'access commute modes' as opposed to 'primary commute modes' showed a similar pattern.

Changes in primary commute mode

	Modal Split in Percent						
	Home Work	Walk	Bicycle	Motorcycle	Auto	Bus	Rail*
Before Earthquake	3.9	21.5	9.1	2.3	21.2	3.1	38.9
January, 1995+	68.1	1.3	1.8	3.6	1.0	2.8	21.2
April - May, 1995	8.0	19.2	11.7	2.6	17.9	2.8	37.8
October, 1995	3.9	23.6	10.1	2.1	21.2	1.8	37.3

* Includes shuttle bus substituting rail service.
+ Immediately after the earthquake.

A second survey of 2,252 households in heavily impacted areas of the coastal Hanshin corridor was carried out in December 1995. In general, again, patterns of 'primary commute mode' in March appear to be broadly similar to pre-quake choices. Interestingly, for all households surveyed, there had been a slight increase in rail (+2.5%) and motorcycle use(+2%), at the expense of the car (-5%). However, a subset of 882 households who specifically did not change their address between the two time periods only showed a significant increase in motorcycle use generally (+2%). The study also showed an underlying variability in mode choice. For example, 27 people had swapped from walking/cyling to rail, and 21 had swapped from rail to walking/cycling.

There was some (potentially) contradictory evidence:

Matsumoto et al (1996) surveyed 524 residents of impacted areas (mostly male university employees) between June and August 1996. Respondents were asked whether their use of household automobiles had increased, decreased or stayed the same since the earthquake.In general, respondents from heavily impacted areas showed greater volatility in car use, and seemd to have decreased their car use more than in other areas. This appears to contradict Matsumura's results, although it is explicable if the reduced use of the car reported is due to less frequent trips, rather than a change of mode for specific trips.

Hino et al (1996) surveyed 900 firms from the Kobe and Hanshin areas, and showed that the % of firms in which more than 70% of employee commuted by car fell from 32.9% to 23.1%. Without dates for the survey, it is difficult to assess its relevance.

Summary:

Generally, the Kobe earthquake had a major effect on traffic. Immediately following it, traffic in the main Hanshin corridor fell by 71%, and was still only 41% of previous levels by June 1995. Even considering any alternative routes that people may have diverted over, there seems to have been a substantial reduction in car travel as a whole (-27%).

The main reason seems to be changes in trip frequency and distance. In June, those in the impacted area were making 0.5 trips less a day generally, Travel for non-work activities was particularly affected, and reduced by as much as two thirds in the hardest hit areas (due to changes in frequency and distance). Those in less impacted areas continued to make about the same number of trips for non-work activities, but they were generally shorter.

The dramatic reduction immediately following the earthquake may also have been due to a short-term change in 'mode choice', as about 70% of commuters chose to work from home. However, patterns of mode use quickly re-established themselves, with no major changes. "This, however, may be a unique phenomenon in this case, as the earthquake impacted both highway and rail networks".

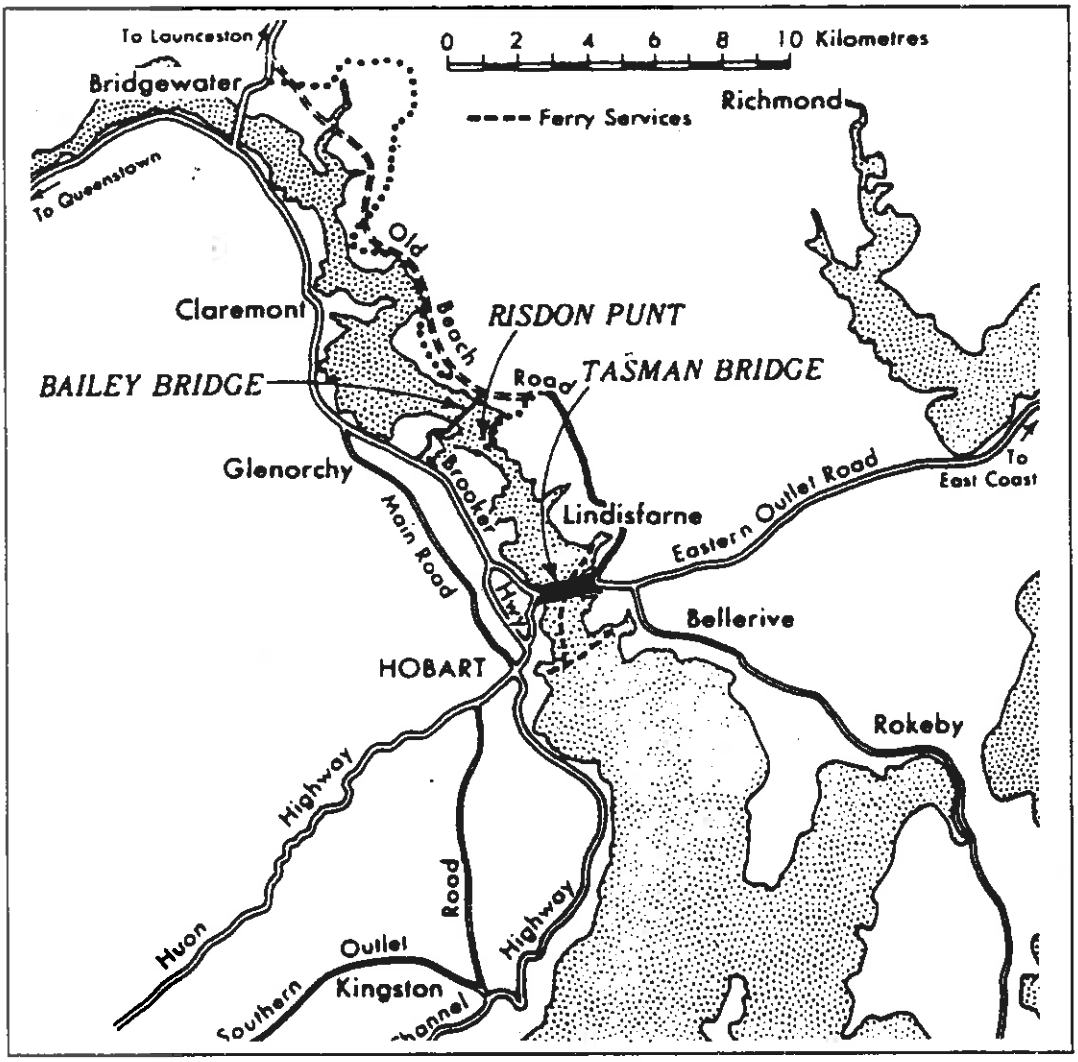
Caveats:

There are numerous caveats about the data sources used, which are given in far greater detail in the annex.

More generally, it is obviously incorrect to directly attribute the changes in travel behaviour to damage of the transport networks alone. Following the earthquake, there was also substantial disruption to shops, offices, houses and other facilities (including parking), with knock-on effects for incomes and lifestyles, which will all have affected where people could chose to travel to. Nonetheless, given that the restoration of most facilities will have proceeded at approximately the same speed across the area, it is still notable that travel for work was restored prior to travel for other purposes, that residents were still visiting facilities nearer to their homes nearly 5 months after the earthquake struck, and that there was no significant change in mode use.

19. Hobart - Tasman Bridge collapse 1975

Source: Lock & Gelling 1976a + b, Lock & Bowyer 1978, Hensher 1979, Sharples 1997



On Sunday 5th January 1975, the Tasman Bridge in Hobart (Tasmania) was destroyed, when a bulk ore carrier collided with it. It was the main link with the town centre (situated on the western shore of the River Derwent) for 50,000 people living in dormitory suburbs on the eastern shore. Post collapse, travellers were faced with a 50km diversion along poor quality roads to the Bridgewater bridge, two ferry services (from Lindesfarne & Bellerive), and a small vehicle carrying punt (from Risdon).

Initially, an RAAF helicopter, followed by 3 army landing barges, were made available for emergency medical use. The ferry services were augmented by extra boats, such that 12 ferries were available by the end of 1975. The ferry terminals and access routes were upgraded. Meanwhile, a temporary Bailey Bridge was constructed, and opened on 16th December 1975. Roads leading to both the Bridgewater and Bailey Bridges were upgraded on both sides of the River. The Tasman Bridge was eventually re-opened on 8th October 1977. Gradually the ferry services were cut back as a result.

A range of monitoring studies were carried out, of which few methodological details are available. Where possible, these are given in the main text.

Changes in daily movement:

	1974 (average)	March 1976	Change
Average weekday vehicle flow across the River Derwent	43,930	17,000 (+)	-26,930 (-61%)

	1974 (average)	Oct. 1975	Change
Approximate number of daily person trips across the River Derwent into Hobart	40,000	22,000	-18,000 (-45%)

(Clearly, these two statistics are not compatible, as 43,930 vehicles cannot have been transporting 40,000 people. Other information suggests that the person trips refer only to those made in the East to West direction, whilst the vehicle flows are two-way.

Number of East-West person trips in the morning peak

Date	Ferry & Punt	Bridgewater/ Bailey Bridge		Tasman Bridge		Total	Change in person trips*	Change in trips by pv*
		Bus	Pv	Bus	Pv			
1973	150	-	-	2616	10159	12925		
1974	150	-	-	3000	10350	13500		
5/1/75	Tasman Bridge collapes							
10/75	8150	--	1850	--	--	10000	-3,500 (-26%)	- 82%
16/12/75	Bailey Bridge opens							
1976	7051	782	3241	-	-	11074	-2,426 (-18%)	-69%
5/10/77	6219	434	3757	-	-	10510	-2990 (-22%)	-64%
8/10/77	Tasman Bridge re-opens							
12/10/77	1650	150	939	3225	6153	12117	-1383 (-10%)	-33%
19/10/77	1298	130	1028	2690	6636	11782	-1718 (-13%)	-26%
2/11/77	1141	150	808	2698	6805	11702	-1798 (-13%)	-26%
16/11/77	915	115	703	2597	7139	11469	-2031 (-15%)	-24%
7/12/77	787	120	729	3013	7380	12201	-1299 (-9.6%)	-22%
15/3/78	327	160	743	3020	8200	12450	-1050 (-7.8%)	-14%

*Change is the % change in trips related to 1974. The change in trips by private vehicle discounts any trips made by private vehicle via the punt. Numbers are likely to be sufficiently small that they would not affect results anyway.
The morning peak is defined as 7-9am for 1973, 1974 and 1976. For the other data, it is defined as 6.30-9.00am. Pv refers to private vehicle.

- **Summary of impacts on overall trip patterns**

Lock & Gelling (1976b) report that: "the loss of the Tasman Bridge initially reduced the number of daily person trips by 45%, whereas the peak period reduction was 26%. As the peak period predominantly consists of journey-to-work trips, movement at this time will remain more constant. Nevertheless, a reduction of 57% in off-peak travel would not be expected. Apparently a high number of non-work trips have been amalgamated, totally suppressed or satisfied by eastern shore facilities. With the improvement in cross-river links in 1976, the total number of trips has risen, but to a level well below the 1974 figure"

Similarly, by 1978, Lock & Bowyer report, from a modelling exercise, that "...the short-run mode/route predictions for bus and ferry were of the correct order. However, the total trips by private vehicles on the Tasman Bridge are lower than predicted. This would appear to be due largely to fewer suppressed trips being regenerated than were expected."

Meanwhile, "the traffic on the western shore remained substantially unaltered, indicating that extra trips were being generated within the western suburbs".

- **Summary of impacts on modal transfer**

Initially, there was obviously a large modal transfer, and "a stable traffic pattern emerged. This pattern did not change in substance, despite considerable road improvements, until the temporary Bailey Bridge was opened".

By October 1976, "Most operators had... undertaken some form of survey of their regular commuters....the overwhelming majority of commuters stated that they would continue to patronise the ferry service after the bridge re-opened"

However, the Bailey Bridge opening clearly did have an impact and a survey of 647 drivers using the Bailey Bridge revealed that 58% had previously been a passenger on a ferry or a punt.
290 of the surveyed trips were destined for the central area, of which 61% had transferred from a non-car mode. Moreover, 77% of these drivers actually passed an eastern shore ferry terminal on the way to the bridge, and 47% had previously used that ferry or punt service.

Hence, Lock & Gelling (1976b) comment "from an inspection of initial 1976 river crossing movement data, it was postulated that, irrespective of the standard of the public transport system, any improvement in facilities and capacity will quickly be filled by private motorists".

Eventually, in October 1977, the Tasman Bridge re-opened, and traffic did transfer across. However, Lock & Bowyer (1978) note that "the demand for buses was quite high and numerous complaints were received from the public about overcrowding. It is likely that this early experience caused a swing away from this form of transport." Equally, "a series of ferry service rescheduling took place...Each change was accompanied by a further loss in patronage, and ...by March 1978, ferry and punt patronage had fallen to pre-collapse levels and total travel was approaching pre-disaster levels as patterns of movement became re-established"

Therefore, passengers did transfer back to car, although the change took longer than expected, the cut back of alternative modes had a reciprocal impact. Moreover, it is notable that, even by March 1978, there was a greater reduction in car trips, that in the number of person journeys overall.

- **Impacts on journey times**

Immediately after the collision "what had been a 10-15 minute trip became a 1.5-2 hour journey in each direction", with long queues forming at the ferry terminals. As the alternative modes were put in place, the problems were alleviated, such that "9 months after the collision, little queuing for passenger ferries took place". However, shortly before the re-opening of the Tasman Bridge, door-to-door travel times for commuters were still approximately double what they had been before the collapse.

Meanwhile, "the morning peak in 1974 was 7-9am, but in 1975 and 1976, this had extended to 6.30-9am". "A positive result of the disaster has been the acceptance by the State Government of 'flexitime' working arrangements. Many Departments have introduced this scheme to alleviate pressure on the ferries, and to spread peak traffic volumes on the western shore"

- **Impacts on vehicle occupancy**

Vehicle occupancy fell from 1.62 persons to 1.46 persons, following the Bridge collapse. "This difference is probably due to the absence of the 'drove passenger' trip element".

- **Other short-term impacts**

Lock & Gelling (1976a): "A sudden feeling of isolation has been created, particularly for the elderly and handicapped, as virtually no community medical and health facilities exist on the eastern shore...Early social perception surveys have indicated that it is the insecurity and isolation from normal facilities that has created the most marked general response"

- **Other, long-term impacts**

Lock & Gelling (1976a): "As a result of the Bridge severance, Government facilities are being provided on the eastern shore and private industry is contributing by opening branch offices, shops and entertainment facilities".

- **Additional insights**

Rosemary Sharples (1997) provides some more personal insights into the impacts:

She was a secondary school student on the Eastern shore at the time and reports that "they had just built a new matriculation college (sixth form equivalent) on the eastern shore, so the collapse wasn't a major problem for me. It was, however, part of the reason for me going into a residential college in my first year at university".

She also highlights that traffic is now better regulated on the bridge, and that "the collapse of the bridge caused some relocation of services, and, I believe, industry. A bus depot was opened on the eastern shore...and...the boat builders...moved from fishing boats to ferries. Bob Clifford experimented with various sorts, from standard diesels through hovercrafts to catamarans. Thus was born International Catamarans, and thus began the rise of the catamaran ferry, like, for example, those on the Isle of Wight crossing and the SeaCats on the English Channel !".

Overall summary

The collapse of the Tasman Bridge led to 45% person trips being originally suppressed, with a far larger reduction in off-peak trips (57%) than peak-trips (26%). Moreover, the majority of remaining trips shifted to non-car modes. As the temporary Bailey Bridge re-opened, a significant shift to the car took place, and some of the trips were regenerated. When the Tasman Bridge re-opened, further shifts towards increasing numbers of trips, and increasing car use then occurred. However, it is notable that six months after the bridge re-opened, (and over two and a half years after its original collapse), peak period cross river trips were still 8% less than they had been, and the number of private vehicle trips were 14% lower than previously.

Meanwhile, people had obviously made a variety of adaptions, (like Rosemary Sharples' decision to live in a residential college near her university), and in the longer term, a number of jobs and facilities relocated to the eastern shore.

Modelling considerations:

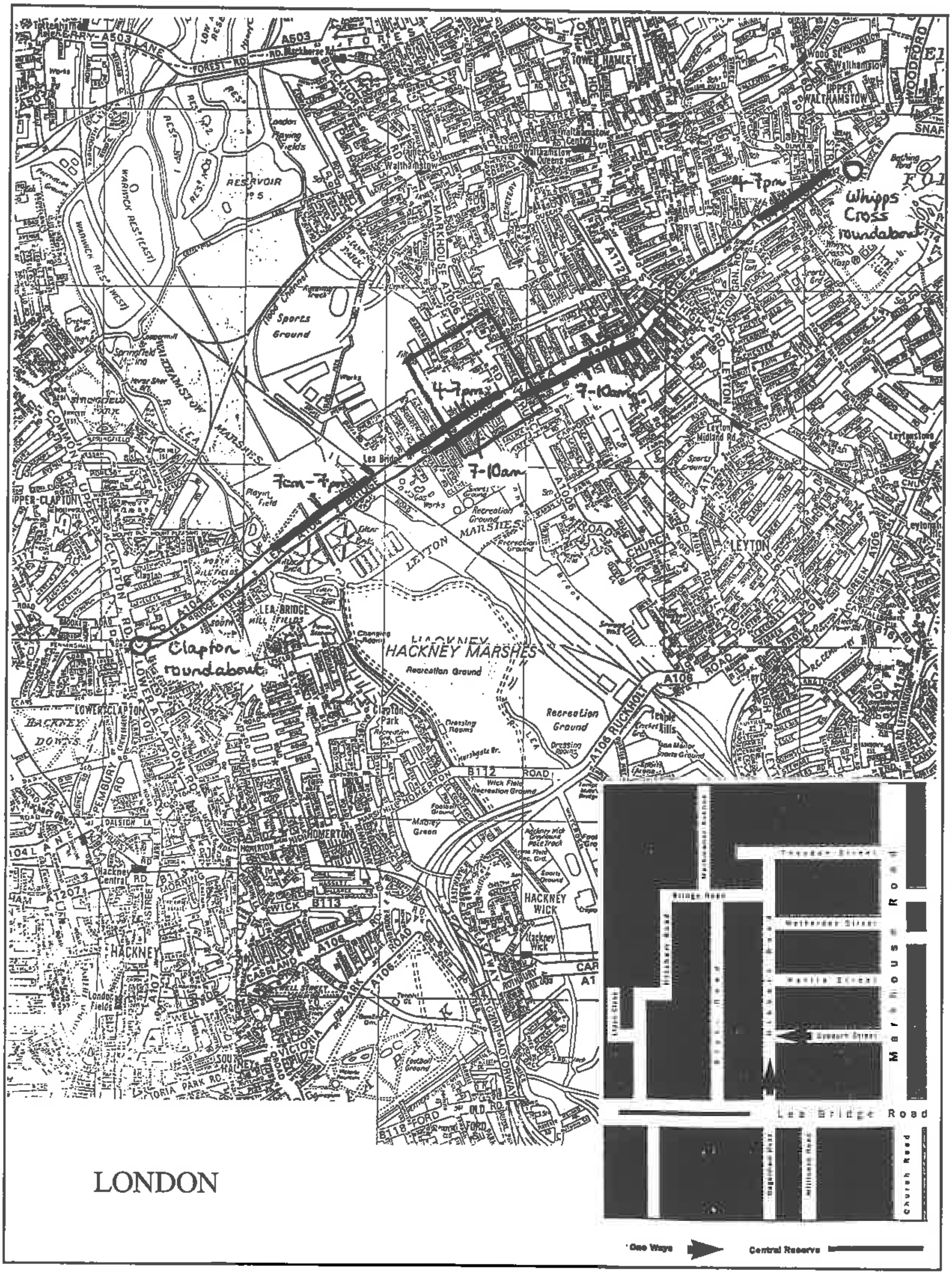
Hensher (1979) reports on the use of a multinomial logit model to predict the mode and route market shares associated with the reopening of the Tasman Bridge, which is based upon a theory of individual choice behaviour where alternative options are discrete. The work is mainly presented "to illustrate the potential of this relatively new microeconomic approach to demand modelling", although he comments that "the empirical application has produced some important policy outputs", namely that car availability and unconstrained parking appear to be key factors in mode choice. For further understanding of this study, readers are referred to the original paper. Lock & Bowyer (1978) also report on modelling work, and again, readers are referred to their original paper. Their main conclusion has already been given above.

Caveats:

Few survey details are available. Specific caveats are recorded above.

20. London - A104 Lea Bridge road bus lanes 1994

Sources : Daunton 1997 (personal correspondence), London Borough of Waltham Forest 1995, MVA Consultancy 1995.



On 1st November 1994, 5 stretches of bus lane were introduced on the A104 Lea Bridge Road, a major route running across Hackney Marshes between central London, and the London Borough of Waltham Forest (LBWF). The westbound bus lanes operated in the morning peak, and the eastbound bus lanes operated (mainly) in the evening peak. They were introduced to improve general bus services and to persuade London Transport to reinstate several bus services into central London (no.38 & no.55) that had been withdrawn in 1990, because of the problems of running a reliable service.

On August 14th, 1995, an experimental central reservation was also introduced on the A104, plus some side street restrictions, to try and reduce rat running north of the A104. There were then plans in October 1995, to take out this reservation, and, instead, close 2 other roads as a better way of dealing with the rat running.

To assess the effects of the measures, a number of different surveys were available:

- Annual monitoring figures from the LBWF for 10 major routes in the Waltham Forest area

- Surveys undertaken by the MVA Consultancy to monitor the effects of the bus priority measures. Before surveys were largely undertaken in March/April 1992, and after surveys were undertaken in June 1995. Surveys included:

- turning count movement surveys (partly supplied by the LBWF) 1989-1992, and February 1995, used to calculate aggregate traffic flows.

- queue length surveys over 3 days in March/April 1992 at 5 locations in the morning peak, and 6 locations in the evening peak, followed by queue length surveys over 5 days in June 1995 at 5 locations in the morning peak, and 4 locations in the evening peak

- 4/5 journey-time runs for both bus and car in each peak, and in each direction, in March 1992, between Clapton Roundabout and Whipps Cross roundabout (4.7km). 20 equivalent bus journey time runs, and 10 equivalent car journey time runs in each peak, and each direction in June 1995.

- bus occupancy and headway surveys on a single day in March 1992, at 4 locations, with comparable monitoring in June 1995.

- Information collected by the LBWF relating to the road closures proposed to stop rat running. Survey details given with the tables, where available.

Aggregate effects:

Data from annual LBWF monitoring:

'All vehicles'	1993	1995	Change
Lea Bridge Road E11	34,070	31,102	-2968
Other routes (Ruckholt Road E10 & Forest Road E17)	77990	77831	-159

Data from the MVA report:

"In general, the traffic flows along Lea Bridge Road are lower in 1995 by about 25% in the morning peak, and 30% in the evening peak"

"Queue lengths have remained of a similar order or shorter".

Car journey times (in mins)	March 1992	June 1995	Change
Average car journey time - westbound morning peak	25.42	25.11	-0.31 (-1%)
Average car journey time - eastbound evening peak	14.22	14.57	+0.35 (+2%)

Impact on bus services	March 1992	June 1995	Change
Average bus journey time (mins) - westbound morning peak	25.15	19.73	-5.42 (-22%)
Standard deviation for bus journey times (mins) - westbound morning peak*	4.48	3.18	-1.3 (-29%)
Average hourly bus volume - westbound +	11.5	12	+0.5 (+4%)
Average hourly bus patronage - westbound +	249	221	-28 (-11%)
Average bus journey time (mins) - eastbound evening peak	18.53	17.45	-1.08 (-6%)
Standard deviation for bus journey times (mins) - eastbound evening peak*	2.15	n/a	n/a
Average hourly bus volume - eastbound +	20.5	23	+2.5 (+12%)
Average hourly bus patronage - eastbound +	373	360	-13 (-3%)

* The smaller the standard deviation, the greater the bus service reliability.
+ Data were collected at two eastbound and two westbound sites. These have been added together and averaged, for this table.

Data from the LBWF report:

Time of day (am)	6	7	8	9	10
Hourly westbound traffic flow as % of 24 hour westbound traffic flows, 1990.	7.8	9.5	8.5	7.5	5.8
Hourly westbound traffic flow as % of 24 hour westbound traffic flows, 1995.	7.0	7.7	7.1	6.6	6.7

	Before bus lanes (1990-1992)	After bus lanes (1995)	After central reservation (Sept.1995)
24hr vehicle flows on A104 (east & westbound)	44,846[3]	--	41,087[4]
Traffic flows into Markhouse corner junction (vehicles, am peak hour)	2840	1860	2460
Traffic using rat runs (24hrs) north of A104 (Bridge Road)	(3188)	4,806[5]	3188[6]
Traffic using rat runs (24hrs) south of A104 (Dagenham Road)	(431)	431[7]	1102[8]
Journey times westbound (as per MVA report)	25.42[9]	25.11[10]	25.7[11]

Dates of surveys, where available, are given as footnotes.

Summary:

As a result of the bus lanes, traffic flows on Lea Bridge Road have clearly reduced, and the annual monitoring figures suggest that there has been no obvious transfer to other major routes across the marshes. However, there clearly has been some increase in rat running, first to the north of Lea Bridge Road, and latterly, to the south. An overall estimate of the changes is made as follows:

12 hour 2 way vehicle flows on...	Before	After (Sept 1995)	Change
A104	34,070	31,102	-2968
Other major routes across the marshes	77,990	77,831	-159
Rat runs	3619	4290	+671
Overall change	115,679	113,223	-2456 (-2%)

To create this table, it has been assumed that discrepancies between the LBWF report and the annual monitoring figures represent the difference between 12hr and 24 hr traffic flows. It also assumes that the rat running figures can be used as 12 hour vehicle flows (which makes sense, since not much rat running is likely to occur during the night !)

Thus, car traffic appears to have declined, car journey times have remained approximately constant, and traffic queues are the same length or shorter. There is also some evidence that, for remaining traffic, there has been some peak spreading.

[3] 10/9/90
[4] 18/9/95
[5] 13/3/95
[6] 11/9/95
[7] 7/8/95
[8] 18/9/95
[9] March 1992
[10] June 1995
[11] 7-14/9/95

Bus services appear to have improved in time and reliability in the morning peak westbound, and marginally improved in the evening peak eastbound. The number of services during the monitoring increased slightly, whilst patronage declined by 3-11%. (It should be noted that this is in the context of a 40% decline in bus patronage in 1990, when the two services were cut between London and the LBWF).

Other effects:

In April 1997, London Transport re-instated one of the bus services that had previously been removed due to problems of congestion.

In May 1995, a survey of the two rat running areas showed that 85% were in favour of the central reservation, and 85% were also in favour of the further road closures proposed in their area.

Caveats:

MVA note a series of caveats with their data:
For the traffic counts - "these findings have to be treated with caution, as most counts were for one day only and a strict comparison for a neutral month has not been possible".
With the car journey times - "there is a suspicion that the average car journey time in the 1992 survey was an overestimate".
Overall - "there is a suspicion that changes in signal operation at the Markhouse Corner junction may have affected the results".
It is noted that bus patronage was only monitored over one day, and that none of the surveys were carried out at exactly equivalent time periods.

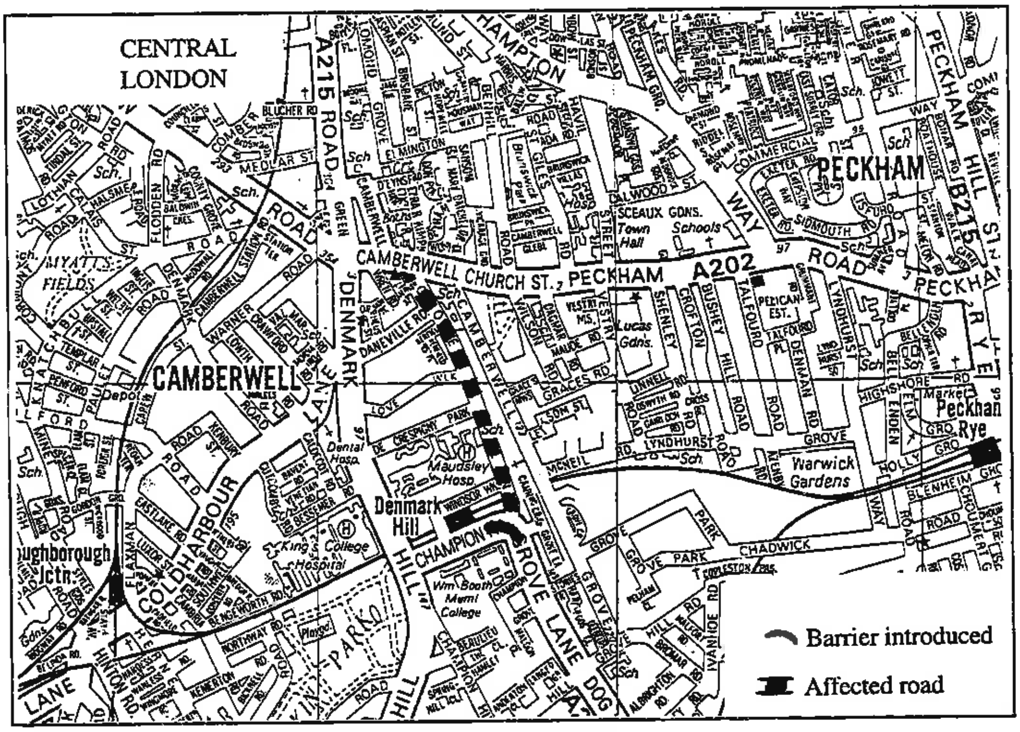
There are also various missing details for the LBWF data. With the annual monitoring figures, there is no information about the dates of the surveys, the time period that the flow represent, or the location of the traffic counters. It is not possible to tell whether the road closures proposed in October 1995 have taken place.

The table of %s of traffic flows in the morning peak hours has been created from data read from a graph, and may therefore be slightly inaccurate

Overall changes on Lea Bridge Road have been discussed here. There were some differences in the impacts of the bus lanes on different parts of the road, and at specific junctions.

21. London - Grove Lane / Champion Park

Source: GLC 198*



In Southwark, in the 1980s, the GLC introduced a strip in the middle of Champion Park to prevent a right turn onto part of Grove Lane. At the time, Grove Lane was being used as a northbound rat run by over 700 vehicles in the morning peak hour, and local residents were unhappy with the situation.

Traffic impacts:

	Change in northbound traffic flow in the area of Grove Lane	Significant changes in traffic on any other road	Total change
Vehicles per hour	-500	0	-500

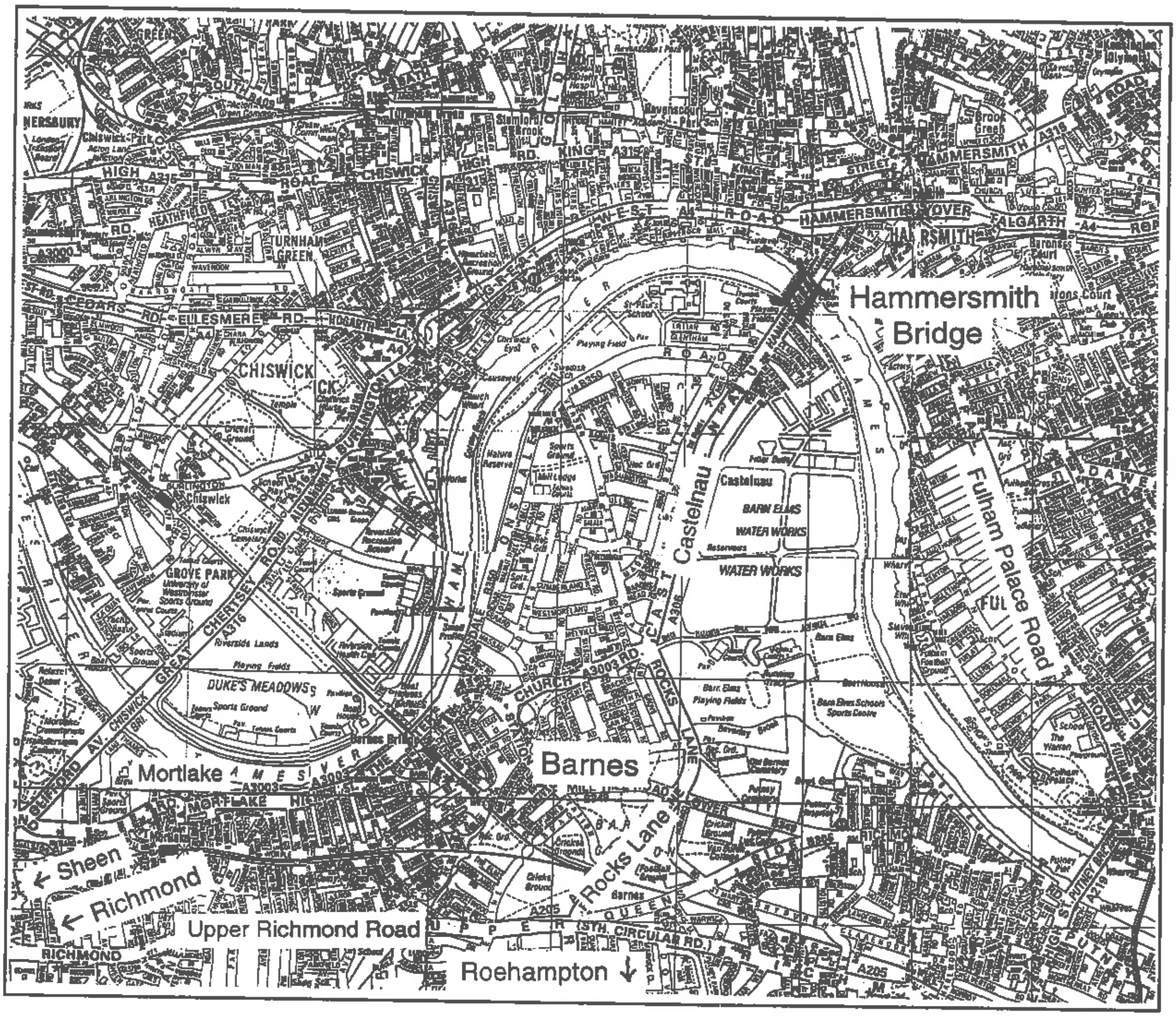
The report notes:
"Before the scheme was introduced, police feared that there might be increased delays to traffic including buses....After the scheme had settled down...London Transport reported that the scheme had been successful in reducing delays caused by traffic turning right into Grove Lane. Local and traffic police report that they have not experienced any problems as a result of the new scheme."

Caveats:

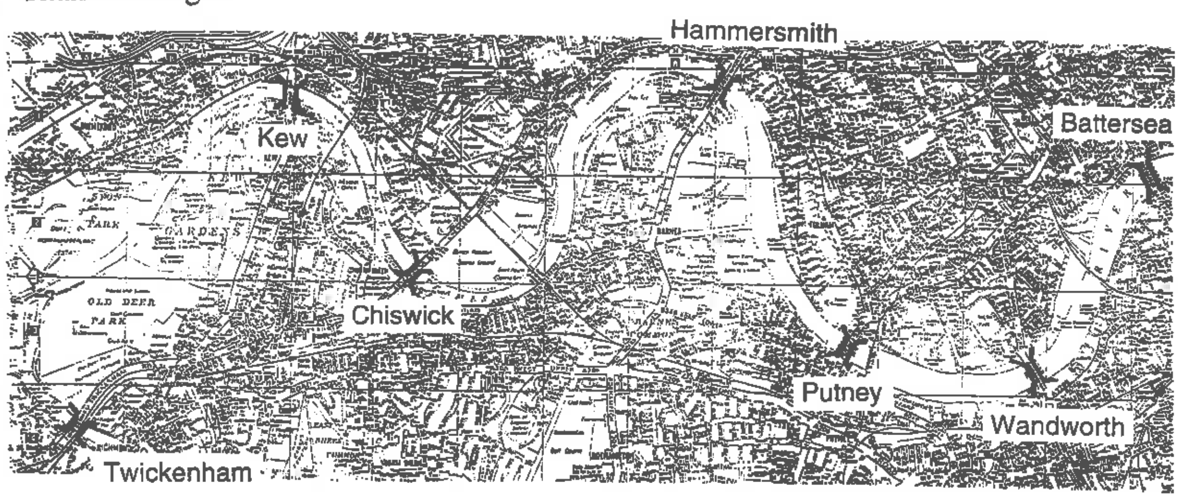
No information is available about when the layout of Grove Lane was changed, and the data comes from a relatively brief report.
The nature of the change is slightly confusing. Effectively, it *has* reduced the capacity of the network to carry northbound traffic, as vehicles are prevented from transferring onto the residential street. However, this has occurred without any specific road closures.This example therefore illustrates the complexities of defining 'road capacity', and the need for a detailed understanding of 'available road space'.

22. London - Hammersmith Bridge closure 1997

Sources: Accent Marketing & Research 1997, Brown 1997, Tim Williams 1997, Evening Standard 3/2/97, Irving Yass 1997, Hallé (1997)



Thames Bridges:



On 2nd February 1997, Hammersmith Bridge in the south-west of London, was closed to all traffic apart from scheduled buses, motorcycles, cycles, pedestrians and emergency vehicles, due to structural weaknesses. Prior to the closure, it carried approximately 30,000 vehicles a day.

Data and analysis about the impacts of the closure are available from a number of sources, as listed above. In particular, London Transport Buses employed Accent Marketing & Research to assess its effects, and a monitoring group was also set up by the Traffic Director (whose findings are reported by Brown 1997).

The picture that emerges from these studies and the various data available, is complex and still not fully understood. At the time of writing, London Transport Buses are looking more deeply into the survey work, and carrying out further analyses to clarify the results. The Traffic Director's monitoring group, as at December 1997, concluded that "the validity of certain key statistics had to be questioned", and that "the data, generally, did not yet support robust conclusions". There has been a discussion in the correspondence columns of local and national newspapers, with claims and counter-claims of residents' experiences in particular local and more distant streets. Because the issue has been a high-profile one, which has evoked substantial public interest and some passion, there has been a tendency for any observed developments in the area to be attributed to Hammersmith Bridge.

The reader should therefore read the following account with some caution. As far as possible, all of the available results are reported, drawing attention to the many caveats that apply to each. Finally, the authors' own, necessarily tentative, conclusions are summarised. These are stronger in relation to the local effects than the more distant effects, for which the data are less clear.

Further research into the impacts of Hammersmith Bridge closure is still being carried out.

Report of 'day one' effects from the Evening Standard (3/2/97):

"dire warnings that the closure would result in the greatest road chaos ever seen in London largely failed to materialise. Early reports suggested Chiswick Bridge to the west and Putney Bridge to the east were bearing the brunt of the displaced traffic, but by 8.30am, both police traffic monitors and AA Roadwatch reported that congestion was not as bad as on many other Monday mornings".

Report of 2-3 week effects from interview surveys by Accent Marketing & Research:

Accent Marketing and Research distributed 12,000 cards on Hammersmith bridge on Friday 31st January inviting drivers to take part in a survey. 1,246 (about 10%) were returned within two weeks, and 973 usable telephone interviews were then carried out between 14-28th February.

Respondents were asked about their previous and current trip making behaviour, with specific probing of "a typical work journey" and "a typical non-work journey" that were affected. They were then asked about how they had appraised their alternative travel options, "any other changes" they had made, how they viewed their new travel and what they thought about the bridge closure. Respondent characteristics were also recorded, together with their willingness to participate in a future follow-up survey in 6 months time.

Prior to the bridge closure, 71% of respondents made work trips (for commuting and employers business) by car over the bridge, at an average of 4 a week, and 68% made non-work trips (all other trip purposes) by car over the bridge at an average of 1.8 a week. Information recorded about changes to these trips can be summarised as follows:

Changes to trips made by car over the bridge for:	Work	Non - work
% trips no longer made	5%	20%
Changes to trip destination	No change	5% fewer trips made to W postcode, and 2% more trips made to SW postcode
Changes in trip frequency	No change	Slight fall
Changes in vehicle occupancy	Slight fall	Slight fall
Change in reported journey time of remaining trips	50 → 65 minutes	37 → 57 minutes
% trips for which people no longer use car	16%	20%
% trips transferred to Underground, bus or train	7%	9%
% trips transferred to bike	2%	1%
% trips now made on foot	7%	9%
% trips for which people still travel by car	79%	64%
% who said they diverted over Putney Bridge	44%	46%
% who said they diverted over Chiswick Bridge	47%	50%
% who said they diverted over Battersea, Wandsworth, Kew or Twickenham Bridges	23%	15%
% who said they diverted over Chelsea, Richmond, Albert, Vauxhall or Lambeth Bridges	6%	3%
% who said they diverted over other Bridges*	4%	2%

* In general, bridge diversions mentioned do not add to 100% as respondents often mentioned more than one bridge. Diversions as far away as Runnymede (on the M25), Waterloo, Blackfriars and Chertsey (on the M3) were mentioned, although only by a few respondents.

Taking into account the number of people making each type of journey by car, the frequency of those trips, and the time they were taking, some overall impacts on car travel were calculated:

For journeys over the bridge per respondent:	Before	After	% change
Number of trips made by car per week	4.1	2.9	-29%
Reported time spent travelling by car per week (in mins)*	173	186	+7.5%

*Concerns have been expressed about the accuracy of these figures, on the basis that many surveys show that people tend to overestimate journey time increases, when reporting them.

Responses were then solicited about "any other changes" people had made. 52% said none, while others quoted a range of things. Examples of some of the changes people had made (together with the number of mentions) are given below.

- left earlier or later (211, 22%)
- changed shopping location (96, 10%)
- changed journey time (67, 7%)
- work/meetings at home, or rearranged appointments (29, 3%)
- considered moving house, moved house, moved house earlier than planned (9, 1%)
- considered changing job (3, <1%)
- got firm to deliver shopping (2, <1%)

Respondents were then asked to respond to various statements about the bridge closure.

At least two thirds felt that there had not been enough warning about the bridge closure, although 76% agreed or agreed strongly that it was the right thing to do, given the safety considerations, and that "it is fair to allow buses to continue to use the bridge". There was also strong agreement that it has improved conditions for buses, cyclists and pedestrians.

However, at least 61% feel that their own journeys are now worse, in terms of cost, journey time, comfort, convenience and reliability", although 6% also think their journeys are better in terms of all those attributes. 26% had considered and rejected using public transport.

Potential sources of bias:

This survey is particularly interesting, because it enables the experience of individuals to be traced, rather than just reporting the behaviour of average groups. However, there is also a general problem with this methodology (as discussed in Chapter 3), and there are also a number of specific issues, some of which were identified as important problems by the Traffic Director's monitoring group. These are reported below.

- Inconsistencies in the Accent Marketing & Research report.

There is a discrepancy between the proportions of people reported as making trips by car before and after the bridge closure, as recorded in the executive summary, and the numbers of people referred to as doing so on p9 and p14 of the report. As quoted here, the impact on trip numbers is taken from the executive summary, whilst the impact on time spent travelling is mainly taken from p9 and 14, since these are what the references refer directly to. If the alternative figures were used, the implied reduction in trip numbers would be 26% and the implied increase in time spent travelling would be 8.5%.

- Natural variability or 'churn' of behaviour

For some of the responses recorded, like 'moving house', it is probable that the closure of the bridge was only one factor in the decision making. Therefore, some of the traffic reduction may only partially be attributable to the bridge closure. However, it is notable that the time period between the before and after surveys was very short, and that the numbers of people making such big changes was very small, in comparison to the overall reduction in the number of trips recorded. Moreover, various classes of people were discounted from the survey (eg. 13 people who were away on holiday or business; and 15 who could not be located at the telephone number they gave), thus minimising potential bias due to this 'natural variability' of activity.

It has also been noted that in London, many people do not have a sole commute mode, but often use public transport perhaps one day a week. However, the results probably already reflect this, since the average weekly frequency of work journeys by car was recorded as being 4 (not 5).

- Self-selected sample

The third possible source of bias comes from the fact that the sample were, to some extent, self-selected, and may therefore be unrepresentative of bridge users in general. Specifically, the Traffic Director's Group states that "the self-selecting sample and small percentage return associated with Accent's work for London Transport Buses was such that robust conclusions could not be drawn without a far deeper analysis, particularly of locational bias". In particular, as reported in Brown (1997), roadside interviews were carried out as part of a 1991 London Area Transport Survey, at Rocks Lane, a site 2km south of Hammersmith Bridge. Cars travelling northbound at this point are felt to be a reasonable proxy for those using the Bridge. The average journey length recorded in this survey (27.2km) is longer than the trip length implied by the journey times recorded by Accent Marketing and Research, and therefore, there may be some bias in the survey sample towards those with trip ends more local to the Bridge.

Follow-up survey

More information should become available soon from a second wave of the Accent Marketing and Research survey, which has been carried out in October. Preliminary results show greater reductions in traffic, and follow-up interviews are being carried out with about 65 individuals to assess the validity of their responses, and the degree to which their changes in behaviour can be attributed to the bridge closure.

Report of effects from traffic count data

The report by Brown (1997) summarises the results of a number of different traffic counts that were assessed, as part of the Traffic Director's monitoring of the bridge impacts. The monitoring group anticipated that the bridge closure would result in "private vehicular traffic transferring to other bridges in the locality exacerbating congestion during peak hours", and "drivers switching modes and using public transport".

Traffic count information was obtained as follows:
- traffic counts on bridges undertaken by bridge authorities for LOBEG (London Bridge Engineers Group)
- traffic counts on roads in the vicinity of the bridge provided by highways authorities

Previous work by STC5, (part of the Department of Environment, Transport and the Regions), was also used.

The following table reproduces information from STC5 and shows two-way all day average traffic flows. In three cases, figures were not available for 1995 or 1996. The most recent data, collected in October 1997, was provided directly by the bridge authorities.

24 hr traffic flows	October 1994	October 1996	March 1997	October 1997
Battersea	25,087	25,482	36,034	31,581
Wandsworth	56,840	47,437	55,001	52,501
Putney	55,003	49,608	70,754	57,103
Hammersmith	30,678	33,591	3,000*	3,092
Chiswick	49,715	--	51,352	40,760
Kew	44,587	--	63,742	60,115**
Twickenham	49,595	--	50,192	48,440

* Estimated figure   **Data was factored from a single lane count

This information can be summarised as follows:

		Putney, Hammersmith and Chiswick Bridges	All bridges given in table above
Oct. 1994		135,396	311,505
Mar. 1997		125,106	330,075
Oct. 1997		100,955	293,592
After 1 month	Overall change	-10,290 (-7.6%)	+18,570 (+6%)
	Change as % of traffic over Hammersmith Bridge	-33.5%	+60.5%
After 8 months	Overall change	-34,441 (-25.4%)	-17,913 (-5.8%)
	Change as % of traffic over Hammersmith Bridge	-112.2%	-58.4%

These figures appear to imply that there were traffic reductions in the immediate local area, and that there may also have been traffic reductions over a wider area in the longer term. It is notable that the 3 bridges screenline (1 month) suggest that about 30% of the trips previously made over Hammersmith are no longer made, which is consistent with the results of the Accent Marketing and Research survey.

However, there are numerous problems and potential sources of bias of the data that need to be considered, and the Traffic Director's Group concluded that:

"Considerable differences exist for counts on some of the bridges between survey periods. For example, average two-way traffic flows on Putney Bridge appear to have fallen by around 13,500 between March and October 1997, whilst Chiswick Bridge has seen a reduction in flow of over 10,000 vehicles per day during the same period.

The apparent changes in traffic flows on Putney, Chiswick and Kew Bridges cannot easily be explained. Further data and analysis at a more detailed level is required to explain the magnitude of the change implied by the data supplied".

Specifically, the following potential sources of bias and inaccuracy can be identified:

- Day-to-day and seasonal variability: These may have affected the comparisons between March and October figures.

- Traffic growth, which would have been expected to occur over the period. A comparison of Road Traffic Statistics Great Britain 1994 and 1997[1] suggests that traffic flows in London have increased by about 4% generally over that time, implying that this 4% traffic growth has been suppressed in the area around Hammersmith, and should be considered in conjunction with the recorded traffic reduction of 5.8%.

- Other changes being made in the surrounding areas. For example, major road works were being carried out on Putney Bridge in 1996, which affected travel patterns in that year, such that some changes in 1997 may be the reassertion of previously suppressed trip patterns. Numerous other local changes are also likely to have been taking place that could have affected traffic flows over the bridges.

- It is not clear that the bridges form discrete, alternative crossings. For example, some people may zig-zag across Twickenham Bridge, and then across another. Nonetheless, the aggregated counts should still give an indication of whether overall flows are increasing or decreasing, even if the figures cannot be directly translated into numbers of journeys.

- It is possible that some of the traffic may have diverted even further afield, although the results from the Accent Marketing and Research data suggest that this is only likely to apply to a very small proportion of journeys[2].

What is clear is that all of the traffic from Hammersmith Bridge has not simply transferred to the two closest neighbouring bridges (Putney & Chiswick), and that the closure of Hammersmith Bridge cannot be solely responsible for the all of the traffic increases elsewhere, as, overall, vehicle flows initially increased by more than the displaced traffic anyway. The implication that traffic growth has been suppressed, and that there have been overall traffic reductions over a wider area in the longer term is an important finding, deserving serious consideration.

Other data:

The Traffic Director's Group also reports on traffic counts carried out by the London Borough of Richmond on 6 roads local to the bridge, in either March or October 1997 (and sometimes both). However, there is no 'before' data with which to compare most of these counts, and

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[1] Data are taken from tables 3.3 of both editions, and refer to the average daily motor vehicle flows on all major roads in Greater London, calculated on an index of road length to be 28,300 vehicles in 1993, and 29,400 in 1996.

[2] Specifically, if it is assumed that people divert over the bridges in proportion to the number of times each bridge was mentioned as a diversion route, 92-96% of trips should have diverted over the bridges included in the table. Moreover, if anything, 92-96% will be an underestimate since closer bridges are likely to be used more often.

information is also not available from potentially more affected sites in the London Borough of Hammersmith and Fulham. They conclude that "there is anecdotal evidence that other roads (eg. Upper Richmond Road West, Fulham Palace Road) are suffering from increased congestion", but that further "evidence of changes in journey times and/or traffic flows would be required to confirm this inference".

Reports of impacts on bus patronage

Data on changes to bus services were available from Bus Wayfarer data and Quality of Service Indicators and have been collated by London Transport Buses. These are reported by Hallé (1997) and Brown (1997).

Three bus services use Hammersmith Bridge - the 33, 72 and 209 (which was previously the 9A service). Following the closure, extra buses were added to the 33 service, whilst the route of the 209 was shortened and the number of buses on it were reduced slightly. Overall, the total number of buses over the bridge was increased from 38 to 41 buses per hour.

The impacts on the three services can be summarised as follows, with additional information given below:

		33	72	209
Approximate reductions in journey times (mins)	Northbound (morning peak)	7-9	7-9	3
	Northbound (other times)	2-5	2-5	1
	Southbound (all times)	1-3	1-3	1-3
Estimated waiting times	Before (mins)	2.15	2.65	2.02
	After (mins)	1.23	1.7	1.35
	% change	-43%	-34%	-33%
Patronage	October 1996	53,384	23,228	37,863
	October 1997	61,219	28,333	48,168
	% change	+14.7	+22	+27.2

Journey times and estimated waiting times: These are quoted for the entire bus route. However, there have been some local increases in journey times, notably on the 209 approach to Mortlake in the morning peak, and some local increases in unreliability (due to congestion), notably on the 33 in the Sheen area.

Patronage: Figures have been given for particular sections of each bus route (Richmond to Hammersmith, Roehampton to Hammersmith and Mortlake to Hammersmith, respectively). Changes have been more dramatic in particular areas. For example, boardings of the 209 have doubled in Mortlake, boardings of the 33 have increased by 46% in Barnes and Castelnau, and boardings of the 72 have increased by 75% in Roehampton. Furthermore, patronage has apparently "increased continuously since the closure", suggesting an upward trend.

Overall impacts on services using Hammersmith Bridge

In general, Hallé reports that the combination of reduced running times and improved reliability have brought savings to bus passengers estimated at about £400,000 per annum, and that "all three routes have gone from being poorly performing routes to among the best routes operating in Inner London". However, there has also been a significant rise in complaints, due to crowding, and it is recognised that either more buses or bigger buses are needed to address this. He notes that the bridge closure has achieved major improvements outside peak hours (as well as during them), and all improvements are considerably greater than those provided by "a conventional with-flow bus lane", which "existed for northbound buses the whole length of Castlenau from Barnes to the bridge for many years".

Impacts on other routes

The impacts of the closure on bus routes using other bridges are unclear. Hallé (1997) states "there is no clear evidence of worsening journey times or reliability on bus services using other bridges. There was concern that conditions at Putney Bridge in particular would worsen but, in general, there have been no significant difficulties". However, Brown (1997) states that "route 220 which uses Putney Bridge and Route 391 which crosses Kew Bridge have experienced increased running times following the closure". (This discrepancy may be explained if the journey time increases referred to by Brown were small enough to be considered 'insignificant' by Hallé. No data are available in either case to enable an assessment to be made, which is perhaps notable, since if there were dramatic figures about worsening services, it would be surprising that Brown did not quote them).

Other information:

Yass (1997), of London First, comments: "Consultations we have had with businesses in the area during the summer indicated that, with a few exceptions, it has not caused them much difficulty".

Summary and conclusions:

The results of the closure of Hammersmith Bridge are complex, and analysis is still proceeding. The different agencies involved have not yet reached a common view on the interpretation of the figures, and consider that the existing data is not sufficiently reliable to draw substantive conclusions.

Our summary and tentative conclusions from the existing data are made below. However, it is clear that numerous caveats remain in relation to each of the data sources, and it is certain that this is not the last chapter in the continuing analysis of Hammersmith Bridge.

- *Summary of results (at face value)*

Source	Time period	Change in...	Result	Probable main source of bias
Evening Standard	Next day	Observed gridlock/chaos	None	Subjective impression

Accent Marketing & Research	2-3 weeks	Number of trips	-29%	Over-representation of local trips. Subjective over-estimates of journey time increases.
		Reported time spent travelling by car	+8%	
Bridge counts	1 month	Traffic over 3 local bridges	-8%	Seasonal variability
		Change as % of Hammersmith trips	-33%	
		Traffic over 7 local bridges	+6%	
		Change as % of Hammersmith trips	+61%	
	8 months	Traffic over 3 local bridges	-25%	Exclusion of 'natural' traffic growth
		Change as % of Hammersmith trips	-112%	
		Traffic over 7 local bridges	-6%	
		Change as % of Hammersmith trips	-58%	

- *Impacts on overall traffic levels:* It seems robust to conclude that traffic across the immediately neighbouring bridges is very substantially less than would be expected if all the Hammersmith Bridge traffic had diverted to them. In general, all data sources consistently suggest that there have been short-term traffic reductions in the *local* area, possibly in the order of 30%. The magnitude of such reductions appears to be far greater than the 'inaccuracies' that might be caused by the various potential sources of bias which are operating. Hence it seems viable to assert that the *total* volume of traffic in the *local* area is not as great as before. However, some streets have certainly suffered an increase, and congestion may have got worse, as discussed below.

  Traffic over more distant bridges has gone up, though attributing all of this increase to the Hammersmith closure is untenable because of the numbers. Specifically, more traffic has been found across the 7 bridges screenline, than ever used Hammersmith Bridge before its closure. Hence, the short-term traffic impacts across a wide area are unclear.

  In the longer term, the bridge counts imply that traffic reductions in the local area may be greater, and may have spread over a wider area. This is consistent with the preliminary findings from the second survey by Accent Marketing and Research. However, these findings are currently subject to further investigation and analysis.

  It is notable that people are obviously making a more complex range of behavioural adaptions than simply diverting to the nearest alternative routes, as all of the traffic from Hammersmith Bridge has not simply transferred to the two closest neighbouring bridges.

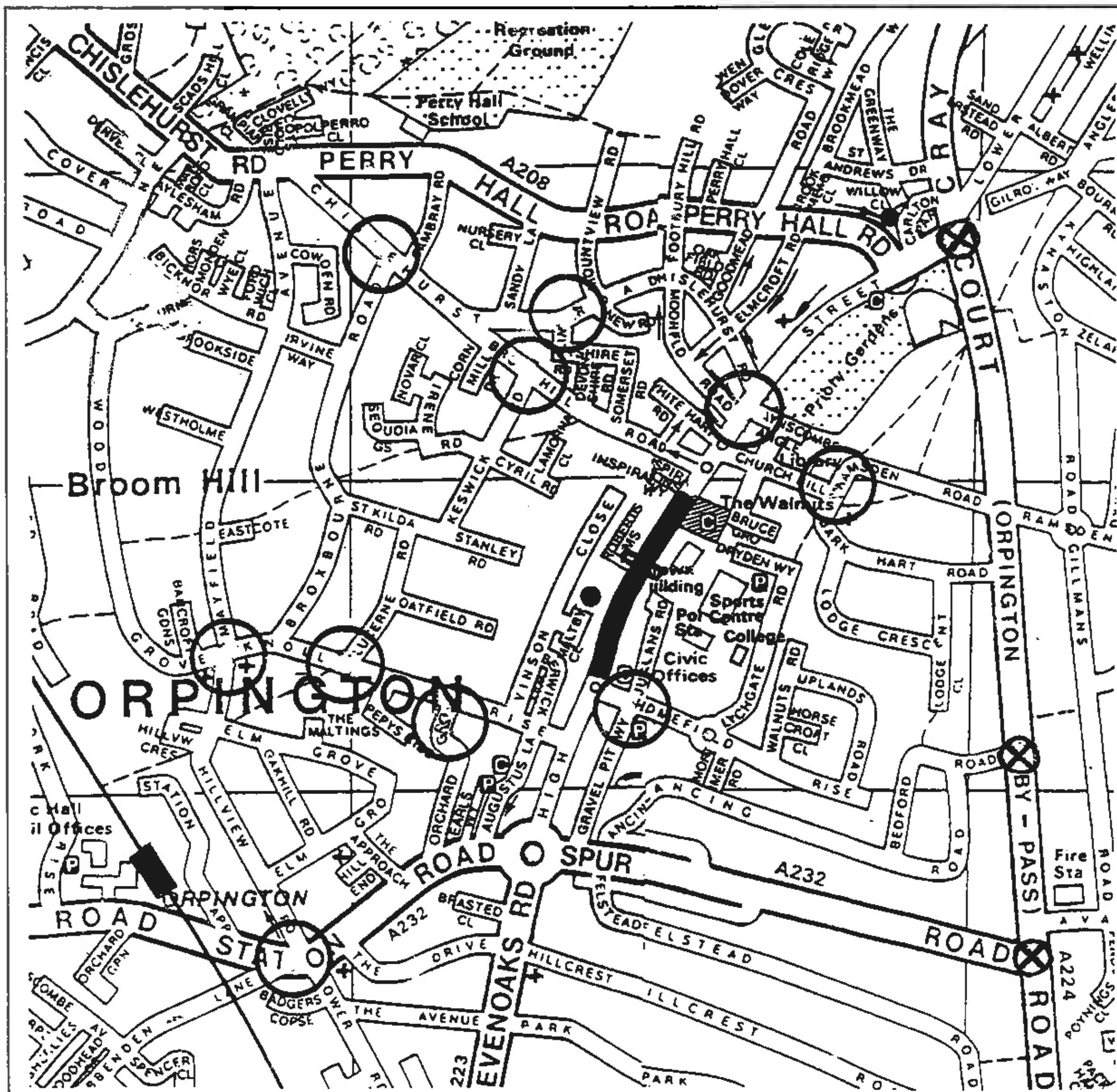
- *Impacts on congestion*: The degree of congestion on neighbouring roads has probably got worse. There is no concrete data on this either way. However, it is important to note that *even if* the largest estimates of traffic reduction are the most accurate, the remaining displaced vehicles could still cause traffic conditions on other roads to get worse, and the two findings are not incompatible. As discussed in Chapter Three, this would be expected, and it is likely that remedial traffic measures may be called for in those areas. However, the actual effects on congestion require direct measurement, since anecdotal reports are obviously influenced by subjective bias, and do not allow for potential traffic growth that could have occurred anyway.

- *Impacts on bus services:* Although there may now be a few localised problems for the bus services using Hammersmith Bridge, the overwhelming results are that those services are now faster and more reliable. Patronage has increased dramatically, and continues to do so. The impacts on services on neighbouring bridges are unclear, although there is no evidence that they have got dramatically worse.

- *Implications for monitoring:* Monitoring the effects of any capacity reduction will be complex because there will undoubtedly be other changes occurring in the study area at the same time, and because people will be making other decisions which have implications for their travel behaviour. Hence, it is not possible to give a simple, watertight explanation of where the traffic from Hammersmith Bridge has gone, because no such explanation would ever capture the reality of the situation, regardless of the care taken with the methodology.

23. London - Orpington High St. closure 1996/7

Source: key reference - Bell 1997. Other references: Bell 1996, Dyce 1995, Martin & Dyce 1995, Atkins Wootton Jeffreys 1995a, b.



Key:
- Restricted section of High St
- Traffic counter on High St
- Traffic counters on Court Rd
- Traffic counters across residential area

In April 1996, a section of Orpington High Street in the London Borough of Bromley, was closed on an experimental basis to all vehicles except buses, cycles, taxis and permit holders between 10am and 4pm. This followed an intensive consultation and discussion period. In March 1997, it was decided to rescind this order "subject to a new scheme being agreed with all interested parties to maintain as many benefits as possible from the experimental scheme". Better signing has also been introduced to reduce through movements and improve information about the car parks in the town. These decisions were based on numerous surveys, which are reported below.

Aggregate impacts on traffic

Hourly off-peak vehicle flows#	March 1996	June/Aug 1996+	February 1997
High St.	1105	760	744
Flows along Court Road*	2109	2240	2510
Aggregate flows at 10 junctions across the residential area	4975	4607	4951
Total	8189	7607	8205

Off-peak, or 'inter-peak' defined as 11am-3pm.
* Three junction measurements on Court Rd added and averaged.
+ Residential junction surveys carried out in June, other surveys carried out in August.
Residential surveys carried out on weekdays, other surveys done on Saturdays

The figures given above suggest that shortly following the introduction of the scheme, there was a decline in traffic (possibly of about 7%). However, by the following year, Bell (1997) reports that "traffic patterns have settled...and returned to pre-scheme levels".

The Knoll area is also discussed specifically, as previous traffic calming measures "had reduced traffic volumes from 9,000 to 6,000 vehicles a day". Immediately following the High St. closure, traffic volumes along Knoll Rise rose again, although they then declined by 9% between June 1996 and February 1997, and "the trend indicates reduced use of traffic calmed streets".

- **Bus services**

"Bus operators have not been able to quantify the benefits to bus services in terms of increased patronage. However, in terms of efficiency, Centre West London Buses Ltd indicate a 3-4min improvement in journey times from one end of the High St. to the other".

- **Pedestrian flows**

Hourly pedestrian flows measured between 11am and 3pm at a central point on Orpington High St rose from 4129 people in December 1994 to 4908 people in December 1996, an average increase of 19%.

- **Personal injury accidents (PIA)**

From April 1996 to February 1997, one PIA was recorded between 10am and 4pm, and 2PIAs were recorded outside these hours. In the three years prior to the scheme, 15PIAs were recorded between 10am and 4pm, and 8PIAs were recorded outside these hours.

- **Environmental improvements**

Monitoring on the High Street in early March 1997 suggested that, during the controlled hours, "background noise levels are reduced by at least 5dB and kerbside levels of carbon monoxide are reduced by at least 75%".

- **Enforcement**

The infringement of the zone by unauthorised vehicles was "a common complaint across all areas of consultation". The rate of illegal entries was 200 vehicles per hour in June 1996, which had dropped to 65-70 vehicles by February 1997, due to additional signing, police enforcement and a growing awareness of regulation. Infringement was higher on Sundays, at a rate of about 700 vehicles per hour, which was mainly attributed to a lack of knowledge that regulations applied.

- **Accessibility for the mobility handicapped**

There has been some discontent that disabled Orange Badge holders have been excluded from the restrictions. To attempt to address this, disabled parking close to the town centre has been extended, Dial-a-Ride services are permitted to enter the central area and a Shopmobility scheme is being set up.

- **Parking**

Comparing ticket sales between April & December in 1995 and 1996 at one of the council's car parks revealed that ticket sales rose by 7.5%. (During December, parking fees were reduced to 10 pence for stays of up to four hours which increased parking by 14% for that period). However, ticket sales from a privately operated car park were recorded as going down by 11.6% (although the company did increase its prices during the survey period).

- **Impacts on trade**

A survey of 300 businesses in Orpington town centre during February 1997 revealed that 74% did not support the scheme. 62% of the businesses claimed that the scheme had led to a small (21%) or considerable (41%) decrease in business. This decrease in trade was expressed most commonly amongst retail traders with 5 or less staff.

Hillier Parker carried out a relatively small study of 10 companies with stores in Orpington and elsewhere to try and assess the validity of these claims. Generally, this suggested that there had been a downturn of trade in Orpington of 5% compared to other local areas, although it was not clear whether this was due to the traffic scheme, or other factors (like external competition).

It is notable that 83% of businesses supported a general town centre managament initiative launched in January 1997, and 26% indicated that they would contribute to funding it.

- **Public opinion**

A survey of 618 pedestrians in Orpington High St in January 1997, following on from a similar exercise in July 1996 suggested that 45% of respondents liked the scheme "a little" or "a lot", whilst only 36% disliked it "a little" or " a lot". Comparison with the July figures suggested that, whilst the overall proportions of pro- and anti- support remained fairly constant, the number disliking it a lot had declined, whilst the number liking it a lot had increased. The greatest complaint was that it had not stopped traffic from entering the High St. completely.

Conclusion

"the scheme has achieved significant improvements to the environment of the High St, and provided tangible benefits for bus services, the quality of the shopping environment and pedestrians. However, studies revealed a persistent problem with enforcement of the scheme...In addition, three quarters of traders in the town are against the retention of the scheme. On balance... despite achieving most of the original objectives... the weight of opinion and loss of trade outweigh the technical success of the scheme", (Bell 1997).

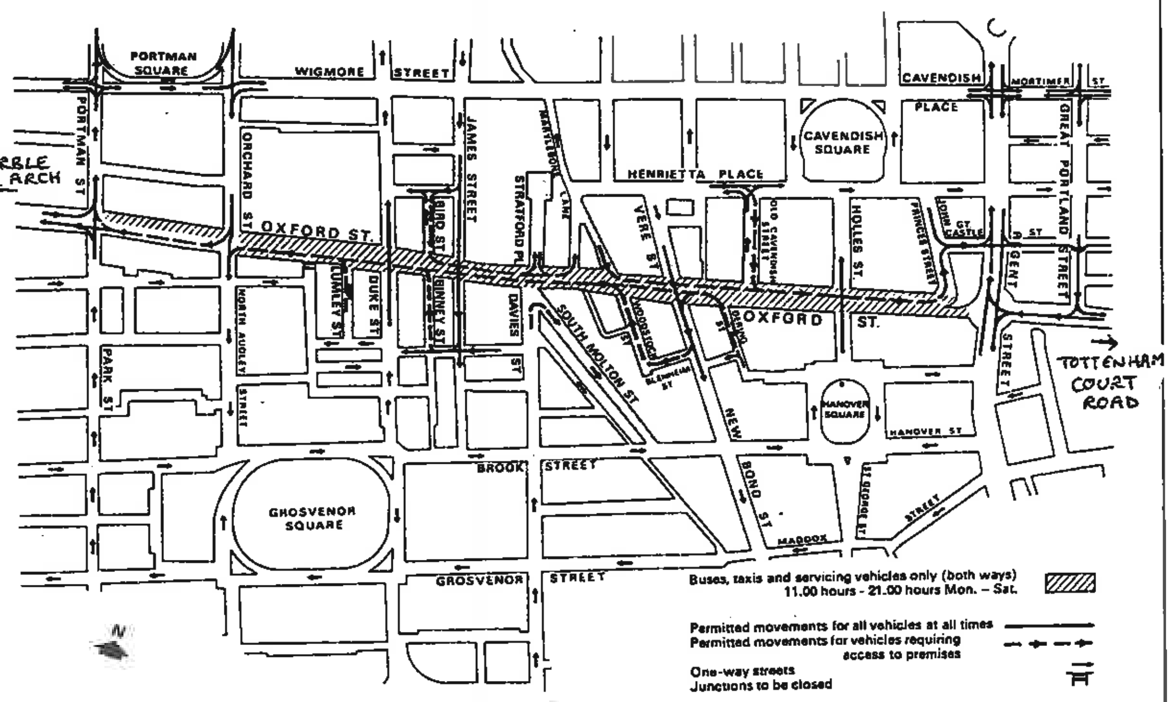
Caveats and comments:

Because of the difference in timing of the surveys, and because of the way the residential junction flows have been aggregated, it is not entirely clear what the overall traffic counts refer to. However, due to the nature of the network, it is difficult to defined a clear set of parallel routes for Orpington High St, and the figures recorded do provide some indication of the changes made, since each row of the table is internally consistent in the way that the traffic has been measured.

In considering the loss of trade, it is notable that experience of pedestrianisation elsewhere suggests that this is not uncommon in the first year of the scheme, but that trade often improves significantly in later years, to above the original level, (Hass-Klau 1993). Clearly, it is not possible to say with any certainty whether this would have occurred in Orpington.

24. London - Oxford Street 1972

Source: Elliott 1997, Turner 1997, Turner & Giannopoulos 1974, Parker & Eburah 1973, Abousief & Townsley 1973.



Oxford Street experimental scheme: traffic arrangements from November 1972.

In 1972, a section of Oxford Street was closed to private cars, and allocated to buses, taxis, cyclists, and pedestrians, as an experimental scheme under Section 9 of the 1967 Road Traffic Regulations Act. This occurred as a result of political pressure to improve conditions for shoppers at Christmas time as there was severe conflict between "the twin roles of Oxford Street as a traffic route and a shopping centre". The traffic restrictions were introduced in several phases between October and December, and applied between 11am and 9pm, Monday to Saturday. At the same time, work was carried out to widen pavements, narrow the carriageway, introduce seats and trees etc.. Complementary changes were also made to the traffic management arrangements on surrounding streets. Altogether, the scheme cost £82,000.

Only 9 months elapsed between the original briefing of the consultants, and the opening of the scheme, which was an exceptionally short time for a scheme of this type. Therefore, as expected, many adjustments were subsequently made to optimise the scheme, including changes to some turning bans, extension to a vehicle loading bay, reducing the operating hours to 11am-7pm, etc. As part of this adjustment procedure, Turner (1997) highlights the importance of 'queue management' at local blackspots. This involved the introduction of 'throttle points' at locations before traffic reached problem junctions, so that constrictions occurred in places where people had opportunities for diversion and where queues that did form were likely to be shorter. The relocation of queues from the Brook St./New Bond St. junction, to the Brook St./Park St. junction was critical in avoiding the build-up of long queues on sections of Brook Street.

In July 1973, the GLC confirmed the scheme and planned to extend it along the remainder of Oxford Street, as far as Tottenham Court Road.

To monitor the scheme, a number of surveys were carried out across the affected area by the GLC, consultants Brian Colquhoun & partners, and Westminster City Council. These included:
- Traffic counts: Automatic traffic counts of one-directional flows were carried out at 18 locations in August and October 1972. Hand tally counts were made at 72 junctions in March and October 1972, and Feb/March 1973.
- Speeds: For cars, a large central area survey was carried out in Spring 1971, and complemented by a survey on 6-7 infill links affecting Oxford St. in August 1972. Further surveys were carried out in October 1972 and Feb/March 1973. For taxis, surveys on 6 two-way origin-destination pairs were carried out in August, October and December 1972, and Feb/March 1973.
- Buses: results from continuous monitoring by London Transport were made available
- Pedestrian delays: surveys of time delays to pedestrians crossing the streets were made at 5 junctions in August, October and December 1972, and Feb/March 1993.
- Accidents: The continuous records collected by the Metropolitan police were made available
- Noise and fumes: The Scientific Branch of the GLC monitored noise at 20 locations, and fumes at 12 locations, in August, October and December 1972, and Feb/March 1973
- Public opinion: Surveys of pedestrians, residents and retailers were carried out in December 1972 and Feb 1973. Results from a Road Research Laboratory survey of pedestrians on Oxford St., carried out in October 1972, were also made available.

Impacts on traffic:

Oxford St was estimated to be the most congested site in London, and cited as a source of "severe congestion" on 42 occasions in 1969. Flows of 2-2,500 vehicles were expected around Christmas time, clashing with major pedestrian flows, as described below. Following the closure, the impact on sample peak hour flows was calculated as:

Vehicle flow per hour	**Before**	After	Total
Wigmore St.	**1600**	1850	+250
Oxford St	**1800**	950	-850
Brook St	**1300**	1350	+50
Grosvenor St	**1150**	1200	+50
Total	**5850**	5350	-500 (-8.5%)

Looking at the wider area, "no consistent traffic increase was detected on roads outside those immediately adjacent to Oxford St". Specifically, a decline of 80 vehicles an hour was noted on Marylebone Road (the first major east-west route to the north of Oxford St), although "this could easily have been a local daily variation in a flow of about 3000 vehicles per hour".

Giannopoulos & Turner emphasize that the figures quoted are averages, and that specifically, "the rerouting has caused different degrees of change over different lengths of these streets". Moreover, the changes were different for different categories of vehicles. For example, discounting the buses and taxis on Oxford St (35% of the flow), there was an overall traffic reduction of about 15% for other types of vehicles in the corridor as a whole.

Abousief and Townsley note that "traffic is tending to avoid Oxford St. outside the hours of the ban", and, looking at flows over time, state that "traffic restraint by congestion has been proved possible, but requires a settlement period which can extend up to two months".

Turner (1997) also notes that the ability of the diversionary routes to take the increases in traffic was partly due to the queue management measures, and partly due to better parking enforcement.

Other impacts:

- **Impacts on journey times and travel speeds**

On Oxford St. itself, average speeds increased from 9mph to 20mph, and there were substantial reductions in journey times, as described in the section on bus performance.The average overall journey time along a route through the major surrounding streets fell steadily, and levelled off after 3 months at 25% of its level in the first week of the scheme. Generally, there were no significant delays on particular routes, apart from in the westbound direction to the north of Oxford St. where increases in journey time were recorded. Most journey times for taxis were reduced, with the best result being a reduction from 16 to <8 minutes, however, the time spent on a typical trip by private car did increase by 15%, from 4.6 to 5.3 minutes.

- **Impacts on bus performance**

Prior to the scheme, bus journey times varied from 15 mins to 80 mins for the 1.2 mile length between Tottenham Court Road and Marble Arch, with average speeds of only 3.6mph. Following the scheme, overall bus journey times reduced by more than 4 minutes in each direction, and there were significant increases in reliability. Two bus routes were rerouted to Oxford St. to take advantage of the new conditions. London Transport estimated that time savings to bus passengers were approximately worth £250,000 per year, of which about £150,000 could be attributed to increased reliability. There were also estimated savings of over £85,000 in operating costs each year. Increased use of buses resulted in more than £65,000p.a. in extra fares.

- **Impacts on pedestrians**

Prior to the scheme, pedestrian flows of more than 16,000 pedestrians per hour were recorded in November, and over 30,000 at peak times during Christmas. Such flows would usually require a 47 ft footpath. However, at the time, only 27ft pavements existed, and there were considerable delays for those waiting to cross the Oxford St.. Following the scheme, pavements were widened, and, on average, gaps in the traffic doubled in duration, and the waiting time for a suitable gap to cross the road dropped from about half a minute to a few seconds.

- **Impacts on accidents**

Prior to the scheme, Oxford St. was the most dangerous street in London, with 265 injury accidents per year, (55% involving pedestrians), costing £375,000 pa. Following the introduction of the scheme, serious accidents in "the whole area likely to be affected by the Oxford St. closure" were markedly reduced (by over 50%), although slight accidents rose, showing an net increase in accidents of 13% over the first five months. Turner and Giannopoulos (1974) note that

"strangely, by far the greatest increase has occurred outside the period in which the ban operates", and that "to establish statistically significant results, a longer period of study is needed". In the longer term, reductions in all types of accidents were hoped for.

- **Impacts on noise**

Only small changes in noise level were recorded, both in the areas of diversion and on Oxford St. itself, (because, although flows were reduced, vehicle speeds increased, and the noisier engined buses and taxis became present in greater numbers). However, recorded changes did not correspond with public perceptions. For example, in an opinion survey, 26% of people in an area where noise levels had declined stated that they were "more annoyed" by noise.

- **Impacts on air pollution**

In Oxford St. itself, carbon monoxide and smoke pollution decreased substantially, to levels equivalent to general ambient levels. There was relatively little increase in the streets taking diverted traffic. Specifically, carbon monoxide levels changed from 17 to 4ppm on Oxford St, and 18 to 24 ppm on diversion routes. Smoke levels changed from 370 to 180$\mu g/m^3$ on Oxford St and from 240 to 270$\mu g/m^3$ on diversion routes.

- **Public opinion**

Pedestrians: During the sales peak period in December and January, questionnaires were distributed in major stores, Underground stations and car parks. 86% of respondents (sample size 455) thought Oxford St. more pleasant and almost a third wanted more schemes extended to other shopping areas in Central London. A later survey interviewing pedestrians found 95% in favour of the scheme.

Residents: A 20% sample of the 1500 households in the area showed 85% regarding the scheme as a success.

Shop managers: 255 interviews were conducted in ground floor businesses most affected by the changes. Shop managers in Oxford St. regarded the scheme as a major success, although those on other streets were less happy, identifying problems with parking, and with loading and unloading goods.

Hotel managers: Interviews with managers at the 15 hotels/hostels in the study area suggested that the scheme had had little effect on their business.

Publicity and consultation

The scheme was supported by publicity which began in May 1972, and included press releases, TV reports, consultation with objectors, distribution of 250,000 leaflets and adverts in the papers using the phrases "from December 1st, Oxford Street should be a better place for people" and "cars will not be welcome". Oxford Street stores arranged their own publicity, and British Rail offered cheap rate tickets with special discount facilities in the stores.

Parker & Eburah note "The scheme was introduced on an experimental basis, without full prior consultation with all those likely to be affected. However there was extensive publicity... [and]...Provided extensive 'before and after' surveys are carried out, and provided the scheme can be discontinued promptly if it is found to be unacceptable, an experimental scheme of this kind in fact provides a very good means of public participation. It allows those concerned to assess the effects of the scheme at first hand before deciding what value they place on such things as convenience as opposed to environmental improvement. A more conventional public consultation exercise before the scheme was introduced would have required considerable powers of perception on the part of all involved to anticipate what the effects of the scheme would be".

Design considerations

Prior to the engineering work, it was recognised that "the finished results should be aesthetically satisfactory", "special environmental improvements, seats and trees should be provided and were essential to public acceptance of the scheme", "works should be completed with minimal disruption to traffic and shoppers", "any part of the scheme should be capable of rapid modification or removal" and "costs should be kept low".

Modelling considerations

Turner & Giannopoulos describe the development of an assignment model to forecast the effects of the Oxford Street closure, which later became the basis for TRRL's CONTRAM. They report that "the simulation model was valuable in predicting pinch points, in determining junctions most in need of improvement, in deploying police and traffic wardens, and above all in giving confidence that the system could be made to work, even in the absence of any road construction to take diverted traffic".

Overview and criteria for success:

Abouseif & Townsley 1973:
"During the settling-in period of the scheme, retiming traffic signal phases at critical junctions, changes in traffic movements and layout arrangements, attentive police enforcement, and drivers' increasing knowledge of the congestion pattern were all major factors contributing to the experiment's initial success and the reduction of congestion to a minimum level after three months".

Turner & Giannopoulos 1974:
"Success from this experiment despite gloomy forebodings of massive congestion in the absence of new road construction will encourage similar part-time restricted vehicle bans...The public were disenchanted with what they regarded as an inevitable subservience to the car...This experiment has successfully redressed the balance of convenience between pedestrians and drivers". [Moreover] "Flexibility conferred by the experimental powers, and the acceptance of an "Avert Chaos" philosophy were essential to the successful adaptation of the experiement."

Turner 1997:
"Golden rules for successful change:
1. Square the press
2. Make sure the establishment is not inconvenienced
3. Master the technology
4. Follow/lead the money".

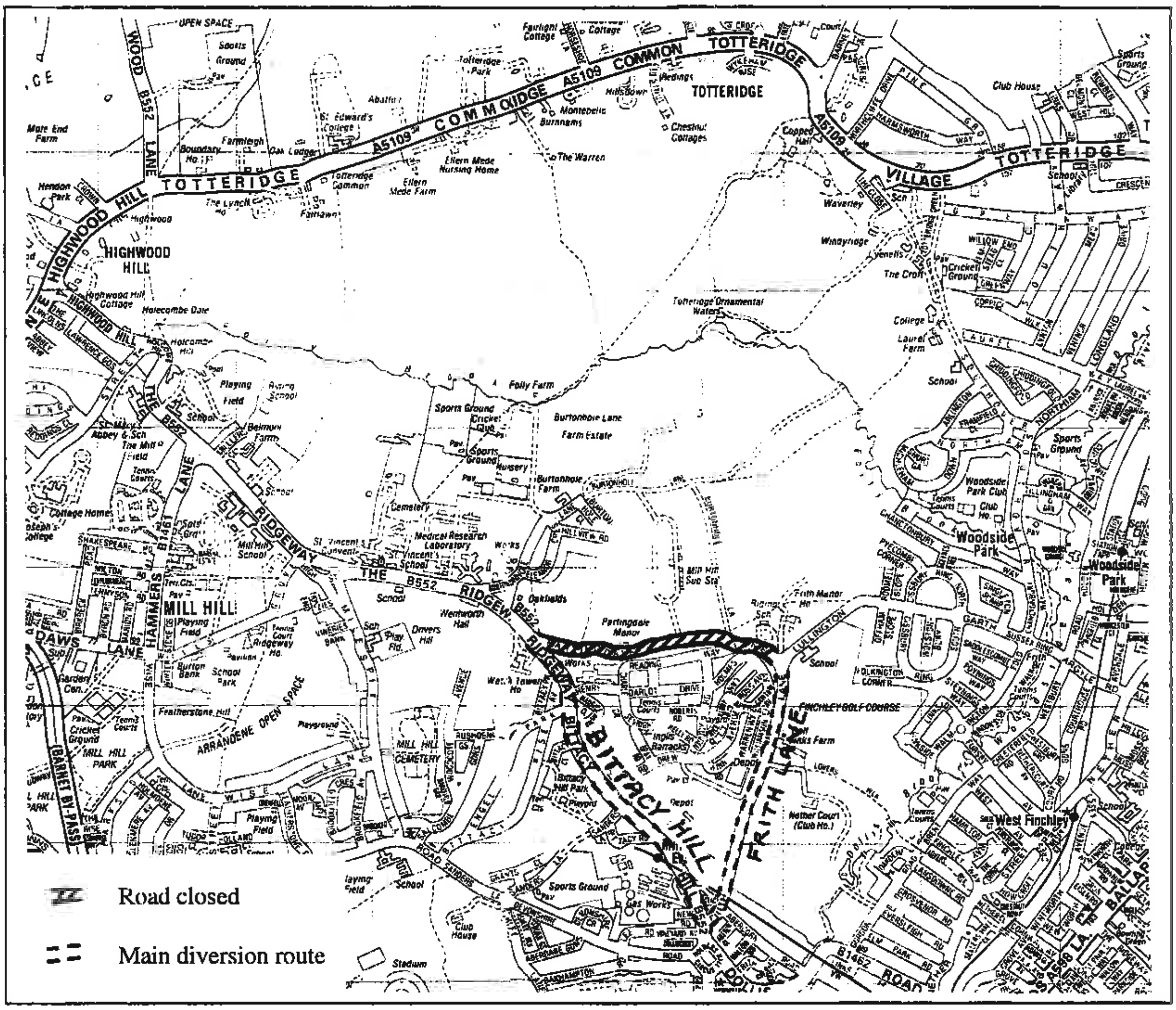
With respect to these, he notes that Oxford Street retailers had an increased turnover of many millions due to the increase in pedestrians. Also, the scheme apparently came close to failure when the Prime Minister launched an attack (via the press) on the leader of the GLC, after being stuck in a traffic jam near Oxford St, and when the Chair of Claridges personally visited the transport office to complain that foreign dignatories, US and UK security staff visiting Claridges felt like sitting targets on Brook St. (This was prior to the introduction of the queue relocation measures, which reduced the queues).

Caveats

Data reported here refers to monitoring carried out up to seven months after the scheme opened. It is possible that there were further reports reporting on the longer term impacts of the scheme, but there are great difficulties with obtaining information following the abolition of the GLC.

25. London - Partingdale lane closure 1997

Source: London Borough of Barnet 1997, Elliott 1997, Simpson 1997



Partingdale Lane is a narrow country lane, forming the northern side of a triangle surrounding Inglis Barracks, which has no through roads. The most obvious alternative diversion route is via Bittacy Hill and Frith Lane, which is an extra distance of approximately 0.6 miles. On 11th March 1997, "in response to ongoing concern from local residents about the speed, volume and potential safety problems of traffic using the lane", Partingdale Lane was closed on an experimental basis, by erecting a gate which only allows access for the emergency services, Inglis Barracks security patrols, pedal cycles, horses and pedestrians.

To monitor the closure, 'before' surveys were undertaken on 12th December 1996 and 16th January 1997, with 'after' surveys on 12th June and 18th September 1997. Measurements of volumetric traffic counts, queue lengths and delays were made, in three time periods (7.30-9.30am, 11.30am-1.30pm and 4.30-6.30pm) on Partingdale Lane, Frith Lane and Bittacy Hill.

"It should be borne in mind that there will be an element of seasonal variation in the results and that surveys which cover a single day are a snapshot of the situation which can be influenced by events, weather etc. However, it is still considered that the results broadly reflect the conditions on a normal weekday during the school term".

Aggregate impacts on traffic volumes

The following analysis is based on information from the Barnet Council report. Data from Frith Lane is used to establish the amount of traffic using the main diversion route, since all vehicles wishing to get from one end of Partingdale Lane to the other must go via Frith Lane. (Data from Bittacy Hill would provide a less good comparison, since there are a number of routes where vehicles could turn off on its western side). Pedal cycles are excluded from the analysis

Two-way traffic flows 8-9am	Before (average Dec./Jan.)	3 months after (June)	6 months after (September
Partingdale Lane	579	7	9
Main diversion route	847	1233	1179
Total	1426	1240	1188
Change (from before)		-186 (-13%)	-238 (-17%)

Two-way traffic flows 12.30-1.30pm	Before (average Dec./Jan.)	3 months after (June)	6 months after (September
Partingdale Lane	140	6	2
Main diversion route	723	777	635
Total	863	783	637
Change (from before)		-80 (-9%)	-226 (-26%)

Two-way traffic flows 5-6pm	Before (average Dec./Jan.)	3 months after (June)	6 months after (September
Partingdale Lane	269	8	7
Main diversion route	949	1180	921
Total	1218	1188	928
Change (from before)		-30 (-2.5%)	-290 (-24%)

These results can be summarised as follows:

Changes to overall traffic total for Partingdale Lane and Frith Lane	After 3 months		After 6 months	
	Traffic volume	%	Traffic volume	%
8-9am	-186	-13%	-238	-17%
12-1pm	-80	-9%	-226	-26%
5-6pm	-30	-2.5%	-290	-24%

Similar analysis carried out by Simpson (1997), using raw data from Barnet Council for the two hour time periods originally surveyed, produced the results overleaf:

Changes to overall traffic total for Partingdale Lane and Frith Lane	After 3 months		After 6 months	
	Traffic volume	%	Traffic volume	%
7.30am - 9.30am	-217	-9%	-501	-20%
11.30am - 1.30pm	-236	-14%	- 475	-28%
4.30pm - 6.30pm	-90	-4%	-391	-17%

Summary

All of the above analyses suggest that there has been significant traffic reduction in the local area, where traffic diversion was expected to be a problem. Moreover, traffic reductions have increased during the period of the closure. Proportionally, the traffic reductions have been largest in the off-peak period, although it is notable that the traffic reduction in the 8-9am period is greater than that in the 7-30-9.30 period. This is probably because traffic has spread itself more evenly through the peak (such that some of the 8-9am traffic is travelling earlier or later).

This analysis does not allow for people who may have diverted over longer distances. Some individuals were identified who did so. However, longer distance diversion would have offered little advantage outside the peak period, since the shorter available diversion evidently had spare capacity. In the peak period, an advantage would only have been gained for the proportion of trips whose origin or destination were a considerable distance outside the survey area, and in a limited range of geographical orientations with respect to the triangle. It is therefore likely that surveys over a wider area would have shown only a small difference from the effects found - enough to account for a little of the 'disappearing' traffic, but by no means all of it. It is also possible that there was some retiming of trips to before 7.30am or after 6.30pm, as there are no traffic counts available for these periods. However, there was no sign of a net retiming from peak to interpeak.

- **Impacts on vehicle queues and delays**

The junction of Frith Lane and Bittacy Hill was presumed to be the place where the displaced traffic could cause the most inconvenience, particularly during school term-time. Following the closure, "the June 1997 survey results show ... delays of 8 minutes, with a typical associated queue length of about 500 metres on [the southbound Frith Lane] arm at the peak period (8am to 9am). Other arms of the junction experience no serious problems and, for the remainder of the day, the junction copes from all directions. Similar surveys undertaken during September 1997 showed no serious problems on any area throughout the day". Generally, "the extent of the additional queues and delays is confined to the Frith Lane approach and then only for the morning peak period during school term-time. It is less of a problem than envisaged by officers prior to the implementation of the closure"

According to Simpson (1997), a roundabout previously put in at the junction has helped traffic to flow smoothly, and he estimates that the average increase in journey time caused by the diversion is only about 2 minutes. He also highlights that there are no longer turning movements from vehicles trying to enter and leave Partingdale Lane, which has reduced hold-ups in these locations. Notably, the eastern end of Partingdale Lane is near a school, which traffic used to queue back to, whilst at the other end, "there was quite often a queue of vehicles stretching back half the length of Partingdale Lane" as they waited to turn out.

- **Impacts on other road users**

"Early indications are that... use of the lane by cyclists, horse riders and walkers has increased".

- **Impacts on safety**

A survey of Partingdale Lane on 18th September 1997, between 7am and 7pm, showed 22 cyclists, 7 horses and riders and 92 pedestrians. "The lane does not have footways and therefore these users have to share the carrriageway with motorised traffic".

Prior to the closure, the personal injury accident record showed that in the three years previously there had been 2 speed related accidents on Partingdale Lane, and 29 on the diversion route. (Simpson also notes that, on Partingdale Lane, at least 2 horses had been killed and that "there were regular incidents of vehicles colliding with lamp-posts, fences and each other"). Since the closure, there have been 2 accidents on the diversion route. "It is too early (in statistical terms) to make any definite statements about the impact of the closure but indications are that speed related accidents will reduce in Partingdale Lane without an adverse effect on the diversionary route."

- **Public opinion**

During the closure, the Borough Council received three petitions and 18 letters for the retention of the closure and five petitions and 125 letters requesting the re-opening of Partingdale Lane. The Council concludes that "there has been a significant level of objection to the proposal, but also there is support for the retention of the closure, to maintain the environmental and policy benefits of the measures". Simpson (1997) notes that most complaints were "about the inconvenience of the detour".

Design considerations

Prior to the road closure, rumble strips were installed, rather than closing the road, however these proved noisy, and, according to Simpson 1997, "drivers found that some of the effects of the strips could be minimsed by travelling over them at speed". Therefore, the road was closed instead.

Explaining the traffic reduction

Simpson (1997) comments: "Reading the protest letters at the council offices was quite interesting...One woman now uses Totteridge Lane (the A5109) to travel east to west. (I imagine that transferring traffic from a narrow country lane onto an A road is precisely the kind of result traffic planners are looking for). Others reveal that they have had to change their journey times or reorganise shopping and social trips to make life easier". He argues that such adjustments would help to explain the decline in traffic that has occurred.

Evaluation

"The benefits derived from the closure further this Council's, and central government's policies to protect the environment, promote sustainable forms of transport and reduce traffic....It is the officers' view that the closure should be retained".

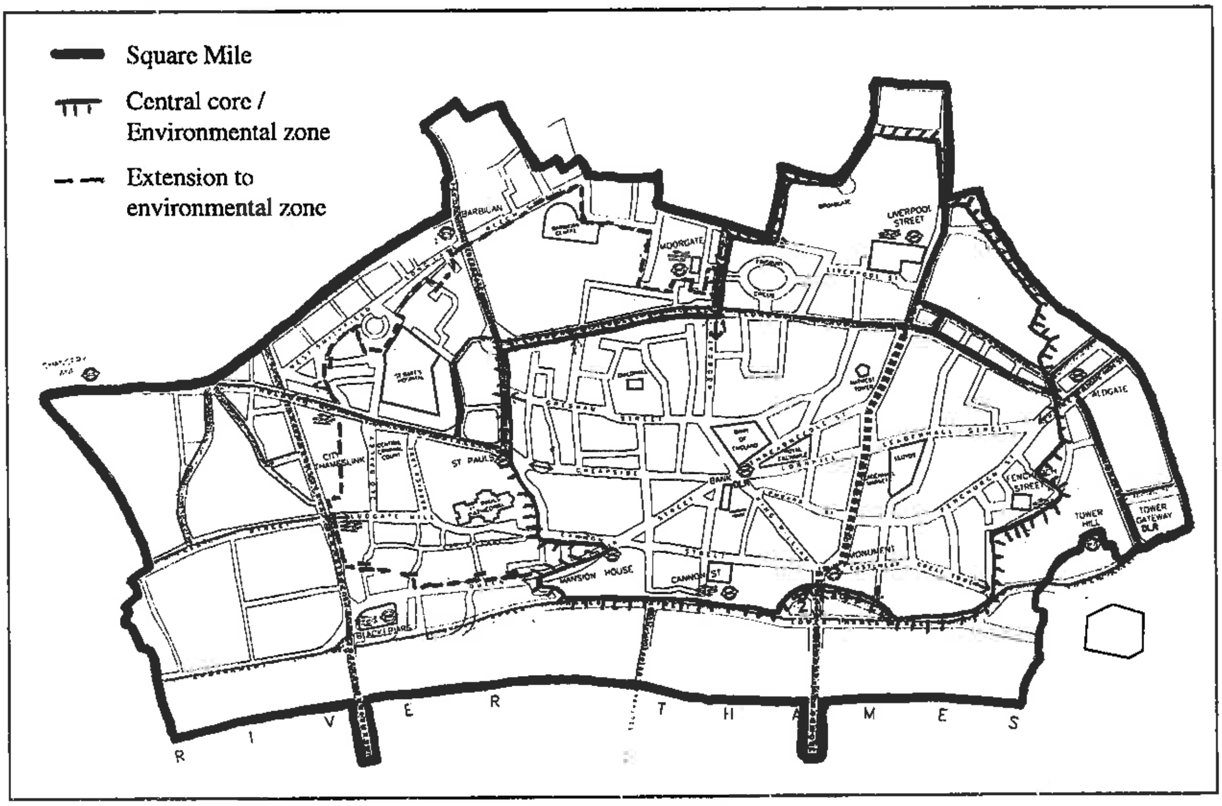
Caveats / Comments

Simpson is a resident in the area who believes that the road should remain closed. Therefore, where his views are quoted, they are identified as his. All other quotations are taken from Barnet Council information.

As highlighted above, data are based on one day traffic counts, and may be skewed by seasonal and day-to-day variability, particularly given the relatively small sizes of some of the flows. Further survey work is being undertaken by Barnet Council to assess the impacts of the road scheme more fully. Results should be available in June.

26. London - 'Ring of Steel' 1993

Source: Key reference - Weiss 1995. Other references Harvey 1997, Weiss 1991a/b,1992, 1993, 1995b & 1997



The 'City of London' or 'Square Mile' is a small area covering the core of London's financial services industry. Daily (in 1993), there were approximately 250,000 vehicle movements and 600,000 pedestrian movements. Vehicles tended to be delivery vans, business clients and through traffic, as over 90% of the workforce arrived by public transport.

Consequently, a scheme known as 'The Key to the Future' was devised "to relieve the conflict and daily stresses occurring" between vehicle and pedestrians "by the reallocation of priorities on street to one or other mode". It was due to start in May 1993. A linked scheme, known as 'The Way Ahead' was to concentrate on environmental improvements to the area, and to be implemented shortly after.

The IRA bomb, in Bishopsgate in April 1993, caused a "radical redesign" of 'The Key to the Future' project, and what became known as the 'Ring of Steel' was introduced experimentally shortly after. It involved restricting access to the central core of the city to a small number of roads. 17 minor streets were closed, 13 were converted to one way, and traffic signals were altered at 23 junctions. Privileged access was given to buses and taxis at all but two entry points, and junctions within this 'core' or 'environmental zone' were retimed to give pedestrians greater priority. Meanwhile, traffic signals on a 'box' of roads around the central core were linked together and optimised, and some priority for pedestrians on these roads was reduced. The changes were made permanent in July 1994, and the 'environmental zone' was extended on an experimental basis in January 1997.

Aggregate effects on traffic:

	1992	1994	Change
Daily traffic entering the 'Square Mile'	254,192	253,613	-579 (-0.2%)
Daily traffic entering the 'central core'	160,000	120,000	-40,000 (-25%)

Further data on traffic flows entering the Square Mile show that they have been approximately constant at 250,000 for the last 10 years.

Traffic reduction in the central core "is equivalent to a single queue of cars stretching from Harrods to Cardiff", and "around two thirds of the small streets have benefitted from significant traffic decreases"

Additional effects:

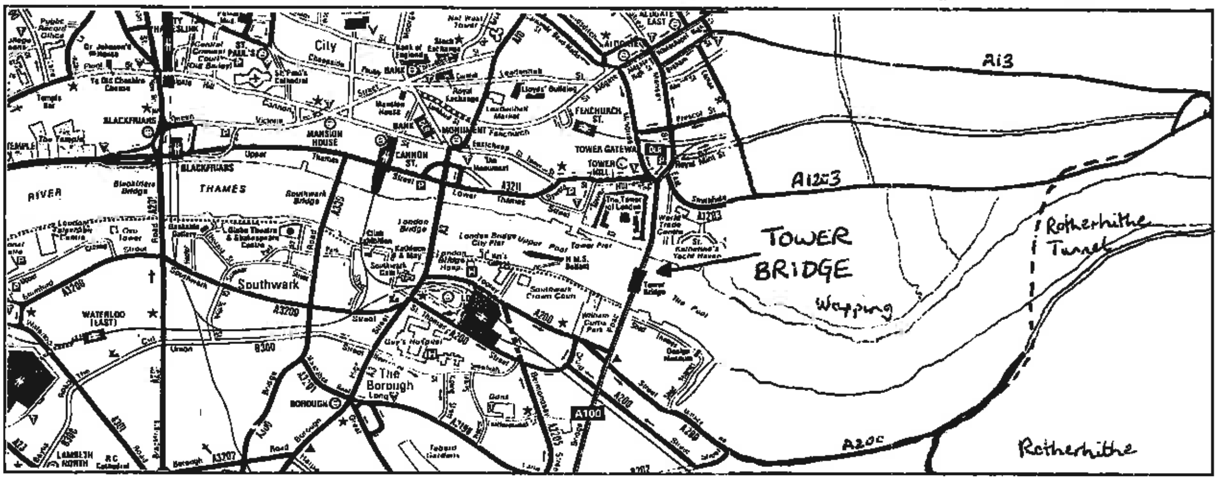
- "Sections of the major traffic route along the Embankment now carry 20% greater flows with shorter overall journey times"
- "Bus journey times are essentially unchanged".
- The scheme has significantly improved road safety, with a 39 % reduction in casualties in the central core, and a 23% reduction in casualties in the Square Mile overall. In the 30 months before July 1993, there were 829 casualities, compared with 640 casualties in the 30 months after. "This represents a saving of £3.5million per annum on accidents alone".
- "Overall air pollution monitoring has suggested a 15% reduction in pollution"
- "The scheme remains extremely popular with the majority of businesses, workers and City visitors who continue to support its retention."

It is worth emphasizing that the philosophy behind the scheme was not to reduce traffic, but "to manage total network capacity as against individual site-specific scheme capacity in order *not* to create significant traffic suppression". Specifically, the aim was to "separate the local servicing needs from longer distance movements".

In analysing its success, Jo Weiss argues that the scheme involved "little more than a few techniques well-known within the industry", and that "such principles are applicable in any other urban area and, with intelligent design, should prove equally effective". He also highlights the importance of "the political support of the Corporation" and "a complete overview of the project".

27. London - Tower Bridge closure 1993

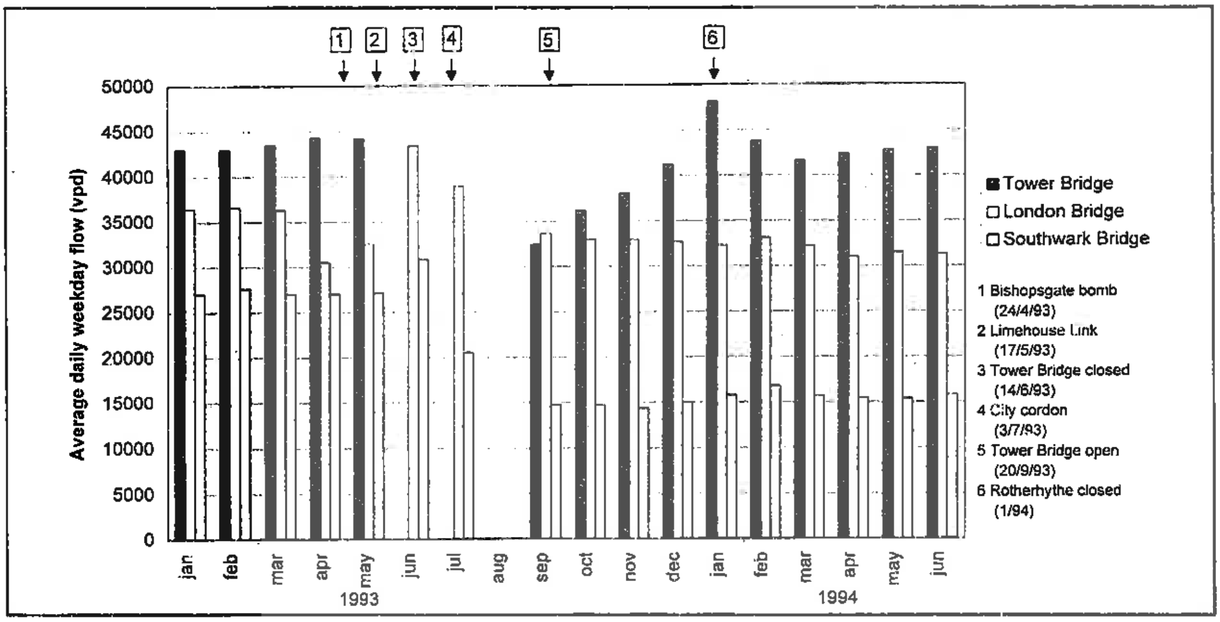
Source: Weiss (Round Table 1997), Harvey 1997, Sorenson 1997, Lavendar 1997, Fink 1997



In 1993, Tower Bridge closed between June and September for repairs.

Average 24hr weekday vehicle flows	May 1993	July 1993	Change
Tower Bridge	44,242	0	-44,242
London, Southwark and Blackfriars Bridges	103,262	111,999	+8737
Total	147,504	111,999	-35,505 (-24%)

A more detailed plot of part of the data was also available, as shown here.



No data counts were carried out during this period for Rotherhythe tunnel, the closest river crossing east of Tower Bridge. However the City Engineer's Department at the Corporation of London reports that this was operating at capacity at the time, and was therefore unlikely to have been able to accommodate many extra vehicles.

As well as diverting east, it is also possible that traffic diverted further west than Blackfriars Bridge. The next two western bridges are Waterloo and Westminster. Junction counts carried out in August and October, suggest that flows in August (when Tower Bridge was shut) were actually about 30% less on Waterloo Bridge (-16,000 vehicles), although they increased on Westminster Bridge by about 20% (+9,000 vehicles).Looking at bridges further upstream, no data counts were carried out on Lambeth and Vauxhall bridges during this period, although comparison of 1992 and 1993 data, suggest that generally 1993 flows on Lambeth Bridge were lower than usual (-6,000) although higher on Vauxhall Bridge (+3,000).

Hence, in general, although some traffic probably did reroute out of the local area, there are not consistent traffic increases elsewhere that are clearly attributable to Tower Bridge closure, and, overall, further traffic reductions appear to have occurred. As reported in the Westminster Bridge case study, traffic flows over all of the bridges do seem to have been generally lower in 1993 than in 1992 or 1994.

Untangling the specific effects of Tower Bridge closure are complicated, however, because of other changes that were occurring at the same time.

In the immediate vicinity, roadworks at Ludgate Circus finished in June 1993. Together with traffic signal optimisation, this substantially increased the capacity of Blackfriars Bridge. Meanwhile, ongoing roadworks south of Southwark Bridge, together with one way restrictions, constituted an ongoing restriction of the capacity of Southwark Bridge. The cordon around the City of London was also introduced.

Further upstream, changes were also being made to the other bridges, as reported in the Westminster Bridge case study, together with minor maintenance work, which would have caused traffic to redistribute at different times (and which possibly accounts for the reduction in traffic on Waterloo Bridge in August).

Summary:

Identifying the effects of the closure of Tower Bridge are complex, however it does seem to have caused a real traffic reduction in the local area. After all, the Limehouse link completion and changes at Blackfriars Bridge should have increased traffic not reduced it, and specific observation of the city cordon (reported as the 'Ring of Steel' case study) suggests that it is not likely to be indirectly responsible for the traffic reduction, as it has not had any overall suppressive effect on traffic (although there has been some redistribution of vehicles from Southwark Bridge to Blackfriars).

Moreover, the loss of traffic from the local area does not seem to be due to longer diversions further east or west, as, although there were changes in traffic flows over other bridges during that time, overall traffic flows in 1993 were lower than in 1992 or 1994, and analysis of Waterloo and Westminster bridges shows that there was no clear traffic increase, and that immediate local policies were likely to have had more of an impact.

The Tower Bridge closure highlights that changes in one part of a road network are likely to occur at the same time as changes are being made elsewhere. Moreover, it is notable that it took nearly four months for traffic levels on Tower Bridge to resume their former magnitude.

Comments and caveats:

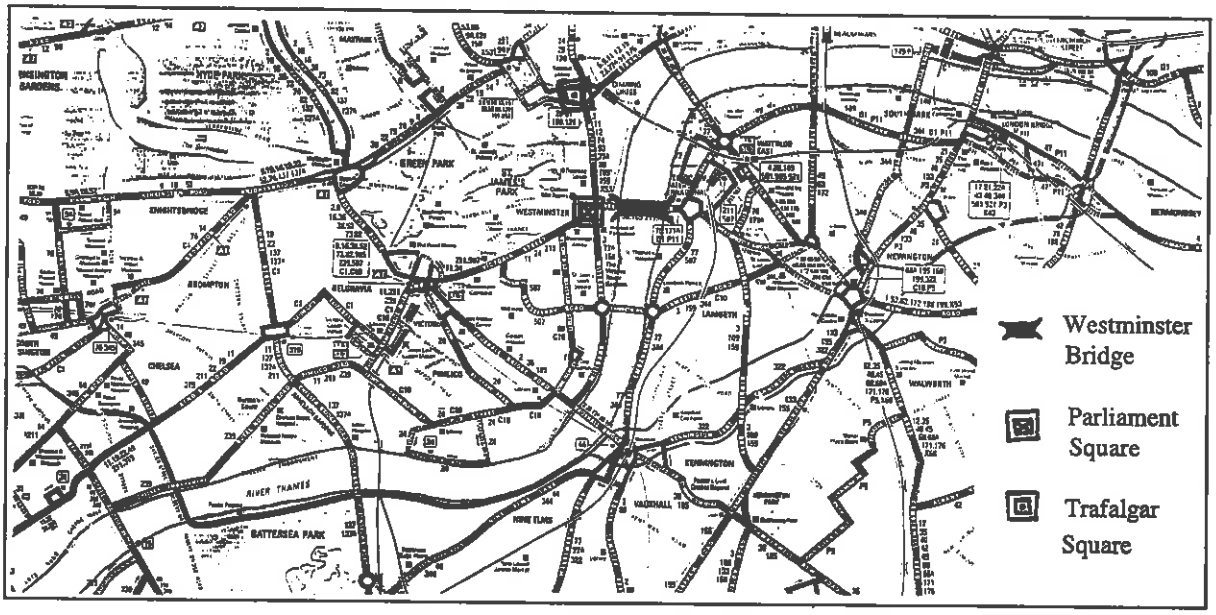
Ideally, comparable data for April and July for all bridges further upstream and downstream of the City of London are needed to assess the Tower Bridge closure. However, discussion with relevant London boroughs reveals that this was never collected. Moreover, the situation would always be complicated by policies occurring elsewhere anyway, and, regardless, it is interesting that traffic did *not* make the obvious diversions to the bridges in the immediate vicinity.

The variation in traffic flows shown may also be partly due to seasonal variance in traffic flows generally, although this is unlikely to account for all of the traffic reduction which was recorded.

The changes in flows recorded on Waterloo and Westminster bridges between August and October may partly be due to differences in counting methodology, since the two counts were done for different purposes, by different organisations.

28. London - Westminster Bridge 1992-1997

Source: Ruth Sorenson (1997), Malcolm Murray Clark (1997)



Various changes have been made around Westminster Bridge, which have indirectly reduced the traffic capacity of the area. Specifically, road works were carried out on Bridge Street (the road between Parliament Square and Westminster Bridge) in 1992. Traffic management for the Jubilee Line Extension was introduced in Parliament Square on 30th May 1994, and strengthening works on Westminster Bridge commenced in February 1995.

Annual bridge counts provide some evidence of the effects.

Traffic impacts

24 hour 2-way vehicle flows (weekday averages)	1992	1993	1994	1995	1996
Battersea, Albert, Chelsea & Vauxhall Bridges	132,604	112,640	144,538	146,624	--
Lambeth Bridge	36145	29862	37913	37335	--
Westminster Bridge	41105	47,151	41,739	41,284	39,039
Waterloo Bridge	50083	53,103	52,363	54,291	56,199
Blackfriars, Southwark London & Tower Bridges	162806	121514	146473	151658	--
Total for Westminster, Waterloo and Lambeth Bridges	127,333	130,116	132,015	132,910	--
Total for all bridges	422743	364270	423022	431,192	--

The data suggest that traffic flows over Westminster Bridge have been declining slightly since 1993, although traffic flows in general have increased. However, there are various complicating factors.

First, other policies implemented in adjacent locations (two of which are discussed in other case studies) may have affected internal traffic flows. Specifically, the Ring of Steel was introduced in 1993. Tower Bridge was also closed for 6 months in 1993. In 1994, subway construction to the south of Blackfriars Bridge restricted traffic to two lanes in each direction for a period. None of these policies, however, would have resulted in an influx of traffic from outside the area, which could explain the traffic increase.

Second, there are some problems with the data. Bridge traffic flows are collected in October by the Department of Transport, and individual London boroughs, and are now collated by WS Atkins. Charles Cresswell, of WS Atkins, notes that there has been some controversy over whether there has been enough consideration of local changes being made near the bridges to ensure that the traffic counts are 'representative'. Westminster City Council (WCC) also provided corrected data for Westminster and Waterloo Bridges for 1993, as the figures given in the main table from WS Atkins were 7 day average flows for this year, rather than weekday average flows. Where corrected data has been provided, it has been used here. However, it is possible that there are inaccuracies in figures for the other bridges as well.

Summary

In general, the only safe conclusions that can be drawn are that, to some extent, traffic does redistribute between bridges, and that this is in the context of general traffic growth. Partly due to the difficulties and confusions of traffic flow measurements, partly due to the 'masking' effect of general traffic growth, and partly due to the complex range of alternative policies and maintenance work that are likely to be being undertaken in other areas, it is not possible to judge from the existing bridge flow data, where the traffic from Westminster Bridge has gone to, or whether, in fact, it is useful to think of Westminster Bridge traffic as representing a particular, and relatively fixed group of people, who are distinct from those using other bridges.

Other data

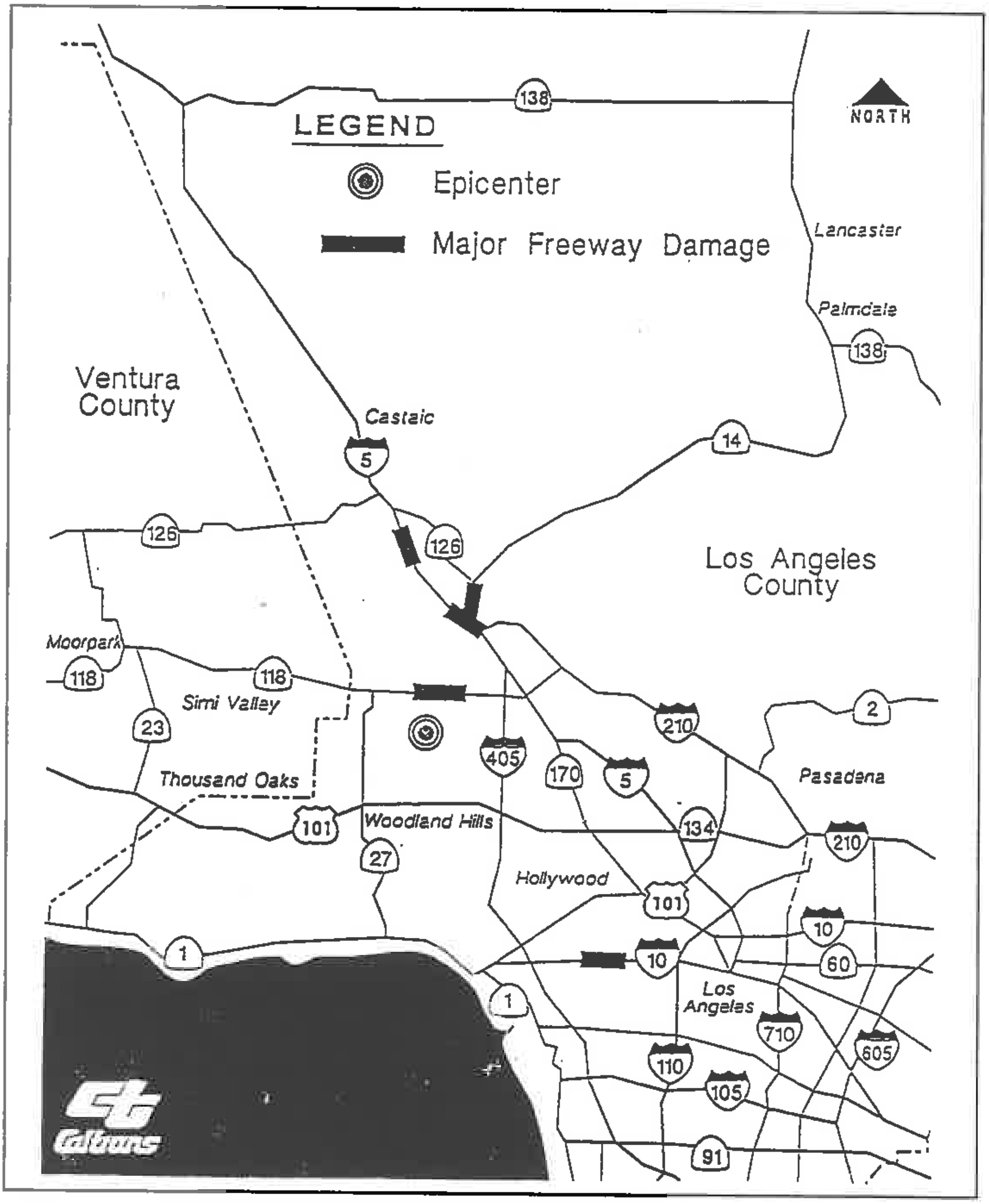
The 'World Squares for All' study is currently looking at ways of improving the access to, and the enjoyment of, many sites in the area of Trafalgar Square, Whitehall and Parliament Square. The amount of space to be taken away from general traffic, if any, has yet to be decided.

As part of this work, a postcard survey was distributed to drivers at 10 entry points to the area between 7-11am and 4-7pm, on 28-30th January 1997. 27,000 postcards were issued to a 42% sample of the total traffic. Usable returns were received from 5,300 drivers, a response rate of nearly 25%. The survey asked about the journey people were making when they received the postcard, and about how they would react if traffic measures caused this overall journey time to increase. The results are as follows:

If journey time increased, % who would...	Hypothetical journey time increase:	
	10 mins	20 mins
Make journey at same time, by same route	66	31
Use alternative route	23	43
Travel at different time of day	7	13
Use public transport	3	10
Change destination	<1	1
Not make trip	<1	2

29. Los Angeles - Northridge Earthquake 1994

Source: Wesemann, Hamilton & Tabaie 1995, Urban Transportation Monitor 1994



On 17th January 1994, an earthquake of magnitude 6.8 struck Southern California, causing substantial destruction, including significant damage to 4 freeways. These were:

- Interstate 5, a north-south route connecting southern California to central and north California
- the interchange of I-5 and State Route 14, which links Los Angeles with the three dormitory towns of Santa Clarita, Lancaster and Palmdale
- Interstate 10, the world's busiest freeway and the principal east-west route through Los Angeles
- State Route 118 , an east-west route connecting Los Angeles and Ventura counties.

Immediately following the earthquake, a substantial programme of emergency measures and transportation recovery plans were put into place, by the Californian Department of Transportation (Caltrans), in conjunction with a number of other agencies. In the short term, this included establishing primary detours to the four highways, with High Occupancy Vehicle (HOV) lanes designated on the I-10 and SR-14 detours. Signals were adjusted regularly to maximise capacity on all detours, particularly during the peak. Extra Metrolink rail cars and buses were brought in, additional Park-and-Ride sites were built around the Metrolink rail lines, staggered working hours were encouraged and new tele-commuting sites and rideshare match programmes were introduced. Meanwhile, contracts for rebuilding the freeways were let in record time.

To monitor what happened, a huge range of surveys was undertaken to track changes during both the recovery period, and following restoration of the freeways. These surveys included:

- Freeway traffic counts at 10 strategic locations on impacted freeway sections
- Hourly traffic volume counts on detours and re-opened freeway sections
- Vehicle occupancy and classification surveys on detour routes and re-opened facilities
- Travel time runs and delay studies on detour routes and re-opened facilities at different times of the day
- Arterial street traffic counts using automated traffic counters
- Service and ridership assessments for buses, gathered on a weekly basis
- Service and ridership assessments for Metrolink commuter train services
- Six in-depth surveys, targeting key groups affected by the freeway closures, to assess changes in travel behaviour, people's perceptions of how they were affected, and how well Caltrans had responded to the emergency.
- Home interview surveys of travellers from the four corridors in May 1994, and October 1994, to assess changes in behaviour
- Surveys of transit riders during reconstruction, carried out on-board buses, and at Metrolink stations, with a follow-up survey of Metrolink passengers in October
- A telephone survey of companies involved with freight transportation, followed up by a survey intercepting truck drivers at key entry points into the Los Angeles region, in May and June 1994.

This information has been processed by Wesemann, Hamilton and Tabaie, and a selection of it is reported here

In relation to this data, it should be noted that

- The changes recorded are the changes compared to conditions *before* the earthquake.
- The authors say that, of the trips recorded as 'eliminated', "not all of these travellers ceased making their trips in their entirety, but changed their trip origins, trip destinations or both. In addition, some motorists may have ceased making some trips on some days"
- In relation to both the HOV lanes, the authors record that both were well used, but (partly because of this) "users of HOV lanes gained a moderate travel time advantage of [only] approximately 5 or more minutes over those persons who drove in the mixed-flow detour during peak periods of the day...[hence] large shifts to ridesharing do not appear to have occurred..because the travel time advantages on the... HOV lanes were not substantial enough to offset the additional time required to pick up and drop off passengers"
- Metrolink trains were the main transit alternative used for all of the freeways apart from the I-10, where only buses were available.

I-5

Daily vehicle trips	Pre-quake (pre 17/1/94)	Reconstruction (18/1-17/5 1994)	After re-opening (post 17-18/5/94)
I-5 (and primary detour)	133,000	88,000	127,000
Regional routes	--	7,000	(same as pre-quake)
Parallel arterials	9,000	35,000	18,000
Total	--	130,000	--
Change		-12,000	-3,000

Prior to the earthquake, approx. 186,000 people used the I-5

	Reconstruction	After re-opening
Change in number of people driving	-18,000 (-9.6%)	+4,000 (-2.2%)
Change in % people making drive-alone auto-trips	-4% (from 65 to 61%)	
% who changed their trip start time	56%	
Change in number of people using transit	+6000	+2000
Change in use of telecommuting	+1%	
Number of trips eliminated	12000 (6.4%)	-6000 (ie. trips generated)

Additional information:
- there were few close alternative routes, due to the mountainous topography in the I-5 corridor.
- "74% of the new riders interviewed in May intended to continue using the Metrolink trains at least as frequently after the reopening of the I-5 mainline. Reasons given included "avoiding travel delays on the freeways (and detours) and reducing stress of commuting....Employer incentives were also mentioned as a reason contributing to the long-term Metrolink usage".

SR-14

Daily vehicle trips	Pre-quake (pre 17/1/94)	Reconstruction (18/1-7/81994)	After re-opening (post 7/8/94)
SR-14 (and primary detour)	130,000	108,000	125,000
Regional routes	--	2,000	(same as pre-quake)
Parallel arterials	9,000	15,000	9,000
Total	--	125,000	--
Change		-5,000	-5,000

Prior to the earthquake, approx. 182,000 people used the SR-14

	Reconstruction	After re-opening
Change in number of people driving	-16,000 (-8.8%)	-7,000 (-3.8%)
Change in % people ridesharing	+1-2%	
% who changed their trip start time	58%	
Change in number of people using transit	+2,000	+1,000
Change in use of telecommuting	1%	
Number of trips eliminated	14000 (7.7%)	6000 (3.3%)

I-10

Daily vehicle trips	Pre-quake (pre 17/1/94)	Reconstruction (½-12/4/1994)	After re-opening (post June 1994)
I-10 (and primary detour)	310,000	130,000	295,000
I-105	177,000	182,000	178,000
Local streets	560,000	692,000	275,000
Total	1,047,000	1,003,000	1,045,000
Change		-44,000	-2,000

Prior to the earthquake, approx.1,564,000 people used the I-10

	Reconstruction	After re-opening
Change in number of people driving	-58,000 (-3.7%)	-3,000 (-0.002%)
Change in vehicle occupancy on primary detours (persons per vehicle)	+0.2 (1.4--1.6)	0
Change in % people ridesharing	+1-2%	
% who changed their trip start time	38%	
Change in number of people using transit	+2,000	--
Change in use of telecommuting	+2,000	+1,000
Number of trips eliminated	56000 (-3.5%)	3000 (-0.002%)

Additional information:
- Buses acted as the main transit alternative. (Metrolink commuter rail was not available)
- 3% of the total respondents cited reasons such as unemployment and change of work site for eliminated trips. "These individuals were considered as part of the constant turnover in the corridor and were not counted as reflecting any behavioural change".

- Low levels of telecommuting "may have been [due to] a lack of long-distance commute trips in the corridor"

SR-118

Daily vehicle trips	Pre-quake (pre 17/1/94)	Initial reconstruction (until 21/2/94)	Mainline detour opened (after 21/2/94)	Full recovery (post 3/9/1994)
SR-118 (and primary detour)	125,000	54,000	110,000	123,000
US-101	319,000	328,000	322,000	319,000
Local streets	90,000	132,000	96,000	90,000
Total	534,000	514,000	528,000	532,000
Change		-20,000	-6,000	-2,000

Prior to the earthquake, approx. 172,000 people used the SR-118

	Initial reconstruction	After mainline detour opened	Full recovery
Change in number of people driving	-25,000 (-14.5%)	-5,000 (-2.9%)	0
Change in ridesharing	No change		
Change in number of people using transit	+1,000	+1,000	+1,000
Change in use of telecommuting	+1,000	+1,000	0
Number of trips eliminated	24,000 (14.0%)	4,000 (2.3%)	0

Additional information:
- Traffic gradually stabilised at each stage
- changes to the road network elsewhere may also have influenced traffic flows
- Metrolink commuter rail was the main transit alternative used, and some increase in patronage was maintained. "This can be largely attributed to the expansion of services...and the overall satisfaction of Metrolink riders with the service available to them"

Summary:

Wesemann, Hamilton and Tabaie sum up their results as follows:

"Travellers responded in significantly different ways in each of the four damaged corridors...their decision making followed a logical hierarchy based on specific trip making requirements and travel time thresholds, as well as their perceptions of the suitability of each choice for their own particular travel needs"

"In the I-10 and SR-118 corridors, numerous convenient roadway alternatives existed that allowed automobile travellers to change routes and continue to drive without significant delays. Therefore mode shifts to ridesharing and transit were very limited. By contrast, because roadway alternatives were limited in the I-5 and SR-14 corridors, many travellers were forced to either change to other travel modes, change their time of travel or eliminate discretionary trips. Metrolink commuter rail served as [the main] alternative to thousands of travellers in the I-5 and SR-14 corridors."

"Following the reopening of the damaged facilities...travel patterns in all impacted corridors reverted to pre-quake levels. The only exception is the additional ridership of Metrolink on the Santa Clarita line (which continues to have an increased ridership of up to 3,000 passengers)...for a variety of behavioural reasons, including reliability"

"Potential reasons for this shift back to pre-quake travel behaviour are:

- All damaged facilities were reconstructed in record time...Even travellers who had tested and used various alternatives to the drive alone mode, may not have had enough time to get accustomed to a different travel choice
- All travellers experienced some delays during the reconstruction period. However, for the most part, these delays were not significant enough to effect a major change in travel mode
- while the HOV facilities were used to capacity during reconstruction, these facilities did not provide enough of a benefit in time savings to offset the time required to stage carpools or vanpools
- buses shared the same roadways as other vehicles, and thus provided no increased incentive for a change in mode
- most travellers in Los Angeles county continue to need to utilize the private automobile as the primary mode of travel, partially due to the decentralised nature of the activity centres and the lack of convenient and accessible transit interlinks between many origins and destinations".

Caveats:

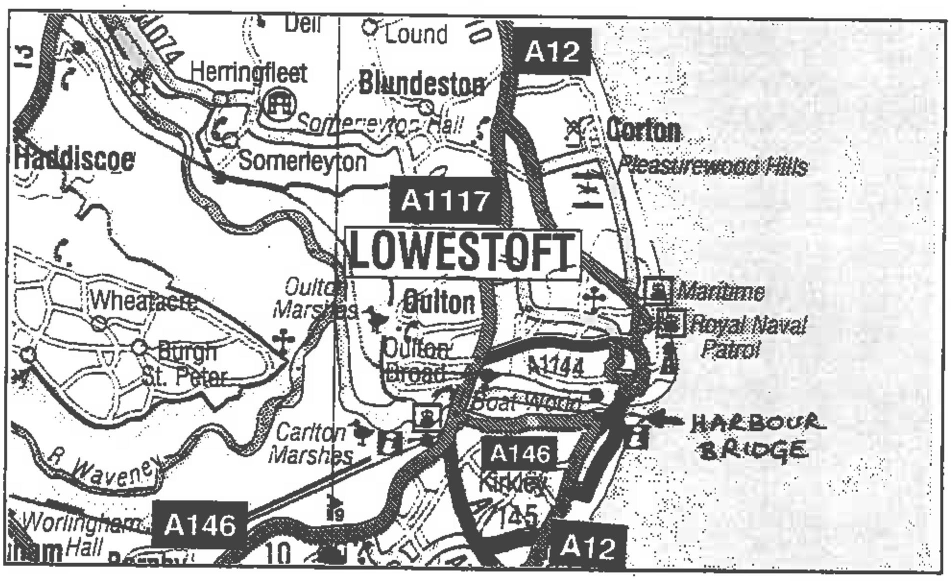
The original paper includes a huge range of material, which is summarised in a number of tables, and supplemented by long descriptions in the text. The material is drawn from a vast range of surveys, and details of the specific surveys used, the dates when they were undertaken, and the way in which they were processed, are described in a comprehensive set of detailed footnotes. In this summary, it has not been possible to repeat all these details.

The original paper also reports on the I-5 and SR-14 in a joint section (presumably because some of the detours that people used were the same from the two routes, and because one joins the other). However, since it also provides separate information on both, and since they were restored at different times, the two are reported separately here, for the sake of clarity. (The points of overlap in the data have been considered and allowed for in this summary).

More generally, it is important to note that the changes in travel behaviour quoted during the restoration will partly have been due to the dislocation of many facilities, not just due to damages to the road network. However, those respondents who cited 'unemployment' or 'change of work site' as a reason for a change in travel were discounted from the analysis anyway, as reported above. Moreover, the contrasts between the coping mechanisms adopted in different corridors are still indicative of the differing transport opportunities available, since the indirect causes for change are likely to have been of relatively similar magnitude.

30. Lowestoft 1997

Source: Eyres 1997



Lowestoft, in Suffolk, is bisected by a river, with 2 bridges linking the two halves. The main 3 lane Harbour bridge forms part of the A12 trunk road, and carries about 12,000 vehicles a day. It has a contra-flow system operating, with two lanes northbound before 11.30am, and two lanes southbound afterwards. In February 1997, one lane was closed for about a month, so that there was only one lane operating in each direction.

Impacts:

Eyres reports: "Interestingly, I am not aware that there was any traffic problem as a result...The only complaint was a single letter in the local paper, and even that was relatively mild". He highlights that this is in contrast to very short term closures, when "the raising of the bridge to allow a ship through can cause intense anguish".

He also emphasizes that impacts seem to have been less than those which occur through natural variability, as usually: "substantial congestion (by local standards) can build up in the direction of 'one lane on bridge' [and] it is said that, as a consequence, traffic levels have not risen over the Harbour bridge as they have elsewhere in Suffolk".

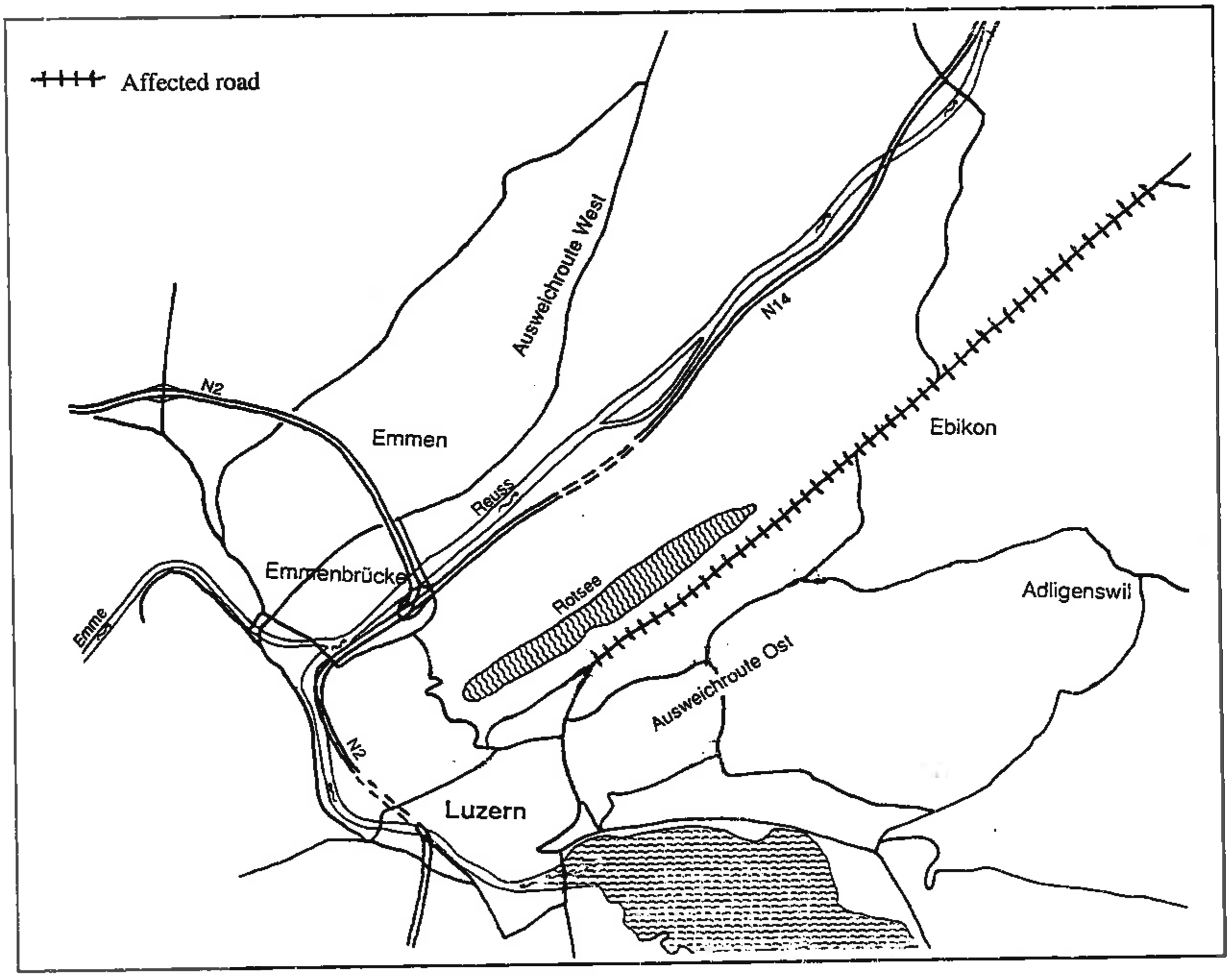
He concludes: "I should like to see the bridge reduced permanently to two lanes for motor traffic, with the extra space released to pedal cycles [and better access for buses]. People locally will complain that the resulting congestion will be impossible to cope with, but I doubt it.....The February lane closure provides some indication that permanently removing one lane of motor traffic from Lowestoft's Harbour bridge would be effective at reducing traffic flows, without adding significantly to congestion".

Caveats:

The closure was in February/March, which is not the busiest time of the year.
Eyres is a local resident of Lowestoft, reporting on his observation and opinions of the bridge closure. It has not been possible to obtain actual traffic data about the bridge from the council.

31. Lucerne 1993-94

Sources: Berg, W. & Bärtsch, D. 1995



Lucerne is a small town of about 61,000 inhabitants in the French part of Switzerland. Its hinterland (canton) serves 320,000 people. In 1993/94 a major link road in Lucerne was reduced to one lane because of road works. Traffic lights were installed to allow one way traffic. There were two fairly obvious alternative routes. Counts before and after took place on three roads.

Impacts on traffic

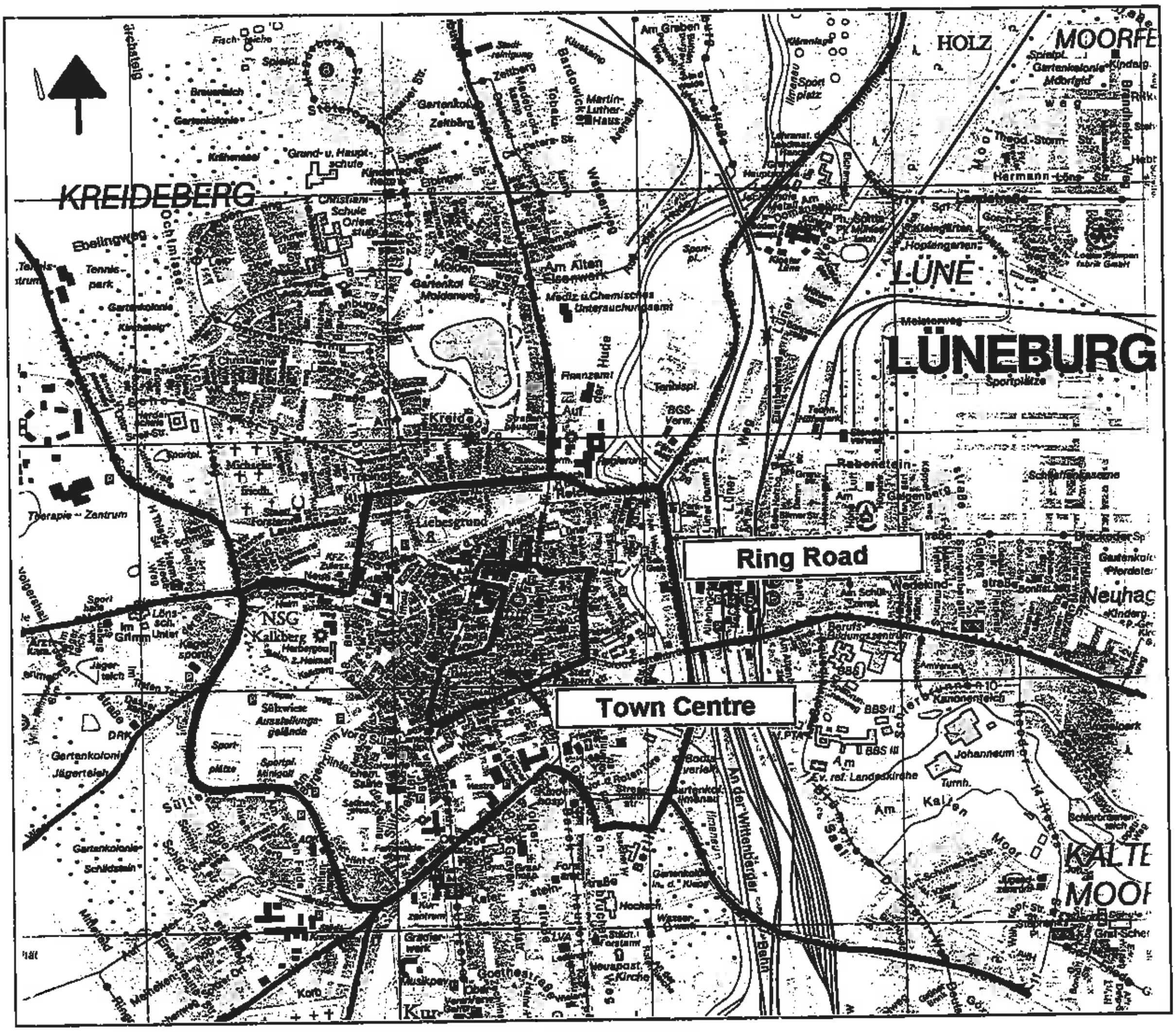
On the first day of work the congestion length was 2.2km and buses had delays of up to 30 minutes. On the second day the delays and congestion had nearly disappeared. However congestion developed on one parallel route. '*After that traffic behaviour had adjusted itself*' (Berg W. & Bärtsch D. 1995, p. 31).

During the day, traffic was reduced by 25%, of which 5% was due to seasonal changes. The capacity limit was reached during the morning and evening rush hour. The sum of the three counting places (over 24 hours) seemed to be identical in the before and after study (ibid, Anhang 5, p.10), with a traffic reduction of 10.5% on the affected road.

Overall, 80% of drivers kept to the same route and had on average a delay of 2.5 minutes. There was a maximum congestion delay of about 10 minutes, on some occasions, during the evening rush hour, when about 20% changed their route. At other times 10-15% used other routes. Other reactions, such as transfer to another transport mode (public transport or cycling), change of time period or not making a trip did not occur in a form that was noticeable. The possibility to change to other routes showed that the road network had enough spare capacity, and it seems that the congestion delay was so short that it was not worth it for 80% of car drivers to change their route or mode.

32. Lüneburg 1991-1994

Source: Pez 1994, Hass-Klau 1996, Luneburg City Council, local newspapers, bus operator, and observation by Hass-Klau.



Lüneburg is located about 50km south-east of Hamburg. It is a small town with only 64,000 residents but the wider hinterland includes about 250,000 inhabitants. Being a historic town, motor vehicle traffic has been perceived as a problem for many years. Car ownership is high, amounting to 510 cars per 1000 inhabitants. During the last 15 years car traffic increased by about 20% on the trunk roads leading to the town centre.

As a result of the high level of motor vehicle traffic in Lüneburg and the daunting forecasts of further growth, the Town Council decided to prepare a environmentally friendly transport policy strategy which was politically agreed in 1990. It included large scale pedestrianisation, closing the town centre to cars, constructing a large cycle network and improving public transport.

The overall objective of the plan was to encourage people to leave their cars at home, especially for short journeys and to travel by public transport, cycle or on foot. It was hoped that the policy measures would result in a reduction of 25% of car trips inside the ring road. It was considered important that the traffic diverted from the town centre should not have an adverse effect on the outer roads.

The implementation of these new transport policies began in 1992 and most changes had been completed by Autumn 1994. An ESRC research project enabled the author (Hass-Klau) to observe and monitor this town centre closure at the time.

Lüneburg has a designated inner ring road which largely consists of a number of traditional dual lane carriageways roughly forming a ring at about 1km distance from the town centre. The average traffic flow at various counting points on the ring was 24-29,000 motor vehicles per day.

The recommendation of the traffic consultant, based on modelling, was that in order to be successful with this new transport strategy, some parts of the inner ring road had to be widened to four lanes to accommodate the estimated diverted traffic. The Town Council took the view that, although following the advice of the consultant might avoid some criticism and controversy, it would have been far more expensive, more motor vehicle traffic would have been generated in the long run, and the gains achieved by the road widening would soon have been lost. Therefore the Council decided against this approach, and the plan was implemented without the recommended road widening, though some junctions received minimal additional capacity for buses. During 1993 and 1994 new traffic signals regulating the traffic flows on the ring road were installed.

One of the first policies was to give public transport priority throughout the town by means of priority signals and bus lanes, and although the town was happy to pay for this, there was great reluctance to pay any additional subsidy to the bus operator. From Autumn 1993, hourly limited-stop bus services have been running from the outer areas of Lüneburg to the town centre and one year later more frequent bus services have been introduced with the financial help of the town. According to the local newspaper the first limited-stop services gained about 20% more passengers.

A comprehensive cycle plan was quickly adopted and an extensive cycle network was built including segregated routes along roads, and general improvements to other cycle facilities. The overall aim was to increase cycling so that 34% of all trips inside the town are made by bike.

Before 1993, Lüneburg already had a number of well established pedestrianised streets. With the change in transport policy the pedestrianised area was trebled, so that it covered most of the historic town centre. In some of these newly car-free streets, access was provided for cyclists, public transport, taxis, residents and service vehicles. The main change brought about was the closing of additional parts of the town centre to vehicular traffic in May 1993. Exceptions were made to allow access for buses, taxis, and certain private and commercial vehicles. Consequently, there are now no through routes across the town centre and all through traffic is diverted onto the ring road.

Although there was a high level of publicity, it was widely expected that these road closures would initially bring complete chaos to the town centre as drivers attempted to follow their normal routes. Eighty police officers were on patrol on the first day to enforce the new regulations and a strong police presence was maintained for the first week. This was very necessary as, at first, there were few physical measures to prevent vehicles entering the town centre. Even on the Monday, workmen were observed still painting new cycle lane markings on the roads and marking out the position of pinch points. The situation was further confused by a number of roadworks on the periphery of the town centre.

Impacts of the 1993 town centre closures

Observations tended to confirm the view that congestion and chaos were less than had originally been feared. Traffic jams were observed on the roads entering the ring road from outside Lüneburg and on sections of the ring road. There was also congestion within the centre on the evening of the first day of closure as people who had parked their cars in central car parks left the town.

During the first days, a steady stream of motorists tried to enter the restricted areas of the town centre and were redirected by the police to alternative routes. The police generally adopted a high profile but 'soft' policing style, especially in the initial days. A few car drivers attempted to enter the town centre via the cycle lanes, driving happily along with two wheels on the pavements. This was discouraged.

Effects which had been achieved by 1994 are shown below.

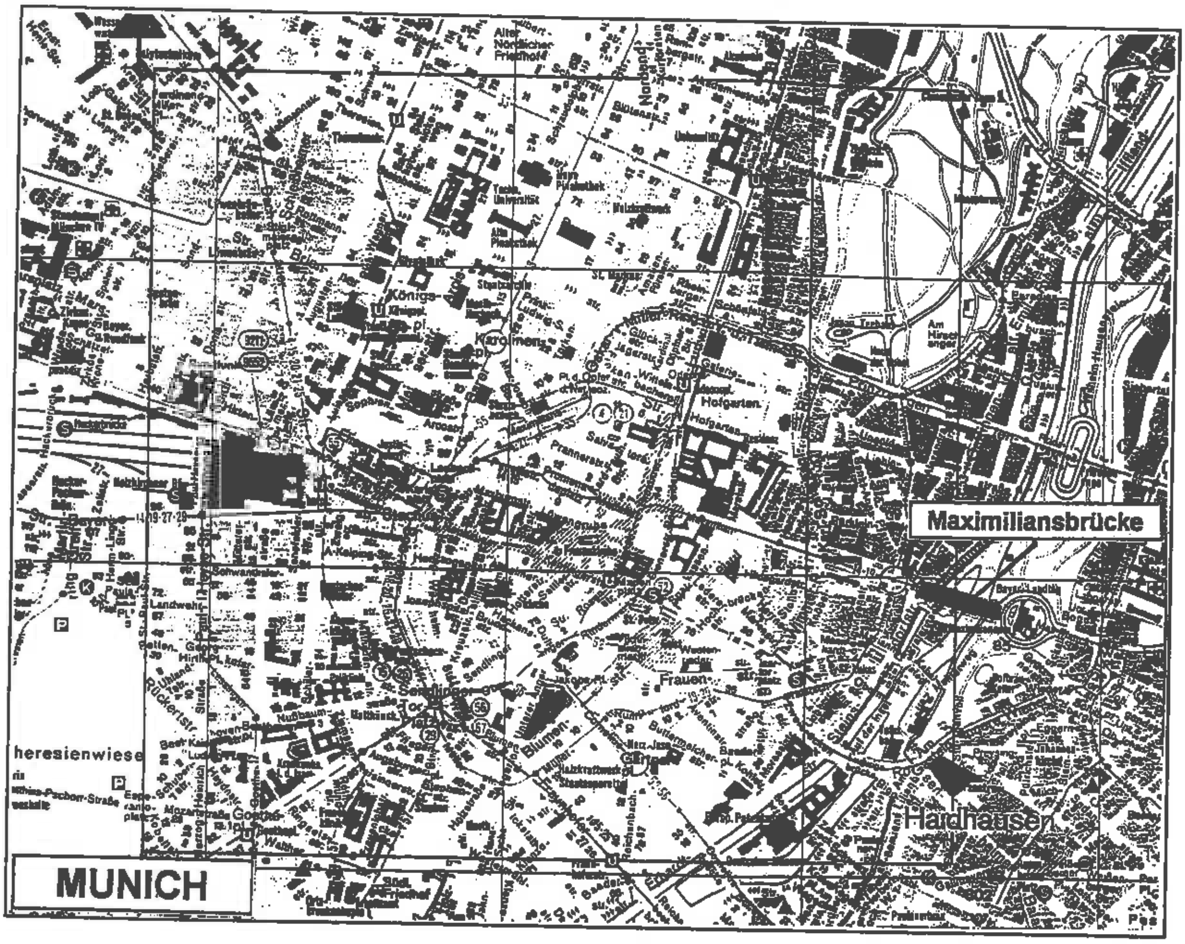
Change in traffic flows on ring road and major roads					
Mode	1991	1994		1991	1994
	absolute totals		change	modal split in %	
Cars	106,002	90,597	-14.5%	81.0	73.3
Motorbikes	1,720	1,889	9.8%	1.3	1.5
Bus passengers	7,095	6,490	-8.5%	5.4	5.2
Cyclists	7,905	12,541	58.7%	6.1	10.2
Pedestrians	8,136	12,067	48.3%	6.2	9.8

According to the traffic counts, there was a significant decline over 1991-1994 in the number of cars on the inner ring roads and the roads leading to the town centre. The same counts indicate a large increase in cyclists (59%) and pedestrians (48%). The figures for bus travel are misleading because the weather was much better during the 2 survey days in 1994 than in 1991. Hence a number of people who took the bus in 1991 cycled or walked in 1994. According to the public transport operator, bus travel was much higher for the whole year of 1994 than three years before.

Car ownership in Lüneburg only slightly increased by 1% in the time period, which indicates a slower growth rate for the city than for the region, where there was an increase of about 9%. An additional important effect has been the reduction in the personal injury accidents by 13.5% from 422 to 365 in one year (1993/94).

33. Munich 1970-1995

Sources: Hass-Klau 1997a, Landeshauptstadt München 1996, Hupfer 1991



Munich is a city of 1.3 million population in the south of Bavaria. It has an extensive pedestrianisation scheme in the city centre and has invested heavily in suburban and urban rail. It is an important example of the development of traffic policies in large cities, which can present different problems to those of smaller self-contained towns and cities. A fuller account is given in Hass-Klau 1997.

The City has carried out regular traffic counts since 1970. In total, traffic flows across the outer cordons have more than doubled since 1970. Since 1989 traffic flows have been stable everywhere within the city and there was a slight decline in 1993. Traffic flows crossing the Isar river in an east-west direction grew by only 28% over more than two decades, from 1970 to1992. (Landeshauptstadt München 1996, p.24). The north-south traffic flows increased in similar proportions by 32% between 1991-1995. These figures have to be seen in the context of the growth in car ownership, which increased by 84% over the same time period.

The modest growth rate in traffic flows in the city was only made possible by a doubling of public transport passengers between 1970-1992, or, in other words, public transport use increased 4 times as rapidly as the number of motor vehicles. The ratio of motor-vehicle users to public transport passengers at the Isar border changed from 63:37 in 1970, to 54:46 in 1992 (ibid, p.25).

Munich Bridge closure 1988

In 1988, a main bridge (Maximiliansbrücke) to the south-east of the city centre needed to be closed for repair. It is one of the four bridges which lead directly to the inner ring road, surrounding the traffic restrained city centre. At the time, the bridge carried 32,000 motor vehicles/24 hours. The two neighboring bridges carried traffic flows of 36,000 and 35,000 motor vehicles (24 hours) respectively. The technical forecast predicted no serious problems after car drivers got used to the situation. Most traffic was expected to use the neighbouring bridges, and some people were expected to transfer to the newly opened underground lines (U4 and U5).

In contrast, in the public discussion, it was seen as being impossible that the two neighbouring bridges could carry all of the additional traffic. Total traffic chaos was predicted. There was even talk of the need for a provisional bridge, though this was prevented by the high cost and the need to fell some trees.

Impacts on traffic

Shortly before the closure the public opinion become more and more Cassandra-like. '*There was talk that 300,000 car drivers would be trapped in the jam'......... 'On the day of the closure the only jam which occurred was among the masses of reporters, camera teams and photographers who were all waiting for the traffic jam which never took place. This was the comment of the local newspaper on the 8th November 1988* (Hupfer 1991,p.6).

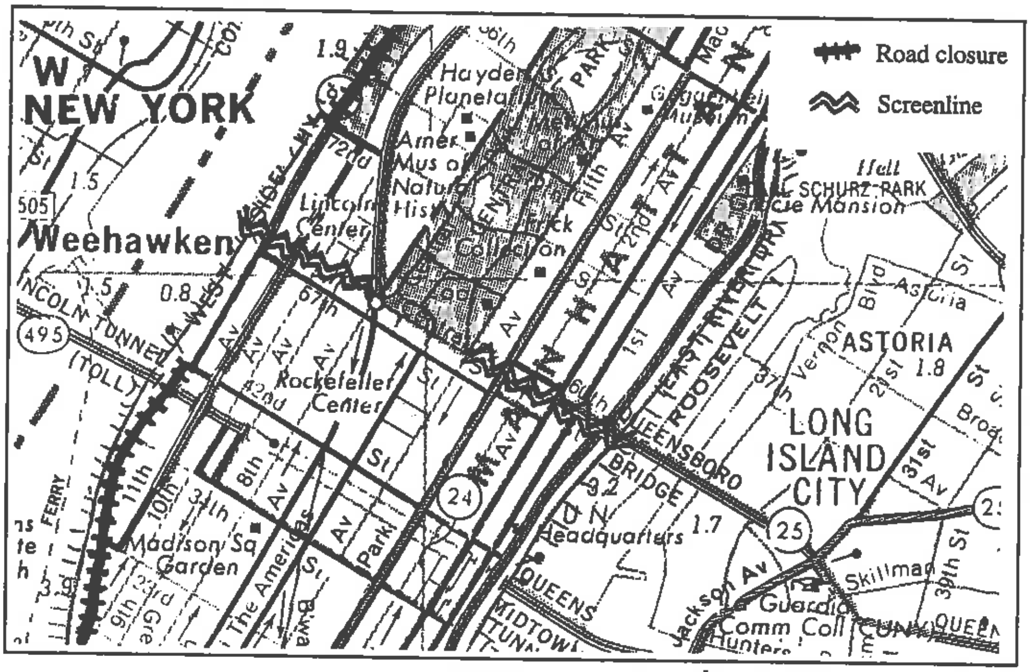
24hr traffic flows	Before	After	Change
Maximiliansbrücke	32,000	0	-32,000
2 neighbouring bridges	71,000	103,000	+32,000
Totals	103,000	103,000	0

During the closure both bridges took all of the additional traffic. The normal traffic jams increased slightly. Very few car users transferred to the newly opened underground lines. When the local authority was asked why no chaos had happened, they said that the ongoing construction work of the underground made drivers aware of constant capacity reductions somewhere in the city, or in other words people got used to bottlenecks (ibid , p.6).

This case deserves special mention as it is the only one reported where the total volume of traffic before and after the change was the same, though, as described above, the wider context was one of longer term traffic restraint and increased public transport use.

34. New York 1973 (USA)

Source: Convissor 1996



In 1973, sections of 2 highways, which form a continuous link along Manhattan's West Side, were closed due to structural problems, leaving only a short link (between 72St and 42St open). An appropriate screenline was taken across 60 St.

Total 24hr 2 way traffic flow	Before (1973)	After (1974)	After (1975)
West Side highway (remaining section)	110,000	50,000	50,000
Arterials	420000	430000	420000
FDR Drive	110000	120000	125000
Total	650,000	610,000	600,000
Total		-40,000 (-6%)	-50,000 (-8%)

Caveats: No further information was available

35. Norway - Street Enhancement Programme 1991-95
Oslo 1997

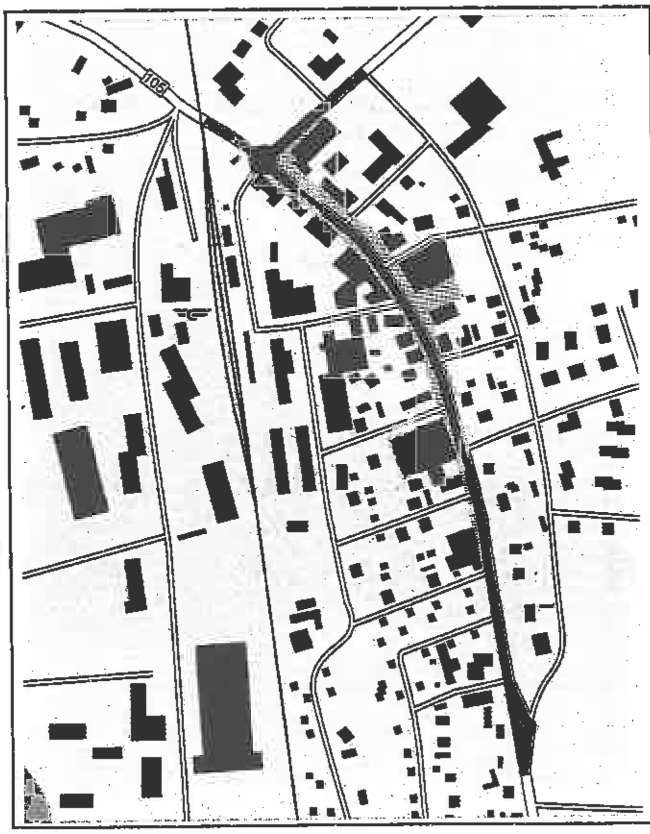
Source: B Sandelien 1997, Norwegian Public Roads Administration 1996a and 1996b with translation of some material by Sandelien

Street Enhancement Programme 1991-95

In 1991, five towns across Norway were chosen to form part of a demonstration project on street enhancements. In each town, the main route through the town centre was narrowed, and redesigned to try and improve the environment of the town, to encourage a lower and more even speed of traffic, and to generally resolve the "numerous conflicts of interest" that arise, due to the different functions that a main thoroughfare needs to provide, including provisions for "through traffic, footways, cycle lanes, local traffic, shopping, and general use by the inhabitants".
Stretches of state highway of 400-750m were treated, and road widths were reduced from 7-14 m down to 5.5 - 6.5 m. In most cases, there is no alternative route to the enhanced street.

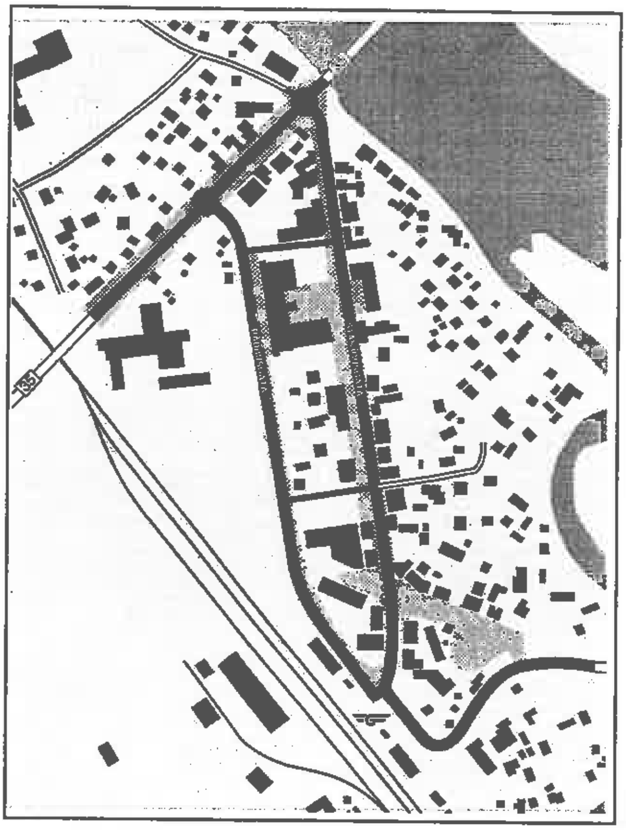
The five towns chosen (shown overleaf) were the municipal centres of their municipalities, and were:

- Rakkestad, in the south east of Norway. The population of the municipality is approx. 7,000, and the population of the town and adjoining housing areas is approx. 3,500. Road width was narrowed from 7-7.5 to 6.5 m, and the speed limit along the road was reduced from 50 to 30km/hr.
- Hokksund, in the south of Norway.The population of the municipality is approx. 15,000, and the population of the town is approx. 6,500. Road width was reduced to 5.5 m in some parts, and the speed limit along the road was reduced on Radhusgata St. from 50 to 40km/hr. Elsewhere, it effectively remained at 50km/hr.

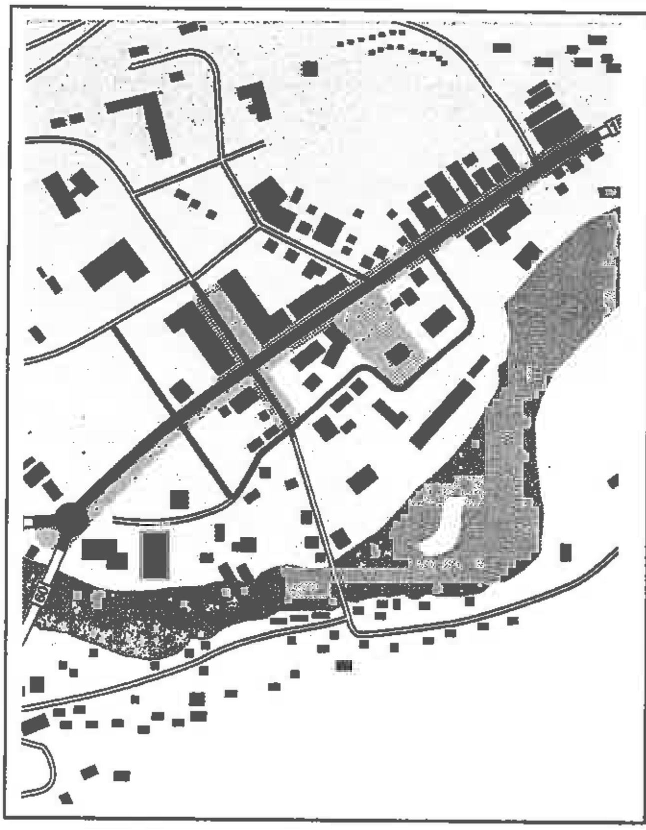


Rakkestad

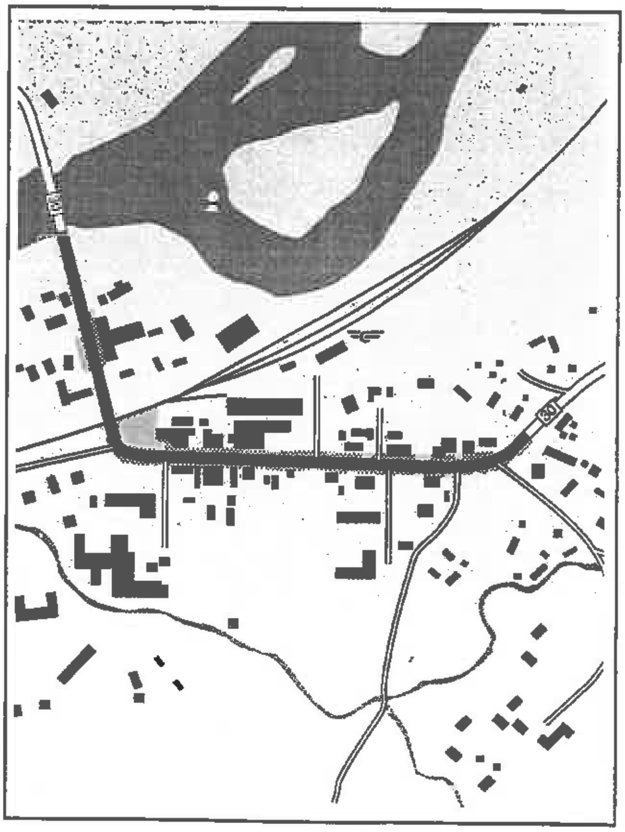
Hokksund



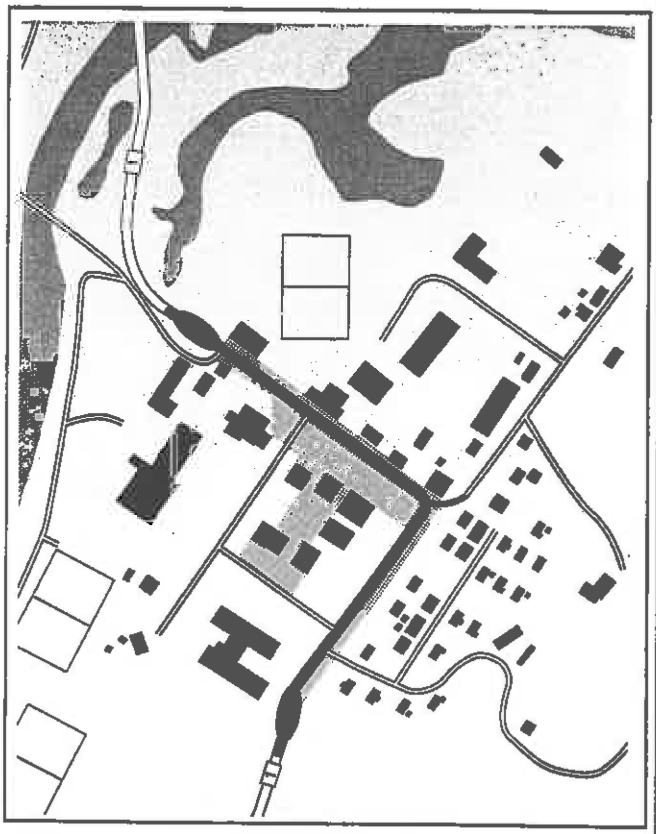
Stryn



Os



Batnfjordsøra



- Stryn, on the western Norwegian coast.The population of the municipality is approx. 6,700, and the population of the town is approx. 2,000. Road width was narrowed from 12-14 to 6.5 m, and the speed limit along the road was reduced from 50 to 40km/hr.
- Os, in the east of Norway.The population of the municipality is approx. 2,100, and the population of the town is approx. 500. Road width was narrowed to 6.2 m. The speed limit along the road remained at 50km/hr.
- Batnfjordsora in the west of Norway.The population of the municipality is approx. 2,900, and the population of the town is approx. 600. Road width was narrowed from 7.5-8 to 6.5m, and the speed limit along the road was reduced from 50 to 40km/hr.

To assess the impacts of the changes, traffic data were manually collected over 2-3 days in May/June 1992, and May/June 1995. Specific explanations relating to the data are given in the table below.

Parameter and Town - Street name	Before May/June 1992	After May/June 1995	% Change
Average number of vehicles per day[1]			
Rakkestad	7,000	6,800	- 3
Hokksund rv 35 (national road #35)[2]	11,300	10,000	- 12
Hokksund/ - Rådhusgata	7,100	-	-
Hokksund/ - Stasjonsgata	(1,600)[2]	2,900	(+80)
Stryn	4,100	4,500	+ 10
Os	2,400	2,400	0
Batnfjordsøra	1,800	2,100	+ 17
Average traffic speed km/h[1]			
Rakkestad	42	33	- 21
Hokksund rv 35 (national road #35)[2]	50	33	- 34
Hokksund/ - Rådhusgata	46	(30)[4]	(- 35)
Hokksund/ - Stasjonsgata	(25)[3]	29	(+ 16)
Stryn	37	29	- 20
Os	40	35	- 13
Batnfjordsøra	45	41	- 9
Deviation of the mean speed km/h[5,6]			
Rakkestad	8.6	6.7	- 22
Stryn	8.0	7.8	- 3
Os	10.1	8.3	- 18
Batnfjordsøra	11.5	10.5	- 9
Share of through traffic in %[7]			
Stryn	22	28	+ 27
Os	37	46	+ 24
Batnfjordsøra	43	57	+ 33

\- Not registered
1 Average for all screenlines, totals both directions
2 Afterstudies are done on only one of the two screenlines on national road #35
3 Only for the three last days of the before study due to constuction disturbances and ongoing events in the streets
4 Unreliable results. Measurements for only two hours due to technical problems
5 Only for one screenline in the most central part
6 Not calculated for any screenlines in Hokksund
7 Average of all observations, totals both directions

In general, traffic has only obviously reduced in one town (Rakkestad), whilst it has remained constant or increased in the other four. However, traffic speeds have largely reduced, and have also become more stable (as indicated by the reduction in deviation in mean speeds). Moreover, through traffic has become a greater proportion of the overall traffic flow, which is described as "a positive result", presumably because it implies that more local traffic is now using other modes.

In explaining the differences between the towns, it is highlighted that for Hokksund rv 35 "there are to some extent alternative routes", whilst the large increase on Hokksund/Stasjonsgata is probably due to the reopening of two key intersections at its north and southern ends. Traffic increases in Batnfjordsora may also be due to the opening of new infrastructure nearby, shortly before the start of the project.

To explain changes in speed reductions, it is concluded that "an average speed level of 30-40km/hr can be reached with a road width of 6.5 metres between kerbstones in combination with other measures", and that the differences between the towns are largely due to the density of the buildings, and the distance they are set back from the road.

Moreover, control sites for Os and Batnfjordsora indicate that there is a certain amount of variability in traffic levels, speeds and reliability anyway.

Other effects:

- "Pleasing surroundings have been created [and] the visual environment in the five towns shows a significant improvement"
- "Reports indicate that shopping has increased and there is a higher level of interest in building new houses"
- "Based on the speed reductions...there is reason to expect future accident figures to be reduced by 20-40 %"

Additional information:

Values in 1995 Norwegian Kroner	Total cost of project	Anticipated savings in the first year alone*
Rakkestad	15,000,000	1,790,000
Hokksund	37,400,000	1,320,000
Stryn	28,700,000	860,000
Os	10,600,000	200,000
Batnfjordsora	9,700,000	70,000

*These are only the savings expected from reduced accident costs, and do not include any savings due to the utlitiy upgrades, and so on that were carried out during the road redesigns.

Comments:

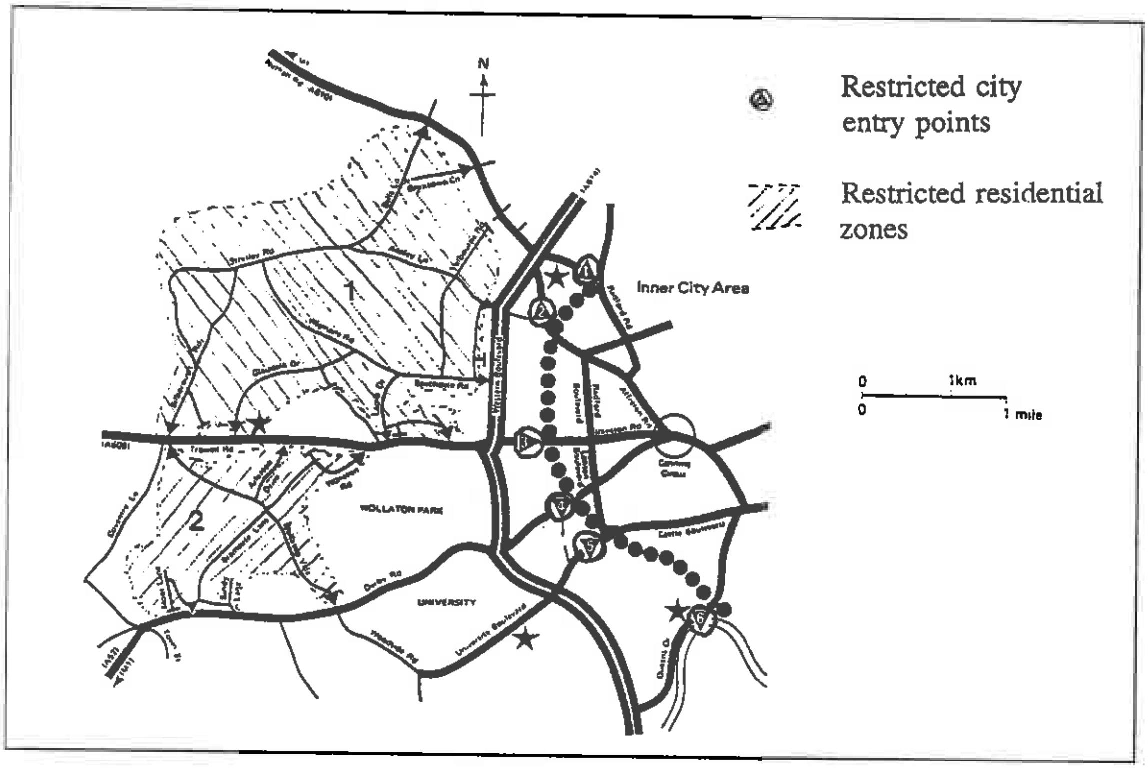
Given that traffic flows have not reduced, it is not clear that capacity has truly been reduced in the five towns. However, road width *has* clearly been reduced, which would usually be taken as a sign that capacity had, and average speeds have also gone down. Therefore, this is an important case study, as it indicates the unclear relationship between physical capacity provision, and the actual amount of traffic that can use a road system. The indirect impacts on shopping and housing (which, to some extent, have generated traffic) also highlight the complexity of responses that can occur as a result of (apparent) capacity reductions.

Oslo 1997

Sandelien reports on changes being made to 'Finnmarksgata', a major route running north-south through a semi-dense area in the central part of Oslo, which is being narrowed from 4 lanes to 2, with left turning lanes at intersections. "The political process [behind this] was a long and interesting story", however "the project is not going to be subject for special studies or surveys". Apparently, this is partly because changes elsewhere on the network have offset the capacity reductions and reduced the importance of the street, and also because there is a "serious traffic bottleneck" at the northern end of the street, which limits capacity anyway. Hence, "capacity can be reduced in Finnmarksgata without too serious consequences".

36. Nottingham Zones & Collar 1975/6

Source: Vincent & Layfield 1977



Between August 1975 and 1976, a 'Zones-&-Collar' experiment was in place in the western part of Nottingham, which aimed to selectively delay non-bus traffic, and give priority to buses between 7.30 and 9.30 am. Traffic was restricted from leaving 2 residential zones, and entering the city at a collar of six points. Buses were given special lanes to get them past the restrictions, and 4 Park-and-Ride sites were introduced.

Data to assess the effects of the scheme were obtained from home interview surveys, and a variety of on-street surveys, carried out before the scheme in April/May 1975 on weekdays in school term time, and at corresponding times in 1976.

	1975	1976	Change
Cars entering traffic 'collar' between 7.30-9.30	13,380	13,150	-230 (-1.7%)

In general, bus journey times were reduced by less than one minute, and the punctuality of buses was not improved. Significant delays were not imposed on car traffic either. Only about half the traffic leaving the residential zones experienced delays (on average 1-2.5 mins), and average journey times increased by a maximum of 1.5 minutes.

There were no significant changes in accidents, or the mode of transport used by residents of the two zones. The Park-and-Ride buses carried an average of only 5 passengers each. Only 55% of these passengers had previously travelled by car.

There was a decrease in through traffic taking short cuts through the residential zones.

Various mechanisms are assumed to account for the aggregate effects:

First, drivers changed their behaviour, in a number of ways, including:

- changes in driving style

"It was found that driver behaviour changed when faced with the imposed delays to the extent that, despite shorter green times, the traffic discharged over the stop line at a higher rate".

- infringement of zone-&-collar lights and bus lanes

Infringements occurred at a rate of about 2000 in the 2 hour morning peak. "Approximately one-quarter of these were vehicles passing traffic signals at red, the rates of infringement at some zone-&-collar signals being several times those observed at other non-restraint signals".

- minor changes in route

"The scheme produced a redistribution of traffic between the main radial roads leading into the City, but this probably resulted in little increase in vehicle kilometres."

- minor changes in the timing of journeys

At the 95% confidence level, there was a significant decline in vehicles travelling through the collar between 8-8.30am, and an increase in vehicles travelling between 7-7.30am, suggesting that there was a small but significant shift towards travelling earlier.

Second, it was difficult to impose very long delays on traffic approaching the collar, due to the restricted space for storing queues, and it is noted that, even where long queues could be created, "these did not necessarily result in large imposed delays".

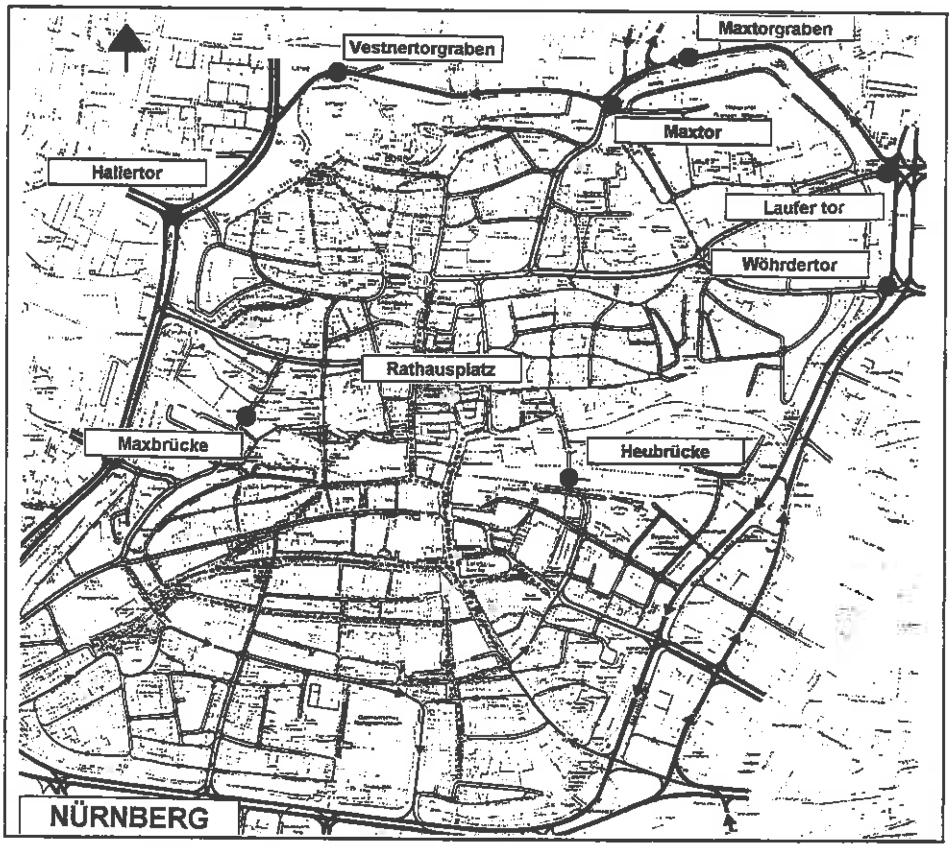
Third, about 95% of drivers passing through the collar had free parking in the City Centre, and no attempt was made to regulate this

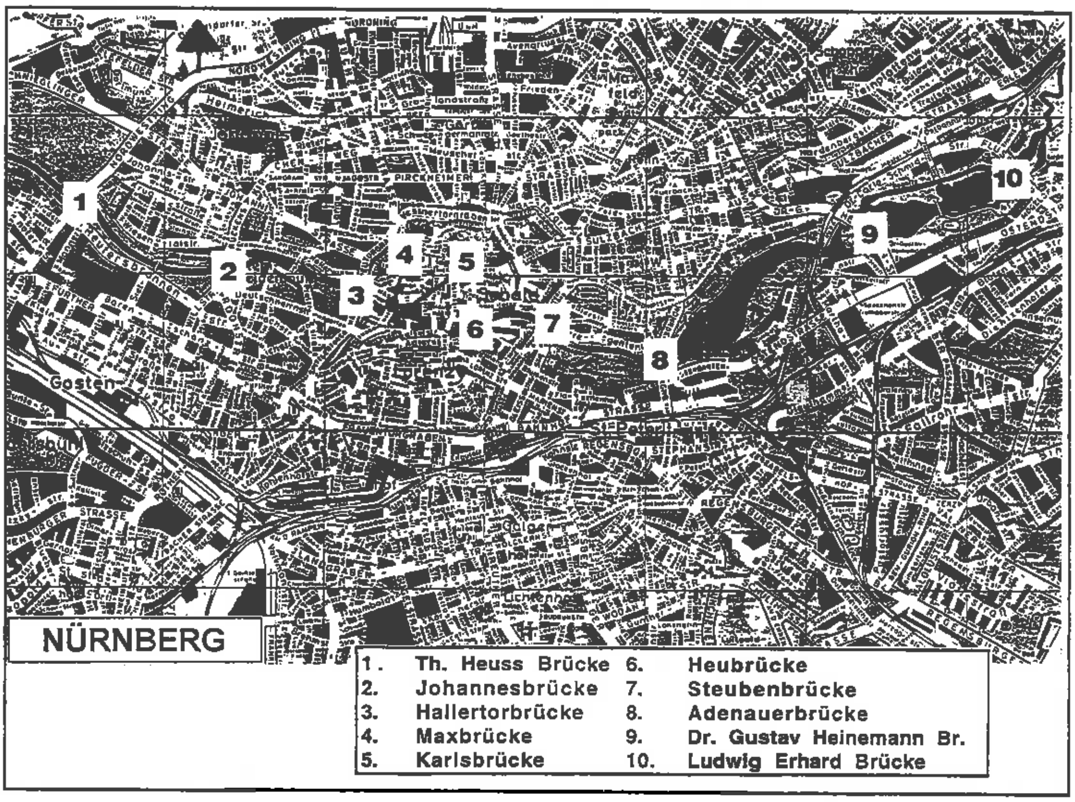
Fourth, between the surveys, in real terms, bus fares rose by 20/25% and petrol costs fell by 20%.

Caveats: In some ways, this is not really an example of road space capacity reduction, since no meaningful reduction seems to have occurred. However, it was designed to be, and the reasons why it wasn't are important.

37. Nürnberg 1988-94

Sources: Hass-Klau 1992, 1997a, 1997b, Pharoah 1992, Nürnberg Stadt 1997 (source for tables)





Nürnberg is a city of 480,000 inhabitants located in the north of Bavaria. This city has been mentioned in a number of British transport publications, and has been a particular research interest of the author (Hass-Klau), who has lived there. Nürnberg is a city well-known throughout Germany for its successful environmentally-friendly transport policies which it has pursued for more than 20 years. It has one of the largest pedestrianisation schemes in the country and is the smallest city in Germany which has built an underground system.

The conversion of the town centre was implemented in a phased way over an extended period, which meant that even after most of the streets were pedestrianised, there were still a number of routes through the town centre, and the closure of the last major through route was controversial, vigorously opposed by the traders, and well researched. Moreover, relevant data were available to study this event in more detail. The last remaining traffic corridor in the city centre accommodated about 25,000 motor vehicles/24 hours in 1988. In October 1988 part of this street was closed at a location in front of the historic Town Hall *(Rathausplatzsperrung).* In order to make sure that car drivers could not squeeze through other historic streets, some other changes in traffic orders were made. Access for public transport and cyclists was still permitted.

Impacts on traffic in the historic part of the city

Count locations	July 1988 MV/16h	Forecast MV/16h	Real change MV16h	Counts Jan 1989 MV/16h	Counts Jul 1990 MV/16h	Counts Jul 1991 MV/16h	Counts Jul 1993 MV/16h
Rathausplatz	24,584	-24,584	-24,584				
Wöhrder Tor	15,899	-1,000 to -2,000	-1,606	14,293	14,974	13,600	10,780
Laufer Tor	13,877	-4,000 to -5,000	-5,526	8,351	9,773	8,205	9,310
Maxtor	13,577	0	+540	14,117	13,538	12,819	10,033
Maxtorgraben	3,150	1,400 to 2,400	+1,446	4,596	6,447	7,098	8,136
Vestnertorgr.	6,754	1,800 to 2,500	+1,389	8,143	9,692	8,726	7,804
Heubrücke	9,390	800 to 1,200	-1,761	7,629	7,795	6,138	(1)
Hallertor	22,369	-7,000 to -8,000	-12,259	10,110	10,727	10,099	9,761
Maxbrücke	6,852	-800 to -1,300	-3,399	3,453	2,582	2,532	(2)
TOTAL	91,868*	-9,600 to -11,400	-21,176	70,692	75,578	69,217	55,824

Source: Stadt Nürnberg 1994 (1) and (2) extension of pedestrianised area

*This obviously includes the traffic on Rathausplatz (24,584 vehicles), whilst the other counts in this row do not, as Rathausplatz was closed. The total for the other counting locations (excluding Rathausplatz) was 67,284 prior to its closure.

Forecasts were made of the effects at each of the counting points, and allowed for some expected traffic reduction, of between 9,600 and 11,400 vehicles. The actual reduction was about twice as large, at 21,176, after the first traffic count in January 1989. By 1993, a total of 36,044 vehicles had disappeared from these roads.

Impacts on traffic across the city, as evident from bridge flow data

To find the 'missing traffic', traffic flows on the bridges inside the outer ring road (mostly 4 lanes) were studied. Strangely enough, the flows had fallen there as well.

At Hallertorbrücke, [1]west of the city centre, traffic fell by 7.4% between 1988 and 1989. There was a further decline at Hallertorbrücke in 1990, but traffic flows increased in the following years. In 1993 flows were still 3.5% below the 1988 level.

One could argue that people tried to cross a bridge even further away (Johannisbrücke), however a study of this bridge and revealed a very similar story. Traffic stayed stable or had fallen slightly in 1989 (0.3%), increased in 1990 (7.8%) but in 1991 the traffic flows had fallen by 21.4% in comparison to the 1988 level. In 1993 the level was about the same as in 1988.

There was an increase at the eastern side of the city centre on one bridge (Steubenbrücke) by 2,842 vehicles (7.8%) in 1989. This grew further by another 12.3% (4816 vehicles in 1990) but declined the following years (1991 and 1992)and increased slightly in 1993. In total the bridge showed an increase of 20% since the city centre street had been closed. On the next bridge, Adenauerbrücke, there was a decline of 4,644 vehicles (11.8%) which remained constant in the following years. In 1993 there was a slight increase, to a level which was still 6% below the 1988 figure.

Therefore the analysis was extended to cover all the bridges in Nürnberg (in total 12 bridges). These are counted regularly and are seen by the traffic engineers of the city as an indicator of the north-south traffic flows. The figures are shown below.

Traffic flows over 12 bridges screenline:					
Year	Total	Percentage	Year	Total	Percentage
1981	224,839	100.0	1988	253,988	113.0
1982	220,800	98.2	1989	241,831	107.6
1983	234,361	104.2	1990	245,756	109.3
1984	237,094	105.5	1991	245,853	109.3
1985	239,696	106.6	1992	244,469	108.7
1986	244.963	109.0	1993	238,312	106.0
1987	249.182	110.8	1994	236.980	105.4

Source: Stadt Nürnberg 1994

In total, there was a decline of 12,157 vehicles or 4.8% between 1988 and 1989. Maxbrücke, Obere Karlsbrücke and Heubrücke are included in these 12 bridge. These are located in the city centre and declined by 7,196 motor vehicles. There were then some significant changes in 1993 in the city centre so that the three city centre bridges only carried very small amounts of traffic and traffic on all bridges declined fractionally from 1992 - 1993 by 2.5%. The total traffic flow

[1] Hallertorbrücke is part of the inner ring road and should not be confused with Hallertor. At Hallertor the decline of traffic flows was about 55% between 1988 and 1989.

figures declined by about 7% from 1988 - 1994. A new count was undertaken in July 1997 but the results are not available yet. But recent years indicate that traffic flows have regained the level of 1988.

Impacts on traffic at the outer cordon to the city

Changes in traffic flows at the outer Cordons
1984 to 1985 = 4.3%
1985 to 1986 = 2.2%
1986 to 1987 = 6.3%
1987 to 1988 = 2.9%
Closure of the city centre road
1988 to 1989 = 3.4%
1989 to 1990 = 4.3%
1990 to 1991 = 0.8%
1991 to 1992 = -2.2%
1992 to 1993 = 2.5%

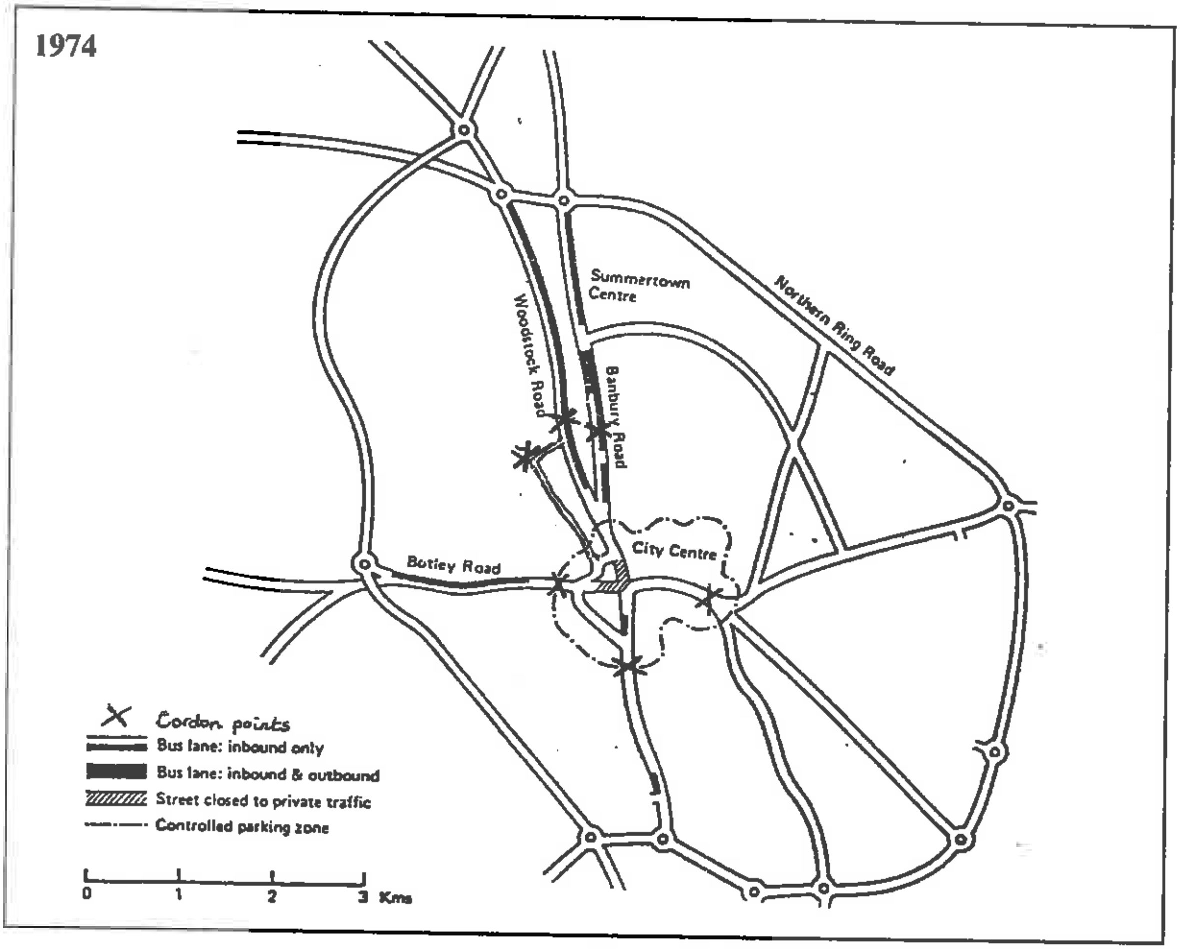
Counts were carried out in July of each year.
Source: Stadt Nürnberg 1994

In comparison to the city centre and most of the traffic flows at the bridges, traffic flows at an outer cordon round the city fluctuated from year to year, with an average increase of about 4% per year from 1984 to 1988, whilst pedestrianisation was still being implemented. This growth reduced to an average of less than 2% per year from 1988 to 1993, when pedestrianisation was nearly complete. Car ownership continued to increase over the period, from 172,056 in 1977 to 242,939 in 1993, giving a 41% increase.

The figures quoted here do not reflect the very much larger reductions in town centre traffic that resulted from earlier phases of extensive pedestrianisation.

38. Oxford - road closures & bus lanes 1974

Sources: EMITS 1996/97, Oxford City Council Highways & Traffic Working Party (1994), Papoulias & Dix (1978)



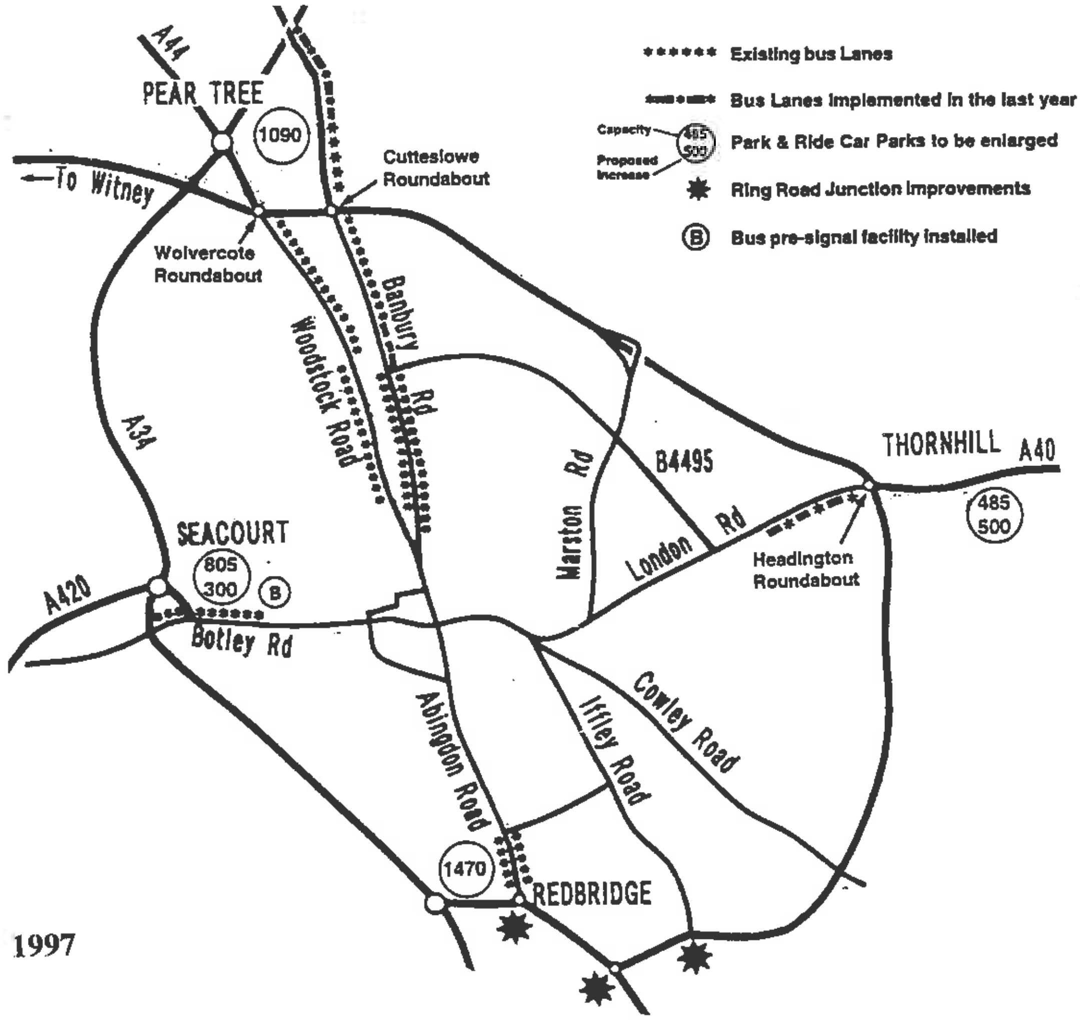
In mid-1974, bus lanes were introduced along several major routes in Oxford. Their introduction followed the closure of two major central shopping streets to private traffic, parking restrictions near the centre, and the introduction of two Park-and-Ride services.

Since then, Oxford has had a general "Oxford Transport Strategy" which has involved some changes and extensions of bus priority, and a major increase in the provision of park and ride spaces. The current situation is shown overleaf:

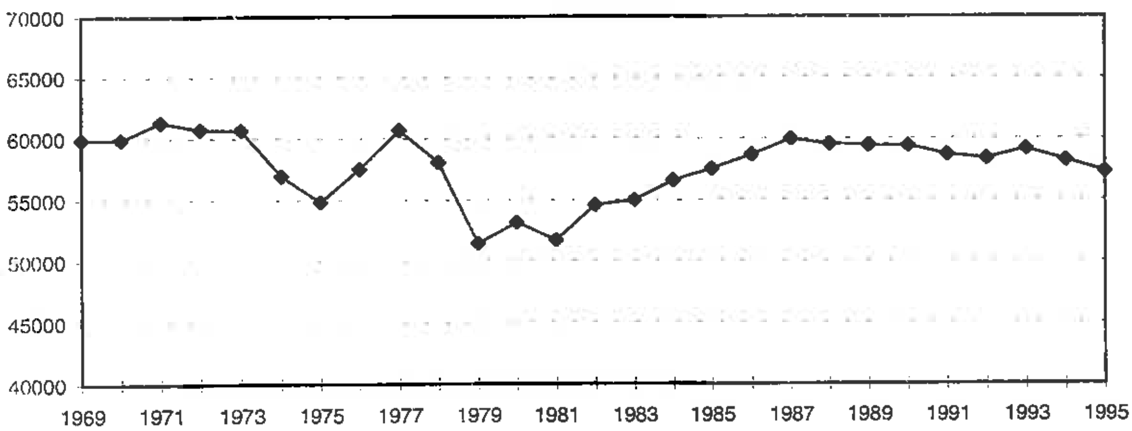
Aggregate impacts on traffic :

	1973	1975 (1yr)	1979 (5yrs)	1984 (10yrs)	1989 (15yrs)	1995 (22 yrs)
24hr weekday motorised traffic flows entering the central cordon	60684	54820	51450	56599	59483	57267
% change (compared with 1973)		-9.7	-15.2	-6.7	-2.0	-5.6

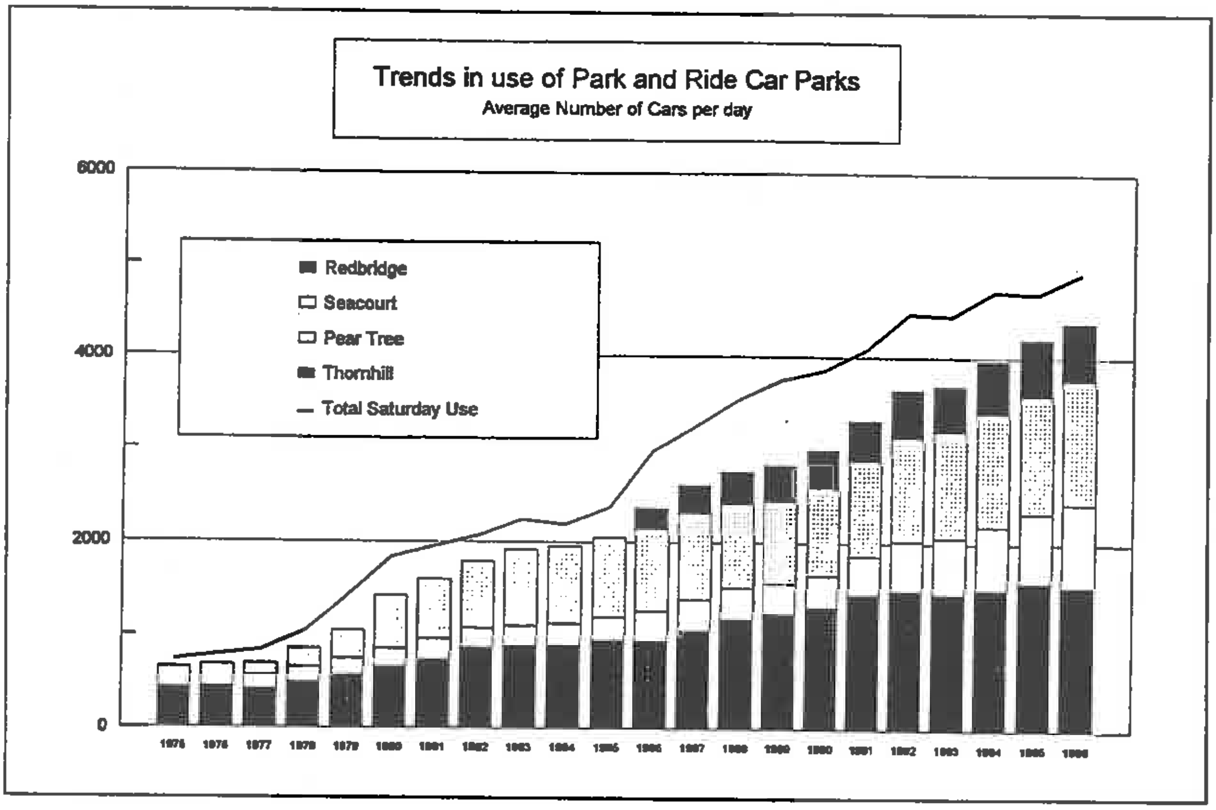
To put these changes in context, changes in the traffic flow are compared more generally with the change in Park & Ride usage.



24 hr weekday traffic flow entering central cordon of Oxford



The dip in the early 1970s may partly be explained by the oil crisis, although judging by the modest reduction in 1973, it is unlikely to account for all of it. The reduction in 1979-81 is best explained by the recession.



Specific impacts of the bus lanes:

Numerous monitoring surveys have been carried out to assess the specific impacts of the bus lanes, and in general, the bus operators estimate that there has been a 40% increase in overall bus patronage during the last 10 years. On a more local scale, for example, the introduction of the bus priority pre-signal on Botley Road in late 1995 is estimated to have reduced bus journey times by 12% (EMITS 1996/7).

An early survey of the bus lanes carried out by Papoulias & Dix (1978) demonstrates the complexities of the bus lane impacts. Their studies included:
- a survey of 1,436 car users, 7.30-17.00, Thursday 7th & Friday 8th November, 1974
- a survey of 1,361 bus users, 7.30-16.00, Monday 4th-Wednesday 6th, November 1974
- a survey of 848 cyclists, 7.30-17.00, Saturday 15th & Tuesday 18th February 1975

The results were:

- the number of people regularly using buses rose by 6.7%, and 15% of previous bus patrons reported making increased use of the service.

- 6% of bus users (96 people) reported having swapped from car or cycle.

- 53% of car users felt unaffected by the lanes, whilst 8% approved, 9% were ambivalent, and 28% disapproved. The majority of 'benefits' perceived to result from the lanes related to 'smoother' driving conditions, (63% of all positive comments), whilst complaints about increased hazards and longer journey times constituted the bulk of complaints. However, based on other observations, Papoulias & Dix argue that "perceptions of journey-time increases were [probably] overestimated, a likely contributory factor being the occurrence of intermittent delays of a frustrating nature".

- 2% of motorists said they had changed their travel patterns, with 13 people saying that they'd changed their usual route, and 8 people saying they had changed their usual shopping centre.

- 59% bus users felt that the quality of their journey was unaffected by the changes, although the 'unaffected' proportion was greatest on the less congested routes.

- 22% of cyclists felt unaffected by the changes, whilst 65% approved of the scheme, 5% were ambivalent and 7% disapproved.

- A separate study of accidents suggested that there might have been some increase on particular roads, particularly "as a temporary phenomenon, until the bus lanes were fully established", but that "it certainly does not seem to have been of sufficient magnitude or severity to justify abandonment of the bus lanes on grounds of hazards and danger alone".

In general, response rates represented 40% for car users, 24% for bus users, and 59% of cyclists. Papoulias & Dix note that those who don't respond are likely to be those least affected by the bus lanes, and so all the percentage 'changes' recorded could be smaller for the total population than they are for the sample.

Summary:

In general, the central road closures, the bus lanes, and the other measures do appear to have had an effect on overall traffic flows, as traffic levels in 1995 were still not as high as they had been in 1973. Moreover, Park & Ride has attracted numerous customers, and the bus lanes have resulted in a general increase in bus patronage, with an overall increase in patronage of about 40% in the last 10 years. Hence, there has been a substantial increase in person trips into Oxford City Centre, without a concurrent increase in car trips, and car drivers/passengers have become a smaller proportion of those travelling into Oxford..

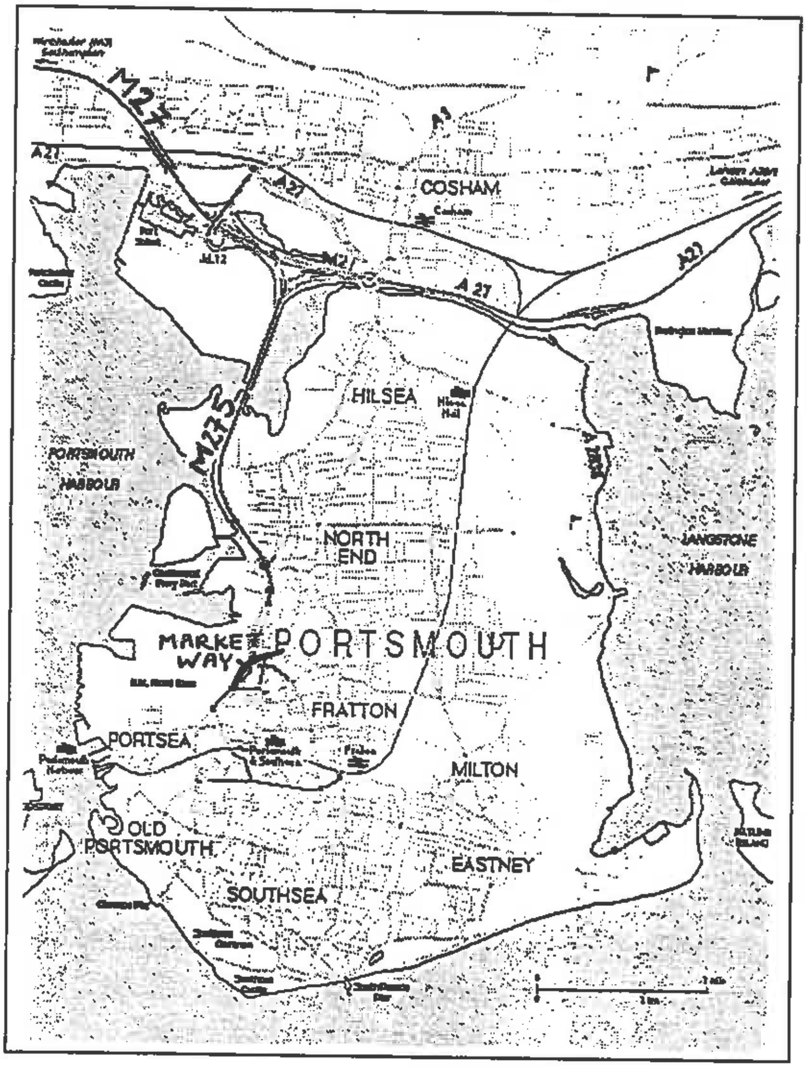
However, whilst the increase in bus patronage may represent the substitution of *potential* car trips into Oxford, it is difficult to directly link changes in existing traffic flows with changes in bus use, as shown by the markedly different profiles of the graphs of traffic flow and Park & Ride patronage. The early study of bus lanes suggests that the actual impacts on behaviour are relatively complex, with, for example, some cyclists becoming bus users, whilst some motorists changed route or went elsewhere. Therefore, the traffic measures have reduced traffic, and the improvements in bus services have attracted new customers and increased the number of people travelling into Oxford. However, it is not clear that the two phenomena are simply or directly linked.

Caveats:

Specific caveats relating to the 1974/5 bus lane survey are reported in context. There is more information relating to the performance of the bus lanes that there has not been time to process.

39. Portsmouth - roadworks 1995

Source: Black & Hallsworth 1995, Denyer 1997



Portsmouth has a specific geography that influences its traffic patterns, as the majority of the city is situated on Portsea Island, and there are only three major roads into or out of it. In February 1995, road works began on the main western route into Portsmouth, and severely reduced its capacity by about a third. Roadworks were in place on Market Way for about 6 months and on the M275 for 3-4 months, with short-term additional roadworks on the M27.

The roadworks "caused heavy congestion", and the University of Portsmouth undertook a survey, in the summer of 1995, to establish how car drivers were reacting to the situation. A questionnaire of 10 questions, with substantial space for comments, was distributed. 1547 questionnaires were returned, a response rate of 38%. Analysis of people's home locations suggested that a representative 'spread' of people had replied, with some bias to those living along the affected corridors.

Unfortunately, there is no complementary traffic count information, as according to Paul Denyer, the City Engineer, "although there are permanent traffic counters on the M275, linked to the City's UTC system, there are no count facilities on [alternative routes], nor were any manual counts undertaken at this time...it is more likely there was a conscious decision to *avoid* carrying out surveys during the inevitable disruption to traffic patterns".

Selected Results:

Q3. 'How much time have the roadworks *added* to each journey in/out of Portsmouth (minutes per journey) ?'

Time	0	1-9	10-19	20-29	30-39	40-49	50-59	60+
Percent	8% (129)	9% (136)	43% (672)	18% (279)	13% (194)	4% (54)	(5)	(1)

The authors do note that "A negative effect of asking the question in this way may have been to encourage people only to think of the time added", and that "people often exaggerate, as the longer waits in traffic will always be more frustrating (and memorable) that those times when the traffic might be flowing relatively quickly".

Q4. 'Please tick any of these statements that may reflect you method of coping with the roadworks'

Statements that may reflect their method of coping	No.
a) I cannot (or do not need to) make changes, I simply put up with the traffic	683
b) I take other people (or share a lift with others) - so that we don't all have to drive	75
c) I have adjusted my travelling times to miss the worst of the congestion	677
d) I have stopped coming into Portsmouth, whenever possible	159
e) I have avoided travelling by car	145
f) I use my car/ travel by car - but now use another route	407

Q5 then asked whether adjustments were working and whether they would be continued after the roadworks ceased.

In general, the comments suggest that

- Changes in travel time were associated with leaving home earlier for commuting trips, making more use of flexitime, and adjusting schedules generally

"If I have a social event in the City in the evening, I don't bother going home because it wouldn't be feasible"

Opinions about whether adjustments would continue were mixed:

"Yes, I will continue starting earlier as I can travel quicker outside the rush hour"

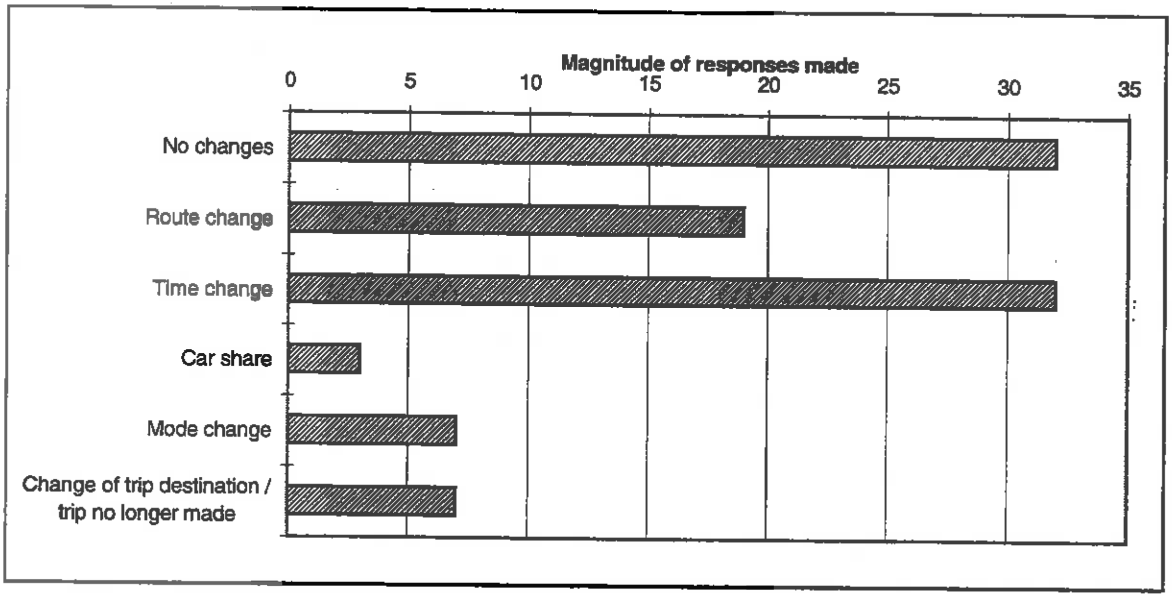
"[No] It leaves us with precious little evening by the time we get home and have dinner"

- Of those who said they avoided journeys into Portsmouth, some people were now working from home, and a lot of people said that they had started using more local shops and facilities, and would continue to do so.

"Having been forced away from Portmouth has made me look at other shopping and leisure centres and it has made me realise what I have been missing...after roadworks I will still avoid Portsmouth for lesiure and shopping"

- Avoiding travel by car was mainly associated with changing mode, with walking, cycling, trains, buses and ferries all being used as alternatives. 80% felt that their adjustment was working, and many said they would continue to use them after the roadworks, for reasons like "*less stressful*" and "*more reliable*".
- Alternative routes (inlcuding rat-runs) were used fairly widely, particularly if they provided a more reliable journey time, or if they enabled the driver to keep moving. A lot of people "highlighted the importance of local radio on their travel options", and they also commented that they swapped back (or would swap back) to the M275 when congestion was less, as other routes were more hazardous.

Recasting the responses (and calculating percentages as a fraction of the overall responses) gives:



Interestingly, this imples that, *if* adjustments were made in proportion to the spread of responses received, then those which eliminated car trips in Portsmouth (changing mode, changing trip destination or no longer making trips) would equal about 14% of the total sample.

Q7 (For those who did not or could not make changes) 'please let us know *what prevented you* from changing your usual habits in any meaningful way. (Tick any that apply)'

Reasons people could not, or chose not, to make adjustments to their travel	**Response**	**% of total**
Start time is dictated by need to take children to school	13% (168)	11%
Need car for "work activities" during the day	29% (388)	25%
Have to take equipment/ bags etc.	12% (164)	11%
Need car for after-work activities, eg shopping, social, etc.	18% (243)	16%
Extra time taken was not significant enough to warrant change	28% (378)	24%

Interestingly, some people said that they 'needed' a car for work activities simply to look obliging, as not doing so would not "create the right impression" with their employer.

Q8. 'Were there travel adjustments that you would like to have tried and which might have made things easier, had they been available locally ? (please tick any that apply)'

Alternative	Number	% of all respondents
Walking on a safe route	30	2%
Bus	128	8%
Park and ride (bus)	230	14%
Cycling on a safe route	173	11%
Train	209	14%
Park & ride (train)	217	14%

Clearly, modal change was considered, although the authors note that there could be problems providing park and ride, that various impracticalities and a lack of safe facilities were mentioned as the reasons for not cycling, and that people said they had been put off walking because it was unpleasant or unsafe. With respect to bus and train, they note that, in some cases, there were relatively local services available, and highlight that non-use may relate to a lack of information about them, or the perception that services are not close enough. Other options that respondents said they would have liked, included greater use of flexitime in companies, high occupancy vehicle lanes, time restrictions on car use, and traffic restrictions in the city centre.

In a subsequent question, 58% said they thought that their home location was a major constraint on how they travelled into Portsmouth, not because of distance, but because of remoteness from 'quality' public transport facilities. For those who did not think it was a constraint, the reason was not nearness to public transport, but often because they had made a conscious decision to live outside Portsmouth (and were therefore prepared to put up with the consequences), or because they lived near a motorway (and therefore did not feel constrained).

Q10. 'The present disruption will be over in a few weeks, but what if present traffic congestion levels were to become "the norm" in the future throughout Britain - what long term options would you consider for travelling to work ? (please tick all those that apply)'

Move house	10% (160)
Move job	14% (215)
Switch to bus always	11% (170)
Still travel to work by car	57% (875)
Cycle	18% (273)
Walk	7% (104)
Switch to train always	19% (297)
Park & ride	21% (326)

Of the 57% who said they would continue to travel to work by car, 14% also said they would also consider other options, meaning that only 48% would not consider making any significant adjustments at all.

A wide variety of long term options was obviously considered, although some people noted constraints on their decisions. For example, negative equity was mentioned as a problem for moving house, together with the desire to keep children at particular schools. A number of people described the inadequacies of other modes (including price), and the lack of foreseeable viable alternatives, arguing that they were essentially 'car dependent'.
"House sale would be a financial disaster/job availability negligible/public transport unreliable and still has the same problems in traffic/too far to walk/unable (diability) to cycle/park-and-ride creates other delays and expenses/train too far away from home and costs far too much"

Others simply believed the car gave the benefit of flexibility, and that they had paid enough taxes that they should be catered for. Others refused to believe congestion could get that bad, or were waiting for changes to be promoted by the government.

Interestingly, modes were valued according to different aspects. For example, many people highlighted that cycling was desirable because of the control it gave you, or the health benefits, but did not mention cost, although cost was seen as a significant drawback of bus and train use.

Other long-term options suggested by respondent included high-occupancy vehicle lanes and car sharing programmes, increased tele-working, and more motorcycle use.

Summary

The authors highlight that this study was able to evaluate the impacts of congestion increasing very rapidly, and therefore has some insights into how people might react in the future. However, "respondents could have some confidence that the future would be better", and "some adjustments, such as shopping elsewhere, were perfectly feasible" whereas, in the long term ""we cannot ALL escape permanent nationwide congestion".

Their findings suggest that perhaps 11% of trips into Portsmouth were no longer made, whilst the majority of people "adjusted by modifying their use of the car. They did not abandon their car. Commonly people indulged in time-buying behaviour".

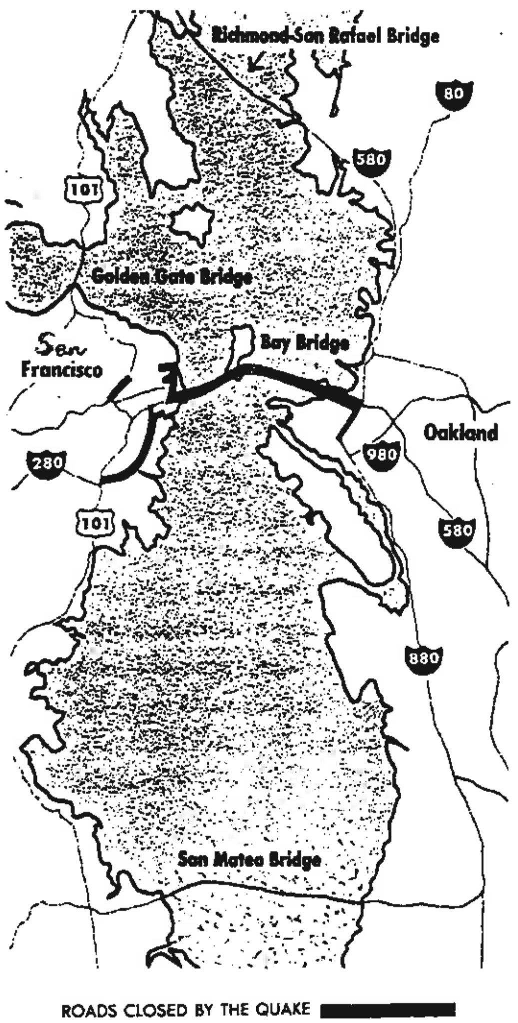
In the longer term, over half the respondents would consider other options, and some adaptions could bring additional benefits (like making more use of local shops), or be relatively easy to achieve (like changing the culture in organisations where employees feel obliged to bring their car into work). Many people would consider using an alternative mode of transport. However, most do not believe that they currently have attractive alternatives available, and highlighted a wide range of problems with them. The results also showed how much a car has become seen as part of a 'flexible' lifestyle, important for allowing trip combination and luggage carrying, and how much "people are tied into home and work patterns", where transport considerations are only part of locational decisions in which other factors may over-ride the 'price' of driving and congestion.

Caveats:

The material reported here is only a (hopefully unbiased) selection from the fuller report.
p19 was missing from the original report that this summary is taken from.
There is a minor dicrepancy between p14 and p22 in the original report about the number of respondents recorded as making no adjustments in behaviour.

40. San Francisco - Loma Prieta earthquake 1989

Source: Hansen & Weinstein (1991), Deakin (1991), Webber 1992/3, UITP Express 1996-6, Peter Hall 1997.



On October 17th 1989, the Loma Prieta earthquake struck San Francisco, causing substantial destruction. Various freeways were damaged, including the Bay Bridge (I-580), the Cypress Freeway (I-880), the I-280, the Central Freeway (US-101) and the Embarcadero Freeway (I-480).

Various emergency measures were put into place, including the introduction of a ferry service between the East Bay and San Francisco. Most of the freeways were restored over time, apart from the waterfront Embarcadero Freeway which was demolished, and the area below was revitalised with pedestrian zones and a light rail line.

A variety of commentators have reported on the earthquake, focusing on different aspects, and therefore their reports are summaried separately here.

Deakin 1991 - the Bay Bridge closure

Prior to the earthquake, the Bay Bridge carried 245,000 vehicles and 400,000 people daily. The damage it sustained was considered to be the most significant of the earthquake damage, as the alternative options for car drivers involved 20+ mile diversions along already congested routes, which "for most travellers, would be far too time consuming to be considered". With the other freeways, "although congestion and travel time increased, the alternative routes permitted most trips to be made with relatively little disruption".

Therefore, two surveys were undertaken to assess the impacts of the closure. The first involved a 10 minute telephone interview with 534 respondents from the East Bay area who worked in San Francisco. 69 East Bay respondents who did not work in San Francisco also surveyed as a control. These telephone interviews were carried out between 14-17th November, shortly before the re-opening of the Bay Bridge, and respondents were asked about travel both immediately after the earthquake, and at the time of the survey. The second survey was carried out in March 1991 to try and assess the longer-term impacts of the earthquake, however only 41 people were actually surveyed, due to resource constraints, and partly because "we could no longer locate over 40% of our sample at their previous phone number and another seven percent had switched jobs".

Impacts on work travel

"After a couple of days, most survey respondents went to work on their regular schedules...Although most commuters reported [that they had] tried several different ways to get to work [including driving an alternative routes]...the vast majority of commuters quickly settled on an alternative ***mode*** of travel". Mode changes are shown below:

% use of different modes	Before	November 1989	March 1991*
Drive alone	37	10	33
Shared ride	24	1	28
Bus	10	1	40
BART (underwater train)	35	75	
Ferry	--	10	
Other	8	3	

* based on very small sample size

"Most respondents reported that their work travel times changed only marginally (under 15 mins) from the times they had routinely travelled before the earthquake".

Some other changes were also recorded

% who adjusted their schedules by more than two hours a day	5%
% who made additional stops on the way to or from work (ie. trip chaining)	-11% (from 31% to 20%)
% respondents who were now working from home	5%
% respondents whose workplace had relocated	2% (13)
% respondents whose workplace was closed	0.02 (1)

Employers offering commute alternative incentives	+4% (from 7% to 11%)
Employers who made formal changes in work schedules	+10%
Employers allowing flexible working hours	+23% (from 7% to 30%)

"Overall, most respondents - 69% - felt that their trip had gotten harder...On the other hand, 15% reported that their trip had gotten easier...Interestingly, pre-quake BART and ferry users who continued to use the same mode after the quake were the most likely to complain about worsened travel conditions".

By 1991 "no significant changes in commute hours were reported"

Impacts on non-work travel

After the earthquake, the rate of non-work trips to San Francisco dropped from 0.6 trips per week to 0.36 trips per week for those still working in San Francisco, and less than 0.3 trips per week for all respondents. The greatest losses were in social and recreational trips, whilst "travellers reported that they found ways to get to scheduled appointments for medical care". However, by 1991 "no significant changes in the number of weekly non-work trips made to San Francisco were reported"

Control Sample

"East Bay residents who did not travel to San Francisco for work before the earthquake, but did go to work in the East Bay exhibited similar patterns of change, although their drive alone share before the quake was much higher than for the San Francisco commuters and remained so...Many were affected by short-term or longer-term closures or repair delays on their usual driving routes...Immediately after the earthquake, many switched to ridesharing, bus or BART, but as repairs were made and facilities reopened, most went back to driving alone...Also like the San Francisco workers, the East bay workers reported less trip chaining after the quake than before, and were more likely to cut non-work travel, especially social and recreational trips".

Deakin concludes that:

"The 1989 Loma Prieta earthquake and, in particular, the temporary loss of the San-Francisco-Oakland Bay Bridge had far less drastic consequences for East Bay to San Francisco commuters than many had feared....Most experienced only temporary disruptions in their journey to work, because they were able to quickly shift to other modes for the duration of the bridge closure. Non-work travel fared less well, however, and substantial reduction in such trips were reported, although travel for scheduled appointments such as medical trips was little affected. A brief follow-up survey conducted 17 months after the quake found that little or no permanent change in travel patterns has occurred as a result of the quake, although a small net increase in rail transit ridership did appear to have been retained [as evident from other surveys]...The follow-up survey also illustrated that changes in residential location and other household characteristics are fairly frequent".

Hall 1997, Deakin 1991 - the impacts on BART

The BART (Bay Area Rapid Transit) underground trains across the bay formed one of the main alternatives used by commuters. According to Hall, ridership doubled the day after the earthquake, and Deacon reports that BART statistics and surveys showed that about 30,000 new riders were retained once the Bay Bridge was restored

Hansen & Weinstein 1991 - the East Bay ferry service

Hours after the earthquake, a ferry service was introduced between the East Bay and San Francisco, as a means of travel for commuters. Patronage for this service stabilised at 8-10,000 passengers a day, after the earthquake, then fell to 3.5-4,000 after the Bay Bridge reopened in November. Service cuts at the end of December caused it to plunge again to about 1,500 daily passengers, and further service cuts in March led to a further ridership fall to under 500 people.

Hansen and Weinstein carried out an on-board survey in at the beginning of November 1989, with two waves of follow-up phone surveys in December 1989 and March/April 1990. Over 1000 passengers were included in the first survey, whilst sample sizes for the two follow ups were only 60 and 51 people respectively. Their results demonstrate how the ferry declined as a popular mode for commuting.

Mode used most frequently for commuting	December 1989	March 1990
Ferry	48%	13%
Drive alone	11%	13%
Carpool	15%	21%
BART	10%	9%
Bus	16%	30%
No longer commuting	0	11%
Other	0	2%

Moreover, people proved unable to accurately predict what their future use would be. For example, "those from the first survey who had predicted they would only use the ferry service occasionally in the future were actually riding more, by the second survey, than those who predicted they would ride five or more days per week".
Common reasons for stopping using the ferry were that it was too slow, too expensive and getting to the terminals was too much hassle, compared with the speed, prices and convenience of other modes. "Respondents generally appear to have lost enthusiasm for the ferry service as time progressed, the memory of the earthquake emergency faded, and many commute patterns returned to normal".
Meanwhile, the ferry service has been made permanent, with a subsidy of $5 per round trip. In concluding, the authors argue "In the view of some, the East Bay ferry service, like the removal of the Embarcadero freeway, will prove to be one of the silver linings of the Loma Prieta earthquake. More likely, the service will be one of the earthquake's more enduring costs".

UITP Express 1996-6 - the Central Freeway repairs

"At the end of August this year [1996], San Francisco was forced to close to all traffic one of its major highways, the Central Freeway, to repair damage from the 1989 earthquake. The massive tailbacks that were predicted to accompany this closure failed to materialise, however. Indeed, fewer cars actually took to the roads.
It should be said that the general public had been warned of the expected traffic chaos, while a parking ban had been introduced along alternative parallel routes and additional police officers deployed at major intersections. Even so, road transport experts are still trying to figure out where the 80,000 or so cars a day have gone. Given that there has only been a slight increase in the numbers using public transit, speculation has grown that the missing commuters are car-pooling, cycling, arriving and leaving work later, or tele-commuting.
Whatever the reason, many people are delighted that it is possible to do without the Central Freeway. Those living close to the route are hoping for a development similar to that of the waterfront Embarcadero Freeway".

Webber 1992/3 - overview

"The big news from the Bay Area's 1989 earthquake was that the transportation disruptions were only inconvenient, not dreadful...Congestion was bad in some places, but even there we never did suffer the dreaded 'gridlock'".
He argues this is for two reasons. First, "transport redundancy protected the Bay Area from severe disaster". He highlights the huge range of different travel options available in the city, which could take up the slack from the damaged ones.
Second, "transport systems, like market systems, have self-adjusting and self-correcting processes

built into them. Urban travellers are remarkably adaptive. In the short run, given the chance and given adequate information, they're remarkably quick to find ways round bottlenecks by adjusting their travel routes, times and modes. In the long-run, through the workings of labour markets and land markets, both job locations and residential locations get readjusted to accommodate traffic congestion and other constraints in the transportation system...Those short run adjustments were clearly evident during the Los Angeles Olympic games when dire predictions of horrendous traffic jams proved wrong, mostly because travellers anticipated the congestion and took counter measures to avoid it".
He also highlights the adaptability of transportation agencies in dealing with the disaster, and the adaptability of employers - "some accommodated by adopting flexi-time work schedules, others shortened the working week, relocated work places close to employees homes, permitted tele-commuting from home, and in other ways tried to adjust..."
He concludes that "to a large degree, we can rely on the autonomous and adaptive responses of...individuals, employers, suppliers, and various private and government organisations to accommodate spontaneously", but also argues that more redundant infrastructure needs to be built if the region is to survive a bigger earthquake in the future.

Summary

In general, the Loma Prieta earthquake, and subsequent repairs, seem to have caused far less disruption than might have been expected. In particular, the loss of the Bay Bridge, which used to carry 245,000 vehicles or 400,000 people daily, seems to have been remarkably uneventful, adding less than 15 minutes to the majority of commuter journeys. Whilst alternative routes to the other freeways do seem to have been used where they represented an 'easy' option, most commuters across the Bay appear to have swapped to other modes, notably the underground BART train and the ferry. Meanwhile other travel adaptions have also been made, including alterations in working practises to facilitate some shifts in journey time, and the suppression of some social and recreational trips.

In the longer term, there has clearly been some change to travel patterns in certain places, as shown by the demolition of the Embarcadero freeway. Bay Bridge users seem to have largely reverted to previous travel patterns, with a rapid decline in ferry use, although 30,000 new BART passengers were retained. (This represents 7.5% of previous Bay Bridge users, and by implication, 7.5% of the vehicles).

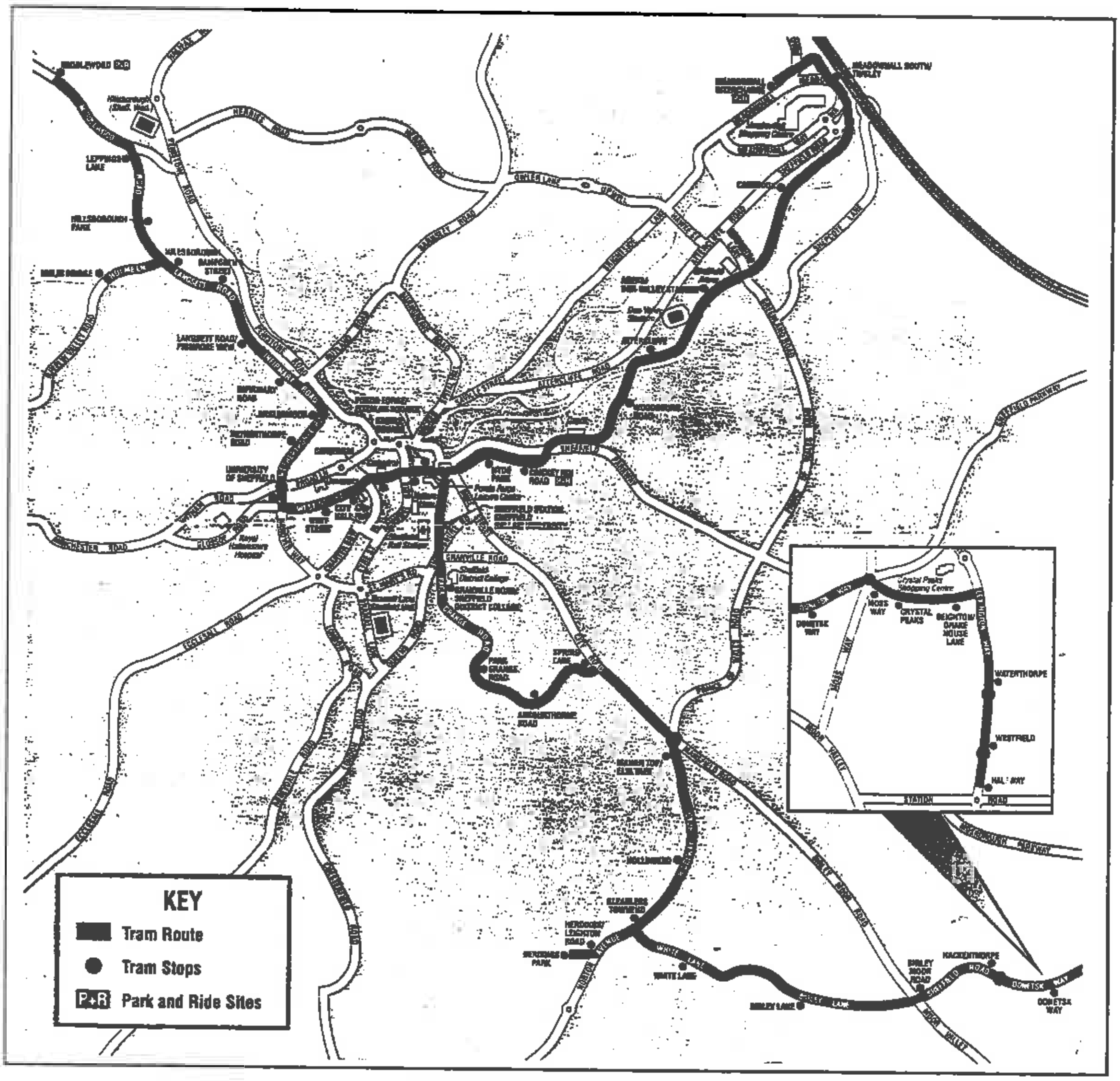
The other notable finding was the substantial turnover in respondents' jobs and housing, which may also have been a result of the disruption caused by the earthquake.

Caveats:

The sample sizes for the 1991 survey of East Bay residents was too small to be anything other than indicative of overall changes.The follow-up surveys of the ferry users are also very small, although the general decline in ferry use that they show is backed up by the decline in patronage figures recorded.

41. Sheffield Supertram 1994/5

Source: Graham Parkhurst 1997



Sheffield is a city of approximately 520,000 inhabitants, situated in central England. The South Yorkshire Passenger Transport Executive (SYPTE) developed plans for a 30km light rail system for the city known as 'The South Yorkshire Supertram', half of which was to run on-street. This subsequently opened in phases between March 1994 and October 1995.

To assess the impacts of Supertram, a comprehensive assessment has been undertaken by WSAtkins & TSU. However, no data is yet available, as the reports are still being checked by the clients. However, a small-scale study was carried out separately by Parkhurst (1997), involving two waves of in-depth interviews with 36 households, undertaken in Autumn 1993 and Autumn 1995. Although the sample size is too small to provide statistical measures of responses occurring, it does provide indications of the *range* of responses people made.

During construction

- **Changes in route**

Drivers met the potential delay caused by the construction work with various different routing strategies. Some resigned themselves to fate, due to the extent of the works, whilst many opted for a dynamic approach, varying their routes on different days in response to new conditions, and even more immediately, by changing route during a journey. Most of these switches involved moving part of the journey from principal roads to 'back-routes', and there was also the desire to keep moving. A typical comment was
"...rather than actually sit in the car and crawl, if we had to go in peak periods then I would choose another route...It might take a bit longer: the journey might not be six miles, it might be 10 miles, but at least I would be travelling".
However, for some people, this was an extension of normal behaviour: they varied routes anyway or had routinely avoided travelling through the city centre by car.

The situation was inherently far worse for bus passengers than car passengers, as although the buses did vary routes in response to congestion, any variation had to be pre-determined, and the buses still needed to serve their main traffic generators, many of which coincided with the areas of worst delay. Passengers would try to limit their personal delay, however. For example, one woman noted she got off the bus early and walked the final part of the journey.

- **Changes in timing of trips**

The evening rush hour was reported as being extended by an hour. Where people could reschedule activities, they did. For example, one person had altered her working hours to avoid the worst of the rush hour, whilst another only shopped in the city centre during off-peak times of the day.

- **Changes in mode choice**

Most changes in mode were made on an evaluative basis, and the shifts were in contrasting directions depending on each personal situation. In some cases, short additional journeys were made on foot, because it was quicker than queuing by car, and the bus was used *more* due to the high level of congestion, to avoid burning extra petrol and the stress of driving. On the other hand, use of the bus was *reduced* if delays could be avoided or minimised by using other modes

- **Changes in destination choice**

Some locations were in all practical sense ruled out by the combination of diversions that would be needed to access them, whilst others were accessible, but very inconvenient, such as the shops at Manor Top and Hillsborough, so some visits were deterred. Some people were avoiding activities which normally took place in the city centre altogether.

- **Trip suppression**

In general, some trips were suppressed, and the rate of social trip-making was particularly reduced. Apparently, a typical comment was
"I think people are not going out unless they really have to"

Following construction

The vast majority of households felt that, with the exception of roads in the Hillsborough area, the parts of the Sheffield network that had been affected by Supertram construction had returned to normal.

A few others felt that the previous conditions had not returned, but this was not necessarily the result of Supertram. Some people felt that the new traffic management arrangements had made car driving harder, whilst others felt it was not so much more difficult, but less attractive.

There was also the view that other problems had to some extent taken over: other roadworks were now in progress, or general traffic levels had risen in the interim. Further to this was the perception that traffic had not yet fully returned to its old routes and the observation that conditions were worsening as people continued to return.

General

- **Changes in driving styles**

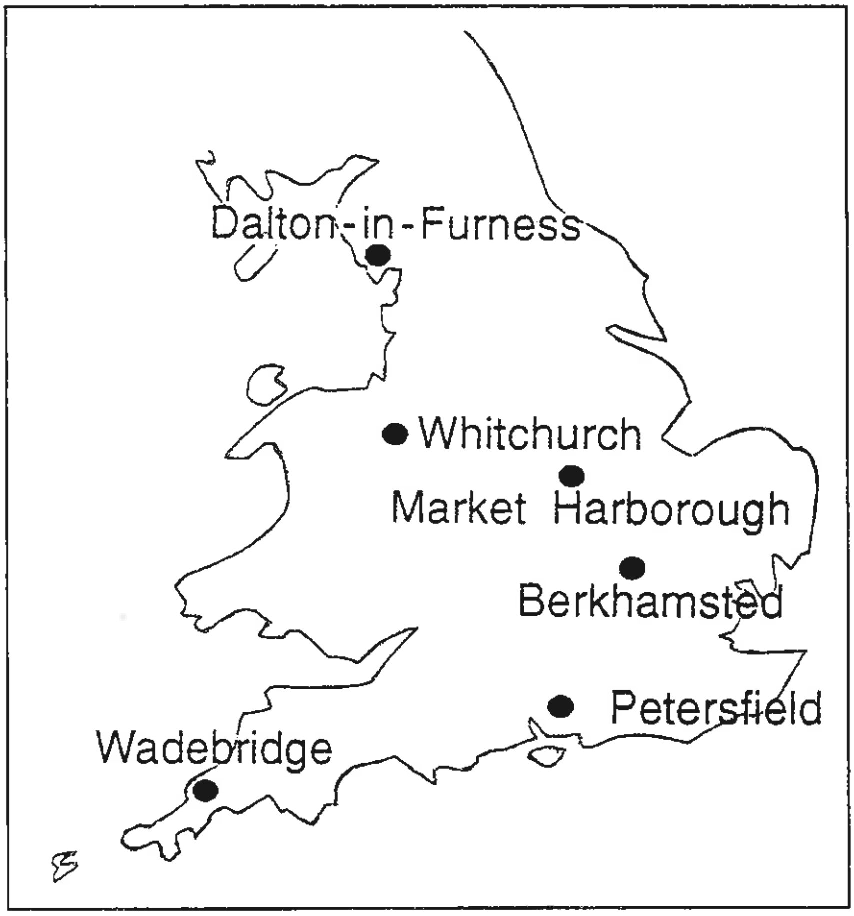
In interacting with Supertram, most people discussed the general difficulties of driving on the tracks, which were worse when wet, and some people even admitted avoiding certain roads because of the tracks. Other drivers described adaptive behaviour, being careful to straddle the lines, rather than drive on them
"You drive to try to keep your tyres off...you've got to weave. I mean, some parts, the inner rail is very close to the kerb, and other parts it isn't, so, I mean, you can straddle it left and then you've got to move, to straddle right, so... It's changed your driving habits"

- **Complex responses**

Overall, the survey highlighted the complexities in the way people react, and the way that different people make different choices, due to a whole spectrum of personal and locational factors.

42. Six Towns Bypass Project 1992-5

Source: Ross Silcock 1995, Barrell & Robson 1995, Barrell (1997)



In 1991, six relatively small towns were selected by the Department of Transport to take part in the"Bypass Demonstration Project". These towns were Whitchurch in Shropshire, Market Harborough in Leicestershire, Petersfield in Hampshire, Wadebridge in Cornwall, Berkhamstead in Hampshire and Dalton-in-Furness in Cumbria. All towns were scheduled to have a bypass built around their town in the near future.

On the basis that "a bypass, alone, is not the answer to a town's traffic problems", the towns then aimed to make changes to the old trunk route running through their centres to reduce the dominance of traffic and improve the pleasantness of the central environment. These measures effectively reduced the capacity of the old trunk route. Information on the towns, and the changes made, are shown below:

	Whit-church	Market Harboro.	Peters-field	Wade-bridge	Berkham-stead	Dalton in Furness
Population	7,000	16,000	15,000	5,000	17,000	11,000
Increase in pedestrianised space	62%	22%	60%	87%	30%	58%
Carriageway width before	5.5-6m	8-16m	7-12m	7m	9-11m	6-8m
Carriageway width after	2.5m (one-way)	5.5m	5.5m	pedes-trianised	5.5m	5.5m
Change in parking spaces (off and on street)	+56	+50	+6	+15	+28	+22

Aggregate impacts on traffic

	Old trunk route			Bypass		Total		Change
	Before	Interim	After	Interim	After	Interim	After	
Whitchurch	9482	7708	6343	8360	9609	16068	15952	-1%
Market Harborough	15884	11800	9595	8535	n/a	20335	n/a	n/a
Petersfield	26520	9113	8178	n/a	31085	n/a	39263	n/a
Wadebridge	11707	8449	8101	8380	12946	16829	21047	+25%
Berkhamstead	17432	9624	10081	22848	27454	32472	37535	+16%
Dalton	22387	12431	6461	12109	16799	24540	23260	-5%
Total*	61008	38212	30968	51697	66808	89909	97794	+9%

* Totals calculated by adding up data for the four towns with complete information, ie. Whitchurch, Wadebridge, Berkhamstead and Dalton

Dates	Before survey	Bypass opened	After bypass opened	After trunk route changes
Whitchurch	Jan/Feb 92	Mar 92	Sept 92	Oct 94
Market Harboro.	Feb/Apr 92	June 92	Sept 92	Dec 94/ Jan 95
Petersfield	Apr/May/Sept 92	July 92	Nov/Jan 93	Dec 94
Wadebridge	Aug 92	July 93	Aug 93	Aug 94
Berkhamstead	Mar 93	Sept 93	Oct/Nov 93	Nov 94/ Jan 95
Dalton	Jun/Sept 93	Dec 93	Mar 94	Jan 95

These figures provide information about the combined effect of capacity increases and capacity reductions, where the period between 'interim' and 'after' has effectively been a time of capacity reduction. Taking the four towns for which full information is available, there was, on average, an increase of 47% in counted traffic from 'before' to 'interim' - ie.associated with the bypasses, and then a further increase of 9% from 'interim' to 'after' - ie. associated with the town centre changes, plus any continuing uncompleted effect of the bypasses. Such effects were clearly evident in Wadebridge and Berkhamstead where traffic on the bypass continued to grow by very much more than any reductions on the old routes through the town centre. Clearly, the increase in capacity due to the bypasses outweighed the reduction due to the town centre changes, although it is notable that in five of the six towns, the town centre changes *were* required to ensure the transfer of some of the traffic out of the centres. Moreover, in two of the towns, traffic did reduce in the second period, by a very small amount in Whitchurch, and by a larger amount in Dalton (although the area in which Dalton is situated was subject to economic difficulties at the time).

As part of the changes made to the trunk route, a number of issues were noted.

- The importance of appropriate consultation

Ross Silcock (1995) argue that "early consultation, with a well-defined remit, is crucial. Consultation must continue throughout the development of the strategy in order to promote a sense of public ownership of the proposals". During the consultation, various issues emerged. In particular, it was notable that different issues seemed important in different towns. For example, 27% of people saw traffic speeds as a "big problem" in Wadebridge, compared with 59% in Whitchurch. There was also a marked difference of opinion between businesses and their customers. For example, in Petersfield, 79% of businesses saw parking as a big problem, compared with 39% of residents.

During the construction works, Ross Silcock highlight the need for appropriate information. "Although local radio can be used to advantage, in some cases during the project, local radio stations broadcast very misleading statements, to the effect that the town was closed ! Local traders were understandably annoyed by this".

Finally, following the changes, many people commented on the specifics of the designs used, and that the plans and drawings they had seen during the consultation were difficult to relate to. *"They should've given people a chance to see what these things are really like"* (Delivery man in Wadebridge commenting on speed humps)

- The importance of good quality design

A second major focus of the project was the use of good quality, local designs to improve the environment of the town centres. For example, coloured strips of stone were used along the side of streets to give an impression of further carriageway narrowing, and to encourage traffic to slow down. 'Gateways' constructed on either side of the 'inner' and 'outer' entrances to the towns were also used to encourage traffic to slow down, although Ross Silcock (1997) comment that strong designs can lead to "debate which centres on the aesthetic aspects of a gateway, and its value for money as a piece of art [which] can overwhelm the safety issue which it seeks to address". Finally, they note that "in those towns which have comprehensive schemes covering residential areas and potential rat-runs, there is evidence that the measures have reduced traffic on these roads".

- Impacts on speeds

Initially, speeds on the old trunk routes increased after the bypasses, due to reduced traffic levels. However, following that, "speeds were reduced by as much as 50%, as a result of the traffic calming measures. Whilst it is too soon after completion for statistical comparisons of accident records, early indications are favourable".

- Impacts on noise

"The traffic calming measures generally brought improvements in noise levels, by reducing traffic volumes and controlling speeds".

- Impacts on air pollution

"In all the project towns, the sample surveys indicated significant improvements in air quality immediately after the opening of the bypasses... Subsequent changes have been small, but the improvement in air quality has either been maintained or enhanced following the traffic calming schemes."

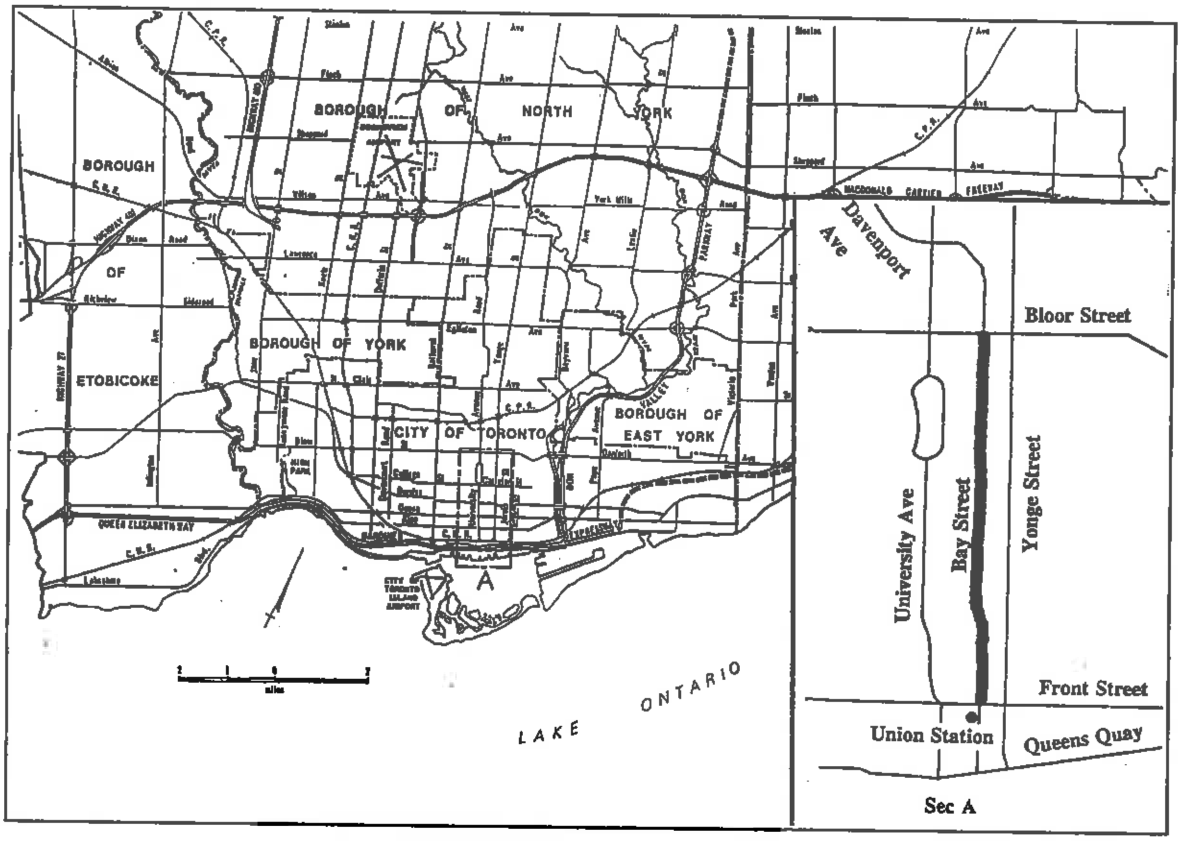
Caveats and comments:

In general, this case study is useful because it clarifies the need to distinguish between overall capacity reductions and locationally specific capacity reductions, and that capacity reductions in one place can be more than offset by capacity increases elsewhere. It also highlights that apparently similar policies, in relatively similar towns, can have markedly different effects.

Barrell (1997) notes that in the case of Wadebridge, recorded traffic increases may not only be due to traffic increases on the bypass, but also due to existing traffic taking more circuitous routes, and thereby getting recorded more than once. Moreover, a link road was built to enable the pedestrianisation of the High Street, which, again, will have offset the capacity reduction.

43. Toronto (Canada) - bus lanes 1990

Source: Shalaby 1997, Shalaby & Soberman 1994



On October 29th, 1990, 3km of bus lanes were introduced along both sides of Bay Street in downtown Toronto. Bay Street is a key north-south arterial which provides access to the financial district at the southern end. The bus lane stretch encompasses 16 signalised intersections and 16 bus stops. The bus lanes are usable by buses, taxis, bicycles and right-turning vehicles between 7am and 7pm on weekdays. 9 left-turning movements were prohibited, and 5 were introduced. No changes were made in traffic signal settings.

To assess the impacts of these measures, Shalaby & Soberman used a range of data, described below.

- The City of Toronto had data on turning count movements, mid-section speeds and vehicle occupancies, by time of day, for June-July 1990 and 1991.
- Traffic speed data were available for 1988 and 1991
- Toronto Transit Commission provided data on delays at traffic signals, travel times and dwell times at bus stops, for buses for June-July 1990 and 1991.
- A floating car survey, and a survey of through saturation flows were carried out (no dates available).
- An on-board patronage survey was carried out, by videoing and counting boarding passengers on 71 trips before the bus lanes were implemented, and 60 trips afterwards, spread throughout the day
- An attitudinal survey of users was available (no other information given about this)

Some of these data, plus a number of assumptions, were input into the TRANSYT-7F model, and a number of simulations were run (with calibration).

AM peak is defined as 8-9am, and PM peak is defined as 4.30-5.30pm.
Auto is used as a shorthand for all motorised traffic except buses.

Measured impacts:

	Before (1988-1990)	After (1991)	Change
Bus travel times (mins) AM peak	12.0	11.6	-0.4 (-3%)
Bus travel times (mins) PM peak	16.5	14.3	-2.2 (-13%)
Auto speeds (km/hr) AM peak	20.5	18	-2.5 (-12%)
Auto speeds (km/hr) PM peak	15.5	16	+0.5 (+3%)

*Northbound and southbound travel times have been added and averaged, as they showed roughly the same pattern.

Bus volumes were increased, and "bus ridership significantly increased immediately after project implementation, even before increasing bus volumes. It was also reported that ridership levels [per bus] during June-July of 1991 were higher than the corresponding values one year earlier". Overall, an increase in ridership of about 25% was recorded.

Auto traffic was reduced, but auto occupancy did not change significantly.

Shalaby notes that "it is not clear cut that the new bus riders were all attracted from the adjacent traffic. It is possible that a large proportion of the new riders were attracted from the two nearby competing subway lines".

He also highlights that changes in journey times are relatively small, and that "the average bus continued to travel the same distance along Bay St. in a longer time than the adjacent traffic, following lane introduction" (despite an improvement in bus travel times generally). Ironically, this was partly because the increased patronage increased the dwell times at the bus stops.

Shalaby and Soberman (1994) conclude that "total travel time is not the best measure of change in bus performance". Instead, they argue that what is important is that time savings "occur on segments where buses previously experienced considerable congestion [and] at traffic signals", and hence "it appears that ridership increases because of the *perception* of an enhanced service by establishing an exclusive lane, even though travel time, in one case, increased".

In the user attitudinal survey, "91% of respondents expressed positive views of the project, and 85% claimed they have a reduced transit travel time".

Simulation results:

Having calibrated the TRANSYT-7F model to replicate measured changes in traffic, it was used to calculate the following numbers for vehicle flows on Bay St.

	Before (1990)	After (1991)	Change
Total bus travel (veh-km) AM peak	58.0	77.5	+19.5 (34%)
Total bus travel (veh-km) PM peak	47	60.8	+13.8 (29%)
Total auto travel (veh-km) AM peak	1405.5	1121.8	-283.7 (-20.2%)

	Before (1990)	After (1991)	Change
Total auto travel (veh-km) PM peak	1606.1	1246.5	-359.6 (22.4%)
Average delay to buses (min/veh) AM peak	3.4	3.2	-0.2 (-6%)
Average delay to buses (min/veh) PM peak	3.5	3	-0.5 (-14%)
Average delay to autos (mins/veh) AM peak	3.3	4	+0.7 (+18%)
Average delay to autos (mins/veh) PM peak	3.5	3.8	+0.3 (+9%)

Further simulations to assess policy sensitivities suggested that
a) if the changes in permitted turning movements had not been made, there would only have been "a minor impact on both bus and through traffic performance".
b) if taxis had been banned from using the reserved lanes, there wuld have been "large delays for the auto traffic", and "the improvement in bus performance...would be far less than the deterioration caused to adjacent traffic".

Summary:

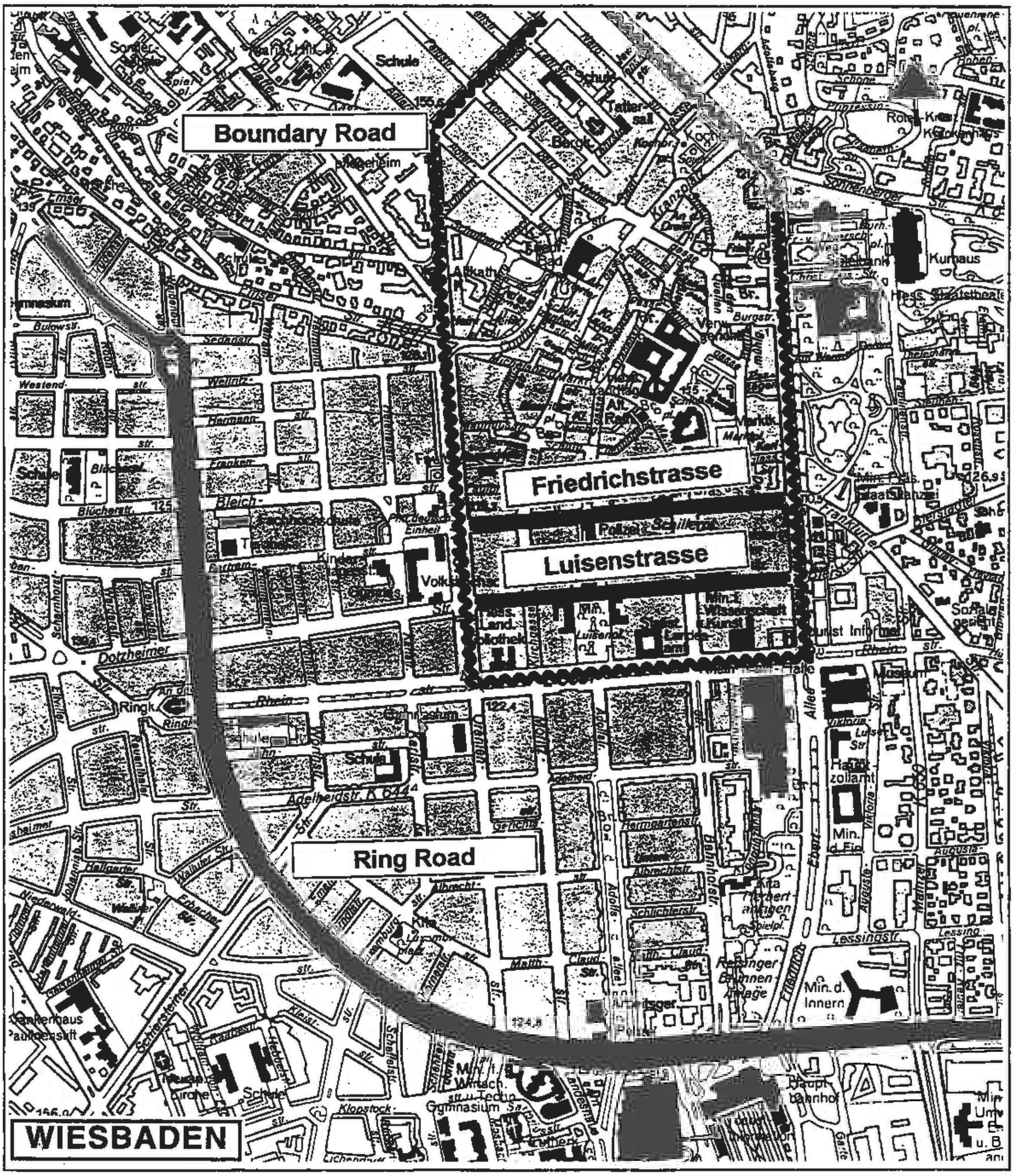
The bus lanes have increased patronage of the bus services by about 25%. Meanwhile, other traffic has reduced on Bay Street by over 20%. However, it is unclear that the new bus passengers are previous car drivers, or whether much of the car traffic has simply diverted.

Caveats:

There are a number of explanatory technical and data caveats in the two papers from which this case study is taken, which need to be read in full to be properly appreciated.

44. Wiesbaden 1991

Sources: Freudl K and Mörner J., 1991 & 1992



Wiesbaden is the capital of Hesse and a town of 265,000 inhabitants. It is the neighbouring city of Mainz and is also located in close proximity to Frankfurt am Main.

Some parts of the city centre in Wiesbaden have a right angular street network. In 1991, the medieval part already had some pedestrianisation, including the Kirchgasse and Neugasse, which were closed in 1990. In addition, plans were made to close two major one way streets in the city centre, Friedrich and Luisenstrasse, allowing access to public transport and taxis only. The hourly motor vehicle traffic flow varied between 400-1100 movements one way in each street, of which 50-60% was through traffic, (70%-80% in Luisenstrasse during the morning peak). A maximum of about 100 buses an hour used these streets. Some parts of Friedrichstrasse had to stay open because of access to two multi-storey car parks, and a full closure was never discussed.

If Friedrich and Luisenstrasse were to be closed, access would have only been possible via Bahnhofstrasse. It was therefore seen as important to forecast the effect this closure would have at the junction Bahnhofstrasse/Rheinstrasse. The result of the calculation (using a method of the addition of critical vehicle flows) was that the junction would have been overloaded in the afternoon, resulting in very considerable queues, and it was thought that the closure of both streets was not possible.

The authors concluded that if a section in Friedrichstrasse was closed *"the Wilhelmstrasse, Rheinstrasse und Schwalbacher Strasse in the western direction would have increases in parts of 400-600 motor vehicles pro hour and in Bahnhofstrasse of up to 400 motor vehicles in one direction"* (Freudl, K. Mörner, J. 1991, p.31). These calculations were for traffic flows between 11.00-12.00.

These forecasts may be compared with counts available before 1990 and after 1992 at the same locations.

Impacts on traffic

Motor vehicle flows in historic inner city plus boundary roads (11-12am)				
	Actual 1990	Actual 1992	Difference	Difference in %
Taunusstr.	1420	620	-800	-56.3
Röderstr.	490	370	-120	-24.5
Schwalbacher Str.	1865	1920	55	2.9
Friedrichstr.*	628	193	-435	-69.3
Luisenstr*	675	173	-502	-74.4
Rheinstr.	1930	2133	203	10.5
Bahnhofstr.	970	1015	45	4.6
Wilhelmstr.	1770	1910	140	7.9

Summary vehicle flows (11-12am)	1990	1992	Change
Friedrichstr. & Luisenstr.	1303	366	-937
Other locations	8445	7968	-477
Totals	9768	8334	-1414 (-14.5%)

An overall reduction in traffic occurred, and there were considerable differences between the actual conditions, and those forecast.

	Actual 1990˙	Forecast **	Difference	Difference in %	Forecast ***	Difference	Difference in %
Schwalbacher Str.	1865	2060	195	10.5	2060	195	10.5
Friedrichstr.*	628	425	-203	-32.3	430	-198	-31.5
Luisenstr*	675	652	-23	-3.4	613	-62	-9.2
Rheinstr.	1930	2275	345	17.9	2415	485	25.1
Bahnhofstr.	970	1273	303	31.2	1043	73	7.5
Wilhelmstr.	1770	1898	128	7.2	2358	588	33.2

* One way

** Friedrich Street closed up to Neugasse but left open for public transport and taxi access

*** Friedrich Street closed up to Neugasse and again between Bahnhofstr. and De-Laspeestr. and a very small part of Luisenstrasse.

In the 'after' research, the authors concluded that inside the historic pentagon all traffic flows had reduced by a third. There was some increase but also some decline of traffic flows on the boundary roads and on the inner ring road, which is located further away from the city centre.

The boundary roads had 13 count locations. The highest growth was between 45% (620 motor vehicles) on a small stretch in Wilhemstrasse. The inner ring road had 8 count locations and there was a maximum increase of 32% (370 motor vehicles) during 11.00-12.00. At the morning and evening peak hours the highest increase on the boundary roads was 48% (780 motor vehicle), at the same location as during 11.00-12.00, and on the inner ring road 26% (740 motor vehicle).

The total changes in traffic flow at these three different locations have been aggregated, as shown below.

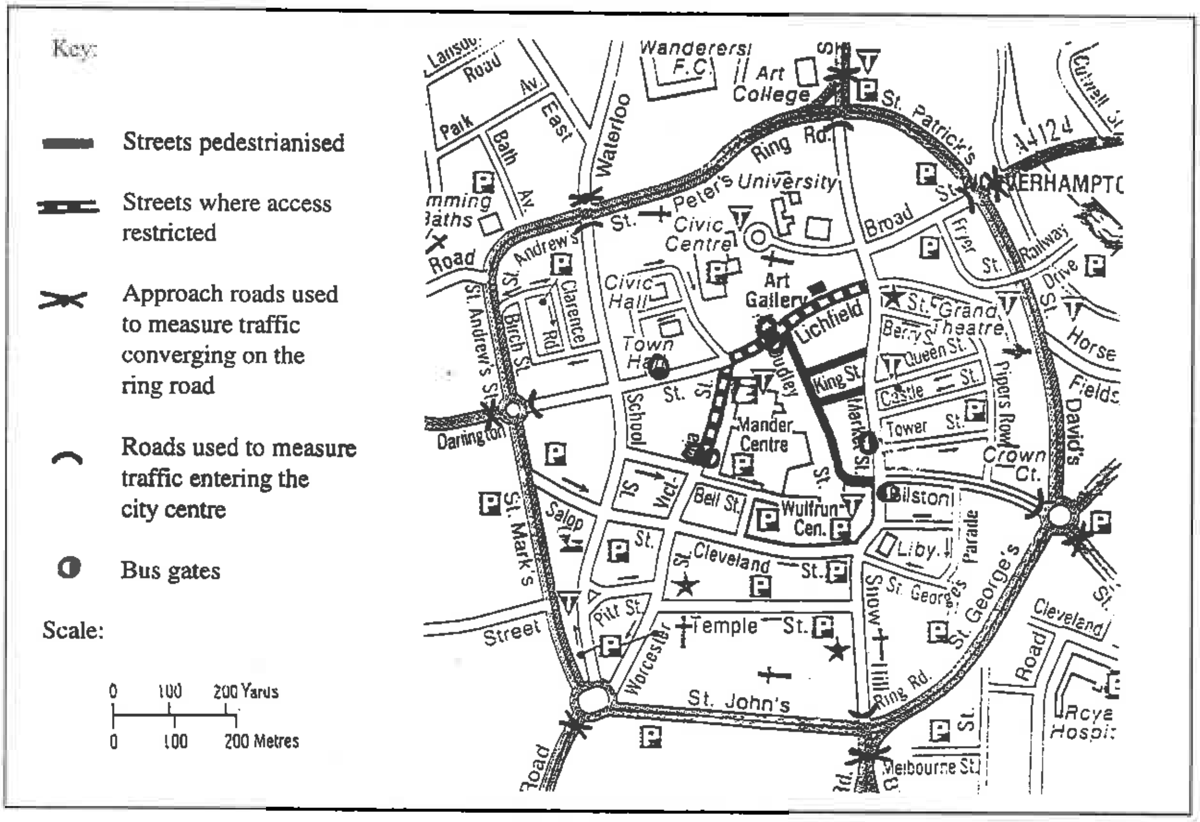
Hour	7.15-8.15	11.00-12.00	16.00-17.00
Inside	-3,010	-2,210	-3,370
Boundary roads	3,180	1,380	2,390
Ring road	2,250	1,110	520
Difference	**2,420**	**280**	**-460**

Source: Freudl, K. & Mörner, J. (1992), pp.5,9,12.

Between 11-12.00 inside the historic pentagon the actual traffic flow declined by 2,210 motor vehicles in comparison to 1990. At the boundary roads traffic flows increased by 1,380 movements and on the inner ring road by 1,110 movements. Adding the increased traffic flows together, then they amount roughly to the diverted traffic inside the pentagon (2,490 motor vehicles). However, this is not the case when studying the morning and evening peak hours. In the morning rush hour 2,420 motor vehicles more than the dispersed traffic inside the historic pentagon were on the ring road in 1992 than in 1990; whereas in the evening rush hour there were 460 motor vehicles less. The latter could indicate a spread of the evening rush hour but the increase in the morning cannot be explained with the available data.

45. Wolverhampton 1987-1991

Sources: Read 1992 & Read 1997



Wolverhampton is a town of 250,000, situated 15 miles North West of Birmingham. It is in competition with Telford in the west, and the Merry Hill shopping centre in the south east, and suffered severely from a decline in manufacturing industry in the early 1980s.

Between 1987 and 1991, a four phase transport strategy was introduced, aiming "to achieve a major impact not only on travel, but also on the future promotion of Wolverhampton as a sub-regional centre". The central core roads were gradually closed to traffic, effectively blocking a major east-west and a major north-south route through the city. All phases were preceded by extensive consultation, publicity and marketing, and changes in traffic patterns were complemented by street upgrading and refurbishment.

Aggregate effects on traffic

24 hour 2-way traffic flows	November 1990	November 1996	Total
Cordon on approach roads outside ring road	222,900	220,300	-2,600 (-1.17)
Cordon on roads within the ring road	81500	69750	-11,750 (-14.42)

Phase 1: "after an 'adjustment' period, drivers soon became used to the arrangements"

Phase 2: "more significant problems arose" Capacity at a critical junction was reduced by 15-20%, and initially "motorists proved resistant to changing route. Severe queuing resulted". However "with continued monitoring and signal adjustment, and some firm political support, the situation became accepted and conditions improved slowly".

Phase 3: "was completed with very few problems", and traffic levels in the north east (where changes were made) were "reduced substantially".

Phase 4: "caused the removal of through traffic" and "changed traffic flows dramatically".

Read (1997): "flows into the town centre have fallen significantly... access, however, has improved dramatically".

General impacts:

Read (1992): "the creation of environmental cells, promotion of quality shopping areas free of conflict, noise and fumes, priority to and introduction of new public transport modes, together with improved pedestrian facilities".

Impacts on commercial activity:

Initially, commercial interests were nervous, and Read (1992) notes the perception that "the presence of vehicles in the street, even if they are passing through, gives the impression that the town is busy". Also, "concern focused on the supposition that removal of through traffic would deny access to car parks and mean diversion to another town rather than access along another route".

Hence, following completion of the fourth phase, a major package of initiatives was used to encourage trade, as Christmas approached. Specifically, measures were designed to "promote Wolverhampton as a quality shopping centre with good parking and easy access". They included better signing and security of existing car parks, the creation of two Park-and Ride sites, general publicity, and half-hourly local radio broadcasts about car parking spaces.

Consequently, car park use rose by 1%, *excluding* Park-and Ride use, which was "particularly gratifying...during a severe recession and against generally reduced travel". Read (1992) also mentions that "it was noticeable how the public responded to the radio broadcasts". In its 18 days of operation, 16,000 people also used the park and Ride. The Chamber of Commerce described the efforts as "an unqualified success".

In 1993, Wolverhampton was awarded the 'Town Centre Environment Award' by the British Council of Shopping Centres.

Criteria for success:

Read (1992) "The principal lessons learnt have been the need to have a clear vision of the future, the importance of harnessing public support through high-profile publicity and consultation, and, when doubts begin, of firm political support".

Considerations for design:

The fourth phase of the scheme was introduced 'overnight', and delineated using extensive wooden planters. Read (1992) notes that, "perversely", the colour of these planters became a main item of contention, and that "Given the scale of outcry...it was little consolation that this was the principal objection to a scheme which had changed traffic patterns and environmental conditions fundamentally".

Implications for modelling:

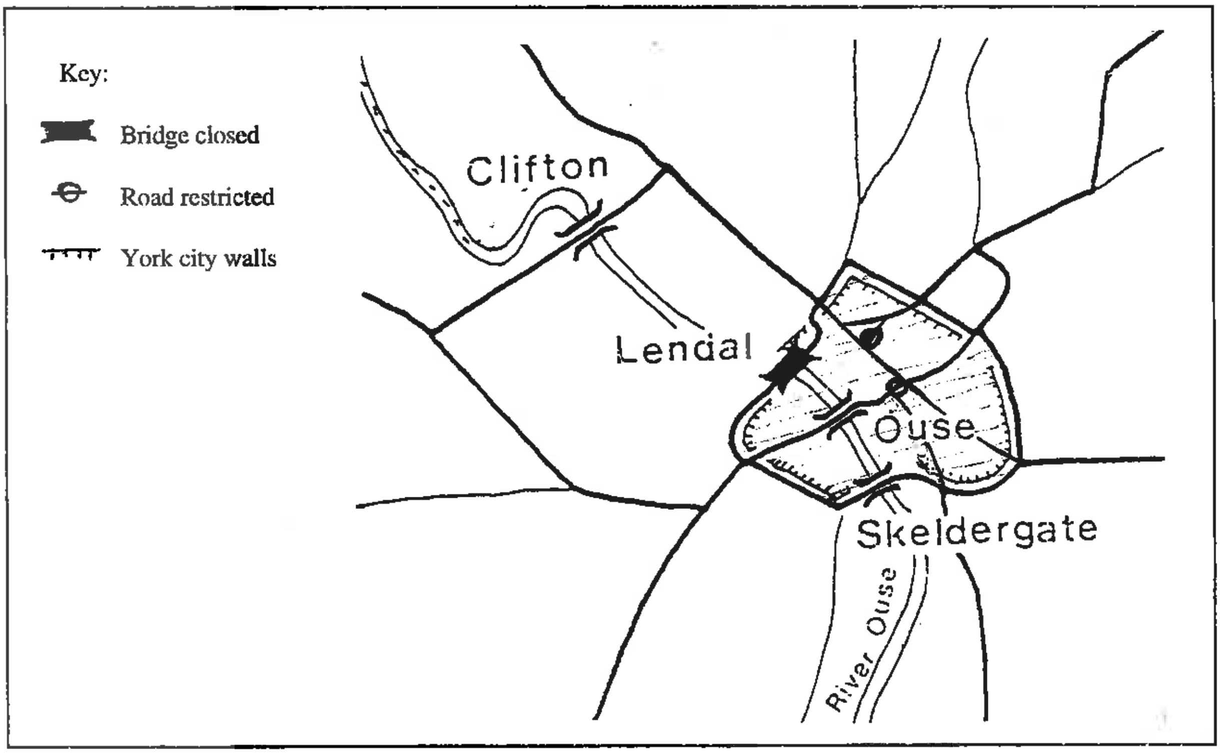
Read (1997): "I remain concerned that models may be used to determine policy rather than inform its development....If detailed assessments had been performed to model what we have done in Wolverhampton then I am confident that any presentation of predictions to Members would have concluded that our vision was unattainable...Modelling may be used to inform a decision of what order to undertake events, but at a local level I would prefer to rely on the knowledge of officers and Members". He further comments on "the wide variations in model parameters and a lack of clarity in the mechanisms underpinning behaviour", and "their limitations in reflecting wider social aspirations".

Caveats:

The two cordons used are incomplete, although it is unlikely that the 'missing' roads would significantly change the overall picture.

46. York- Lendal Bridge Closure 1978-79

Sources: key reference - Dawson (1979). Other references used - King 1979, May & Weaver (1981), City of York (*circa* 1985), King (*circa* 1990), and Parkhurst (unpublished).



On October 4th, 1978, Lendal Bridge, one of the four main bridges across the River Ouse that provides access to the centre of York, was closed for structural repairs for 6 months to all traffic apart from buses, taxis, cyclists and pedestrians. In addition, two major through routes in the centre were also closed except for buses and access, with appropriate signalling changes, to try and limit feared congestion. (The closure was unintentional, but essentially acted as a temporary, "watered-down" replacement, and trial, for a 'Comprehensive Traffic Management' scheme to restrain traffic in York town centre which had been developed after plans for an inner ring road were rejected by the Secretary of State in 1975).

Initially, King (1979) comments that "Early observations of the reorganised traffic patterns suggest that nowhere have conditions become intolerable".

To collect more specific data, a range of surveys was undertaken, concentrating on the afternoon off-peak and evening peak period "as being representative of wider conditions in York". Surveys included:
- a major registration plate matching exercise carried out two days before the bridge closure, and two days after, between 3 and 6pm. About 150,000 registration numbers with associated timings were recorded.
- surveys questioning 300 people driving across the Lendal Bridge between 3pm and 6pm shortly before and after the bridge closure. Respondents were also asked to complete before-and-after travel diaries, which recorded a total of 1,500 trips.
- monitoring of bus patronage, car park usage, pedestrian, cycle and vehicle counts.

The Institute of Transport Studies at Leeds also undertook an "impartial assessment"of the direct effects on trade over 6 months, using performance figures from about 1 in 8 shops in York town centre and comparing them with national figures. As part of the assessment, they also carried out a survey of 500 households in March 1978, to discover how and why their shopping behaviour had changed.

Aggregate effects on traffic

Generally, as shown below, traffic declined by a small amount, although changes were different in different time periods. Moreover, the tables refer to the relatively short term effects. Dawson (1979) comments that "a series of screenline counts across the river showed that by March 1979 (prior to the bridge reopening) flows had crept back to the level of September 1978".

	July/Aug 1978	October 1978	Change
Approx. 16 hr daily volume of light vehicles crossing the Lendal, Ouse, Skeldergate and Clifton bridges *	65,400	62,800	-2600 (-4%)

* These figures have been produced using tables from the City of York statistics, and the % change in light vehicle traffic referred to by Dawson (1979).

	Results from registration plate matching		Results from roadside interviews, on vehicle flows across the river	
	Vehicle flows	Journey time per vehicle	Light vehicles	Heavy vehicles
3-4.30pm	-2%	-11%	-6%	--
4.30-6pm	-5%	-8%	--	-50% (5 - 6pm)
3-6pm total	-3%	-9%	-4%	-19%

Other recorded effects:

- People changed the route of their journey

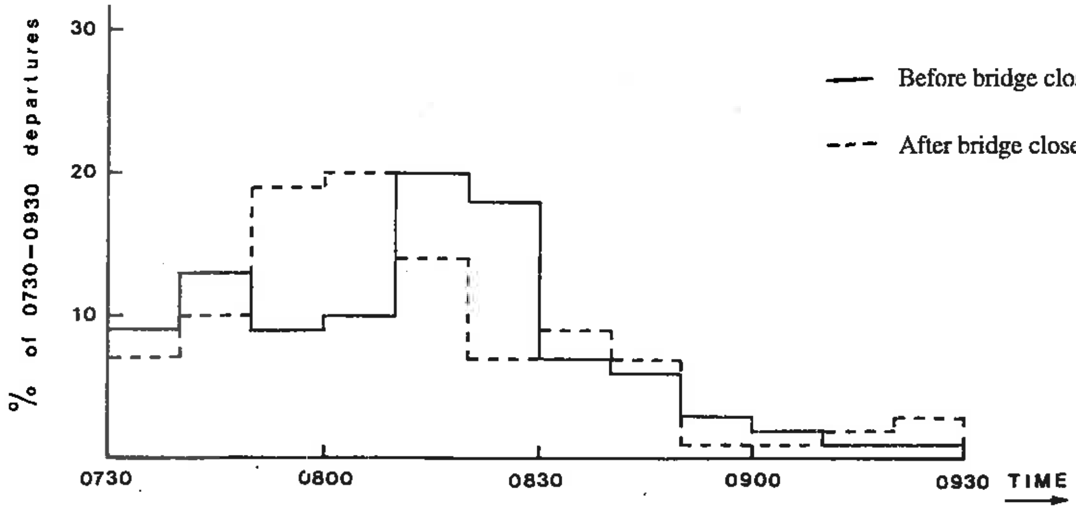
39% of drivers said that they had changed the route of journeys they made into York, and 14% had changed their parking location.

- People changed the time at which they made trips

15% of drivers said that they had changed the time at which they made journeys by more than 10 minutes. Observation of general changes in journey time suggested that the evening peak had flattened and spread (although the average departure times remained the same), whilst there had been a significant shift towards leaving earlier in the morning peak. Changes in departure times for morning peak journey-to-work times are shown overleaf.

A related question on the trip diary specifically asked respondents about how flexible (in time) their journeys were. Responses showed that for over 50% of people, for all trips apart from school escort, leaving 10 minutes earlier or later would *not* be "very inconvenient".

Changes to departure times for morning peak journey-to-work trips:
(sample: 167 'before' trips, 137 'after trips)



Information about the journey time flexibilities of different types of trips.

"If this journey had been made 10 minutes earlier or later, how inconvenient would it have been ? (before / after)"

	EARLIER % saying			LATER % saying		
	Very	Some	Not	Very	Some	Not
a.m. peak work journey	13(10)	33(41)	54(50)	47(51)	25(28)	29(21)
p.m. peak work journey	31(42)	26(17)	42(42)	22(25)	36(42)	42(34)
Shopping	17 (8)	15(19)	67(73)	14(12)	17(21)	69(67)
Firm's business	13 (7)	20(19)	67(74)	22(12)	25(25)	53(63)
School escort	24(26)	39(39)	37(35)	59(52)	31(44)	10 (4)

- Different types of trips were affected in different ways, and by different amounts

Between 3 and 4.30pm, light vehicle trips for shopping and personal business fell by 19%, whilst trips for other traffic actually rose by 6% (presumably partly due to peak spreading). Moreover, a greater proportion of journey-to-work drivers made changes in route choice (50% vs. 39%), and travel time (21% vs.15%) compared to the average changes made.

- There was a minor impact on journey times

Information from the travel diaries suggested that the journey times of specific car trips remained roughly constant, apart from am peak work journeys, which increased by 2.8 minutes (13%).
In general, bus journey times had improved in some places, and declined in others.

- There were no significant changes in mode choice, vehicle occupancy or accidents.

. "Bus patronage and revenue marginally increased", although this was mainly due to greater use by existing passengers, as the central traffic problems had "previously made passengers alight prematurely and walk". There were no significant changes in the occupancy of vehicles crossing the river, or in pedestrian flows in the central area or in recorded accidents in the central area.

- Changes in travelling conditions were perceived in different ways by different groups.

57% of respondents thought driving conditions were worse, whilst 14% thought they had improved, and the remaining 29% thought they were similar or didn't know. 37% thought that conditions for pedestrians were better, whilst 4% thought they had got worse, and 58% were effectively neutral.

- Effects on trade were minor and short-term.

May & Weaver (1981) report that "from the outset, local traders expressed concern about the potential effects of the scheme on trade". However, the recorded changes in trade were relatively small, and fairly short-lived, and "in the light of this particular conclusion, the York Chamber of Trade & Commerce decided not to object to North Yorkshire County Council's proposal to make the subsequent Comprehensive Traffic Management measures permanent"

Specifically, the trade surveys found that for the first three months, trade was below expected levels (-3/5%), however it was significantly above expected levels in January (+5%), and then returned to projected levels in February and March. Food and hard goods stores, and shops generally in the inner part of the city appeared to be most affected. The survey of shoppers showed that there was a decline in the number of trips people said they made into York, however the magnitude of this decline varied substantially between different areas. Moreover, there were various other factors which were partly responsible for the changes. There were floods and severe weather conditions in December and a strike by lorry drivers, which deterred some shoppers. Meanwhile, access to the competing centre of Leeds was improved by the opening of the Tadcaster by-pass.

Modelling considerations:

Dawson (1979) argues for the following modelling framework:

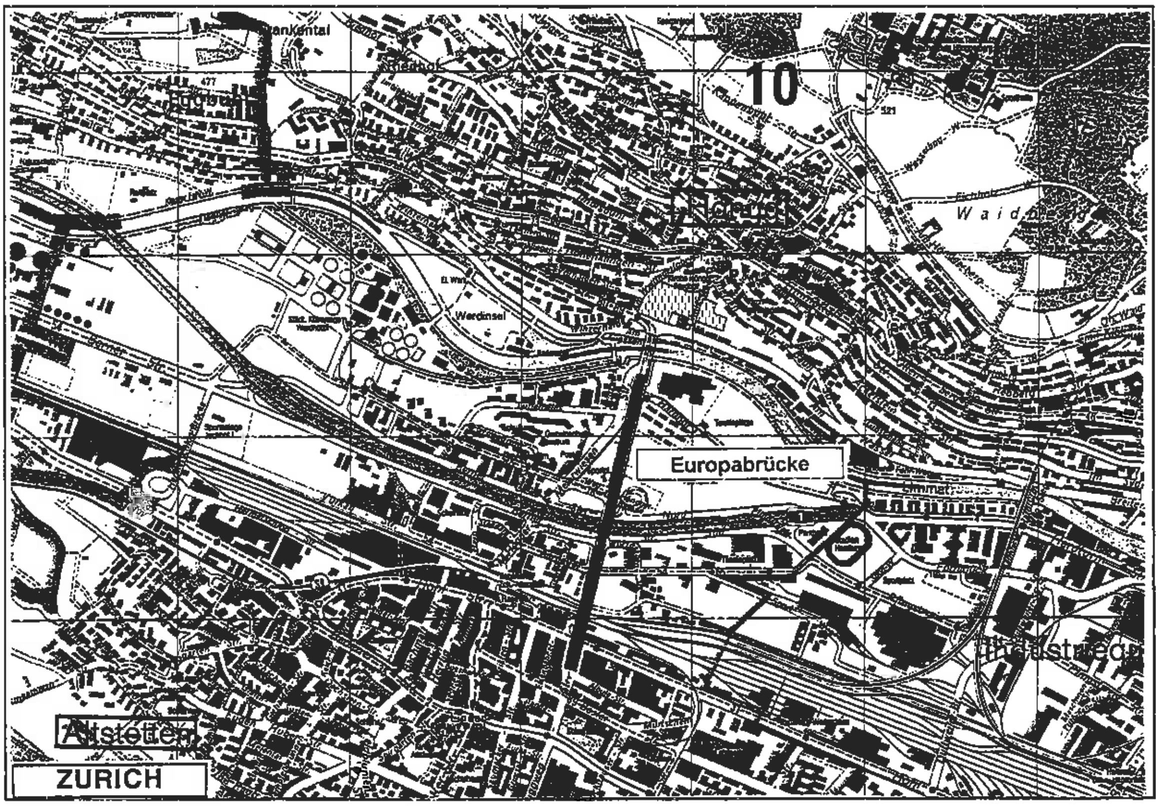
"The measured effects of the Lendal Bridge closure suggest a simple mechanism in action where a previous demand for road space exceeds supply in a new network. Firstly, those trips between fixed destinations and origins that have to be made (mainly journeys to work) continue to be made and almost exclusively by car: motorists take opportunities to 'fine tune' their journey times by changing route and time of travel...Secondly, those trips which do not have such fixed origins and destinations or time of travel (mainly shopping and personal business trips) make greater adjustments...Thirdly, a series of more minor (but important to each individual's journey time) changes such as a change in parking place, passengers or detours are made".

Caveats:

Information has been pieced together from a number of different surveys. In general, this probably increases the robustness of the results, as they confirmed rather than contradicted each other. However, some dimensions of behaviour seem to have been explored more thoroughly than others. Therefore, the responses described here may not be a comprehensive picture of all the ways in which people reacted.

47. Zurich 1980-92

Sources: Berg, W. & Bärtsch, D. 1995, Zurich Stadtplanungsamt 1992



Zurich is the banking capital of Switzerland with 365,000 inhabitants, serving a hinterland of 1.2 million people (Canton). The city is well-known for its promotion of public transport. Figures for trips in the city show that in 1980, 55% used public transport, 26% car, 5% bike and 14% walked. In 1991 for all trips to the city centre, public transport was used for shopping or work by 76%, and only 12% took the car. Even for recreational journeys 70% used public transport and 18% used car (Zurich, Stadtplanungsamt 1992, p.4).

Correspondence from the city of Zurich pointed out that over the years the capacity of the main road network has been reduced, and an S-Bahn built, but there has been limited research about the combined effects of these. Car traffic has stayed stable since the mid 80s and even during the day the increase in traffic flows was minimal. By contrast, in the region of Zurich, traffic growth has been significant. Car ownership increased in Zurich from 263/1000 inhabitants in 1970 to 381 in 1990. In the region it was lower than the city in 1970 (240), but had increased to 444/1000 by 1990. (Zurich, Stadtplanungsamt 1992, pp.14+24).

Closure of Europa Bridge 1991-92

More specifically, some data were available about changes in road capacity due to road works and road closures on the Europa Bridge (Berg, W. Bärtsch, D 1995 Anhang 9). This bridge is an important connection in the west of Zurich connecting Höngg and Altstetten (the direction of the city centre). The total traffic flows were 26,673 two ways during 24 hours in 1991. The lanes were reduced from 4 to 2 between 1991 and 1992.

Impacts on traffic

The count in 1992 showed a reduction of 5% (25,283 motor vehicles/24 hours). At peak hours the number of motor vehicles reduced more than during the day. During the day the reduction was between 4 -7%.

Inbound traffic declined by 14.4% during the morning peak hours (6.00-9.00) and by 14.7% outbound during the evening peak hour (17.00-18.00). In the direction of Höngg, outbound traffic *increased* by 7.4% during the morning rush hours (6.00-9.00) but no convincing explanation was given. Inbound data in the evening rush hours were not available.

There was an increase in traffic flows on the other three bridges in the morning rush hours which was nearly exactly the figure which did not cross the Europa bridge. In the morning between 6.00 - 9.00, 546 fewer motor vehicles used the Europa bridge and 556 motor vehicles more used the other three bridges.

Strangely enough, in the evening rush hours (16-19.00) outbound, instead of an additional 375 movements, nearly double the amount of motor vehicles (708) were counted on the other three bridges than in 1991. The authors saw that 'as *a sign of peak spreading as these additional movements took place between 18.00-19.00'*. Alternatively, it can simply be seen as additional traffic which the bridges were able to cope with and occurred because of bottlenecks at a different places or increase in traffic flows in general (ibid, Anhang 9).

Plates 1 & 2: London - Hammersmith Bridge

Hammersmith Bridge, which was restricted to buses, motor-cycles, cyclists and pedestrians in February 1997. Previously, the bridge carried approximately 30,000 motorised vehicles a day.

Plate 1

Plate 2

Plates 3 & 4: Lüneburg

A typical location in Lüneburg, before and after closure to private motor vehicle traffic.

Plate 3

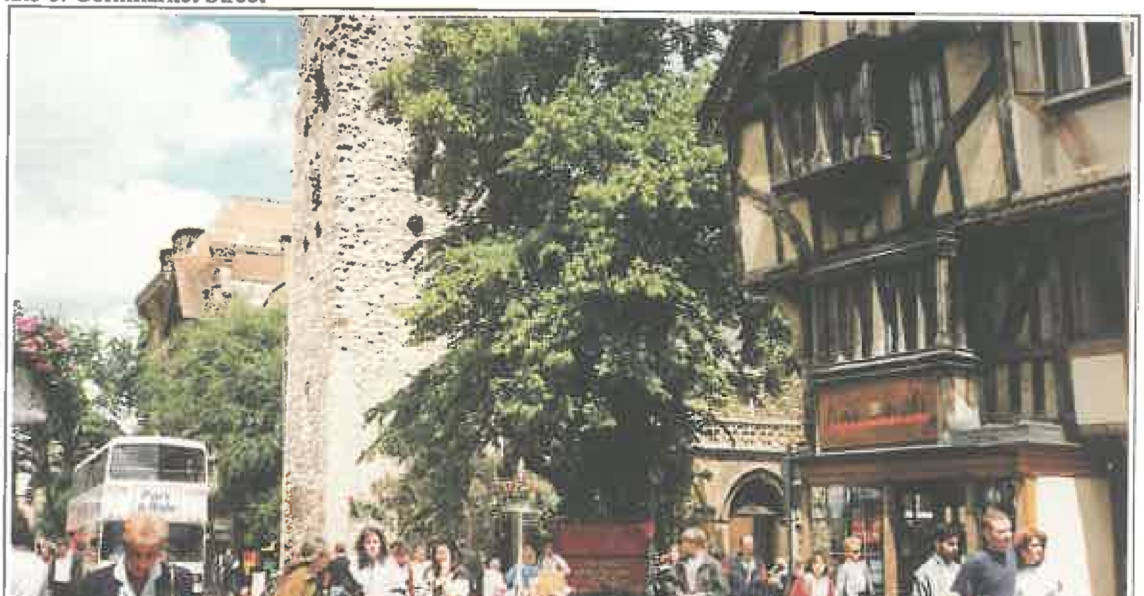
Plate 4

Plates 5 & 6: Oxford

Two locations in central Oxford which were closed to private motorised traffic in the early 1970s

Plate 5: Radcliffe Square

Plate 6: Cornmarket Street



Plates 7 & 8: Sheffield

The substantial disruption to motorised traffic that occurred during the construction of the Sheffield Supertram, and the reallocation of road space following the completion of the tram network.

Plate 7: Construction works for Supertram

Plate 8: Part of the Supertram network that runs on street

Plates 9 & 10: Wolverhampton

Victoria Street in Wolverhampton, before and after the major programme of city centre changes during the late 1980s.

Plate 9: Victoria Street before

Plate 10: Victoria Street after (the white office block in the background of both pictures provides a reference point)

Photos courtesy of Wolverhampton Metropolitan Borough Council

Plates 11 & 12: York

Since the closure of the Lendal Bridge, York has undertaken a broad programme of changes to its central area, which have reduced road capacity for cars, and increased priority for other road users.

Plate 11: Parliament Street in central York - before

Plate 12: Parliament Street in central York - after (note Marks and Spencers on the right-hand side of both pictures)

'Before' photo courtesy of the City of York Council, 'After' photo courtesy of Transport 2000

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Appendix A: Re-examination of SACTRA Evidence on Traffic Induced by Expansion of Road Capacity.

SACTRA (1994) gathered a very substantial body of knowledge which showed that expanding road capacity can induce additional traffic. This conclusion is now accepted in both policy and practice. It clearly raises the possibility that - by simple reversal of the argument - reduced road capacity may lead to the suppression, degeneration or deduction of some traffic, by individual or system responses that are similar to those producing induced traffic. This section therefore reports briefly on a re-examination of the SACTRA evidence (plus updates[1]) to consider the implications for highway capacity reductions.

This re-examination also raises a crucial question: is evidence about the effects of *increasing* capacity truly relevant to the issue of *reducing* capacity? This depends on whether behavioural responses in the two cases are equal and opposite, *ie.* reversible.

Most forecasting and evaluation models used in current practice take it as axiomatic that demand responses *are* reversible, and it would require a major and fundamental change in practice, going far beyond the bounds of this project, to depart from this.

However, traffic suppression, degeneration or deduction is not commonly assumed or accepted. Moreover, there is a strong intuitive expectation that behaviour patterns, once established, are difficult to alter. In assessing the empirical evidence we cannot take reversibility for granted, even though, subsequently, it may be decided to assume reversibility in order to ensure consistency in appraisal.

Hence simply reversing the SACTRA arguments seems over-simplistic, without a strong base of evidence to support this. However, there *are* insights that can be gained from the evidence on which it was based. Therefore, the following summary, to which all the original caveats apply but are not repeated here, takes in turn each of the main strands of evidence about the effects of increasing highway capacity, and considers whether each is relevant to highway capacity reduction, and, if so, what it implies.

- **Literature reviews**

SACTRA gave particular attention to two earlier literature reviews. The first, by Pells (1989) cited 78 published and unpublished studies, theoretical discussions, modelling exercises and traffic counts. In some cases, like cross-sectional analyses of mode choice, reversibility was assumed. There was a wide range of results, with estimated induced traffic ranging from 0% to 76% of observed increases in traffic flows. Broadly, the review suggested that trip retiming could be important in accounting for changes in traffic, together with some trip redistribution, modal change, trip generation and land-use effects.

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[1] The SACTRA material is supplemented by an updating report by Goodwin (1996), a parallel study by the Hague Consulting Group (1996), contributions from other European countries in the CEMT (1997), and reconsideration of important earlier studies, notably Beardwood and Elliot (1986) and others cited in SACTRA (1994).

The second literature review used by SACTRA was more directly relevant, since it examined drivers' responses to increasing congestion. Though quantitative estimates were sparse, Hawthorne and Paulley (1991) found reference in the literature to a wide range of behavioural responses including changes in - choice of route, departure time (including amount of flexitime), mode (including amount of ridesharing), trip frequency, intra-household arrangements for general travel, activity patterns, and the willingness to own cars.

It is interesting that the range of behavioural responses identified in the second review was not narrower or different in type to those in the first. Taken together, the reviews suggest that qualitatively similar behavioural responses may occur when road capacity is either increased or decreased. They did not provide useful evidence on whether these responses are similar in either absolute or relative importance.

- **Interpretation of estimated empirical coefficients for aggregate relationships.**

The next strand of evidence involved interpreting existing statistical information about the relationships between key variables affecting traffic.

The Road Research Laboratory (1965) used a form of gravity model to explain differences in the amount of travel between zones. The results, which were consistent with observation of a number of specific road projects, were then used as the basis for Ministry of Transport guidance on induced traffic until the early 1970s. They showed that the percentage increase in traffic is 2 to 3.5 times the percentage decrease in journey time.

Since the cross-section data on which the model was based contained examples of higher and lower journey times simultaneously, it is equally valid to interpret it as implying the reverse, *ie* that a capacity reduction which increased journey times by 1% might reduce traffic by 2%-3.5%.

A second, more general approach, developed by SACTRA, combined empirical results of studies of fuel price elasticities and of values of time. The former potentially allowed a distinction between short and long run effects and hence a degree of non-reversibility. The latter were based on observations of both higher and lower levels of the variables, and analysed in a way that assumed a reversible equilibrium. The results were cross-checked for consistency against other empirical studies of time budgets, and differential elasticities on car ownership and use. The simplified mathematical argument is given in Figure AA1.

Using the assumptions given in the figure, it is implied that a 10% increase in journey time should cause a 4.5% decrease in traffic volume.

The -0.15 fuel cost elasticity is usually treated as a short-term effect, operating within the first year. There is substantial empirical evidence that the longer-term effect is significantly greater than this. If the longer-term elasticity is of the order of -0.3, the implied journey time elasticity would be nearly -1.0. A 10% reduction in speed should then lead to a longer-term reduction in traffic volume of nearly 10%.

Figure AA1: Defining the relationship between journey times and traffic volumes

Let D be demand, G the generalised cost of travel, M money cost (fuel price), T travel time, and v value of time. Then

$$D = f(G) \quad \text{and}$$

$$G = M + vT$$

The demand elasticities with respect to money E_m and time E_t are:

$$E_m = \partial D/\partial M.M/D$$

$$E_t = \partial D/\partial T.T/D$$

The elasticities are proportional to the relative importance of money and time, as follows:

$$E_m/E_t = M/Vt$$

$$\text{so} \quad E_t = E_m.Vt/M$$

Assume: -0.15 as the elasticity with respect to fuel price; 6 pence per minute as the value of time; average time spent travelling by car per day as 25 minutes; and spending per person per day on fuel costs as 50 pence. Then:

$$E_t = -0.15 \times 6 \times 25/50$$

$$= -0.45$$

This reversal of the SACTRA argument is as valid as the original result, since it is based on an inherently reversible methodology. However, the fact that at least one of the components (the fuel price elasticity) is known to be time dependent enables us to go further. Consider the case where, after a long period of increasing capacity, there is a new policy of reducing it. The delayed effect of the previous increases, resulting from the distinction between short term and long term elasticities, would continue to operate, only being overtaken by the reduction at a later date. Evidence not reviewed here suggests that it might take several years for the longer term effects to become evident. Thus, during this adjustment period, the effect would not appear fully reversible, since delayed responses to the earlier change would be proceeding in parallel with the first responses to the more recent change.

- **Case studies of expanded road capacity**

The arguments reported above were translated by SACTRA into a hypothesis that specific capacity-expansion schemes could induce a range of approximately 0% to 20% traffic in the short run, and a range in the order of 0% to 40% in the longer run.

These figures turned out to be similar to the discrepancies between predicted and observed traffic effects[2]. The actual traffic levels on improved roads were generally about 10% greater than forecast, and the discrepancy was greater on alternative routes. For example, traffic levels on routes supposedly relieved by bypasses, were 25% higher than forecast.

Detailed comparisons of before-and-after traffic counts over longer periods were available for a number of particular road construction projects. The results are summarised in Table AA1.

Table AA1: Summary of specific case studies

Scheme	Interval	Result
Barnstaple Bypass	3 years	Corridor flows +48%. After `NRTF correction', extra traffic +39% on some specific links, and about 20% overall.
M62	5 years	Flow +19% after correction by index for rural roads.
York Northern Bypass	ambiguous timescale	Redistribution, modal diversion and new trips reported by 20% of interviewed drivers.
Severn Bridge	1 year	Authors suggest 44% induced traffic.
London Schemes:		
Westway	4 months	Corridor +14%, Control +2%
M11	10 years	Authors suggest 40%-50% induced traffic
A316	9 years	Corridor +38% (peak 56%), Control +29% (peak 33%)
Blackwall	12 years	Corridor +84% (peak 107%), Control +66% (peak 41%)
	1 year	Screenline +15%
M25/Lea	20 years	Screenline +91% (peak 50%), Control +64% (peak 8%)
	4 months	Corridor +9%
Rochester Way	2 years	Corridor West +26%, East +24%, Transverse +30%
Leigh Bypass	1 year	Screenline +20%
Manchester Ring	1 year	East-West +23%, North-South +15%.

These studies showed a similar range of additional traffic that could not be explained by route choice and general traffic growth alone. Comparison of the second and third columns also indicates that the studies spanning longer time periods usually found larger induced traffic, providing empirical support for the time-dependent responses mentioned above.

Both strands of evidence are consistent with an eminently sensible expectation of human behaviour (that it takes some time for people to adjust to change), and support the conclusion that the time period of observation and evaluation will affect the observed impacts of capacity changes.

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[2] SACTRA did also note an unresolved difference of opinion about whether discrepancies between forecast and actual traffic volumes are due to ignoring induced traffic, or due to other faults in forecasting methods.

An additional important point noted by SACTRA, especially in relation to the Rochester Way Relief Road study, was that the observed changes in traffic flows were heavily influenced by capacity constraints elsewhere and by the specific way in which associated policy measures were implemented, such as the signalling priority accorded to different traffic movements. This conclusion is obviously important in questions of road closures or bus priorities, where any substantial, well-designed scheme is likely to be accompanied by complementary measures in other parts of the network.

- **Differential growth rates**

The last strand of evidence reported by SACTRA relates to traffic *growth.*

Glanville and Smeed (1958) showed that, over a long period, traffic growth on roads that were already congested was much slower than traffic growth on roads which were less congested. Later evidence of this character was cited by the Institution of Highways and Transportation (SACTRA 1994), and by Mogridge *et al.* (1987) whose analysis of data for London extended Glanville and Smeed's approach. Growth in traffic at the outer London boundary cordon has approximately kept pace with the average increase in car ownership, at 2.3% per year. However, the growth rate at the inner London cordon has been 0.8% a year, and in central London has been 0.4% a year. Similar patterns are observed nationally, where traffic growth rates have also been slowest where congestion is worst, and fastest where existing capacity is still spare, or new capacity is provided. From 1980 to 1990, measured traffic on major roads in built-up areas grew by 20%, on major roads in non-built-up areas by 58%, and on motorways by 73%.

These comparisons indicate that high congestion may reduce traffic growth, just as available or expanded capacity may increase it.

- **Conclusion**

Some classes of evidence used by SACTRA were based on comparisons of simultaneously more and less congested conditions. In these analyses, conclusions may be drawn about the implications for reduced capacity with the same degree of confidence (and the same caveats) as about the implications for increased capacity.

Other classes of evidence, notably based on aggregate or disaggregate changes over time, nearly all relate to the experience of increasing capacity. These tend to support the idea of time-dependent responses. Specifically, they imply that responses to reductions in road capacity are unlikely to be *immediately* symmetrical with responses to increasing road capacity. However, they are consistent with the view that the character of the response may be similar in the longer term.

Thus, all the evidence cited is consistent with, although does not prove, the propositions that (a) the effects of increased and reduced capacity *may* be broadly symmetrical and reversible in the long run, but (b) are unlikely to appear so if comparing, for example, the equilibrium effect of a capacity increase with the short term effect of a capacity reduction.

Appendix B: Sources and Acknowledgements

Collation of English-language material involved a literature review, advertising for information in the technical press (eg Local Transport Today 8/5/97) and mail contacts with over 180 individuals working in local authorities, consultancies, government departments and academic institutions. Half-way through the project, a 'round table' forum was held to discuss the issues, attended by about 50 invited experts. German-language contacts were made using networks in Germany, Switzerland and Austria, and direct approaches were made to all German local authorities with over 100,000 population, of which about thirty replied with substantial information, as well as many other expressions of interest.

We are indebted to the immense amount of help we received from these contacts. As well as making the results of their own original research available, people have translated relevant sections of material for us into English, undertaken new analyses of their databases at our request, supplied contacts and information of other potentially relevant information sources, and taken time and effort to explain the context of the policies implemented. This report is therefore reliant, to a large extent, on the work and effort of other people, for which we are very grateful. Thanks are also due to those who sent us additional material which we have not yet had time to process. Subject to resources, we intend that this (and any further evidence received) should be included in an updated supplement from time to time. We are also grateful for the time and effort spent by TSU colleagues Graham Parkhurst and Pauline Cahill during the construction of this report. The project forms part of the research programme of TSU as a designated research centre of the UK Economic and Social Research Council (ESRC). This designation is very gratefully acknowledged, particularly for the support of research into the fundamental processes of travel behaviour change, which underpins the analysis and results of the individual case studies.

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Responsibility for the interpretations and conclusions of this report remains that of the authors alone.

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Bielefeld	Heilbronn	Oldenburg
Bochum	Herne	Osnabrück
Bonn	Hildesheim	Paderborn
Bottrop	Ingolstadt	Pforzheim
Braunschweig	Iserlohn	Potsdam
Bremen	Jena	Recklinghausen
Bremerhaven	Kaiserslautern	Regensburg
Chemnitz	Karlsruhe	Remscheid
Cottbus	Kassel	Reutlingen
Darmstadt	Kiel	Rostock
Dortmund	Koblenz	Saarbrücken
Dresden	Köln	Salzgitter
Düsseldorf	Krefeld	Schwerin
Duisburg	Leipzig	Siegen
Erfurt	Leverkusen	Solingen
Erlangen	Ludwigshafen	Stuttgart
Essen	Lübeck	Trier
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Annex: Impacts of the Hanshin-Awaji Earthquake on Traffic and Travel

Where Did All the Traffic Go?

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Introduction

The Hanshin-Awaji Earthquake, which devastated the densely populated Hanshin (Osaka-Kobe) metropolitan area on January 17, 1995, claimed over 5,300 lives and tore apart the urban infrastructure of the area. A total of 27 major highways were closed at 36 sections, and all rail lines running the coastal Hanshin corridor, connecting the City of Osaka and the City of Kobe, were disrupted for weeks.

The destruction of transportation infrastructure by the earthquake implied substantial reductions in capacity and level of service for prolonged periods, for both highways and public transit. Residents of the impacted area had to make behavioral adjustments to pursue daily activities with the severely limited transportation supply that was available to them. Knowing how these residents made adjustments under the emergency condition, then, would offer insight into how urban residents would modify their travel behaviors when faced with capacity reduction, or decline in level of service, not necessarily due to natural calamities, but due to particular transportation policies and planning actions.

In this report, pieces of empirical evidence available from traffic observations and surveys conducted in the earthquake-impacted area, are assembled in an attempt to gain insight into how individuals would react when transportation supply is drastically and suddenly restricted. Traffic counts are available before and after the earthquake at selected locations on major highways. Unfortunately traffic counts offer only limited information on who is traveling and for what purposes. This is particularly a problem in this case because the earthquake generated new and different types of traffic, for emergency activities, transportation of support materials for evacuees, demolition of damaged structures, removal of rubbles, and reconstruction.

A number of surveys were conducted targeting individuals, households and firms in the area. Their results offer rich information on how residents of the impacted area modified their travel behavior. Many of them, however, are small-scale surveys conducted with limited budgets, typically by university researchers. They quite often target specific sub-groups (e.g., commuters), in specific neighborhoods in the Hanshin area, making it difficult to compare data across studies and synthesize the results. Most critically, it is not well established that the sample obtained appropriately represents the population postulated in each study. Yet, these studies, along with the traffic count data, offer invaluable information on how residents of the earthquake impacted area adapted to the limited transportation supply.

In this report, the transportation networks in the Hanshin area and the system disruptions caused by the earthquake are first described. Traffic count data are then analyzed and inferences are made on how the system disruptions affected traffic generation. Following this, changes in individual behavior are inferred based on survey results. The analyses are synthesized in the conclusion of the report.

System Disruption

The earthquake hit the corridor connecting the Osaka and Kobe areas in which a number of rail lines, expressways[1] and highways concentrated (Fig. 1). The major east-west highways were: Hanshin Expressway Kobe Line, Wangan (Harbor) Line, National Highway 43, and Highway 2. The major north-south route was the Shin Kobe (New Kobe) Tunnel (see Fig. 2). Immediately after the earthquake, Hanshin Expressway Kobe Line and Wangan Line were closed due to structural damage, while Highway 43 and Highway 2 were restricted to emergency vehicles and those vehicles that carried goods and materials for recovery and restoration. Highway 43 operated with some of the traffic lanes closed, with exclusive bus lanes implemented for a period of time. For detailed chronology of roadway restoration and traffic restrictions on these four major roadways in the corridor, see Table 1.

The Hanshin Expressway network was closed in its entirety immediately after the earthquake. As early as 9:00 PM of the day of the earthquake, parts of the network were used by police-led convoys, transporting emergency materials to the most damaged Kobe area (Tsuge, 1995). On January 19, two days after the earthquake, Rt. 14, Matsubara Line, was opened to general traffic. The road length available for service continued to grow since then, with 97 km (48.5%) of the 200-km Hanshin Expressway network available on January 24, and 142.7 km (71.4%) on January 31. After six weeks (February 28), with a total of 157 km (78.5%) operational, most of the expressway lines in Osaka Prefecture were restored. On April 11, after 12 weeks, the network was restored except for the Kobe Line and a section of Rt. 5, Wangan Line, which involved Higashi Kobe Bridge. The entire Hanshin Expressway network was restored on July 1 (Tsuge, 1995).

Meishin Expressway, the first freeway built in Japan connecting Nagoya and Kobe, was closed between Suita Interchange and the Nishinomiya interchange after the earthquake. The whole section was opened on February 17. It took till July 29 that all four lanes were open to traffic between Amagasaki and Nishinomiya Interchanges, however. Chugoku Expressway was open to traffic on January 27, with some sections operating with undivided two-way traffic. By February 12, two lanes were open to traffic in each direction, and three-lane (one way) sections were completely restored by July 21.

Three major rail lines ran in the Osaka-Kobe corridor: Japan Railways (JR) Tokaido Line, JR Sanyo Shinkansen Line, Hankyu Railways, and Hanshin Railways (Fig. 1). All these lines were closed after the earthquake.

The progress made toward the full restoration of JR Tokaido Line, Hankyu and Hanshin lines, is summarized in Fig. 3. Segments closer to Osaka were open within 10 days of the earthquake, while other segments took much longer before they could be restored. The entire JR Line between Osaka and Kobe (San-nomiya Station) opened on April 1. When only parts of a rail line were operational between Osaka and Kobe, passengers were transported by shuttle buses where the rail was not available. This resulted in significant increases in travel time and reductions in service levels. It was not until June 12 that the Hankyu Line became fully operational between Osaka and Kobe. The Hanshin Line was fully operational on June 26 (Murano, 1996).

The Shinkansen Line opened on April 8. Since this "bullet train" line serves primarily long-distance travelers, its opening is not considered to have had discernible impacts on travel demand in the Hanshin area.

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[1] "Expressways" in this report refer to fully access controlled highways, which are commonly called freeways.

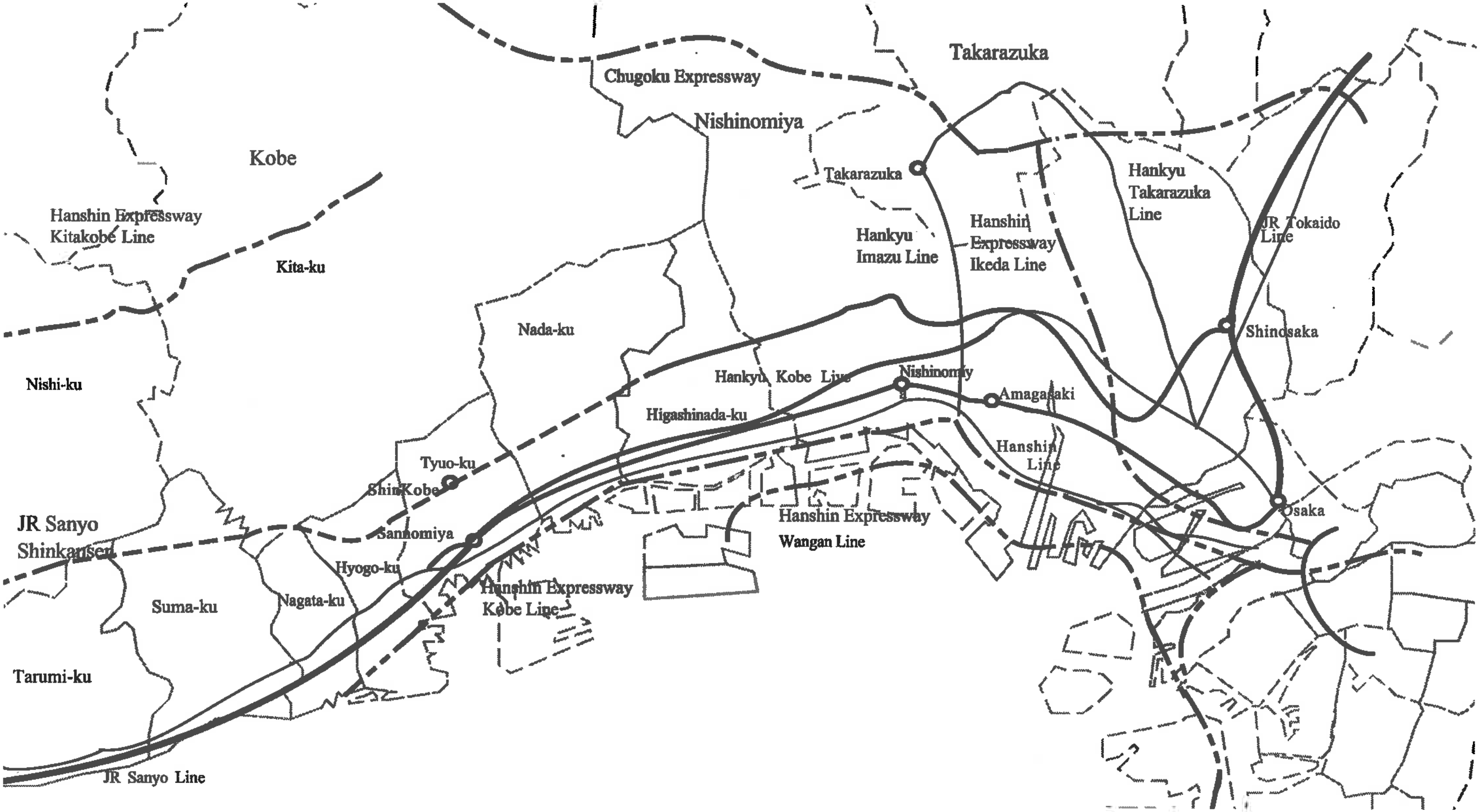


Figure 1. Major Expressway and Rail Lines in the Hanshin Corridor and Vicinity

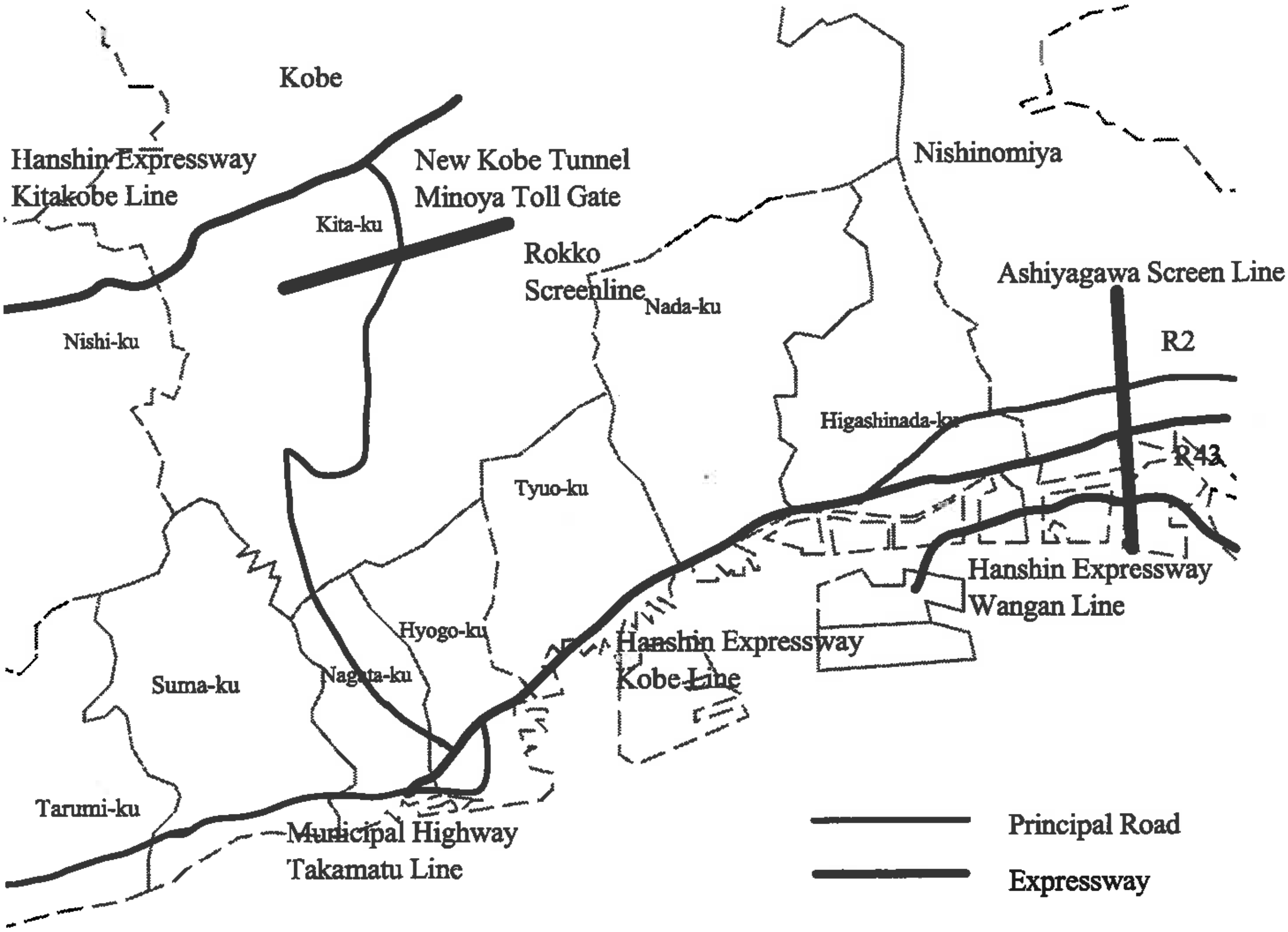


Figure 2. Major Highways in the Coastal Hanshin Area

Table 1: Chronological Summary of Traffic Restrictions in Effects on Major Highways

Date and Days Since Earthquake		Roadway	Traffic Restrictions
Jan. 19, 1995	2	 Hwy 2	Designation of selected roadways as emergency transport routes Osaka-Hyogo prefecture line - Momitori Int.; all day[1]
Jan. 22	5	 Hwy 2	First revision of emergency transport route designation Osaka-Hyogo prefecture line - Tokui Int.; all day[1]
Jan. 23	6	Hwy 43	Installation of bus lanes; Nishinomiya Motomachi Int. - Iwaya Int.
Feb. 1	15	 Hwy 2 Hwy 43	Second revision emergency transport route designation (Hwy 43 added) Utashimabashi Int. - Iwaya Int.; all day[1] Imazu Int. - Iwaya Int.; 6:00 - 24:00[1]
Feb. 23	36	Hwy 43	Bus lane installation revised; Hamanaka Int. - Iwaya Int.
Feb. 25	39	 Hwy 2 Hwy 43 Wangan Line	Designation of selected roadways as restoration transport routes Nishi Oshima Int. - Iwaya Int.; 6:00 - 23:00[2] Mukogawa Int. - Iwaya Int.; 6:00 - 23:00[3] Nakajima - Uozakihama; all day[3]
Mar. 21	63	Hwy 43	Discontinuation of the bus lanes
Apr. 1	74	 Hwy 2 Hwy 43 Kobe Line Kobe Line Wangan Line Wangan Line	First revision of restoration transport routes Nish Oshima Int. - Iwaya Int.; 6:00 - 21:00[2] Mukogawa Int. - Iwaya Int.; 6:00 - 21:00[4] Westbound, Amagasaki Higashi - Mukogawa; 6:00 - 21:00[4] Eastbound, Mukogawa - Himejima; 6:00 - 21:00[4] Westbound, Nakajima - Uosakihama; 6:00 - 21:00[4] (effective Apr. 10) Eastbound, Fukaehama - Nakajima; 6:00 - 21:00[4] (effective Apr. 10)
Apr. 29	102	 Hwy 2 Hwy 43 Kobe Line Kobe Line Wangan Line	Second revision of restoration transport routes Nishi Oshima Int. - Iwaya Int.; 6:00 - 20:00 ex. Sundays & holidays[2] Mukogawa Int. - Iwaya Int. ; 6:00 - 20:00 ex. Sundays & holidays[4] Westbound, Amagasaki Higashi - Mukogawa; 6:00 - 20:00 ex. Sundays & holidays[4] Eastbound, Mukogawa - Himejima; 6:00 - 20:00 ex. Sundays & holidays[4] Nakajima - Rokko Island North; 6:00 - 20:00 ex. Sundays & holidays[4] (effective July 10)
Aug. 7	202	 Hwy 2 Hwy 43 Kobe Line Kobe Line Wangan Line	Third revision of restoration transport routes Nishi Oshima Int. - Iwaya Int.; 6:00 - 9:00 ex. Sundays & holidays[2] Mukogawa Int. - Iwaya Int. ; 6:00 - 19:00 ex. Sundays & holidays[4] Westbound, Amagasaki Higashi - Mukogawa; 6:00 - 19:00 ex. Sundays & holidays[4] Eastbound, Mukogawa - Himejima; 6:00 - 19:00 ex. Sundays & holidays[4] Nakajima - Rokko Island North; 6:00 - 19:00 ex. Sundays & holidays[4]
Jan. 8, 1996	356	 Hwy 2 Hwy 43 Wangan Line	Fourth revision of restoration transport routes Fudabasuji Int. - Iwaya Int.; 6:00 - 9:00 ex. Sundays & holidays[2] Naruomachi Int. - Iwaya Int.; 6:00 - 19:00 ex. Sundays & holidays[4] Westbound, Naruohama - Rokko Island North; 6:00 - 19:00 ex. Sundays & holidays[4]

[1] Excluding designated emergency vehicles
[2] Excluding freight vehicles, buses, taxis, motorcycles and other designated vehicles
[3] Excluding buses and designated vehicles
[4] Excluding buses, taxis, and designated vehicles

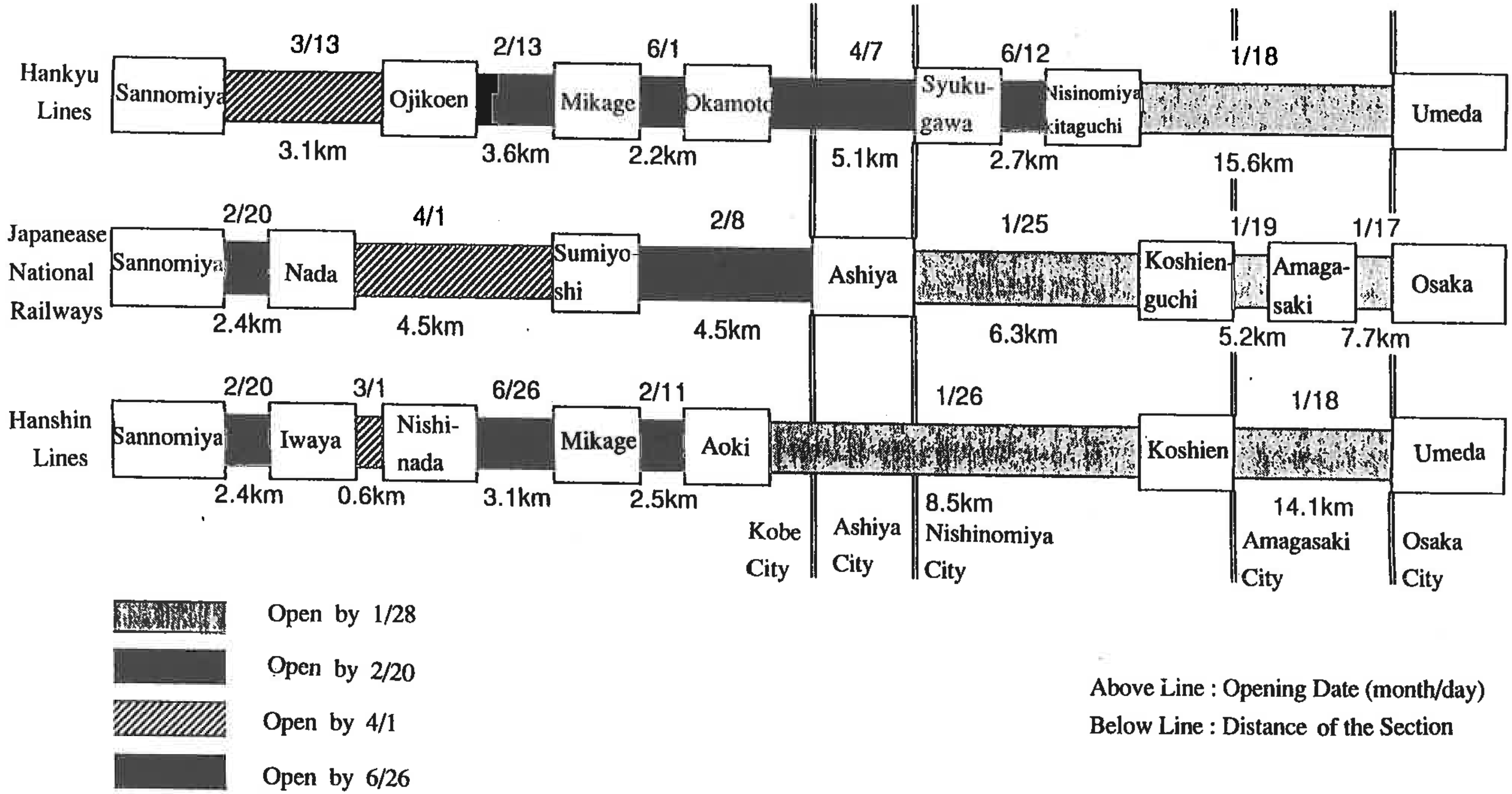


Figure 3. The Progress of Restoration on Three Railway Lines in the Hanshin Area

Source: Murano (1996)

Traffic Counts

Exhibiting dramatic changes in traffic volume, aggregate traffic counts present trajectories of recovery after the earthquake. The total traffic at the Ashiyagawa screen-line (lies parallel to, and in the west of, the Shyukugawa Cross Section shown in Fig. 1) was 252,900 vehicles per day (vpd) before the earthquake (June, 1994). After about two weeks from the earthquake on February 1, the screen count fell to 66,400 vpd, approximately 26% of the pre-quake level. At that point, Hanshin Expressway Kobe Line was closed, only two lanes were opened on the Wangan Line, and Highway 43 operated with four of its eight lanes (Ministry of Construction, 1995). Figure 4 shows the gradual recovery of the Ashiyagawa screen-line traffic as traffic restrictions are relaxed.

The traffic counts at the Rokko screen-line which cuts across north-south highways (see Fig. 2 for its approximate location), on the other hand, show increases by 25 to 35% from the pre-quake level (Fig. 5). This evidently represents detour traffic caused by the road closures and traffic restrictions in the Osaka-Kobe corridor during the period (Ministry of Construction, 1995).

At a larger scale, involving the entire Kinki region (Fig. 6), the road closures and restrictions in and around the Osaka-Kobe corridor evidently generated large amounts of detour traffic. Overall, the amounts of traffic into and out of the Kinki region resumed their pre-quake levels in about one month after the earthquake (Ministry of Construction, 1995). The variations in traffic counts on Highway 9, Maizuru Expressway and Chugoku Expressway shown in Fig. 7 (a) - (c) suggest the presence of detour traffic that used Maizuru Expressway and other routes on the side of the Sea of Japan. Once its four lanes were opened to traffic on Chugoku Expressway on February 12, the traffic on this freeway started to exceed the pre-quake level.

Assessment

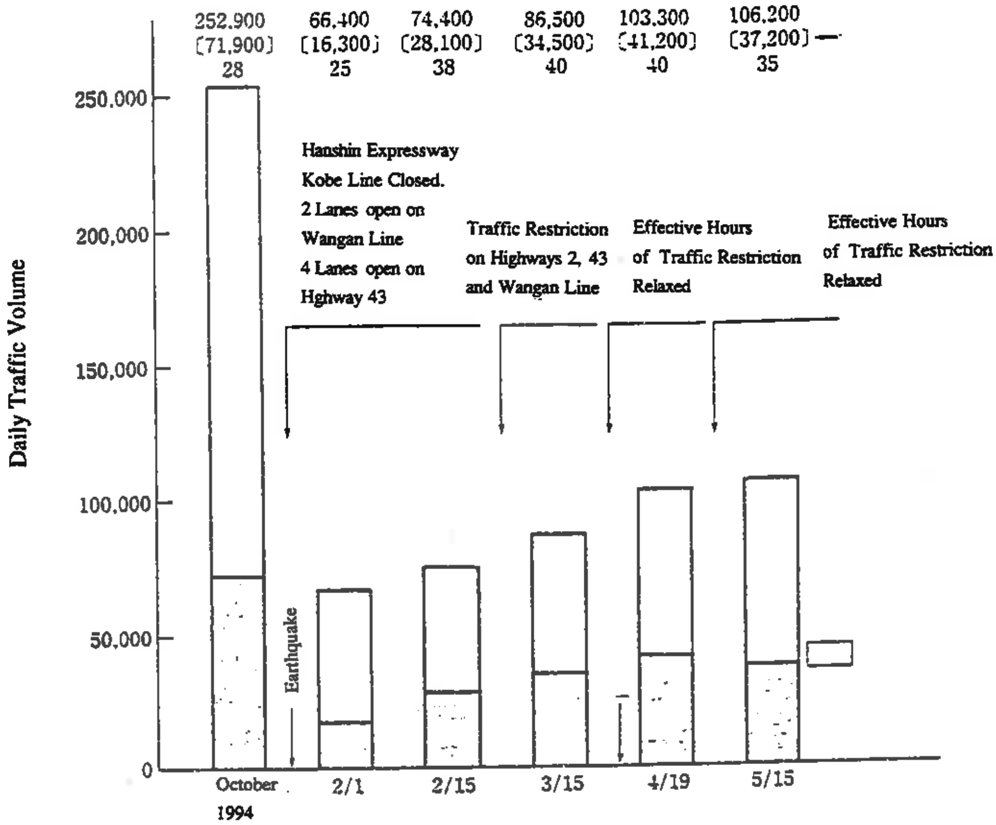
These traffic count data indicate the following:

- About a month after the earthquake, when Chugoku Expressway had started to operate with four lanes, traffic volumes on roadways outside the impacted area of the Osaka-Kobe corridor had resumed their pre-quake levels or exceeded them by up to 10%.

- At the Ashiyagawa screen-line in the Osaka-Kobe corridor, the traffic volume was smaller than the pre-quake level by as much as 186,500 vehicles per day, or by about 74% (Fig. 4). The passenger-vehicle volume decreased also by 74% from 181,000 to 46,300 vpd.

- The increase in the Rokko screen-line count by 18,600 vpd (from 57,100 to 75,700) is substantial, yet it is equivalent of only 10% of the total reduction at the Ashiyagawa screen-line. Thus even if all of the increase at the Rokko screen-line comprised detour traffic from the Osaka-Kobe corridor, it accounts for only 10% of the decrease at the Ashiyagawa screen-line.

Then where did all the traffic go? It is reasonable to assume that much of the traffic just simply vanished. The substantial decreases in roadway capacity, especially in the Osaka-Kobe corridor, resulted in substantial declines in the level of service.



Note: See Table1 for details of traffic restrictions that were in effect at various times after the earthquake

Figure 4. Changes in Traffic Volume at Ashiyagawa Screen-line

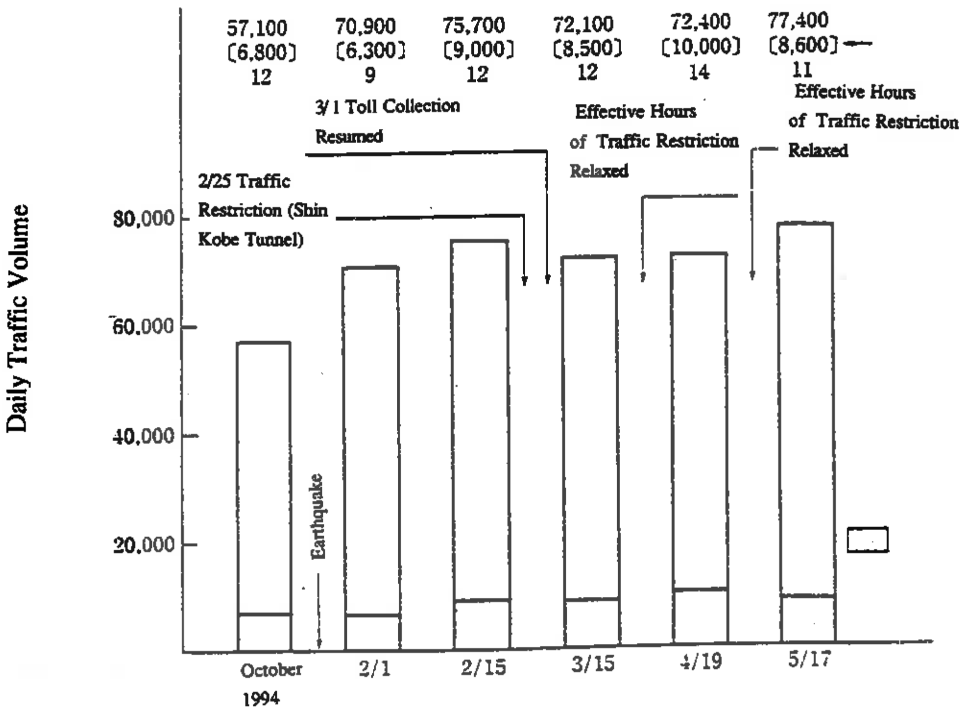


Figure 5. Changes in Traffic Volume at Rokko Screen-line

Source: Ministry of Construction (1995)

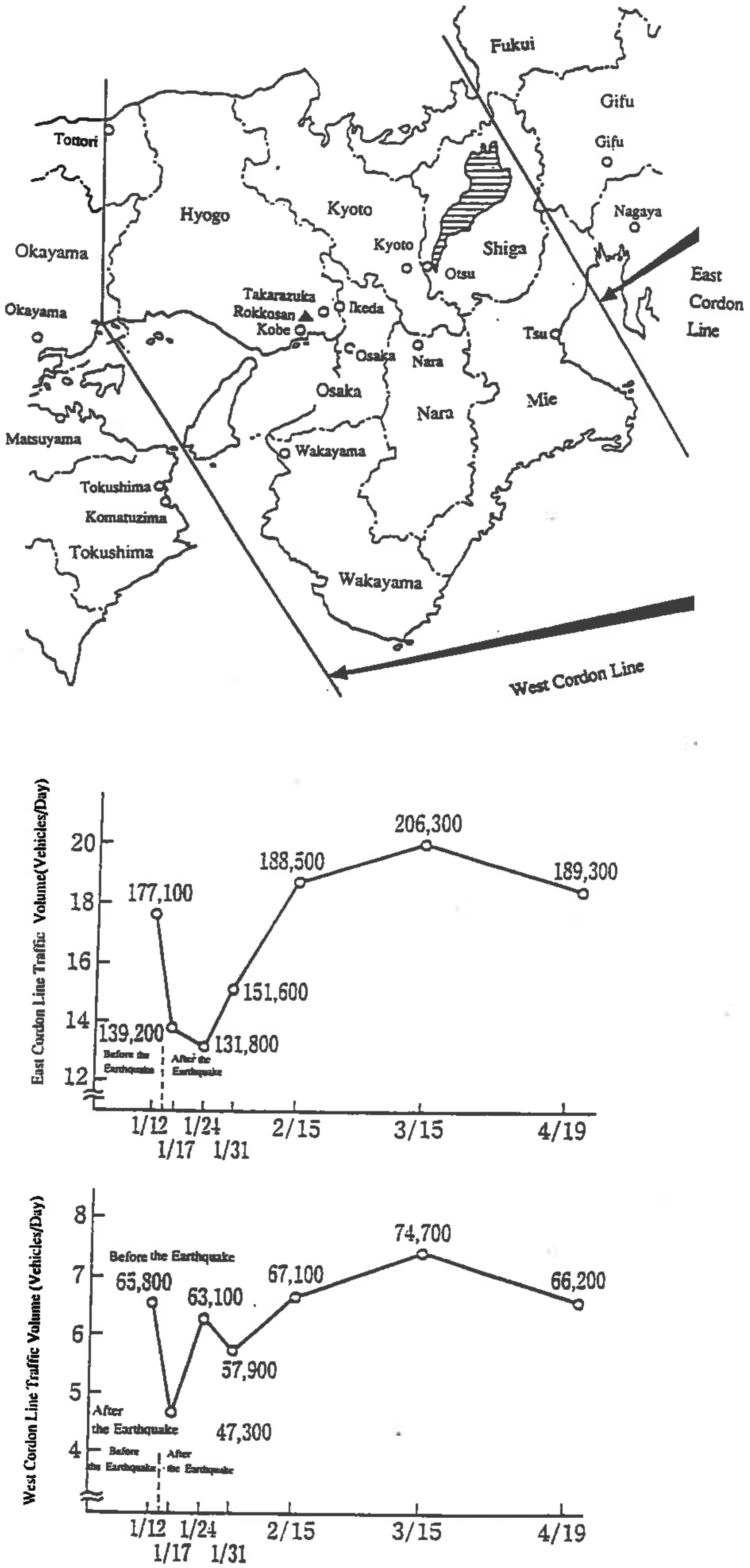


Figure 6. Changes in Cordon-line Traffic for the Kinki Region

Source: Ministry of Construction (1995)

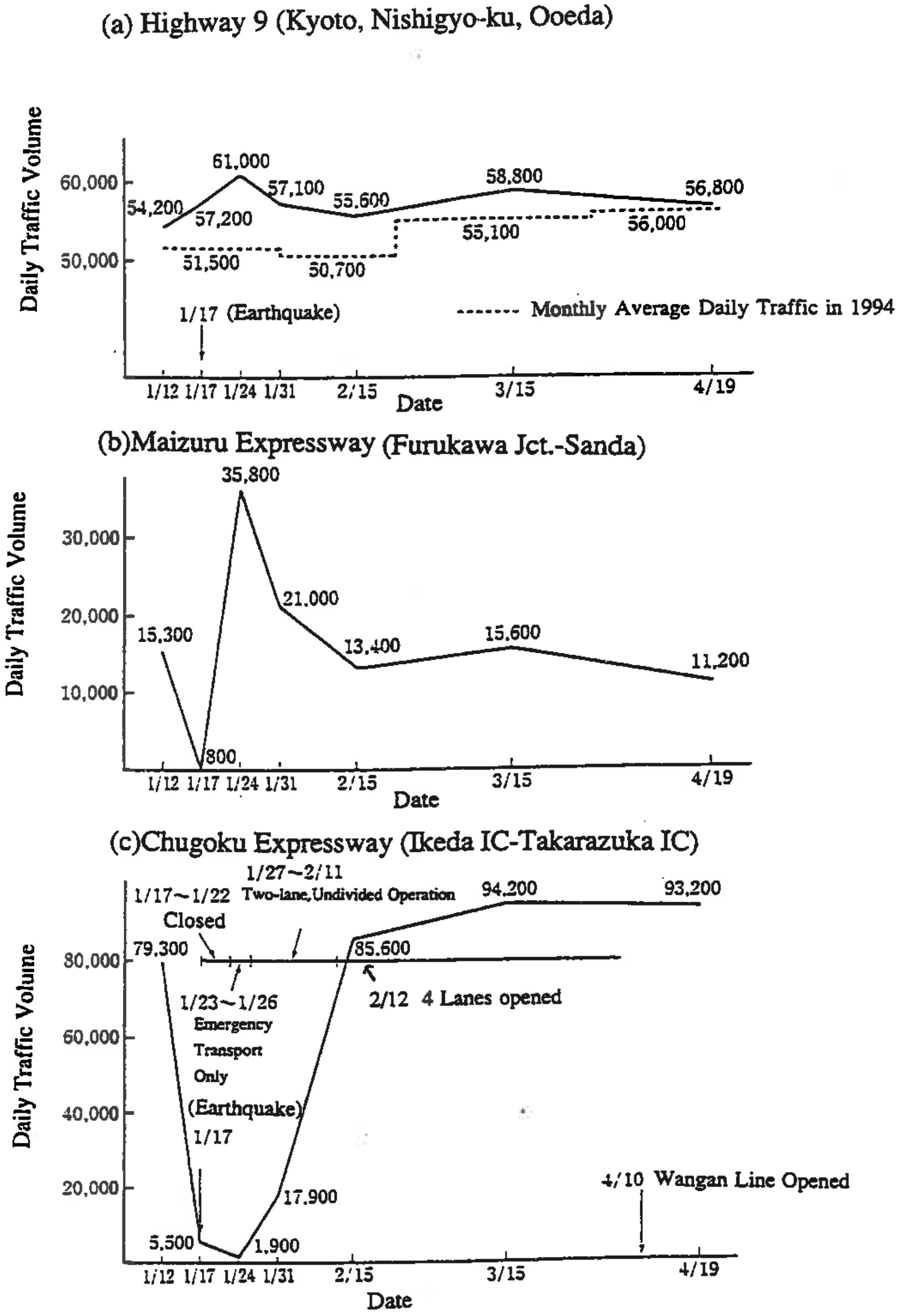


Figure 7. Changes in Traffic Volume at Selected Highways

Source: Ministry of Construction (1995)

Fig. 8 presents the average peak-period highway speed, measured by floating vehicles in the Osaka-Kobe corridor (between the two city halls). The low levels of service, traffic restrictions (see Table 1), and the reduced overall corridor capacity were evidently enough to suppress much of the screen-line traffic.

As another piece of evidence that shows the close relationship between traffic supply and demand, Fig. 9 shows how the total kilometers which were in service increased over time in the Hanshin Expressway network, and how the increases were accompanied with increases in the total number of vehicles entering the network. Weekly cycles are evident in the number of vehicles. It is also evident that the increase in the number of vehicles almost perfectly matches the increase in the kilometers of roadways in service.

It is clear that the supply of roadway capacity is strongly related to traffic volume. But what happened to the suppressed automotive trips _ especially the 186,500 vehicle trips per day that were suppressed at the Ashiyagawa screen-line? Were they suppressed in the strict sense and no trips were made at all any longer? Or were the trips made by alternative modes of travel? Or to alternative destinations? (The analysis so far implies that route changes alone cannot explain the reduction in traffic of the magnitude seen at the Ashiyagawa screen line.) Or is the reduction in traffic volume due to more efficient travel patterns that residents of the area had adopted faced with the low levels of service offered by the highway networks? Probably a bit of all these. Evidence is rather scant, unfortunately, to precisely determine what was exactly happening. Yet available pieces of evidence are put together below, with the hope of offering further insights into how roadway capacity is related to traffic demand.

Evidence Based on Individual-Level Data

Determining what had happened to vehicular trips that were made before the earthquake but were not made after it, obviously requires observation of change before and after the earthquake. Repeated cross-sectional observations will aid in making inferences. For example, one may attempt to infer how much of the suppressed vehicular trips are due to mode shift by inspecting market shares of travel modes before and after the earthquake. More precise and better founded inferences can be made if longitudinal observation of behavior can be obtained from the same behavioral units (e.g., households, individuals, or firms). Such data can be produced by a panel survey, which comprises repeated interviews over time of the same sample individuals, or by retrospective questions in a single cross-sectional survey, by asking respondents recall and tell what they did before the earthquake, in this case. All these designs are used to produce the pieces of evidence introduced below.

Kishino et al. (1996) examined changes in trip rate and mode use based on the results of a survey conducted in July and August of 1995, six to seven months after the earthquake. The survey targeted residents and firms in areas in and around the City of Kobe which were heavily impacted by the earthquake. The survey instruments included retrospective questions concerning changes in travel patterns after the earthquake.

Based on what the respondents reported, the frequency of leaving home declined to 47% of the pre-quake level one week after the earthquake. The frequency gradually increased: to 59% on February 28 (six weeks after the quake), 67% on March 31 (about 10 weeks), 75% on April 30 (about 15 weeks) and 86% on July 31 (about 28 weeks). The reliability of responses to the retrospective questions remains an issue. Yet, the results suggest that a substantial fraction of trips may have been simply suppressed.

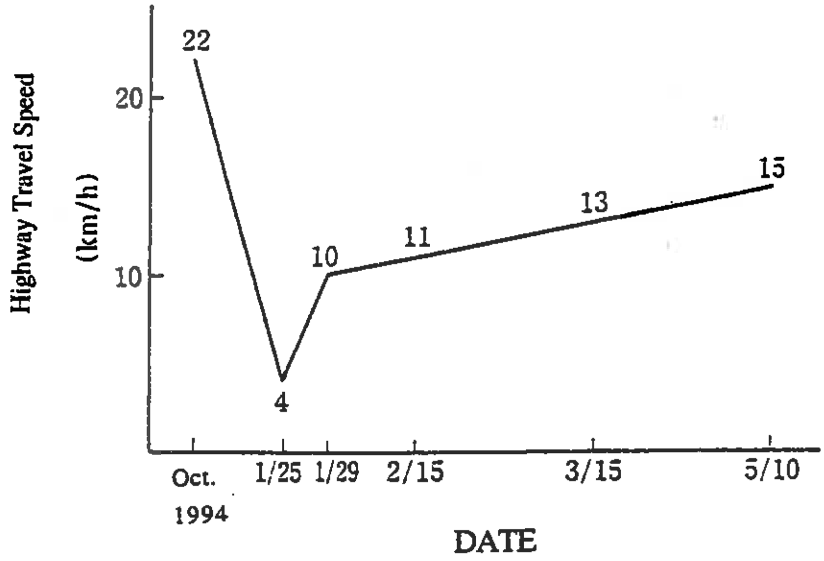


Figure 8. Peak-Period Mean Highway Travel Speed Between Osaka and Kobe

Source: Ministry of Construction (1995)

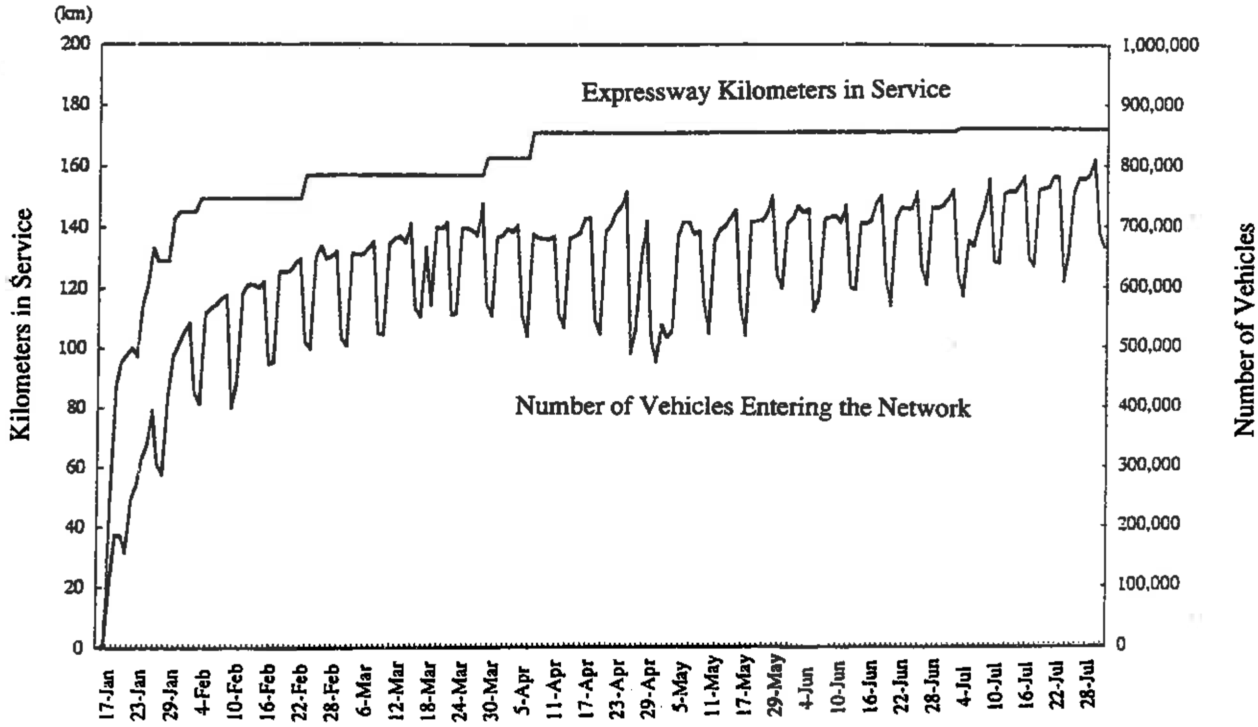


Figure 9. Increases in Expressway Kilometers in Service and the Number of Vehicles Entering the Hanshin Expressway Network After the Earthquake

Source: Tsuge (1995)

Kyoto University Panel Study[2]

We commenced a panel study of sample residents of the Hanshin area in November 1993, with the purpose of evaluating the impacts of the Hanshin Expressways' Wangan Line, which opened in April, 1994. The second wave of the panel survey was conducted in November, 1994, about two months prior to the earthquake. The sample happened to include a few hundred households residing in areas which were severely impacted by the earthquake. With the intent of measuring the impacts of the earthquake on residents' activity engagement and travel, the third-wave of the panel survey was designed and conducted in June, 1995. The questionnaire inquired respondents' action space, time use and travel, and demographic and socio-economic characteristics. Monthly visit frequencies to sub-areas of the study area, which respondents were asked to report in the survey, are first discussed in this section. Following this, travel characteristics obtained from the time-use section of the survey are discussed.

The average frequencies of visiting areas in the Osaka-Kobe metropolitan area are shown in Fig. 10 for before (Wave 2) and after (Wave 3) the earthquake (the sample respondents are weighted according to age, sex and driver's license holding status). In the figure, the Osaka-Kobe study area is divided into 13 sub-areas. In the survey the respondents were asked to indicate the frequencies of visiting the respective sub-areas for non-work purposes during the one month period preceding the survey. The average frequencies are tabulated for respondents from the coastal Kobe sub-area, and those from the coastal Hanshin sub-area, which lies between Kobe and Osaka (the averages include trips by all modes, made for recurring activities such as shopping and social visits, but exclude work, school and work-related trips). Both sub-areas were severely impacted by the earthquake.

Drastic reductions in visit frequencies are evident from the figure. Respondents from the coastal Kobe sub-area show decreased visit frequencies to all sub-areas after the earthquake. Respondents of the coastal Hanshin sub-area also show decreased visit frequencies to all sub-areas, except the North Osaka sub-area. Decreases in visit frequencies to the southern half of the study area are most noticeable. If these reported visit frequencies represent the spatial extension of the respondents' action spaces, then it can be firmly concluded that the action spaces of those residents in areas which were impacted by the earthquake have contracted substantially.

Although not shown in the figure, the analysis indicated that the frequencies of visiting the two sub-areas by respondents from the other sub-areas also decreased substantially after the earthquake. This presumably reflects the severely impaired accessibility to these areas due to the transportation supply disruption in the Hanshin corridor.

Aggregate measures of visit frequencies, mean travel distance, and total travel distance are evaluated for before and after the earthquake, and summarized in Figs. 11 through 13. The last indicator is constructed using reported visit frequencies and mean travel distances between sub-areas. Results are shown for all respondents, and then for respondents from four sub-areas. Overall, mobility declined after the earthquake in terms of all these three indicators (the decreases are significant for visit frequency and total travel distance).

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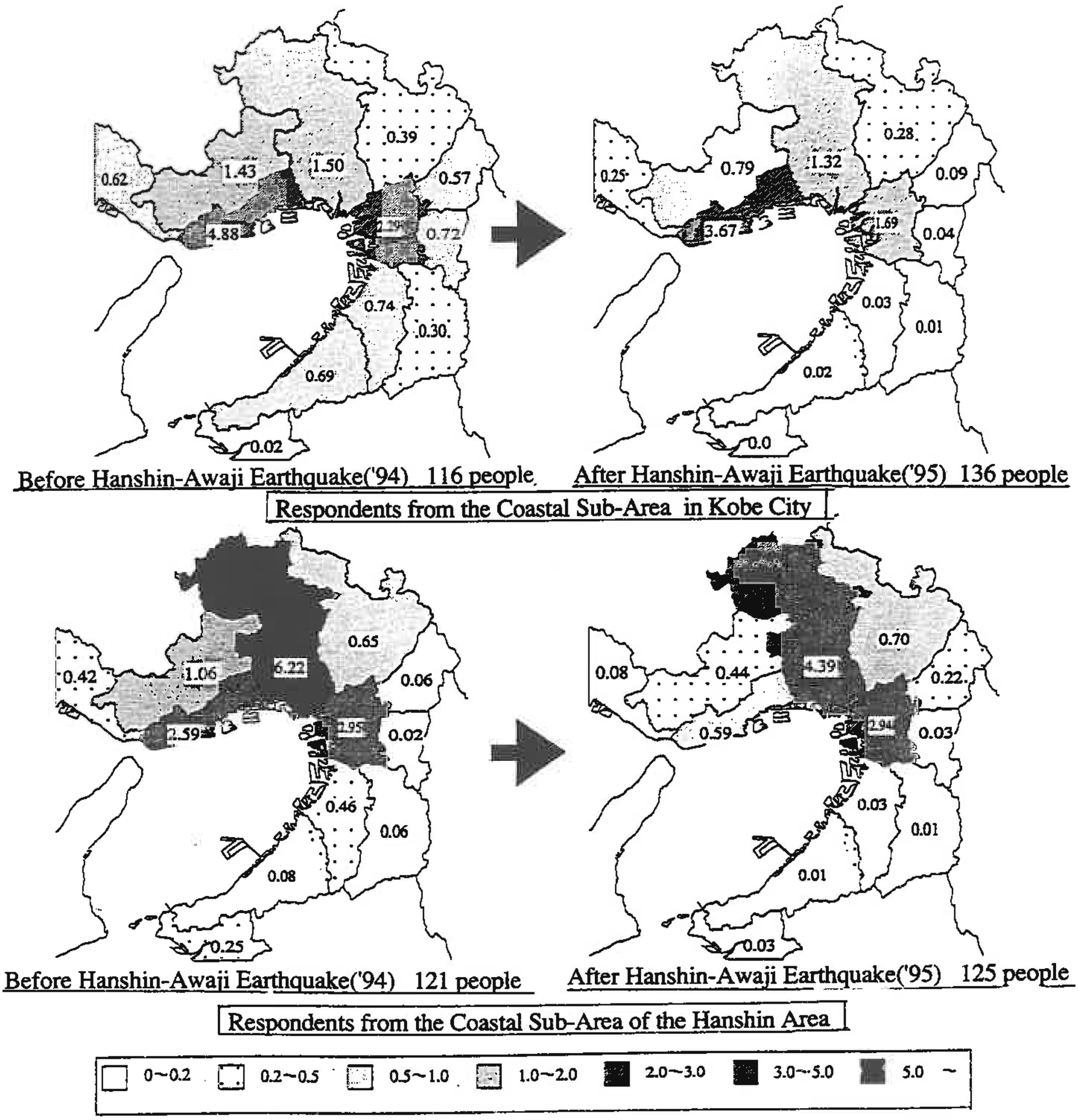
[2] Based on Fujii, Kitamura and Tsuge (1997) and Fujii, Kitamura, Tsuge and Daito (1997).



Note: Respondents are weighted by age,sex and driver's license holding status.

Figure 10. Changes in the Frequency of Visiting Sub-Areas of Osaka-Kobe Region for Recurring Activities Such as Shopping and Social Visits

Source: Fujii,Kitamura, Tsuge and Daito (1997)

Trip Frequency (Trips/Month)

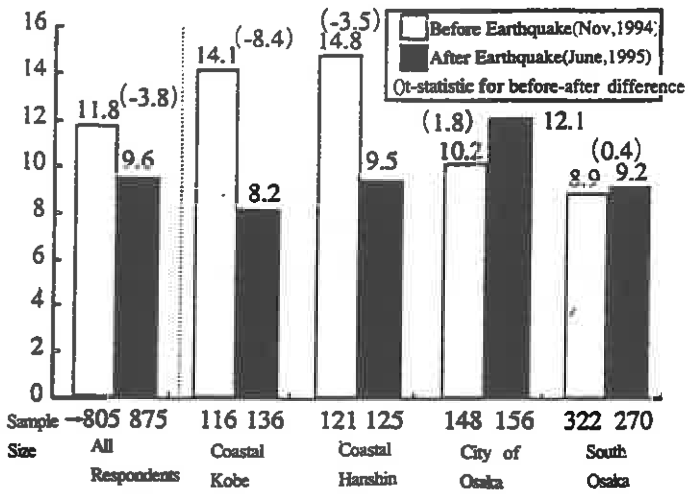


Figure 11.

Mean Trip Distance(km)

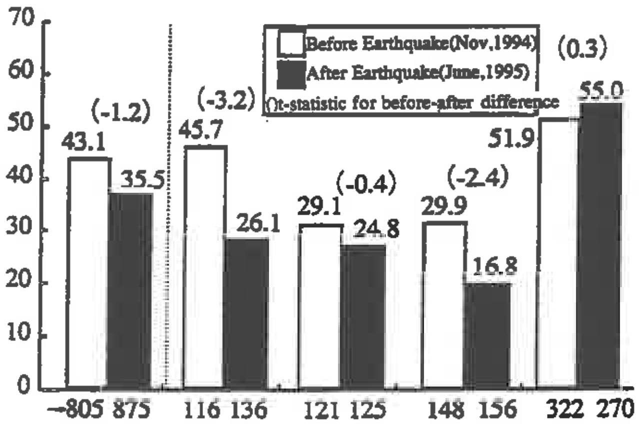


Figure 12.

Total Travel Distance (Person-km/month)

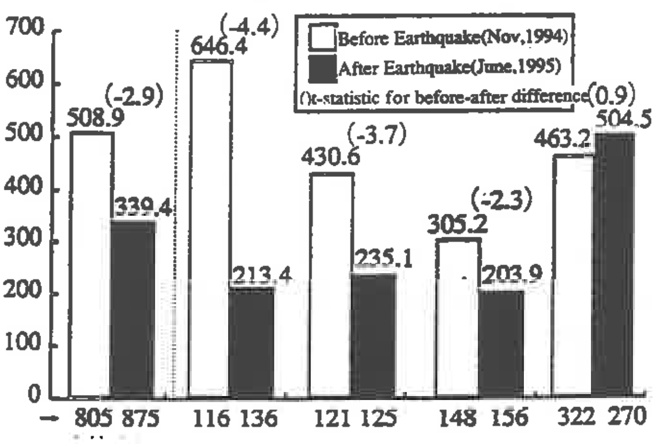


Figure 13.

Source: Fujii, Kitamura and Tsuge (1997)

Respondents from the coastal Kobe sub-area show significant decreases in both visit frequency and mean travel distance after the earthquake. As a result, the total travel distance decreased substantially by two-thirds from 646.4 to 213.4 (km/month). The coastal Hanshin sub-area shows a similar decrease in visit frequency, but not in mean travel distance. The City of Osaka, where the impact of the earthquake was overall relatively minor, shows some increase in visit frequency, but a decrease in travel distance, leading to a significant decrease in total travel distance. The only sub-area which exhibits no significant difference in these measures is the southern part of the Osaka Prefecture, which lies farthest from the epicenter.

The results of the panel study offer clear evidence that the earthquake did affect residents' travel behavior. At the time of the survey (early June), the JR Tokaido Line and Hankyu Line were operational, yet Hanshin Line was only partially operational (Fig. 3). As noted earlier, the Hanshin Expressway network was operational except for the Kobe Line and a section of the Wangan Line. Highways 2 and 43 both operated with traffic restrictions. This had a profound impact on the frequency of visits residents made for recurring non-work purposes and their choice of destination locations, hence the distance of travel for these purposes. The survey results suggest that the amount of non-work travel may decrease by as much as two-thirds (in km/month) in areas where transportation infrastructure is severely disrupted.

Data for a total of 204 individuals are available for both the second and third waves of the time-use section of the panel survey. The sex and employment status of these panel respondents are summarized in Table 2 for the earthquake-impacted area and non-impacted area separately.

Table 2: Distribution of Sex and Employment Status by Earthquake Impact: Panel Sample of 204 Respondents

	Sex*		Employment		Total
	Male	Female	Employed	Unemployed	
Impacted Area	29	20	26	25	51
Other Area	87	68	88	65	153
Total	116	88	114	90	204

*Excludes respondents with missing sex code.
Source: Fujii, Kitamura and Tsuge (1997)

The difference in daily trip rate, mean trip duration, and total travel time are evaluated for before and after the earthquake for each respondent. Table 3 summarizes the results in terms of mean difference between the two periods and t-statistic (for paired t-test), which can be used to test the hypothesis that there is no difference in a mobility measure before and after the earthquake. (Unlike the above analysis of reported monthly visit frequencies, all trips reported over a one-day survey period are included here.)

The mean trip rate of the respondents from the impacted area decreased significantly by 0.50 trip per day, while that of the respondents from the other area increased slightly and insignificantly by 0.15. The t-statistic in the bottom row indicates that the difference between the two groups is statistically highly significant.

The mean trip duration increased in the impacted area very significantly by 8.25 min. per trip, while decreased in the non-impacted area, also very significantly, by 6.91 min.[3] The former can be considered as a result of the disrupted transportation infrastructure, which led to congested roadways and slow rail service, which, as noted earlier, involved bus transport for those railway segments which had not been restored. It is also in part due to shift to slower travel modes after the earthquake. This increase in trip duration, which suggests reduced levels of accessibility, may be a cause of the significant decrease in trip rate seen earlier among the respondents form the impacted area. The significant decrease in trip duration shown by the respondents from the non-impacted area may be due to the contraction in the transportation networks due to the disruption in the Kobe area, as well as seasonal effects (the second-wave survey was performed in November, while the third-wave survey was done in June).

The slight increase in trip rate combined with this decrease in trip duration has resulted in the significant reduction in total travel time shown by the respondents from the non-impacted area. For the respondents from the impacted area, on the other hand, the increase in trip duration is so large such that, despite the decrease in trip rate by 0.5 trip per day, total travel time increased by 3.75 minutes per day. The results clearly show that mobility has declined for residents of the earthquake-impacted area.

*Table 3: Changes in Mobility Measures Before and After the Earthquake**

	Sample Size	Trip Rate		Trip Duration		Total Travel Time	
		Mean	t	Mean	t	Mean	t
Impacted Area	49	-0.50	-3.21	8.25	3.97	3.75	0.46
Non-impacted Area	155	0.15	1.53	-6.91	-5.12	-19.60	-4.47
Total	204	0.02	0.29	-3.98	-3.38	-15.09	-3.88
t between. Groups+		-3.32		5.65		2.56	

* The means represent (post-earthquake value) - (pre-earthquake value).
\+ For the null hypothesis that there is no difference between the impacted area and non-impacted area in terms of the change in the mobility measure before and after the earthquake.
Source: Fujii, Kitamura and Tsuge (1997)

Mode Use

Matsumoto et al. (1996) surveyed residents of impacted areas in June to August, 1996. The sample comprises 524 individuals (a response rate of 65.5%), a majority of whom were male university employees. The survey questionnaire solicited self-assessment of the change in the use of household automobiles before, and six months after, the earthquake. As Fig. 14 shows, respondents from heavily impacted areas (coastal Hanshin area, and central and eastern Kobe) indicated they had reduced the use of household automobiles with more-than-expected frequencies.

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[3] The differences do not imply a change in the duration of a trip from a given origin to a given destination. The reflect changes in destination, travel mode, or other factors that are associated with trip duration.

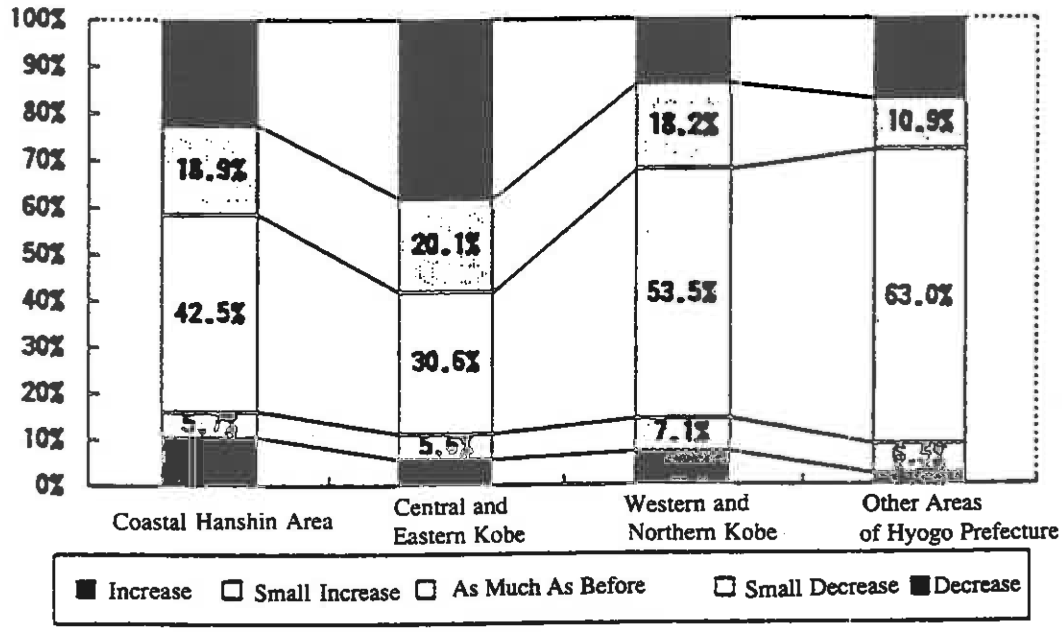


Figure 14. The Change in the Use of Household Automobiles After and Before the Hanshin-Awaji Earthquake

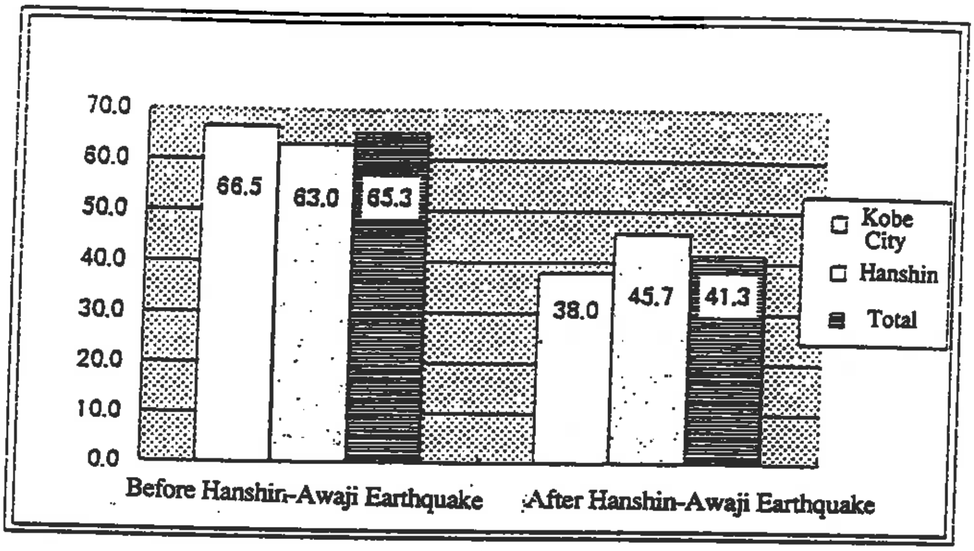
Source: Matsumoto, Odani and Sakoo (1996)

A survey of approximately 900 firms from the Kobe and Hanshin areas by Hino et al. (1996) shows that the percentage of firms in which more than 70% of the employees commuted by their household automobiles, decreased: from 35.6% before the earthquake to 22.9% after the earthquake in the City of Kobe; from 39.6% to 28.9% in the Hanshin area; and 32.9% to 23.1% overall (Fig. 15).

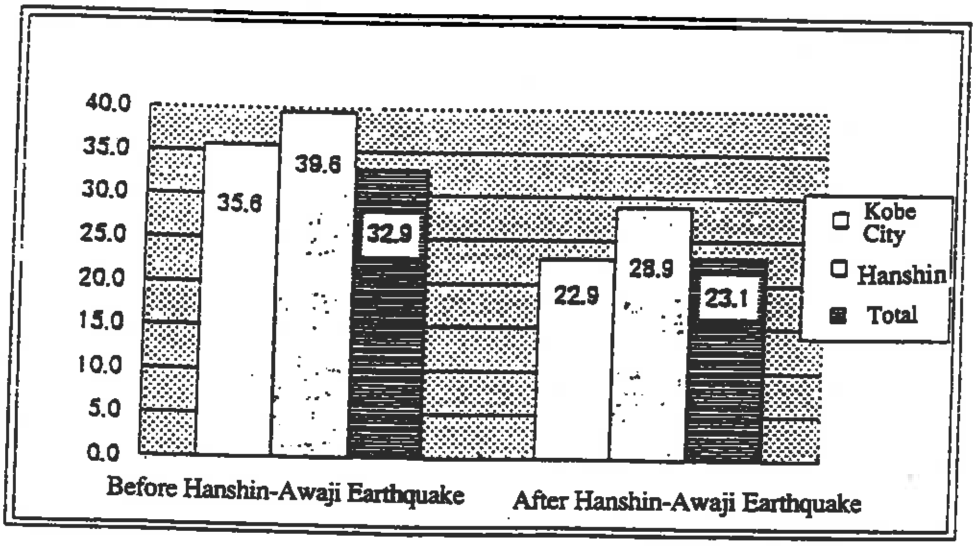
Matsumura et al. (1996a) conducted a survey of residents in the catchment area of the Shukugawa Station of the Hankyu Line in the Hanshin corridor, in October, 1995. This is one of the areas where public transit service was affected heavily for a prolonged period of time because of disrupted railway services. A total of 600 questionnaires were distributed and a sample of 386 residents was obtained (a response rate of 64.3%). Results of the survey show dynamics in commute travel mode use based on retrospective recall questions. No information on trip rates is contained in the article.

Table 4 shows the distribution of the primary modes for commute trips. The most dominant mode in the pre-earthquake period is rail (38.9%); walking and automobile follow this with about the same shares around 21%. Quite interestingly, 3.9% of the sample respondents reported that they had used to work at home before the earthquake.

Nearly 70% of the respondents indicated they were unable to commute to work immediately after the earthquake and stayed home. This rate of reduction is similar to the reduction in daily traffic volume at the Ashiyagawa screen line (Fig. 4), although this may be a mere coincidence. Of those who did commute to work immediately after the earthquake, 66.7% did so by rail, 11.3% by bicycle, 8.9% by auto, 5.7% on foot, 4.1% by the substitution shuttle bus operated by railway companies in sections where rail service was not available, and 3.3% by motor cycle. It turned out that, despite the disrupted service, rail remained to be the predominant commute mode immediately after the earthquake.



(1) Transportation Industry



(2) All Industries

Figure 15. The Percentage of Employers With Over 70% of Employees Commuting by Auto: Before and After the Hanshin-Awaji Earthquake

Source: Hino, Ueda, Yoshida and Suzuki (1996)

By October, 1995, about four months after all rail-lines had been restored, the distribution of primary commute modes had more or less reverted to the pre-earthquake distribution. A slight increase in walk and bicycle and a slight decrease in rail may be noted. One may argue that the disruption of rail service had an irreversible effect on rail patronage, resulting in the decrease by 1.6%. The difference, however, is too small to be conclusive.

Table 4: Dynamics in Modal Split: Primary Commute Mode (i)

	Modal Split in Percent						
	Home Work	Walk	Bi-cycle	Motor-cycle	Auto	Bus	Rail*
Before Earthquake	3.9	21.5	9.1	2.3	21.2	3.1	38.9
January, 1995+	68.1	1.3	1.8	3.6	1.0	2.8	21.2
April - May, 1995	8.0	19.2	11.7	2.6	17.9	2.8	37.8
October, 1995	3.9	23.6	10.1	2.1	21.2	1.8	37.3

* Includes shuttle bus substituting rail service.
+ Immediately after the earthquake.
Source: Matsumura et al. (1996a). Sample size not reported.

The distribution of access travel modes for commute trips is relatively stable (Table 5). Notable is the increase in bicycle and decrease in auto after the earthquake. As for the primary commute mode, the access mode distribution reverted to the pre-earthquake distribution approximately by October, 1995.

Table 5: Dynamics in Modal Split: Access Commute Mode

	Modal Split in Percent			
	Walk	Bicycle	Motorcycle	Auto
Before Earthquake	60.4	13.7	2.7	23.2
January, 1995+	55.3	26.0	4.9	13.8
April - May, 1995	54.6	19.4	4.2	21.4
October, 1995	58.8	15.4	3.0	22.9

+ Immediately after the earthquake
Source: Matsumura et al. (1996a). Sample size not reported.

Matsumura et al. (1996b) conducted another survey in December, 1995, targeting five neighborhoods in heavily impacted areas in the coastal Hanshin area. A total of 4,800 questionnaires were distributed to 2,400 households. The drop-off/pick-up procedure adopted in the survey resulted in 2,252 returns with a response rate of 47%. Retrospective questions were asked about commute trips in three periods: before the earthquake, in early March, 1995, and early April, 1995.[4]

[4] In early March, the Hankyu Line was closed between Nishinomiya-Kitaguch and Mikage; the JR Line between Sumiyoshi and Nada; and the Hanshin Line between Mikage and Nishinada. Highways 2 was restricted to freight vehicles, buses, taxis, motorcycles and vehicles specifically designated for exemption, between 6:00 AM and 11:00 PM. Highway 43 was restricted to buses and designated vehicles, also between 6:00 AM and 11:00 PM. Wangan Line was partially open, and was restricted to buses and designated vehicles all day.

Note that the survey called for the recall of commute travel mode use of eight to eleven months ago.

Quite amazing is the result that the modal split remained relatively stable among this sample of commuters (Table 6). Despite the service disruption, the rail share, when combined with the substitution shuttle bus, increased slightly from the 57.2% before the earthquake to 58.3% in March and 60.1% in April. Corresponding to this is the more noticeable decline in the auto share. Walk and bicycle combined declined slightly from 16.7% before the earthquake to 15.8% in April, while motorcycle and bus show increases. Based on the result, we may conclude that congestion, traffic restriction and closures on major highways had more adverse effects on auto users than did rail closures combined with substitution shuttle bus service on rail users.

Table 6: Dynamics in Modal Split: Primary Commute Mode (ii)

		Modal Split in Percent						
	N	Walk	Bicycle	Auto	Motor-cycle	Rail	Shuttle Bus	Bus
Before Quake	1335	7.7	9.0	19.6	2.7	57.2		3.8
March, 1995+	1120	8.3	7.5	16.3	5.2	46.9	11.4	4.1
April, 1995	1102	8.5	7.3	14.7	4.4	50.4	9.7	4.9

+Total does not equal 100 in the original.
Source: Matsumura et al. (1996b)

The transition in commute travel mode between before the earthquake and early March, 1995, is shown in Table 7 for 882 commuter respondents who did not change their residence addresses and from whom mode use information is available for the two periods. Unlike the results seen in the previous table, rail shows a slight decrease in March, from 537 in the pre-earthquake period to 525 in March, 1995. Otherwise, the turnover table exhibits similar tendencies as does Table 6.

With walk and bicycle, and rail and shuttle bus, respectively grouped together as one mode, 146 of the 882 respondents (16.6%) switched their commute modes between the two periods. Quite notable is the asymmetry that seven respondents switched from auto to motorcycle while only one made the reverse transition from motorcycle to auto. Likewise 14 switched from rail to motorcycle while only 2 switched from motorcycle to rail. Also notable is the asymmetry that 14 switched from rail to bus while only six switched from bus to rail. Yet overall, mode use is relatively stable among those who commuted in March, 1995, as well as before the earthquake, despite the significant supply disruptions.

In early April, the Hankyu Line opened between Shukugawa and Okamoto, leaving two sections closed, between Nishinomiya-Kitaguchi and Shukugawa, and between Okamoto and Mikage. The JR Line was completely restored by then. The same traffic restrictions were effective on Highway 2, but the effective hours were reduced to between 6:00 AM and 9:00 PM. The restrictions on Highway 43 were also relaxed to allow for taxis and to be effective between 6:00 AM and 9:00 PM. Kobe Line was partially open by then. Both Kobe Line and Wangan Line were restricted to buses, taxis and designated vehicles between 6:00 AM and 9:00 PM.

Table 7: Commute Travel Mode Turnover: Before Earthquake and March, 1995

Before Earthquake	March, 1995					
	Walk/ Bicycle	Auto	Motor-cycle	Rail	Bus	Total
Walk/Bicycle	107	4	1	27	0	139
Auto	3	116	7	21	2	149
Motorcycle	1	1	22	2	0	26
Rail+	21	19	14	469	14	537
Bus	0	2	1	6	22	31
Total	132	142	45	525	38	882

+ Includes shuttle bus.
Source: Matsumura et al. (1996b)

Conclusion

The Hanshin-Awaji Earthquake had practically destroyed the transportation infrastructure in the Osaka-Kobe area, especially in the Hanshin corridor which connects the City of Osaka and the City of Kobe. Immediately after the earthquake, when all rail lines and expressways in the corridor were not operational, screen counts indicated that the corridor traffic decreased by about three-quarters. Approximately two-thirds of the sample commuters in a survey reported they worked at home during the period.

In June, 1995, five months after the earthquake and when the infrastructure was partially restored, sample residents of a panel study from earthquake-impacted areas, reported on average 0.5 less trip per day than they did in a period prior to the earthquake. The results of the panel survey also suggest that the amount of non-work travel (in km/month) may decrease by as much as two-thirds in areas where transportation infrastructure is severely disrupted.

Compared to these changes, mode use for commuting, given that a trip was made, remained relatively stable throughout the period of recovery after the earthquake. This, however, may be a phenomenon unique to this case as the earthquake impacted both highway and rail networks.

In sum, reductions in transportation capacity do affect travel. In June, 1995, the expressways in the Hanshin corridor had been only partially restored. These expressways and major highways in the corridor were limited to buses, taxis and other designated vehicles between 6:00 AM and 8:00 PM. One of the three major corridor rail lines had not been fully operational. The substantially reduced capacity and impaired accessibility had the following impacts on residents in the Hanshin corridor:

- reduction in daily trip late by 0.5 trip,
- significantly reduced non-work travel in terms of both frequency and distance, and
- drastic contraction in the action space for non-work activities.

Capacity reduction does affect both trip generation and destination choice (and possibly mode choice, although no strong evidence is obtained in our case). It is inferred that much of the change in travel demand is associated with non-work travel, which may be reduced by as much as two-thirds with the capacity reduction of the magnitude seen after the Hanshin-Awaji earthquake.

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What really happens to traffic when road capacity is reduced or reallocated, and what are the underlying changes in the peoples' travel choices and behaviour that cause these effects?

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The findings of the research will provide help to those planning or considering traffic capacity reduction measures such as city centre traffic restrictions, road closures, bus priority measures or pedestrianisation.

The Report is written by a team of internationally acknowledged experts in the fields of travel behaviour and transport policy. At the ESRC's Transport Studies Unit at University College London, Dr Sally Cairns is a Research Fellow and Professor Phil Goodwin is Director of the Unit. They are joined by Professor Carmen Hass-Klau, of the consultancy Environmental & Transport Planning and Wuppertal University, and an Annex is provided by Professor Ryuichi Kitamura and colleagues from Kyoto University.

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