

## **Evidence on the Effects of Road Capacity Reduction on Traffic Levels**

by Phil Goodwin, Carmen Hass-Klau and Sally Cairns

### **Introduction**

This article describes the findings of a report which was commissioned by London Transport and the Department of the Environment, Transport and the Regions (DETR). Since its publication, it has been welcomed by the Minister of Transport, reported in both the technical and general media, and followed by an announcement that the DETR will issue new guidelines to take its results into account. The authors wish to acknowledge the contribution of Dr Steve Atkins, who was responsible for the inception of the research, and of the worldwide network of researchers and local authorities, who contributed the data and advice that formed the core of the findings. The full report by Cairns *et al*<sup>1</sup> - 274 pages long, with over 200 maps, tables and figures - contains detailed descriptions, analyses and caveats which can only be briefly summarised here. Parallel work was carried out by MVA Limited<sup>2</sup> on the implications of the results for modelling, which will be summarised in the July/August 1998 issue of *Traffic Engineering + Control*.

### **Research context**

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 to favoured classes of vehicle traffic, or to non-vehicle use - is therefore 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 a key issue is the technical feasibility of measures to reduce capacity. 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<sup>3</sup> 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. This is supported by theoretical arguments, specifically those relating to the theory of traffic flow and assignment, appraisal methodologies, network topology, market distortion, feedback effects, the non-transport functions of streets, travel choice and behavioural response. Taken together, these arguments do lead to the expectation that removal of road capacity may naturally lead to some reduction in the total volume of traffic, though not necessarily to an exact symmetry between the SACTRA results and the reverse case, especially in the short run.

The research question, therefore, is almost entirely empirical. What really does happen when capacity is reduced?

### **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 reported 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*’.

To test these statements, evidence was collected 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. This especially applied to analysis carried out by Kitamura *et al* from Kyoto University, which is included in the full report.

Altogether, evidence from over 100 places was collected. Over 60 provided primary case-study material, and included locations in the U.K., Germany, Austria, Switzerland, Italy, The Netherlands, Sweden, Norway, the U.S., Canada, Tasmania [which is actually a state of Australia - *CB*] and Japan. This material was supported by related or partial evidence from many other locations. The U.K. studies include major town-centre traffic schemes (e.g. Cambridge, Edinburgh, Wolverhampton, City of London); bus priority measures (e.g. Belfast, Bristol, Cardiff, Oxford, London); and bridge closures (e.g. London: Tower Bridge, Westminster Bridge,

Hammersmith Bridge; York: Lendal Bridge). These studies were 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 showed a very wide range of results. The sample of case-studies for which complete traffic information was provided showed an unweighted average reduction in traffic on the treated road or area of 41 per cent. Less than half of this reappeared as increased traffic on alternative roads, at the same or different times of the day. Thus the average overall reduction in traffic was 25 per cent of that which used to use the affected road or area. These averages were 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 result, which is less affected by outlying figures, indicates that 50 per cent of cases showed overall traffic reductions, taking affected and alternative roads altogether, which were greater than 14 per cent of the traffic which originally used the affected road. If the nine exceptional cases mentioned are excluded, 50 per cent of the remaining locations showed overall reductions of more than 16 per cent of the original traffic on the affected roads.

The results of those case-studies for which (relatively) complete traffic information was available are shown in Figure 1 above and Table 1 overleaf. It will be understood that knowledge of the particular circumstances of each case-study is necessary for a serious judgement of the implications of these figures. Some specific comments of importance are selected as follows, though it should be emphasised that more detailed judgments about each location should be based on the full report, and on its source documents.

### **General caveats and problems of interpretation**

In every case, there were caveats and problems in obtaining absolutely definitive results. Problems arose 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 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 have been relevant to this study, and require some interpretation. In addition, in many cases, other transport changes have also been implemented in the same time period, such as opening a new bypass, or improving public transport services.

Four main potential sources of systematic bias were identified. These were:

- (1) *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 would not, by itself, cause bias to expected mean values.

- (2) *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.
- (3) *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 per cent to 4 per cent per year. If road capacity itself has been increased elsewhere on the network, this will similarly tend to result in an increase in traffic masking the effect where capacity has been reduced.
- (4) *Partial sampling.* If a survey-based 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 the potential sources of bias applied, the analysis did not make adjustments to compensate for these effects, but drew 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. There is therefore a greater possibility of overestimating the traffic reduction effect in the short-term studies, and underestimating it in the long-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.

Special 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.

### **Understanding the results**

It would be wrong to use as a universal rule-of-thumb a presumption that 16 per cent, or 25 per cent, (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) and 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.

Thus, 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. Figure 2 gives the responses which have been identified in the case-studies.

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 per cent, and anything up to 80 per cent 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 to 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 the particular road, and their replacement by new people making a new set of trips. These new 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 10 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 be unambiguously 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, i.e. 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 enhance or mask the *size* of such a build-up of effect.

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 from the degree, type and credibility of publicity and marketing.

## *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 current 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.

Comments about forecasting procedures were received from various cities with practical experience of successfully implementing major reductions or reallocations of capacity. Many of these respondents argued that they did 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 judgment and policy insight. Many stated 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 decisions how - and whether - to use transport modelling are positive decisions to be taken on their merits in the specific circumstances, not text-book procedures which should always be followed.

The conclusions which follow for practical modelling advice are discussed in the paper by Coombe *et al* in [the July 1998 issue of *Traffic Engineering + Control*].

### **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 (e.g. 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 when traffic reduction

occurs, the disbenefits of schemes will be less than those calculated on the assumption that no traffic reduction occurs. However, clearly the overall effects of schemes will still depend on the balance between benefits and disbenefits.

These arguments are identical (in reverse) with the SACTA analysis of the effects of increasing road 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 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 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 on 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.

## **Conclusion**

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 will 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. 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 results tend to support the view that an integrated transport policy should take account of the interaction between transport and other activities, as well as the interaction between different elements of the transport system itself.

*Specific information for the case-studies used in Table 1*

## **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 (e.g. three 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 could not be inserted into the summary table, due to incomplete information. These include **Portsmouth 1995**, where a potential traffic reduction of 14 per cent was implied; **Lucerne 1993-94**, where a traffic reduction of 10.5 per cent 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 per cent, 18 per cent and 5 per cent respectively. In **Bristol 1991-95**, traffic levels on particular corridors were reported as 'static', or 'increasing by only 2.4 per cent, 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**.

### **Specific caveats and comments**

**Bologna 1972-89** - Over the 17-year period between 1972 and 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 per cent. 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, but was then 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 of changes in traffic flows entering the area specified, it is notable that a survey of through traffic in Gothenburg showed an increase of 6 per cent over a 10-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 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 1994-95** - Data refer to a three-bridges screenline. A 10-bridges screenline showed an increase of 8,170 vehicles, 2 per cent 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 per cent to <-1 per cent after the damaged highways were reopened.

**Norway: Street Enhancement Programme 1991-95** - Traffic counts given are the totals for four 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 per cent to +17 per cent.

**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 per cent in the first year and 6.2 per cent over the first five years. At an outer cordon around the city, traffic fluctuated from year to year, with an average increase of about 4 per cent per year from 1984 to 1988, whilst pedestrianisation was still being implemented. This growth reduced to an average of less than 2 per cent 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 have 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 1992-95** - 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 per cent to +25 per cent. The 'before' and 'after' surveys related to a period of capacity reductions on the old trunk roads through the town centres, which occurred after the 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 1978-79** - Data on 'before' traffic flows have been combined with the reported percentage changes. 'After' traffic counts are not quoted in the original source.

**Figure 2.** *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-swapping);
- elimination or suppression of trips;
- changes in job location;
- changes in housing location; and
- changes in developer choices for locating new developments.

## References

- 1 CAIRNS, S., C. HASS-KLAU and P. GOODWIN. *Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence*. Landor Publishing, London, 1998\*.
- 2 MVA LIMITED. *Traffic Impact of Highway Capacity Reductions: Report on Modelling*. Landor Publishing, London, 1998\*.
- 3 SACTRA. *Trunk Roads and the Generation of Traffic*. Department of Transport, HMSO, London, 1994.

\* *The full reports are available from Landor Publishing Ltd at Quadrant House, 250 Kennington Lane, London SE11 5RD.*