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USER RESPONSE TO NEW ROAD CAPACITY: A REVIEW OF PUBLISHED EVIDENCE

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USER RESPONSE TO NEW ROAD CAPACITY: A REVIEW OF PUBLISHED EVIDENCE

ABSTRACT

This paper presents a review of the known evidence on the various aspects of user response to new road capacity.

The traffic effects of new road capacity have important implications for the appraisal of road schemes. The conventional method for inter-urban roads (and increasingly for urban road projects) assumes that the volume of trips, and their destination between pairs of zones, is given. The only response to new investment that is modelled is re-assignment between routes. Relative to this, new road capacity creates the potential for several effects. These effects include:-

(1) Wide area re-assignment, involving re-routing of trips external to the study area.

(2) Redistribution of trips to different destinations.

(3) Attraction of trips from other modes.

(4) Re-timing of trips.

(5) Generation of trips, consisting of trips which are either entirely new or are made more frequently.

Section 2 details the work which has been conducted to analyse the response to particular road construction schemes, this is largely but not exclusively made up of before and after measurements of traffic flows. Section 3 reviews the more diverse work which is not specific to any particular scheme; this work is concentrated on the modal diversion and departure time aspects of user response. Section 4 presents an overview of the literature on land use/ development effects. The final section draws together the available evidence on the scale of each of effects 1-5 above. Of these, trip re-timing is found to be of high importance, especially in the context of urban trips.

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The views expressed in these reports do not necessarily reflect those of TRRL or the Department of Transport.

Reports in the series are:

The Feasibility of Measuring Responses to New Highway Capacity (by Bonsall PW). TRRL Contractors Report No CR200, due early 1990.

Travellers Response to Road Improvements: Implications for User Benefits (by Mackie PJ and Bonsall PW). Traffic Engineering and Control 30 (9), 1989. Note that this paper was prepared in advance of the TRRL contract.

User Response to New Road Capacity: A Review of Published Evidence (by Pells SR). ITS Working Paper 283, 1989.

Sample Size Determination to Evaluate the Impact of Highway Improvements (by Fowkes AS and Watson SM). ITS Working Paper 282, 1989.

Measuring Impacts of New Highway Capacity: A Discussion of Potential Survey Methods (by Bonsall PW). ITS Working Paper 289, 1989.

Evidence on Ambient Variability and Rates of Change (by Watson SM). ITS Technical Note 257, 1989.

Application of Stated Preference Methods to User Response to New Road Schemes (by Bates J and Wardman MR). ITS Technical Note 258, 1989.

Some Observations on Appropriate Time Scales, Siting and Location of Surveys and on the Use of Panels to Measure Responses to Highway Improvements (by Goodwin PB and Jones PM of TSU, Oxford). ITS Technical Note 259, 1989.

User Response to New Road Capacity: What The Experts Said (by Bonsall PW, Mackie PJ and Pells SR). ITS Technical Note 260, 1989.

Calculation of Costs of Surveys to Measure User Response to New Road Capacity - Worked Examples for Typical Schemes under Alternative Survey Strategies (by Bonsall PW). ITS Technical Note 261, 1989.

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1. INTRODUCTION

1.1 Data Sources

This paper presents a review of published evidence on user response to new highway capacity with a particular emphasis on that relating to urban schemes.

The main source of references for the review was expected to be a search of IRRD titles carried out by TRRL using keywords as follows:

- (Road scheme/road improvement/new capacity/new road/highway investment/ highway improvement/highway scheme/new highway) + (response/behaviour/traffic /impact).
- (Generated traffic/fixed matrix/variable matrix/peak narrowing/peak spreading/ time of day).
- (Budget/landuse/forecast/prediction/generation/distribution/modal/category/ classification/interaction). This group, from within the traffic, traffic theory and traffic planning files, having been specified by Mr J Downes of TRRL in the context of other work but forwarded to us for information.

In practice, however, most of the evidence was instead traced through previous reviews (by Allard, 1987; Bonsall, 1985; and Wilcock, 1988).

Most of the evidence referred to is derived solely from traffic counts with very little information having been published using data from roadside or household interviews. some of the interpretation of original data is quite controversial and is open to alternative interpretation - we have attempted to highlight such situations.

1.2 Background

The project of which this review forms a part was concerned to establish the feasibility of measuring responses to new highway capacity including:

1 - reassignment (local and "wide area")
2 - redistribution
3 - change of mode
4 - retiming of trips
5 - increased frequency (including entirely new trips).

It was conducted against a background of standard practice whereby only in wholly exceptional circumstances does scheme appraisal take account of effects other than local reassignment.

1.3 Structure of the report

The evidence is presented in 3 parts:

- analyses of response to identified schemes (primarily based on before-and-after measurements of flow)
- analyses of a more general nature not related to specific schemes (with particular emphasis on evidence on modal diversion and choice of departure time)
- analyses of land use and development effects.

A concluding section then draws together evidence relating to the effects 1-5 above.

2. SCHEME-SPECIFIC STUDIES

2.1 Urban roads

The number of detailed studies of the user response to new urban roads is very limited; however a number of interesting studies have been carried out by the GLC in the mid-1980's, a detailed account of which now follows. This section draws on the work of Purnell (1985) and Beardwood and Elliot (1985). The roads selected for study were as follows:-

(1) A40 Westway
(2) M11
(3) A316 (M3-A312)
(4) Blackwall Tunnels
(5) M25 (A1(M)-M11)

A general picture of the location of these schemes is provided in figure 1.

2.1.1 A40 Westway

Westway, is 2.5 miles of elevated 2/3 lane dual carriageway from the Old Westway (A40) at White city to just west of Marylebone Flyover at Paddington. The road, first opened in July 1970 has undergone a number of improvements since the late 1970's

A before and after study was conducted in May and September/October 1970 to test the initial effects of the road. A control corridor was also studied based on Finchley Road, a north south radial leading into central London. The results are summaried below

Table 1: 24 hour traffic flows before and after opening of Westway.

	Before	After	Change
Westway	123,500	141,000	14%
Fingley Road	127,200	129,200	2%

Source: Purnell 1985.

On Westway itself, 24 hour flow was estimated as 46,900 two to three months after opening. Purnell suggests that 63% of this can be described as re-assigned from the other roads in the corridor and that the remaining 37% is due to a combination of effects 1-5. Table 2 gives the inbound flows for the morning peak hour.

Table 2 AM peak inbound flows before and after opening of Westway

	Before	After	Change
Westway	4,670	5,830	+25%
Fingley Road	5,770	6,150	+6%

Source: Purnell 1985

Purnell explains the higher observed increase in the peak hour as the result of switching from rail to car.

The longer term effects are summarised in tables 3 and 4 below. Here, a further control corridor was introduced, that of the Old Brompton Road Corridor (see figure 1).

Table 3 24-hour 2-way flows in the Westway, Fingley Road and Old Brompton Road Corridors.(000's of vehicles).

Corridor	1969	1970 Before	1970 After	1972	1975	1978	1981	1984
Westway	85.2	94.9	126.3	151.8	170.3	166.6	181.4	177.8
Finchley Road	90.7	102.8	104.3	99.9	101.8	112.9	114.8	112.9
Old Brompton Rd	131.4			138.9	133.3	148.2	148.1	138.9

Source: Purnell 1985

The change in 24 hour flows from May 1970 to 1984 was 87% for Westway Corridor and 10% for Finchley Road Corridor (re-assignment and effects 1-5). The change from Sept/Oct 1970 to 1984 was 41% for Westway Corridor and 8% for the Finchley Road Corridor. During this period the traffic on Westway itself grew by 93%, on Finchley road it was 18%. At a slightly higher level detail, Purnell estimates that of the 85,100 vehicles using Westway itself in 1975, 24% was re-assigned and the remaining 76% was due to effects 1-5.

The level of traffic growth demonstrated here is clearly significant (and well above the national trend between 1970 and 1975) providing a clear demonstration of the potential for traffic growth as a result of new road capacity; however, the level of detail in the data is insufficient to provide more than a very general assessment of from where this traffic had originated.

2.1.2 A316 (M3-A312)

This is a major radial route in South-west London with the section in question being 3-lane dual carriageway (formely dual 2-lane). The widening was completed slightly after the construction of the M3 from Camberley to Sunbury in 1975/76. North of the junction of the A316 with the A312, the road becomes 2-lane dual carriageway. The M4 was selected as the contol corridor, this being in the same general area with similar characteristics as the A316 (figure 1).

Counts had been taken at 3-yearly intervals from 1971 to 1983; the data is summarised in table 4 below.

Table 4: 24 hour two-way flows in the A316 and M4 corridors.

	1971	1974	1977	1980	1983	Change 1971-83
A316 Corridor	52,856	60,055	86,785	94,317	97,413	84%
M4 Corridor	70,153	90,895	103,516	118,392	116,391	66%

Source: Purnell 1985

As can be seen, traffic has greately increased in both corridors over the period. Traffic growth on the A316 itself over the period was 218%. Purnell finds no evidence of re-assignment. The results for inbound peak hour traffic are given in table 5.

Table 5: AM peak inbound flows

	1971	1974	1977	1980	1983	Change 1971-83
A316 Corridor	6,994	9,288	13,655	14,578	14,481	107%
M4 Corridor	11,410	16,145	16,426	19,611	16,135	41%

Source: Purnell 1985

Again dramatic growth is observed, this is especially so for the A316 itself where flows are up by over 300%. Purnell suggests that land use effects may be the dominant factor behind this growth. West London, and Heathrow airport in particular are areas of high development in this period.

2.1.3 <u>Blackwall Tunnels</u>

These two tunnels, each providing for traffic moving in one direction are located in east London. The northern approach to the tunnels links the A102(M) at Bow, and the southern approach joins the A2 at Shooters Hill. One tunnel was built at the end of the last century and a second was opened in 1969 along with the southern approach to Shooters Hill. In 1971/72 improvements to the northern approach were completed.

This analysis was concerned with studying the effect of the change in capacity caused by the opening of the new tunnel and approaches on the crossings themselves and on the other Thames crossings nearby including Tower bridge, Rotherhithe and Dartford tunnels. The corridor was therfore defined to include these crossings. The control corridor was located in west London and centred on Kew bridge. This encompasses all the crossings from Richmond bridge to Hammersmith Bridge. This traffic here includes that from the M3 (see figure 1).

The initial effects of the new Blackwall tunnel are summarised in the following table.

Table 6: Peak period traffic flows in the Blackwall tunnel corridor.

	AM PEAK (0700-0900) NORTHBOUND HOURLY FLOWS			PM PEAK (1700-1900) SOUTHBOUND HOURLY FLOWS		
	1968	1969	CHANGE	1968	1969	CHANGE
Tower Br	1,510	1,400	-7%	1,368	1,504	10%
Rotherhithe Tu	1,033	1,055	2%	969	990	2%
Blackwall Tu	1,287	2,648	106%	1,166	2,376	104%
Dartford Tu	1,114	1,012	-9%	1,030	960	-7%
Total	4,944	6,115	24%	4,533	5,830	29%

Source: Purnell 1985

Morning peak flow through the Blackwell tunnel more than doubled over the 1 year period; changes in traffic at the other crossings were unsubstantial and show no clear pattern suggesting no significant re-assignment. The overall increases in cross river traffic were 25% and 19% for the morning and afternoon peaks respectively.

Data for 12 hour counts shows a similar pattern with a 42% increase in flow at Blackwall tunnel and the slight increases at Tower bridge and Rotherhithe dampened by a reduction at Dartford tunnel. Again no significant re-assignment was identified. In addition, Purnell rejects the idea that the effects are due to any major modal diversion since only 5 buses in each direction served the Blackwall tunnel per hour, and only one rail crossing was in existence.

He therefore concludes that a major proportion of the increased flow, especially in the peak is entirely new, and possibly attributable to a pool of supressed demand for travel across the Thames which had been identified in the peak (GLC 1969).

With regard to the longer term effects of the crossings, table 7 summares data on 24 hour two-way flows. Traffic doubles in the Blackwall Tunnel corridor between 1962 and 1972 and then increases at a slower rate; a similar though less well defined trend is also observed in the control corridor. Peak flows are given in table 8.

Table 7: 24 hour 2-way flows in the Blackwall Tunnel and Kew Bridge corridors

	1962	1972	1982	CHANGE 1962-82
Blackwall Corridor	66,000	133,000	167,000	153%
Kew Corridor	125,000	171,000	205,000	64%

Source: Purnell 1985

Table 8: AM peak hour two-way flows in Blackwall Tunnel and Kew bridge corridors.

	1962	1972	1982	CHANGE 1962-82
Blackwall Corridor	6,300	11,110	12,990	106%
(excl Blackwall Tu)	6,300	8,860	9,430	50%
Kew Corridor	13,600	15,230	14,710	8%

Source: Purnell 1985

It can be seen that there was a large increase in Blackwall Tunnel traffic beween 1962 and 1972 (188%). Comparing the increase in the two corridors, a marked difference is apparent with growth in the control corridor only about 1/13th of that in the Blackwall tunnel corridor.

2.1.4 A406 North Circular Road (Hanger lane to Falloden Way)

This road links the M4 in Gunnersbury to the A104 in North-east London and represents a major northern orbital route within greater London joining all major radial route in existence at the time of the study (1985). The section of the road studied had been subject to two major road schemes, the Neasden Lane underpass (completed in 1973) upgrading the junction between Neasden Lane and the North Circular Road, and the Staples Corner flyovers at the junction of the A5 and the A406 (completed in 1975). In 1976 the M1 extension was opened. No control corridor was used in this study for reasons of practicality.

Table 9 gives the peak hour flows on the Neasden Lane to Staples Corner section of the North Circular Road. This data was collected by the London Borough of Brent.

Table 9: Peak hour flows on NCR (Neasden lane to Staples Corner).

AM Peak	1972/3	1975/6	1978/9	1981/2	CHANGE 1971/2-1981/2
Westbound	1,300	1,500	3,600	3,400	162%
Eastbound	1,100	1,400	2,200	2,400	118%
Two-way	2,400	2,900	5,800	5,800	142%
PM Peak					
Westbound	1,400	1,600	2,200	2,100	50%
Eastbound	1,400	1,400	2,800	3,100	121%
Two-way	2,800	3,000	5,000	5,200	86%

Source: London Borough of Brent

Dramatic increases in peak flow are evident on this stretch of the NCR West of Staple Corner with the largest increases occurring between 1975/6 and 1978/9 after completion of the Staples Corner junction and the extension of the M1 to the NCR. During the AM peak two-way flow had doubled (33% growth per annum), and in the PM peak it had increased by two thirds (22% per annum).

Purnell also noted the marked changes in directional flow illustrated in table 9, particularly after the opening of the Staples Corner junction. In 1978/9 AM peak westbound traffic flows were 64% higher than eastbound flows. In the PM peak eastbound flows were 27% higher than westbound flows. Purnell notes that this tidal pattern is typical for London and concludes that much of the increased flow on the NCR is due to new radial traffic originating from the M1 and seeking alternative routes to reach inner or central London.

An analysis of changes in radial and orbital traffic was also conducted, the results are presented in the following two tables:-

Table 10: 24-hour two-way flows on radial routes in outer north-west London

	1975/6	1977/8	1981/2	CHANGE 1975/6-1981/2
A40	72,200	70,300	81,400	13%
A404	31,500	33,300	33,300	6%
A4088	46,300	33,300	44,000	-5%
A5	30,500	33,300	31,500	3%
M1	-	48,100	46,250	-
A41	64,750	61,050	72,150	11%
A502	24,050	25,900	22,200	-8%
A1	42,550	42,550	35,150	-17%
A598	27,750	29,600	27,750	0
Total	339,600	377,400	393,700	16%

Source: GLC Traffic Monitoring programme.

As Purnell notes, the completion of the M1 extension and Staples Corner has resulted in a large rise in flow on the radial routes which join the NCR from outer north-west London (table 10). Despite some falls in flows on the other radial roads there has been very little re-assignment of traffic to the M1. He concludes that the schemes had resulted in large volumes of traffic being generated, the vast majority of which was probably traffic making a radial movement.

Table 11 shows flows taken at 3 screen lines drawn in a broadely east-west direction approximately parallel to the radial routes in the corridor (see figure 2). Again we see increases on the NCR after completion of the Staple Corner and M1 schemes, but what is also interesting is the fact that flows had tended, generally speaking, to increase on the other orbital routes as well. The absence of evidence of significant re-assignment here leads Purnell to strengthen his conclusion that the increases in flow are largely due to traffic performing a radial movement.

Table 11: 24-hour two-way flows on NCR and alternative orbital routes

	1972/3	1975/6	1978/9	1981/2	CHANGE
Screenline A					
NCR	62,900	53,650	72,150	74,000	18%
Greenford Road	25,900	22,200	31,450	31,450	21%
Victoria Road	18,500	18,500	18,500	18,500	0
Total	107,300	94,350	122,100	123,950	16%
Screenline B					
NCR	53,650	53,650	74,000	72,150	34%
East Lane	20,350	20,350	27,750	25,900	27%
Church Road	20,350	18,500	18,500	18,500	-9%
Total	94,350	92,500	120,250	116,550	24%
Screenline C					
NCR	57,350	49,950	79,550	66,600	16%
Kingsbury Road	22,200	24,050	24,050	27,750	25%
Church Lane	12,950	16,650	12,950	12,950	0
Total	92,500	88,800	116,550	107,300	16%

Source: GLC traffic monitoring Programme.

Purnell also studied traffic flow to the east of Staples Corner to gain a more complete picture of the effects of the schemes; table 12 gives the results for 24-hour flows on the NCR to the east of Staples Corner.

Table 12: 24-hour two-way flows on NCR east of Staples Corner

Section of A406	1975/6	1978/9	1981/2	CHANGE
Staples Corner - A41	46,250	86,950	98,050	112%
A41-A502	49,950	62,900	66,600	33%
A502-A1	49,950	62,900	62,900	26%
A1-A598	85,100	88,800	98,050	15%
East of A598	85,100	86,950	86,950	2%

Source: GLC Traffic Monitoring Programme.

The section of the A41 immediately to the east of Staples Corner has experienced high growth since the opening of the flyover junction and the M1 extension although the increases generally are lower than those observed to the west of Staples Corner.

Finally, Purnell presents flows on all the major radial roads leading from the A406 to inner and central London (table 13).

Table 13: 24-hour two-way flows on radial routes in inner north-west London.

	1975/6	1978/9	1981/2	CHANGE
A40	75,600	72,200	79,600	5%
A404	25,900	27,800	25,900	0
A4088	48,100	27,800	46,300	-4%
A5	27,800	27,800	27,800	0
A41	59,200	64,750	72,150	22%
A502	20,350	25,900	25,900	27%
A598	27,750	29,600	25,900	-7%
Total	284,700	275,850	303,550	7%

Source: GLC Traffic monitoring Programme.

The table shows that the greatest increases in flow occurred on the A41 and the A502. Given the high increases in flows on the A406 between Staples Corner and the A502, Purnell concludes that a significant proportion of the traffic using the M1 extension is continuing its journey on the A41. This in turn appeared to have displaced some traffic from the A41 to the A502.

2.1.5 <u>M25 (A1(M)-M11)</u>

Evidence on the M25 motorway is provided by Purnell 1985 (also reported in Beardwood and Elliot 1985), and Evans et. al. (1986). The latter study provides some interesting data on the early evidence that traffic flows on the M25 would exceed those forecast. Table 14 reproduces their analysis of forecast versus actual flows on different sections of the road.

Of the 14 sections of the motorway for which latest flows were available, the flows on only 3 were within their original forecast; in 8 cases the actual flows in 1986 were 10% higher than the original high growth forecast for 1987. Evans et. al. (1986) provide no explanation of why these flows should be at such levels.

Purnell examined traffic on two stretches of the M25, the north and north-east sections. These are represented by the North Orbital Road (later incorporated into the M25) in 1975, completing a section of the motorway that linked the A1(M) to the A10 (figure 3). This stretch of road stood isolated until a section running from the A10 to the M11 was finished, creating an unbroken stretch from the A1(M) to the Dartford Tunnel by early 1984 (the last 8 sections of table 14). Table 15 shows the changes in 12-hour traffic flows at the northern screen line over a 10 year period.

Table 14: Forecast flows on M25 original, updated and actual (flows in 000's)

Section	Original Forecast	Updated 1984	Measured Flow 1986	Measured as % of Original Forecast
A225-A2	55-75	61-80	-	-
A2-M20	55-70	61-74	-	-
M20-A21	50-60	56-64	41	82-68
A21-M26/A21	50-60	56-64	51	102-85
M26/A21-A22	50-60	56-65	65	139-100
A22-M23	50-65	56-69	72	144-111
M23-A217	50-65	56-64	-	-
A217-A243	40-50	44-53	69	173-130
A243-A3	45-55	50-58	72	160-130
A3-A320	55-75	61-80	87	158-116
A320-M3	60-80	72-85	100	167-125
M3-A30	60-75	67-80	-	-
A30-Airport spur	70-80	78-85	-	-
Airport spur-M4	70-80	78-85	-	-
M4-M40	60-85	67-69	87	145-102
M40-A412	55-60	61-64	71	129-118
A412-A404	55-65	61-69	-	-
A404-A405	65-75	72-80	-	-
A405-A41	45-55	50-58	NOT OPEN	-
A41-M1	45-50	50-53	NOT OPEN	-
M1-A6	30-35	33-37	NOT OPEN	-
A6-A1(M)	40-50	44-53	NOT OPEN	-
A1(1M)-A111	50-55	56-58	-	-
A111-A10	40-45	44-48	-	-
A10-A121	45-50	50-53	58	129-116
A121-M11	50-60	50-60	56	112-93
M11-A12	50-60	56-64	-	-
A12-A127	35-40	39-42	-	-
A127-A13	35-40	39-42	58	166-145
A13-Dartford Tunnel	50-60	56-64	64	128-107

Source: Evans, Lee, and Sriskandan 1986

Table 15: 12-hour (0700-19000 two way flows at the Northern Screenline (000s vehicles (0700-1900)

	1974	1976	1987	1980	1982	1984	CHANGE+
Central area	223	221	240	227	232	240	8%
Inner area	68	83	73	101	101	114	68%
Outer area	153	148	160	172	164	166	8%
External area (incl M25)	9	18	21	26	32	55	511%
Total	453	470	484	526	529	575	27%
M25	-	12	14	18	25	41	242%*
A406	30	28	32	32	31	32	7%

+% change 1974-84
*% chance 1976-84

Source: Traffic monitoring review 1984, GLC.

A 27% growth in total traffic crossing the screenline is observed. Whereas all areas had experienced growth, this was much surpassed by that in the external sector (area including and beyond the perimeter of the M25). It is clear from the evidence contained in the table that flows on the M25 have grown at a higher rate to London as a whole. In order to assess where the increase in traffic is coming from Purnell considers flows on the major alternative orbital route, the A406. Table 15 shows that from 1974 to 1976 traffic flows on the A406 fell by 2000 vehicles. Traffic on the M25 increased by 12,000 vehicles over the same period. From 1976 to 1987 traffic on the A406 grew by 4000 vehicles, then remained fairly constant throughout the remainder of the study period. On the other hand, traffic on the M25 grew at an increasing rate throughout the whole period 1976 to 1987. The obvious conclusion reached is that very little of the traffic on the M25 could be explained by re-assignment from the A406.

Evidence is also provided by the GLC and Hertfordshire County Council on roads north and south of the M25 at the river Lea screenline. Before counts were taken in November 1983 with the after counts some 3-4 months later, the results which are seasonally adjusted, are given in table 16 below.

Table 16: 12-hour (0700-1900) two way flows at the river Leas screenline before and after opening of the M25 (A10-M11)

	BEFORE	AFTER	CHANGE
A414	13,416	9,766	-26%
B181	2,735	2,501	-9%
Essex Road	7,550	7,076	-6%
B194	9,427	8,453	-10%
A121	23,721	17,850	-25%
A110	20,418	16,672	-18%
A406	43,801	39,755	-9%
A503	25,381	24,263	-4%
A102	53,397	50,140	-6%
SUB-TOTAL	199,576	176,476	-12%
M25 (A10-A121)	-	40,487	-
GRAND TOTAL	199,576	216,963	9%

Source: GLC/Hertfordshire County Council

Beardwood and Elliot (1985) also presented this evidence. Discussing the results, they concluded that major road improvements had the effect of generating traffic such that the total traffic in the area increased, whilst the traffic levels on the roads which the scheme was intended to relieve were not greately affected. Moreover, they argue that the results imply that traffic growth in the counterfactual would have been minimal.

The data presented by Purnell and Beardwood and Elliot is not, however, conclusive. The results obtained are constrained by the definition of the corridors in such a way that traffic which appears to have been either redistributed or generated may actually be the result of wide area re-assignment, with corresponding reductions in adjacent but unmonitored corridors.

Street (1985), in a response to this work agreed on the issue of the generating characteristics of roads but argued in addition, that where the primary purpose of a new road is to relieve congestion on existing roads, then any potential traffic generation can be contained by reducing the traffic carrying capacity of existing roads. The capacity of the corridor is therefore not increased by as much as that of the new road. This counters any costs which might otherwise be incurred in terms of costs to public transport users created by modal diversion to car. He also argues that where generation is a result of local economic development which has been stimulated by the road the case for abandoning road building schemes is weaker.

Allard (1987), also commenting on the work of Beardwood and

Elliot (1985) and Purnell (1985) states that work of neither study is definitive. He suggests that there is a need for a study of the motorway as a whole in order to analyse the wider network effects of the scheme. Further, he suggests that an explanation for the higher than expected flows on the road may be partly due to the fact that the other ring roads which were originally planned to accompany the M25 were not built.

2.1.6 East London River Crossing

Beadwood and Elliot (1985) report the results of an exercise to predict the effects of the east London river crossing (ELRC) on traffic flows. They use the GLC's strategic transport model (STEM) (see, for example, Beardwood undated) to study the effects of ELRC on northbound flows across the Thames. The exercise predicts that ELRC fills up without giving any significant relief elsewhere on the network (see figure 4).

2.1.7 The Rochester Way Relief Road (RWRR)

The Rochester Way Relief Road was opened in March 1988 and is a major new radial route in south east London, designed to relieve heavy congestion on a residential road (Rochester Road) and joins the A2 which carries traffic from the Blackwall Tunnel (see figure 1). In this study, carried out by ITS, pre-paid questionnaires were distributed to drivers joining the Road at the Shooters Hill junction from 1400 to 1700 on Monday July 11th 1988. A total of 770 questionnaires were distributed of which 184 were returned, a response rate of 24%. The questionnaire asked about the trip that drivers were in the course of making when given the form, and in particular, how the introduction of the RWRR had affected their behaviour viz that trip (if indeed it had been previously undertaken at all). The study was aimed at identifying the following elements of response, re-assignment, redistribution, re-timing, modal diversion and generation, (induced and new trips). The composition of traffic identified is presented in table 17 below.

Table 17: User response to the RWRR.

Classification	Number	Percent
Reassigned	178	96.7
Redistributed	6	3.3
Modal diversion	5	2.7
Re-timed All	44	23.9
Re-timed earlier	3	1.6
Re-timed later	41	22.2
Generated	18	9.8

Source: Wilcock 1988

As can be seen, nearly all traffic is reassigned since no new trips were recorded and redistributed trips only accounted for 3% of trips. A significant number of trips had been re-timed, mostly having been put back as a result of the road. About 1 in 10 stated that as a result of the road they now made the trip in question more often than before.

2.1.7 Tay Road bridge

Finally, Gillhespy (1968), in a study of the Tay Road bridge, estimated using a simple gravity model formuation, that traffic generated by the scheme would add and extra 48% to flow. In the event no appreciable generation was identified when traffic counts were taken a year after the bridge was opened. Gillhespy noted that generated traffic may take some time to build up.

2.2 Inter-urban road schemes

Studies of the generating effects of inter-urban schemes in this country have concentrated on large scale projects such as motorways (Judge 1983, Purnell 1985) and estuarial crossings (Tuckwell et. al. 1985, Cleary and Thomes 1973). Available evidence from schemes abroad seems to be primarilly concerned with the trip re- timimg effects of schemes, this is discussed in section 2.4 below.

2.2.1 Inter-urban Motorways

2.2.1.2 The M62

The first such scheme to be analysed in detail for its traffic generating effects was the M62, a trans-pennine motorway linking Lancashire with Yorkshire, 107 miles long and completed in 1963. Judge (1983) presents an analysis of the traffic generating effects ofthe motorway at two levels, at the level of aggregate flows across the Pennines before and after opening of the road, and by using traffic modelling techniques to analyse and disaggregate by zone to attempt the identification of re-distributed and generated traffic.

The measure of generation used is a catch-all one including re-distribution and modal diversion. The generation measure is calculated relative to an estimate of traffic flow in the counterfactual based on an extrapolation of the 1970 flow using the nationally based Traffic Index for Rural Roads in Great Britain (DTp, various years).

As can be seen from table 18, the M62 experienced rapid growth in traffic flow but this was largely re-assigned from the surrounding corridors. Between 1970 and 1977 total traffic crossing the screenline rose by 34.3%, whilst traffic on the M62 itself increased by 91%. Although the total flow crossing the screenline was greater than that expected without the M62, the difference was small, varying between 1% and 13% of that expected. Within the change, the M62 corridor showed the most marked growth with gains of more than 50% of the expected flow. This was counterbalanced however by the losses in the adjacent corridors.

By expressing the generation as a percentage of the flow on the M62, a maximum of 18.8% in 1976 is obtained; the change was less than 15% in other years. The overall effect on traffic flow therefore appeared to be quite modest.

Table 18: Transpennine screenline: weekly traffic flows (2-way in 000's) 1970-77

Corridor	1970	1971	1972	1973	1974	1975	1976	1977
Northern	168.9	173.0	176.3	163.7	161.7	164.2	161.9	158.9
Counterfactual	168.9	178.8	187.3	201.5	198.7	201.9	207.5	210.8
% generation	0	-3.2	-5.9	-18.6	-18.6	-18.7	-22.0	-24.6
M62	-	43.1	174.0	179.4	195.6	285.8	286.2	286.7
Others	205.7	172.6	112.8	100.8	121.3	102.9	102.9	106.2
Total	205.7	215.7	286.8	280.2	316.9	388.7	389.1	392.9
Counterfactual	205.7	217.8	228.2	245.5	242.0	245.6	252.7	256.8
% generation	0	-1.0	25.7	14.1	31.0	58.3	54.0	53.0
Southern	69.6	70.0	55.1	50.3	49.5	42.3	48.6	44.6
Counterfactual	69.6	73.7	77.2	83.1	81.9	83.2	85.5	86.9
% generation	0	-5.0	-28.6	-39.5	-39.6	-49.2	-43.2	-48.7
All corridors	444.2	458.7	518.2	494.2	528.1	594.2	599.6	596.4
Counterfactual	444.2	470.3	492.7	530.1	522.6	530.7	545.7	554.5
% generation	0	-2.5	5.2	-6.8	1.1	12.0	9.9	7.6

Source: Adapted from Judge 1983
Notes to table 18: corridor composition. Northern A59, A65 A629; southern A635, A6024, A628

A novel aspect of this study is the attempt to identify the different components of user response using traffic modelling techniques. Judge defines a 4 stage methodology which we reproduce here. The aim is to fit models to the 1970 O-D data to allow the subsequent disaggregation of the 1973 O-D data, The 4 steps are:-

1) Calibtrate a trip distribution model on the 1970 screenline origin destination matrix and netweork

2) Inflate the matrix for 1970 (derived from the distribution model results) and inflate this to 1973 using a secular growth factor but

assuming the M62 has not been built.

3) Using the onal trip attractions and generations from stage 2, plus an inter-onal time matrix obtained from a model of the 1973 network with the M62 in being, an inter-onal trip matrix is synthesised which incorporates the re-distributive effects of the M62.

4) The matrix produced in stage 2 can be loaded to the 1973 network to see what the predicted cross-screenline flow will be. This can be compared with the observed flow allowing some analysis of the change in flow into redistributed and generated traffic.

Further details of the method are given in Judge 1983 where the problems of implementation are also discussed. The overall prediction gained from this analysis was 63,000 trips on the 1970 network becoming 64,000 in the counterfactual with the 1973 network. This compared with a trip rate of 75,000 trips actually observed in 1973. Judge therefore sought a prediction within the range 64,000 to 75,000 (ie. a prediction of 70,000 would have implied 6,000 redistributed trips and 5,000 generated trips). Unfortunately the method predicted 120,000 trips. Judge concluded that the method required further development and suffered in particular from the problems associated with the use of the partial matrix method. This requires that the observed element of the matrix be representative of the matrix as a whole, a condition which was not satisfied in this case. He concludes:-

"Overall, the modelling process has not developed sufficiently to tell us much more about the likely relationship between traffic impact and economic impact than we could already infer from the general data previously presented" (ie. in table 18) (Judge 1983)

2.2.1.2 <u>The M11</u>

This represents the final scheme investigated by Purnell (1985) and concerns a stretch of road between Redbridge in north east London to the A604 west of Cambridge. The road was completed in two stages in 1978 and 1980. The change in flows for both 24-hour 2-way flows and AM peak inward bound flows are given in table 19.

Again we observe increases in flow on both the new road and control corridors with especially large effects in the peak. Purnell suggests that 26% of the peak and 29% of the 24 hour flows can be explained by re-assignment, the rest is due to other effects. He also shows that there was a fall in rail travel from towns served by the M11 whereas in towns further away rail travel had increased (see Purnell 1985 ap[pendix 4). This leads him to conclude that a proportion of generated traffic is due to modal diversion. He also cites re-distribution as a possible effect since the M11 was an entirely new road; he offers no hard evidence on the matter however. Finally he notes that the A10 which also serves the route of London to Cambridge but which lies outside the study corridors experienced an increase in flow of 75% between 1974 and 1983.

Table 19: Changes in flow in the M11 and A23 corridors 1974-1983

	1974	1977	1980	1982	CHANGE
(A) 24 hour 2-way flows					
M11	100,556	106,314	127,970	138,357	38%
A23	63,866	77,724	71,730	82,209	29%
(B) AM peak inbound flows					
M11	14,020	14,861	19,757	21,858	56%
A23	7,739	10,085	9,736	10,257	33%

Source: GLC monitoring programme 1984

2.2.1.3 The York northern bypass

This scheme was completed in December 1988, forming the final section of an orbital ring road around the city, and complementing the already completed southern bypass. This study composed of both roadside interview and postal questionnaires. In this section we present a summary of the results from the York study. A fuller analysis is given in Wilcock (1988).

(i) Roadside interview results.

Traffic was interviewed in both directions over the period 0700 to 1900 on a typical weekday. A total of 2,294 interviews were undertaken from a flow of 13,200 vehicles giving a sample rate of 17.4%. The information gained by the interview will be discussed at a later in the project.

It was possible, in the interview stage to form an estimate of the amount of traffic generation (new and induced traffic). Drivers were asked firstly, how often they used to make the trip between their stated origin and destination before the bypass was opened, and secondly, how often they made the trip now.

The relevant time horizon was taken to be 90 days, a period similar to that in which the bypass had been opened. A response of "once a week" was therefore given a value of 13 trips. Using this simple method it was possible to obtain estimates of the mean increase in trip frequency. Table 20 gives the both the adjusted and unadjusted estimates for all travellers, and for peak and off peak travellers.

Table 20: Estimates of the mean increase in trip frequency for 12-hour 2-way flows.

Sample	Mean generation	Variance	N
All	8.14	415.8	2220
Peak	11.34	596.7	332
Off-peak	7.58	382.15	1888

Source: Pells 1988

On average, drivers were found to be making 8 trips per three month period more than they did before the bypass was opened. Generation is found to be significantly higher for those interviewed at peak times (0700-0900, 1600-1800) than for those interviewed off peak. No significant difference was found between the estimates for the two directions of traffic.

(ii) Components of traffic from questionnaire results.

As can be seen from table 21, generated trips account for nearly 1 in 8 trips and there are also small amounts of re-distribution and modal change. More marked is the amount of trip re-timing with nearly 30% of trips re-scheduled since the bypass was opened. Of these re-timed trips the vast majority are made up of later departures reflecting quicker journey times via the new road.

Table 21. Components of traffic on York Northern bypass.

Classification	Number	Percent
Re-assigned	348	89.9
Redistributed	22	5.7
Modal diverted	10	2.6
Re-timed All	115	29.7
Re-timed earlier	104	26.9
Re-timed later	11	2.8
Generated	46	11.9

Source: Pells 1988

2.2.2 Estuarial crossings

These rather exceptional investments in road infrastructure have been identified in the DTp's Tam and COBA manuals as likely to generate significant volumes of traffic in addition to that which is re-assigned; two such investments are discussed below.

2.2.2.1 The Severn bridge

A study of the effects of the Severn bridge was carried out by Cleary and Thomas (1973). The results of a survey carried out in 1967, a year after the opening of the bridge indicated that 56% of the traffic crossing the bridge had re-assigned, and the remaining 44% had been generated by the bridge, including 12% of total traffic whose drivers had simple travelled to see the bridge. Data for weekdays only suggested that 58% of traffic was generated, including a modal change away from rail of 4-5%

Gershuny (1978) also examined the effects on traffic of the Severn bridge. He reports that:-

" ...in ten of the eleven years for which statistics are available, the average yearly growth in use of the bridge was 3.7%. In the remaining year (1972) the growth was 24%. 1972 was the first year of operation of the London to Bristol motorway. Reference to a road map reveals that, with or without the motorway all traffic between London and South Wales must pass over the bridge, so the diversion of traffic from other routes is not a credible explanation for the phenomenon. The clear inference to be drawn is the completed motorway generated the extra traffic". Gershuny (1978)

2.2.2.2 The Humber bridge

The Humber bridge was opened in 1981 and took 9 years to build. Data from 1977, was grossed up to 1982, and compared with actual flow data collected in that year (Tuckwell et. al. 1985). In addition, predicted flows for 1981 were available. These assumed optimal tolls and no initial depression in flow due to a learning period in which information about the travel opportunities provided by the bridge was obtained. Comparing the grossed up 1977 flows with the measured flows provided an estimate of the generative and redistributive effects of the bridge. The "no learning" estimates illustrate the estimated redistributive effects of the bridge without any time lag; the data is presented in table 22.

The table shows two things, first, that there have been generative effects of the bridge in all cases (line 1 versus line 2), and second, that apart from Glanford, an area which was undergoing industrial development and had not reached equillibrium, the predictions were met or exceeded. Tuckwell et. al. also found that the bridge was important for business/work trips. Since throughout the study period the area was, in line with most of the country, experiencing a severe recession, this had implication for future traffic growth.

Table 22: O-D's from north to south bank of Humber bridge.

To/From		Year	Scun-thorpe	Glanford	Grimsby/ Clee-thorpes	Lincoln	Market Rasen
Hull	(1)	1982	180	47	210	82	4
	(2)	1982	339	567	849	192	72
	(3)	1981	389	1454	822	197	101
Beverley	(1)	1982	59	20	19	20	-
& East	(2)	1982	74	167	178	45	14
Yorkshire	(3)	1981	35	173	133	30	14
Holderness	(1)	1982	6	2	22	8	-
	(2)	1982	39	82	178	28	16
	(3)	1981	23	74	74	25	10

Source: Tuckwell et. al. 1985 Notes (1) 1977 grossed up flows (2) 1982 interview data (3) "no learning" estimates

2.2.3 American evidence

This section reviews work carried out by Smith and Schoener (1978) which aimed to refute claims that there exists a link between trip generation and road capacity changes. The authors set out to test the causal relationship between vehicle kilometers of travel (VKMT) and new road provision for trips by private car. They point to past evidence in the literature which had demonstrated a correlation between VKMT and aggregate road supply per capita (Koppelman 1970, Alan M. Vorhees and Associates 1971, Kopplelman and Shalkowitz 1972, and Berwager and Wickstrom 1972). They do this by analysing the trip inducing effects of a new road, (Interstate 95) in Providence, Rhode Island, USA.

The data sources for the study are household surveys, one conducted in 1961 before the road was built, and another carried out in 1971, after its completion. The authors reject the idea of simply comparing the gross travel statistics for the two periods because of the effect on these statistics of exogenous factors such as income growth and the rise in car availability over the period. Instead they offer a two stage methodology. First, the data sets are divided into two geographic areas, the area defined as inside the zone of influence of the road (the "IN" area), and the area outside this zone (the "OUT" area). Second, the resulting subsamples are classified according to household size and car ownership. It is argued that these precautions are sufficient to facilitate accurate comparisons of travel behaviour before and after the introduction of I95. No analysis of a possible relationship between the road and car ownership is undertaken.

The IN area was defined using a link analysis program, LINKUSE, which was run with a 1971 calibrated network and 1971 O-D (household) interview data. Given an origin zone, the program computes the number of trips originating in that zone that use a given set of links. It was therefore possible to estimate the origins of trips using any link on the I95.

Three measures of travel behaviour were used; car trips per household, VKMT per household, and vehicle hours of travel per household (VHT). Mean estimates for each measure were given, cross-classified by household size and number of cars per household and the following comparison were made:-

1961 IN Vesus 1971 IN
1961 OUT versus 1971 OUT
1961 IN versus 1961 OUT
1971 IN versus 1971 OUT

The authors argue that, in order to control for socio-economic effects it is changes in the matrices of estimates which are relevant, not the changes in individual cells. Setting the level of significance at 10%, the probability that one t-value in a set of 8 will be significant is given by the binomial distribution:-

$$^{n}C_{x}p^{x}(1 - p)^{n-x}, \text{ where } ^{n}C_{x} = n!/(x!\ (n-x)!)$$

Where n is the number of trial, p is the probability of success and x is the number of successes. This gives:-

$$\text{Bin}(0;8,0.1) = [8!/0!(8!)]\ (0.9)^{8}(0,1)^{0} = 0.430$$
$$\text{Bin}(1;8,0.1) = [8!/1!(7!)]\ (0.9)^{7}(0.1)^{1} = 0.383$$
$$\text{Bin}(2;8,0.1) = [8!/2!(6!)]\ (0.9)^{6}(0.1)^{2} = 0.149$$

The probability of obtaining 3 or more significant results from 8 tests is therefore:-

$$1 - 0.43 - 0.383 - 0.149 = 0.038 < 0.1.$$

This differs from the figure of 0.048 given by the Smith and Schoener. However they correctly conclude that with 8 trials up to 2 significant T-statistics may be generated within each matrix and the null hypothesis that there is no change between them cannot be rejected at the 10% level. Using this method the authors derive the following conclusions.

2.2.3.1 <u>Car trips per household</u>

Trips per household for 1961 IN are significantly smaller than 1971 IN data. The same is true for differences between 1961 OUT and 1971 OUT. The differences between trip rates inside and outside the zone of influence in the two periods are not significant however, suggesting, argue the authors, that the road was not responsible for the increased trip making.

2.2.3.2 VKMT per household

In 1961 there was significantly less VKMT per household inside the zone of influence than outside it. In 1971 there was no significant difference. The road had produced longer trips but not an increase in the number of trips

2.2.3.3 VHT

Both inside and outside the zone of influence, VHT had increased between 1961 and 1971, differences between the contemporaneous IN and OUT estimates were insignificant.

In addition to the many errors in the paper which may be due to poor editing, there are two fundamental areas of concern which need to be expressed about the methods and interpretation carried out by Smith and Schoener.

The first area concerns the decision to cross classify by household size and car ownership. By doing this the authors aim to reduce the effect of outside influences on the trip estimates, but this is only achieved at the expense of the reliability of the estimates produced. In fact the sample sizes in the cells for the 1971 data become very small in some cases as is demonstrated in table 23. Moreover, since strict adherence to statistical rules dictates that for sample sizes of below 30, the central limit theorum cannot be relied upon (unless the population variance is known or there are strong reasons to assume that the variable itself is normally distributed), then when comparing the 1971 IN data, only 7 tests can be carried out rather than 8, and when comparing the 1971 OUT data only 3 tests can be carried out. This has not been allowed for by the authors who appear to have carried out the significance tests regardless of sample size. The implications for significance are as follows:-
For 1971 IN

$$\mathrm{Bin}(0;7,0.1) = [7!/0!(7!)]\ (0.9)^7(0,1)^0 = 0.478$$
$$\mathrm{Bin}(1;7,0.1) = [7!/1!(6!)]\ (0.9)^6(0.1)^1 = 0.372$$
$$\mathrm{Bin}(2;7,0.1) = [7!/2!(5!)]\ (0.9)^5(0.1)^2 = 0.124$$
$$0.974$$

and for 1971 OUT

$$\mathrm{Bin}(0;3,0.1) = [3!/0!(3!)]\ (0.9)^3(0.1)^0 = 0.729$$
$$\mathrm{Bin}(1;3,0.1) = [3!/1!(2!)]\ (0.9)^1(0.1)^2 = 0.243$$
$$0.972$$

Where a comparison including 1971 out is carried out, 2 rather than 3 significant results represent a rejection of the null hypothesis. For comparisons including 1971 IN the criterion for significance remains the same as that cited by Smith and Schoener. As mentioned above, the authors conclude that there is significantly more VHT in 1971 OUT than 1961 OUT. In fact only one cell in the matrix (their table 7) produces a significant result; the matrices are therefore not significantly different.

The basic point here is that with such little data for the 1971 OUT respondents, such a cross classification is not useful. The attempt to allow for socioeconomic effects in this case is therefore not justified and tests on the full zone subsamples for the two periods might have more informative.

The second, and more fundamental area for concern relates directly to the comparisons themselves. It is not clear that the authors are making the correct comparisons between the data for the two periods. For example, as quoted above, Smith and Schoener find that VKMT is significantly less for 1961 IN than 1961 OUT but that this difference disappeared by 1971. This implies a growth rate of traffic inside the zone of influence which is greater than that outside the zone over the same period. Smith and Schoener acknowledge this but do not examine the implications fully. In fact it could be argued that rather than comparing the estimates of trip behaviour inside and outside the zone for a given year, as Smith and Schoener do, it would de more useful to analyse the relative growth of traffic between the inside and outside of the zone of influence over the period. Sufficient data is provided in the paper to facilitate the production of gross estimates of this nature for the three travel measures; these are included in table 24 below:-

Table 23: Sample sizes for Rhode Island study: Number of observations in each family size and car ownership Category

	No.of cars	No. of people		
		1	2-3	4+
1961 IN	0	637	792	188
	1	294	2404	1865
	2+	9	526	799
1961 OUT	0	248	295	110
	1	98	1263	1087
	2+	6	358	504
1971 IN	0	57	49	6
	1	41	153	45
	2+	2	116	100
1971 OUT	0	20	9	4
	1	10	57	25
	2+	2	61	66

Source: Smith and Schoener 1978

As can be seen from the table, the relative growth rates of the travel behaviour indicators tell a different story to the comparisons cited by Smith and Schoener. Trips per household for those inside the zone increased at nearly double the rate of trips outside the zone over the 10 year period. Moreover, VKMT increased by 70% inside the zone and only 40% outside the zone. VHT on the other hand, demonstrates a weaker trend with growth inside the zone apparently only slightly higher than that outside the zone. Perhaps this is an indication of an increase in journey speeds as a result of the new road. If this is so, the increase in VKMT could point to a redistribution of trips to between O-D pairs further apart.

The analysis presented in this section suggests that the authors' assertions that:-

> "Since the trip rate matrices for the two geographic areas inside and outside the control were equal at both points in time, the highway could not have been responsible for any increase in trip rates,.....,(and that),.....,it appears reasonable to assume that trip generation is indeed independent of the transport system" (Smith and Schoener 1978)

are clearly unjustified.

Table 24: Relative growth of traffic IN and OUT of zone of influence, 1961 versus 1971

Trip/houshold	Mean	Sample size
Trips per household		
1961 IN	2.36	(7505)
1971 IN	4.35	(567)
% increase	84.3	
1961 OUT	3.23	(3963)
1971 OUT	4.62	(252)
% increase	43.2	
Vehicle kilometers of travel per household		
1961 IN	185.71	(7505)
1971 IN	315.80	(567)
% increase	70.1	
1961 OUT	237.21	(3963)
1971 OUT	333.82	(252)
% increase	40.73	
Vehicle hours of travel per household		
1961 IN	29.18	(7505)
1971 IN	42.40	(567)
% increase	45.3	
1961 OUT	32.76	(3963)
1971 OUT	45.24	(252)
% increase	38.1	

2.3 The effects of schemes on time of travel

In this section, we present some findings concerning the effects of schemes on departure time choice and the associated issue of peak narrowing. The Hague consulting group (1986) conducted a review of the peak narrowing effects of transport schemes, some of the interesting findings of that review are detailed in Kroes (1987).

2.3.1 York

Dawson (1979) conducted a before and after study to evaluate the effects of the temporary closure of Lendal Bridge in York, a highly congested and important link in York's road network. One aspect of change of interest to the author was the effect of the closure on time of travel. To investigate this a postcard interview method was used with participants selected from the responses to roadside interviews carried out after the bridge had been closed.

From the postcard interviews estimates of the change in travel time and behaviour were obtained. Regarding travel time, the only significant change (at the 10% level) was an increase in am peak travel time from 21.3 minutes to 24.1 from a sample of 180 commuters. Regarding behaviour, "change in time of travel by more than 10 minutes" was the outcome for 24% of drivers. "Change of route" was the most important change being the outcome for 47% of drivers. Slight spreading in the distribution of departure times is also noted. Dawson further asked respondents about the degree of flexibility of their departure times, the results are contained in table 23 below.

Table 23: Inconvenience caused by a 10 minutes shift in departure time (before closure (after closure)

	EARLIER			LATER		
	Alot	Some	None	Alot	Some	None
am Commuter	13(10)	33(41)	54(50)	47(51)	25(28)	29(21)
pm Commuter	31(42)	26(17)	42(42)	22(12)	25(25)	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)

Source: Dawson 1979

The results for commuters are broadly in line with prior expectations with later departure causing more inconvenience in the morning and earlier more inconvenience in the afternoon. Shoppers and those on firm's business appear to have the highest degree of flexibility. This evidence of aversion to change in behaviour by commuters might have had a dampening effect on the peak spreading effect of the closure. However the author does not provide the necessary break-down of the sample by journey type for this assertion to be verified or rejected.

2.3.2 Edmonton Canada

In response to a bridge closure in downtown Edmonton in Canada, Stephenson and Teply (1984) found a significant smoothing in the morning peak. Number plate matching surveys were used to identify, among other effects, changes in time of travel before and after the closure of Kinnaird Bridge. The bridge was closed in the early summer of 1978 to facilitate work on network changes. The bridge was situated some 2 kilometers north east of the CBD and formed part of a major radial route. Before the bridge closure traffic in the vicinity of the bridge was highly peaked between 07:45 and 08:00. After closure observed traffic flow was almost constant throughout the period 07:15 to 08:00 after which it increased very slightly to 08:15 and then tailed off over the next 30 minutes before recovering. Using the number plate matching technique the number of drivers passing a checkpoint more than plus or minus five minutes of their before closure time was identified. The analysis showed that whereas about 60% of drivers travelled during the same time (+ or - 5 minutes) every day before closure, this fell to about 20% after closure. The authors claim that this is evidence of the importance of time of travel in trip decision modelling.

2.3.3 Other studies

Van de Hoorn et.al.(1985) found that the opening of a second river crossing at the Lek bridge near Vianen in Holland resulted in significant peak narrowing: over a quarter of the increase in traffic observed in the period 0700-0900 was attributed to re-timing with a similar proportion was due to modal diversion. The remaining half of trips were attributed to changes in route choice.

Kroes details a study by McKinsey which found a latent demand for car travel of approximately 27% of total volume for a dense Western portion of Holland. Over 40% of this latent demand was currently taking place other than at the desired time, and 11% by an alternative mode.

The existence of evidence of peak spreading in London is referred to in Daly et.al. (1985) but no details are given. Further evidence of the occurrence of peak spreading in Manchester is reported to be given in Stebbings (1988) but this paper is not available at the present time.

3. NON-SCHEME SPECIFIC STUDIES

3.1 The constancy of journey times to central London by road and rail: a discussion of the Mogridge conjecture.

Some debate is currently occurring in the literature over the reason for the observed equality of door to door morning inbound journey times in London between car and rail. This finding is coupled by the fact that average journey speeds in London have remained stable at 12 mph for many years. This section discusses the evidence of equality in journey speeds, and the alternative theories which have been put forward to explain both this equality and the stability of speeds over time.

Mogridge (1985), proposed that in situations of suppressed demand for road travel, and where there is a public transport system operating in parallel with the road system, then a mechanism exists which will cause road "improvements" to be counter productive.

Mogridge based his ideas on those of Downs (1977), Thomson (1977) and Wardrop (1952). Wardrop, writing on route choice, suggested that the travel speeds associated with any chosen route between a particular O-D pair would be equal, and less than that on any unused route. Replace the words "speed" and "route" with "attractiveness" and "mode" respectively and we have the gist of the Thomson and Downs conjectures. Mogridge, simply reintroduced the word "speed" and therefore made the conjecture more ammenable to testing. He states:-

"average road and rail speeds for journeys within central connurbations from residences at a given distance under conditions of supressed demand on the road system, will be equal.......the only way to increase the road speed within and around the central connurbation is to increase the speed of the rail (or other high capacity) system" (Mogridge 1985).

Any attempt to increse road speeds will be frustrated as some rail passengers will switch to road (the potential for this is clear when we consider that rail commuters in the London outnumber road commuters by a factor of nearly 7 to 1 (Hamer 1986)). The reduction in fares revenue caused by this switching will, at a constant subsidy level, lead to a reduction in services, reducing average journey times by rail and producing more switching to road. Mogridge believes that the new equilibrium will be characterised by lower speeds by both modes.

The data underlying this conjecture is detailed in Mogridge et. al. (1988) and consists of about 26,000 observations culled from the Greater London transportation surveys of 1962, 1971-72 and 1981-82. The results for 1981-82 peak hour (7-10 am) journeys measured from 2km bands into the city centre (defined as a 6 km radius circle) do appear to show a strong correlation betwen travel speeds for travel by road, rail, and tube. When the data was analysed by Blase (1985) who averaged across 60 degree sectors rather than the complete annuli it was found that the close relationship was not maintained, even allowing for the increase in error due to reduced sample sie (Bly et. al. 1987). In Mogridge et. al. (1988) Blase's findings are presented in more detail. The sectors, numbered 1-6 start due east and work anti-clockwise. For each of the 5 sectors a regression line was estimated with speed as the independent variable and distance as the independent variable. The main conclusions from this analysis presented are:-

1) in 1962 the intercepts and slope coefficients are very similar for each sector.

2) In 1971 the intercepts are dissimilar but the slope coefficients are similar

3) In 1982 neither the slope coefficents nor the intercepts are similar

4) sectors 1 and 4 have similar intercepts and slope coefficients. Sector 4 is the one which has had the most road building in the last 20 years.

Mogridge et. al. (1988) conclude that this data provide some tentative support for the conjecture.

Bly et. al (1987) have put forward alternative explanations for this equality. First, when trying to produce Mogridge's predictions, they find that whereas the process of user response lying at the heart of the Mogridge conjecture is in theory plausible, strong conditions would need to apply in order for the dimmunition of journey speeds by both modes to occur in practice; these conditions are threefold. First, the cross elasticity between road and rail with respect to fares would have to be very high; secondly, and in addition, rail speeds would have to be very sensitive to changes in demand, and thirdly, fares on rail would have to rise much faster than revenue decline. They argue that such a high degree of sensitivity is unlikely to describe the real world situation. Further, they suggest that the observed equality in travel times may be the result of supply factors. Engineers, so the argument goes, have in mind a minimum acceptable speed, when actual speeds dip below this threshold additional capacity is provided in order to prop them up. As Mogride et. al. (1988) comment, however, it is unlikely that an average speed of 12 mph, is considered optimal by planners.

A further possible explanation put forward by Bly et. al. is the effects of changes in catchment area on travel speeds by road and rail. An improvement in the rail service will widen the area around each affected station for which door to door journey times compare favourably with car; this will tend to stabilise car and rail speeds generally. In the same way, road improvements will attract some rail passengers. Although as a result each traveller who has switched is now better off, the marginal car users (living further away) will reduce average door to door speeds, and tend to stabilise the overall average speed by car. Moreover, the extra traffic will cause a fall in speeds due to the speed flow effect. This argument suggests that rail speeds may be determined by car speeds rather than the other way around.

A final explanation offered by Bly et. al. centres on the effect of changes in work location. They argue that improvements in accessibility to the centre may cause some people to switch employment location from the outer areas to the centre. To the extent that overall employment patterns are sensitive to commute times, and given that employment opportunities are likely to be equal for road and rail users, this effect could tend to stabilise travel times by both rail and road

These arguments lead Bly et. al. to the conclusion that:-

> "although there is room for improvement, conventional modelling- properly applied and allowing for generation, redistribution and reassignment can produce a satisfactory explanation for all the observed data which Mogridge has drawn into the discussion without the need for any radical new hypothesis" (Bly et. al. 1987)

In later work, Mogridge et. al. (1988) challenge this assertion claiming that neither of the assignment, redistribution nor modal choice models which they examined are able to reconcile the equality of journey times between modes. They stress the need for the development of more refined techniques.

3.2. Models of departure time choice in congested urban conditions.

This section reviews work on the effects of the variability of travel times on departure time choice in the am peak. There are basically three approaches to the individual's departure time decision which have been developed, these are:-

i) Pure risk approaches (Rees 1974 Jackson and Jucker 1982)

ii) Pure time constraint approaches (Small 1983, Hendrikson and Plank 1984 Pells 1987, Hall 1983)

iii) Hybrid approaches (Abkowitz 1980,81, Polak 1987a)

With the exception of Rees all these studies are concerned with the journey to work. It is beyond the scope of this paper to attempt a full appraisal of the relative merits of these different approaches; the interested reader is referred to Polak (1987a) and Pells (1989). Although the theoretical reasoning behind these approaches differs in quite fundemental ways, they all have the following common basic assertions.

1) Departure time is determined by the degree of variability in travel times in addition to average travel time. 2) Variability in travel times imposes travel costs on the commuter over and above those embodied in a conventional measurement of generalised cost. 3) These costs arise from the uncertainty over arrival time and/or the effects of constraints on the use of time in different activities. 4) The implication for behaviour is that travel is undertaken earlier than would otherwise be the case; if variability is reduced by a new road or improved public transport service, time of travel will be responsive. Commuters will travel at a later time if they can do so and maintain the probability of late arrival to within certain limits. Thus, improving travel conditions on the road in the peak may lead to a narrowing of that peak.

3.3.1 The arrival time loss function

The evidence on this matter is provided by the empirical results of Cosslett (1977), Abkowitz (1981), Small (1983), Hendrikson and Plank (1984), Pells (1987) and Black et. al. (1989).

The idea of an arrival time loss function was pioneered by Cosslett (1977). This states that utility is affected by the time at which an individual arrives at work relative to that which is desired. In a work context, assuming fixed starting times, earlier than desired arrivals cause less disutility than later arrival. Cosslett estimated a multinomial logit model of departure choice for car users to examine the commuter's tradeD off between mean and variability of travel times and the probability of arriving late, on-time or early. Cosslett found that travellers tend to schedule their journeys away from the peak whenever possible.

Abkowitz (1980a,b,1981) applies a similar technique to bus service users. He models service reliability considerations by relating arrival time uncertainty to commuter's perceived loss associated with different arrival times. This hypothetical {arrival time loss function, asserts that as the commuter arrives increasingly later (earlier) than the official start time the magnitude of the perceived loss increases, although at different rates reflecting the greater disutility of lateness than earliness.

The expected loss l, given departure time d, and mode m, E(l\d,m) can be expressed as

$$E(l\backslash d,m)=\int_{d}^{\infty} fm(t\backslash d)\,l(t)\,dt$$

where fm(t\d) is the probability of arriving at time t given departure time d and mode m. A sequential structure to the mode and departure time model is adopted with the output from the latter forming inputs to the former. We are interested in the results of the departure time model.

The departure time model included expected arrival times of five minute intervals that ranged between 42.5 minutes earlier and 17.5 minutes later than the official start time. However the two variables included in the model to represent early and late time loss were significant only at the 17% and 28% levels respectively, clearly well outside the conventions for acceptance as non-zero. When these two variables are omitted, two constants included in the model to represent arrivals of earlier than 17.5 minutes before the start time and arrivals between 17.5 and 2.5 minutes early do become significant at the 5% level (the late time constants remain insignificant). Abkowitz attributes these results to the poor reliability of the data.

Small (1978,82) derived conclusions from an idea similar to Abkowitz's.In his study Small modifies the arrival time loss function to include the effect of different amounts of start time flexibility on the loss associated with late arrival. In accordance with prior beliefs it is found that lateness is less onerous for those with more start time flexibility than for those experiencing rigid work practices. Small also found that commuters were willing to travel up to 2 minutes earlier in the morning to save an anticipated 1 minute of travel time.

A third study that has used the arrival time loss function is that of Hendrickson and Plank (1984). The authors attempt to develop the loss function one stage further by quantifying the values of late and early time. They also try to overcome the problems of data reliability reported by both Abkowitz and Small by measuring the travel times and bus service wait times for travel to Pittsburg CBD as well as conducting a survey of 1800 city centre employees.

To analyse the decisions of their sample of commuters a logit model of departure time and mode choice was estimated. In this model, unlike the previous two, the departure time and mode choice decisions are taken simultaneously. The base model included up to twenty eight alternatives, representing combinations of four modes (car, shared car, bus with walk access and bus with car access) and seven different departure times of ten minute intervals.

The probability of an individual selecting each departure time/mode alternative P_{ijk} is

$$P_{ijt} = \exp(V_{ijt}/\sum_k \sum_n \exp(V_{ijn})$$

where individual i has mode j and departure time t from the choice sets k and n respectively. For each mode choice/departure time alternative the utility V_{ijt} is equal to:

$$V_{ijt} = \beta_0 + \beta_1 FFTT_{ijt} + \beta_2 CONG_{ijt} + \beta_3 (COST/Y)_{ijt} + \beta_4 ACC_{ijt} + \beta_5 WAIT_{ijt} + \beta_6 LATE_{ijt} + \beta_7 (LATE)^2_{ijt} + \beta_8 EARLY_{ijt} + \beta_9 (EARLY)^2_{ijt} + E_{ijt}$$

where FFTT is free flow travel time, CONG is the proportion of total travel time in congested traffic, (COST/Y) is monetary cost divided by income, ACC is walking time, WAIT is waiting time, EARLY and LATE are self explanatory and $EARLY^2$ and $LATE^2$ are quadratic terms postulated by the authors to more realistically represent commuter perception of early and late time (subscripts ijt represent individual, mode and departure time respectively). Most of the coefficients were found to be the expected sign and significant at the 5% level although $LATE^2$ came out negative (it was hypothesised that the unit value of lateness would increase with the amount of lateness) and FFTT and CONG are insignificant. Regarding EARLY the authors omit to publish the coefficient making it difficult to interpret their results. The implied values of late time are \$2.52 for the first five minutes and \$4.79 for lateness of 10 minutes. The falling unit value of late time is implied by the negative sign of the $LATE^2$ coefficient. Taking the $EARLY^2$ coefficient only, the value of early time at work is estimated to be \$0.04 for 5 minutes and \$0.15 for 10 minutes.

Pells (1987) building on the ideas of Knight (1974) and Harrison (1974) estimated the disutility of early arrival at work, this value having been idenfified with the cost of having to allow for the effects on variable journey times on arrival time at work. He found that a set of Leeds commuters typically allowed an extra 13 minutes over and above mean travel time for their journey to work in order to allow for traffic delays en route. Using stated preference methods it was found that, overall, they would be willing to pay 20 pence per day to eliminate this "safety margin". This could be seen as supressed demand for travel at a particular time. Thus, improving road conditions during the peak may lead to a narrowing of that peak; this in turn may lead to an increase in variability. It might therefore be the case that where such supressed demand exists, improvements in the system may cause trip re-timing until all benefit is eroded.

In a recent paper by Black et. al. (1989), in which the authors investigate the behaviour towards travel time variability urban and inter-urban motorway users, it was found that nearly 8 out of 10 drivers travelling on personal business made an allowance for possible delays by travelling earlier. However only 60% of those on business trips and 31% of those on recreational trips acted in the same manner. Black et. al. conclude that safety margin behaviour is related to the degree of flexibility in the destination start time. They also find that there is a strong agreement between reported and perceived travel time distributions.

Work has also been undertaken which relates variability to speed flow effects of different departure time (Ben Akiva et. al. (1984, Mahmassami and Chang (1986), Polak (1987b). In the second of these studies a simulation model is used to produce outcomes of journeys from trip details supplied by participating commuters. Johnston (1987) has also developed a simple model to examine how the shape of peak traffic flows with traffic demand. The model is not calibrated but suggests that even small amounts of journey re-timing in response to changing traffic conditions could have a significant effect on user benefits.

The work presented in this section does not provide direct evidence on the departure time effects of road schemes; what it does provide is an understanding of the decision processes that lie behind departure time choice in conjested urban conditions. No work of which we are aware has applied these ideas to the context of a particular transport improvement scheme, although the potential for trip re-timimg stemming from various changes to the operating environment of a Leeds bus service has been identified by Pells (1987, 1989).

4. LAND USE/DEVELOPMENT EFFECTS.

4.1 Introduction

The section is in two parts, in section 4.2 a general overview of the evidence is provided and in section 4.3 evidence from America on the relationship between land use changes and traffic flow changes is discussed.

4.2 Overview of the evidence

The effect of road improvements on land use development is an important consideration since it is through such developments that much of the long term traffic changes take place.

Studies of the local impact of road investment suggest that substantial improvements in accessibility for example at road intersections and access points, will tend to lead to new developments and changes in land use. Bonsall 1985 cites evidence on this from several authors including Twark et al 1980, Brown and Michael 1973, Babcock and Kasnabis 1976 and Takeda 1972) However the extent of such changes is to some extent determined by the stance of the local planning authorities (For example, see McAlonan 1981). The degree to which any development is genuinely new is also doubtful, and it is likely that it often represents a relocation of existing businesses rather than the generation of new development. Dawson (1979) found that a new motorway system in Glasgow had the net effect of displacing both residents and employment opportunities from the city centre. Further evidence (eg Deleon and Enns 1973) also suggests that improvement in a conurbation's transport system leads to greater dispersal of economic activity throughout the area- typically a tendency to relocate from the centre out along improved radials.

Gregg and Ford (1983) report that in urban areas in the US the amount of development along new roads is largely dependent on existing land use. Buffington (1978) reported that urban areas are affected by road building to a much lesser extent than rural or suburban ones. Established and developed urban areas resist land use change, and because of the general lack of available properties, new businesses were not attracted. This was not the case in a depressed residential area where a new road led to slum clearance and the upgrading of remaining buildings. These findings are echoed by Adkins and Tieken (1958) and Adkins (1957). Duke (1950) in a study in Detroit believed the influence of a new road was limited to about 300 metres on either side of it.

Road building has also been found, somewhat unsuprisingly perhaps, to adversely affect the rate of appreciation of property values for residential houses located on them (see for example, Pensilvania 1973, Palmquist 1980 Gamble et. al. 1974, Langley

1976,1981). Similar results have been found in the UK (Davies et. al. 1971)

There would appear to be a strong relationship between road investment and increased accessibility and the location of retailing activity with shops tending to migrate to areas of high accessibility (Kern 1984). As would be expected, the most significant development takes place on greenfield sites rather than in already well developed locations.

One observes (Parker 1974) has concluded more generally that although there is often substantial development on under utilied sites whose accessibility is increased, the presence or absence of development at any given site is frequently determined by factors other than transport.

The effects of whole town bypasses on retail trade have generally been to reduce passing trade which is then compensated for by trade stimulated by improved environmental conditions.

4.3 Some scheme specific US evidence

A study of the traffic and land-use effects of urban roads in North Carolina was carried out in the mid-seventies by Kasnabis and Babcock (1975,77). These show that it is not just the flow of traffic which is important but its composition since the conflict between fast moving through traffic and slower moving local traffic produces a disproportionate effect both on the level of congestion and the incidence of accidents. The studies which concern the effects of land- use changes on traffic flow do not go into any great depth of detail but that evidence which is given is summarised here.

It is necesary, for the purposes of the following discussion, to differentiate between bypasses (BP) and beltways (BL), the latter being the term used to represent an urban road (designed to facilitate movement from one part of the city to another). In addition, a cross town artery (CTA) is used to divert through traffic from the CBD.

Of the 5 case studies analysed traffic data is given for 4, these are;

Interstate 40: Winston-Salem
Interstate 85: Charlotte
US 1: Raliegh
Interstate 85: Durban

This data is summarised in table 23 below. The schemes themselves are illustrated in figures 5-8.

Table 23: Summary of 4 studies of urban road schemes in North Carolina

Site	Pop. 000's	road type	initial flow	subsequent flow	period (yrs)	Change
I 40	135	CTA	29,000	58,000	10	100%
I 85a	241	BP	12,000	40,000	20	233%
US 1	121	BL	6,000	30,000	10	400%
I 85b	95	BP	11,000	32,000	10	190%

Source: Compiled from Kasnabis and Babcock 1977

The table above shows that substantial increases in flow were observed in each of the 4 cases, the reasons given in each case are now discussed. It is interesting to note that despite a clear acknowledgement by the authors that the roads had either directly or indirectly increased traffic flows, in all cases where traffic problems had arisen they conclude that the solution is to provide additional capacity.

4.3.1. Winston-Salem (I40)

This is a major industrial city; the cross town artery which passes directly south of the CBD was originally designed to transfer traffic from one part of the city to another with no little regard for through traffic. Due to the developed nature of the area no substanial land use effects were reported, however as table 23 shows, traffic flows doubled over a 10 year period. The authors explain this by the fact that the road was effectively used as a bypass and an radial making it the most heavily used road in the state. At the time of writing, flows had stabilised due to the road reaching capacity although a substantial proportion of traffic was avoiding the route at peak times producing a pool of latent demand.

4.3.2 Charlotte (I85a)

Interstate 85 was completed in the late 1950s and runs in an east west direction in the form of a bypass to the northern edge of the city. The city is also served by Interstate 77 which runs north-south as a cross town artery and passes quite close to the CBD. I 85 was originally developed as a bypass in a predominantly suburban area, but by the mid 1970's the city had spread beyond it. The authors claim that the road had a significant impact on this spread of development. As a result, the road changed in character from a bypass to a beltline. For the first several years of operation the road carried about 12,000-18,000 vehicle per day; this grew to 25,000-40,000 by 1971.

4.3.3. Raleigh (US1)

This city experienced rapid growth in the post-war period with a doubling of population between 1940 and 1970. The road, completed in 1961 was planned as a beltline skirting the northern side of the CBD at a distance of about 5 miles. Land use changes were analysed in the period 1961-1971 using planning and census data. A regression approach was adopted to explain population change over the period in specified ones by the distance of each one to the beltline and the proportion of vacant land in each one; the distance variable proven significant (Kasnadis and Babcock 1975).

The increases in traffic (table 23) were explained by the extension of residential areas and the appearance of commercial, office, institutional and other types of land use developments. Again the authors believe that the solution is to provide additional capacity.

4.3.4. Durham (I85b)

This forms part of the same connurbation as Raleigh and Chapel Hill. Interstate 85 ran through the northern edge of the city forming part of a bypass. The road was built over an extended period and was subsequently widened from 2 to 4 lanes. The authors find that the road had a significant effect on the distribution of the urban population between 1950 and 1960, with a large amount of urban growth taking place along the freeway corridor. No effect was identifed for the following decade however.

The traffic impact of the road was to increase flows by nearly 200% in the period 1960-1970 (table 18).

Substantial land use effects were also attributed to interstates 85 and 40 at Greenboro.

This emphasis on the effect on traffic of land use changes may have been at the expense of other effects and no analysis of these effects is provided; the studies do highlight the point however, that it is the composition of traffic as well as volume which is important in determining traffic conditions, with conflicts between inter and intra urban movements being a potential source of congestion.

5. SUMMARY AND CONCLUSIONS

5.1 Introduction

In this section we draw together the various strands of evidence and in doing so identify those areas of user response which are still under researched. The reader will have appreciated that much of the monitoring work conducted outside ITS has simply been content to differentiate betwen re-assigned traffic and that which is due to "other causes", where this has most often referred to a combination of generation, redistribution, modal change and even wide area re-assignment. In section 5.2 we summarise the findings on this aggregate level. In section 5.3 we summarise the evidence from those studies which have either singled out one particular aspect of user response for attention, or which have tried to isolate the responses themselves. In section 5.4 we summarise the findings of the work on land use/development effects and finally, in section 5.5 we make some concluding remarks.

5.2 Evidence on user response at a general level: broad generation

We identified a number of studies which have been undertaken during the last 20 years on the generating effects of road schemes. Most of this has presented results on a general level and often it is left unclear where the increased flows have come from. For the A40 Westway, generated traffic (defined in its broadest sense) was estimated to account for 37% of the short term increase in traffic flow, and 76% of flow after 14 years. In the A316 corridor broad generation was also used to explain the 84% increase in traffic flow which occurred over 12 years. Further, broad generation was used to explain 44% of flow over the Severn Bridge 1 year after opening. On the other hand, no generation at all was apparently observed in the case of the Tay Road Bridge one year after opening.

A study carried out in Providence, Rhode Island, USA purported to have demonstrated that the apparent link between road schemes and trip generation was illusory. The methods and execution of this study however were not appropriate, and the study in fact demonstrated marked trip behaviour changes as a result of the introduction of a new interstate highway.

5.3 Isolating the component effects of user response

In this paper we have presented evidence from a variety of sources and have seen that the effect of new capacity on user behaviour is highly dependent upon the particular setting and the time interval between measurement. Furthermore, it seems that much of the evidence presented is based on deduction and interpretation from incomplete data sets rather than on the rigorous analysis which one might prefer. Moreover, where reference is made to the work carried out at ITS last year, it should be remembered that this was of a pilot nature being intended primarily to provide a test-bed for different survey techniques rather than to produce conclusive results; the findings are included as evidence but should be treated with due caution when trying to make generalisations about the scale of response with regard to a particular aspect of behaviour. Nevertheless, it is useful at this stage to summarise the range in scale of response that we have found, we do this for each aspect of response in turn.

5.3.1 Reassignment

Reassigned traffic has been estimated to account for 63% of flow 5 months after opening of the A40 Westway in London, falling to 24% after 14 years. In the case the M11 London to Cambridge link, 8 years after opening 29% of traffic was said to have reassigned. In contrast, a study of the effects of the opening of a section of the M25 concluded that very little of the traffic using that road could be explained by reassignment from the next-best alternative route, and it has been argued (though not, perhaps, very convincingly) that traffic using the Severn Bridge one year after opening could not be explained by re-routing. Given the lack of detail in the available evidence it has not been possible to differentiate between local and strategic reassignment in any systemmatic manner. We note however that Purnell found no evidence of wide area reassignment in his study of the effects of the A316 widening scheme.

5.3.2 Trip re-timing

Slightly more evidence on trip re-timing is available. In response to the closure of a bridge in Central York, 24% of drivers shifted their departure time by more than 10 minutes producing a slight spreading of the peak flow. Also in response to the closure of a centrally located bridge, many drivers in Downtown Edmonton, Canada, switched their departure time changing the shape of the a.m. peak flow profile from a peaked uni-modal distribution to one which displayed only minimal variation in flow over the period. Over a quarter of the increased flow observed in the period 0700-0900 in Viannen, Holland after the opening of a second crossing of the Lek river was attributed to re-timing; this caused a marked narrowing of peak flow.

Trip re-timing in response to changes in road capacity in London can perhaps be deduced from the differences in the increase in traffic at peak and non-peak times. Thus, in the case of Westway, the 1970 before and after studies show a 14% increase in 24 hour flows but a 25% increase in inbound a.m. peak flows. The data show that peak traffic was measured at 3.8% of 24 hour flow in the before survey and 4.1% in the after survey. In the case of the A316 corridor, a.m. peak flow increased by 107% compared to a 87% increase in 24 hour two-way flows. The proportion of traffic travelling in the a.m. peak increased from 13.2% in the before situation to 14.9% in the after situation. Evidence of long term peak spreading is perhaps provided by the Blackwall Tunnels, where 24 hour two-way traffic increased by 242% in the period 1962 to 1982, the increase in peak period two-way traffic was slightly lower at 220%. Regarding the Rochester Way Relief Road (RWRR) study, 24% of the drivers surveyed in the period 1400-1700 had re-timed their trips. Similarly, 30% of drivers responding in the York Northern Bypass (YNBP) study had re-timed their journeys.

An appreciation of the behavioural mechanisms at work may be gained from the model based study by Small (1983) which suggested that commuters are prepared to depart up to two minutes early in order to save one minute of travel time.

5.3.3 Redistribution

The only studies of which we are aware which have successfully isolated redistribution are the pilot studies carried out by ITS in 1988. In the case of the RWRR, 3% of traffic was identified as redistributed 3 months after opeining, compared to 6% a similar period after the opening of the YNBP. It is appreciated that much of the effect of redistribution would not be expected within the first 3 months of a scheme being opened.

5.3.4 Modal change

Evidence on this aspect of behaviour is also sparse. Modal change from rail to car was estimated to account for 20% of the peak flow in the after survey on the A40 (1160 trips), whereas in the case of the Dartford Tunnels the scope for such behaviour was found to be highly restricted. In the case of the M11, modal change is attributed some importance but no numerical estimates were made. Concerning the studies carried out by ITS, modal change was found to account for 3% of traffic on both the RWRR and the YNBP. More significant is the finding that about a quarter of increased traffic resulting from the opening of a bridge in Viannen, Holland, was due to travellers switching mode.

5.3.5 Generated traffic

Evidence on this aspect of behaviour is again apparently restricted to the ITS pilot work; values for generation for the RWRR and YNBP studies were 10% and 12.4% respectively.

5.4 Land use/development effects

There is a large amount of literature on this topic, most of which originates from America. These studies suggest that road schemes may generate additional traffic due to land use effects, but that this happens more where the initial level of development is low. Studies of schemes in North Carolina demonstrate that there can be great potential for such efects where there is scope for urban expansion and development.

5.5 Final remarks

From the material reviewed in this report, it seems clear that with the notable exception of the former GLC, very little work appears to have been done to monitor the effects of new road capacity on user behaviour, particularly in an urban context. Nevertheless, judging by the evidence available, it appears that rip re-timing is a very important response in urban areas, second only to reassignment.

The vast majority of the evidence in the literature is based simply on traffic counts. rather to our surprise we found very little reference to household or roadside interviews or to travel time studies.

The paper has also reviewed the more theoretical arguments associated with the Mogridge conjecture, which assigns modal change the role of the mechanism which leads to road building in certain circumstances being counter-productive, and the theory of departure time choice. Although not contributing directly tp evidence on the composition of user response, this work does contribute to out knowledge of the underlying mechanisms at work.

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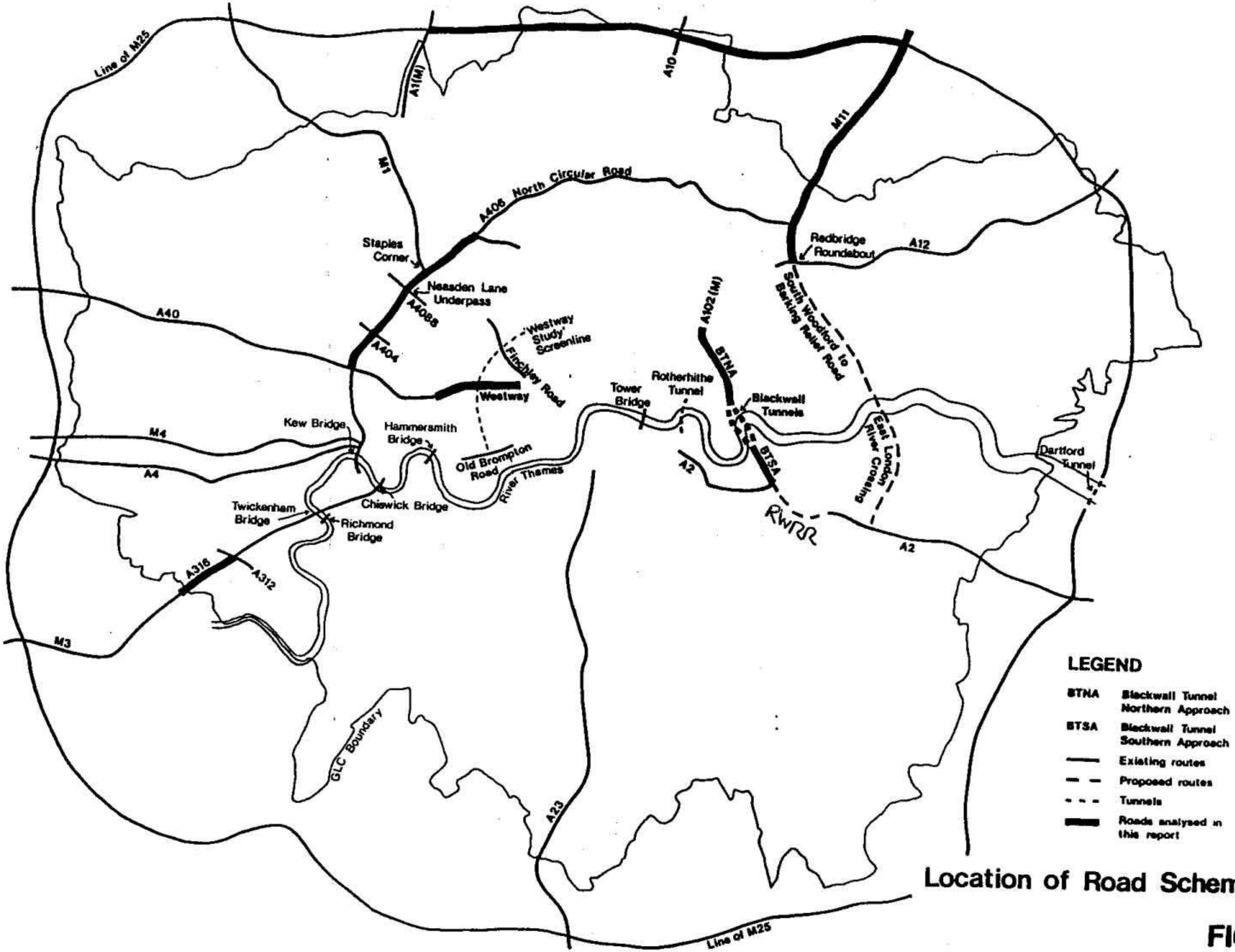
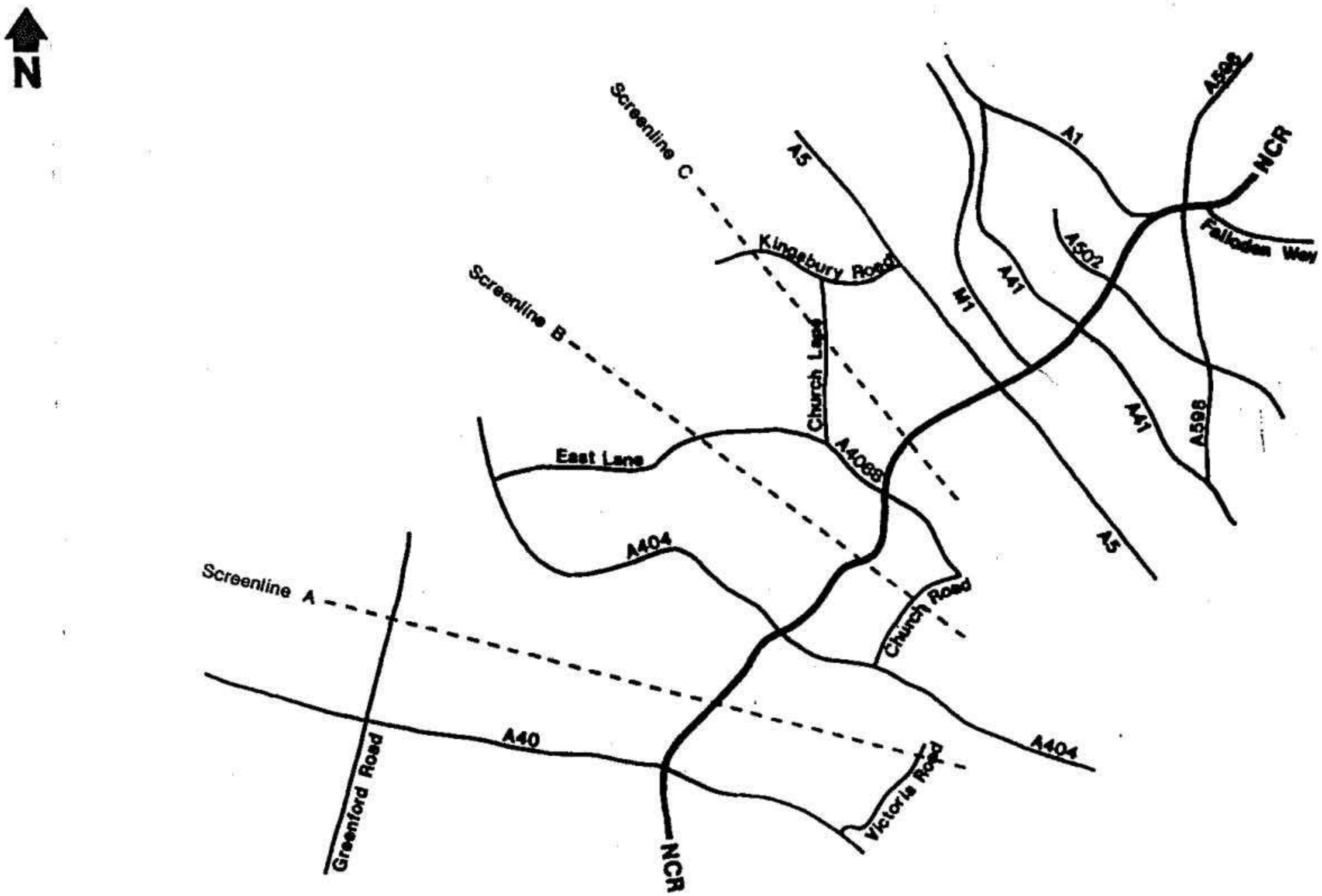


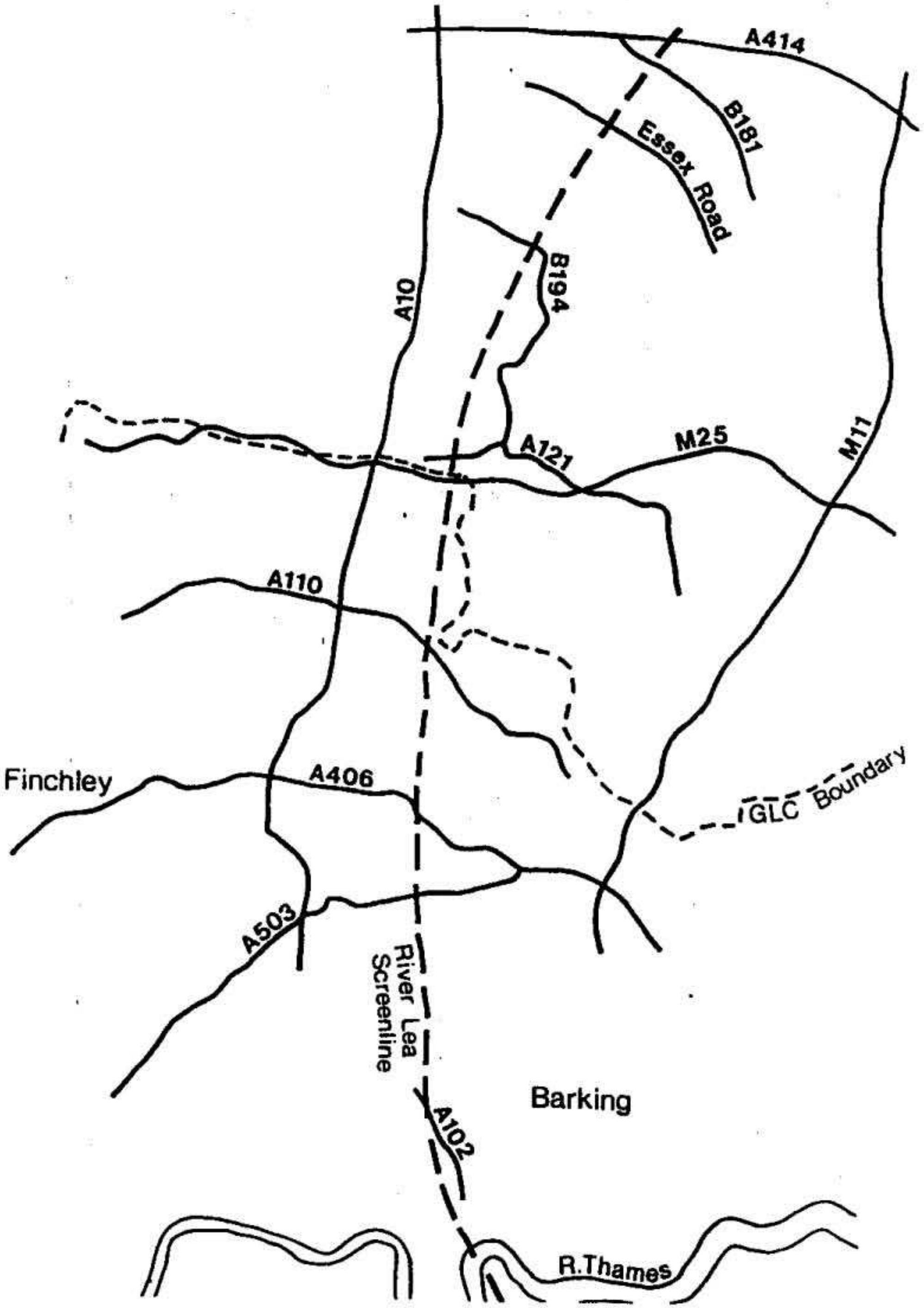
Location of Road Schemes Analysec

FIGURE 1



North Circular Road Study Area

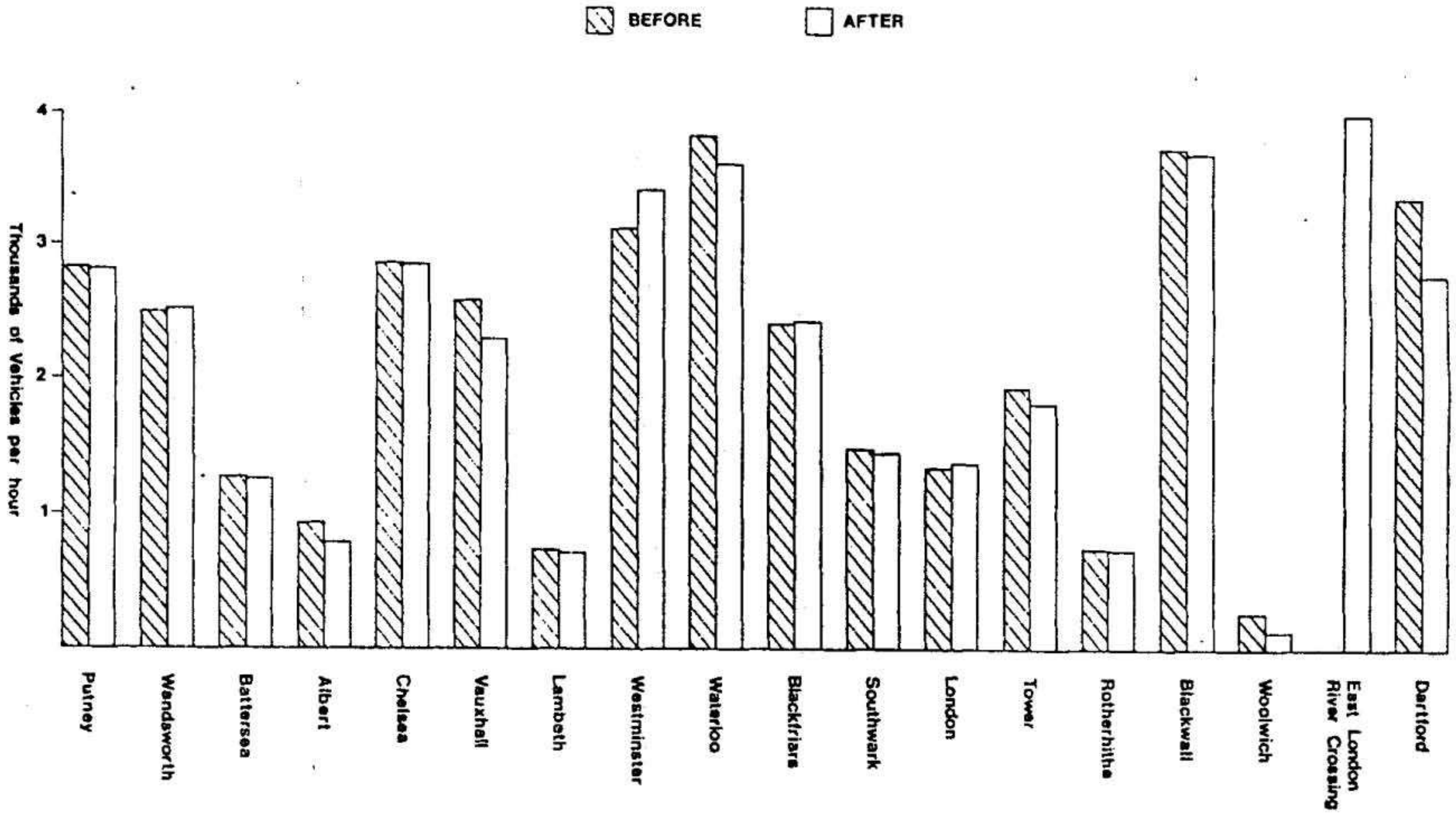
FIGURE 2



M25 Corridor

FIGURE 3

1991 Northbound Flows across the Thames, effect of East London River Crossing



Source: Transport Studies Section, TD/TP/TS. The Greater London Council, 1985

FIG. 4

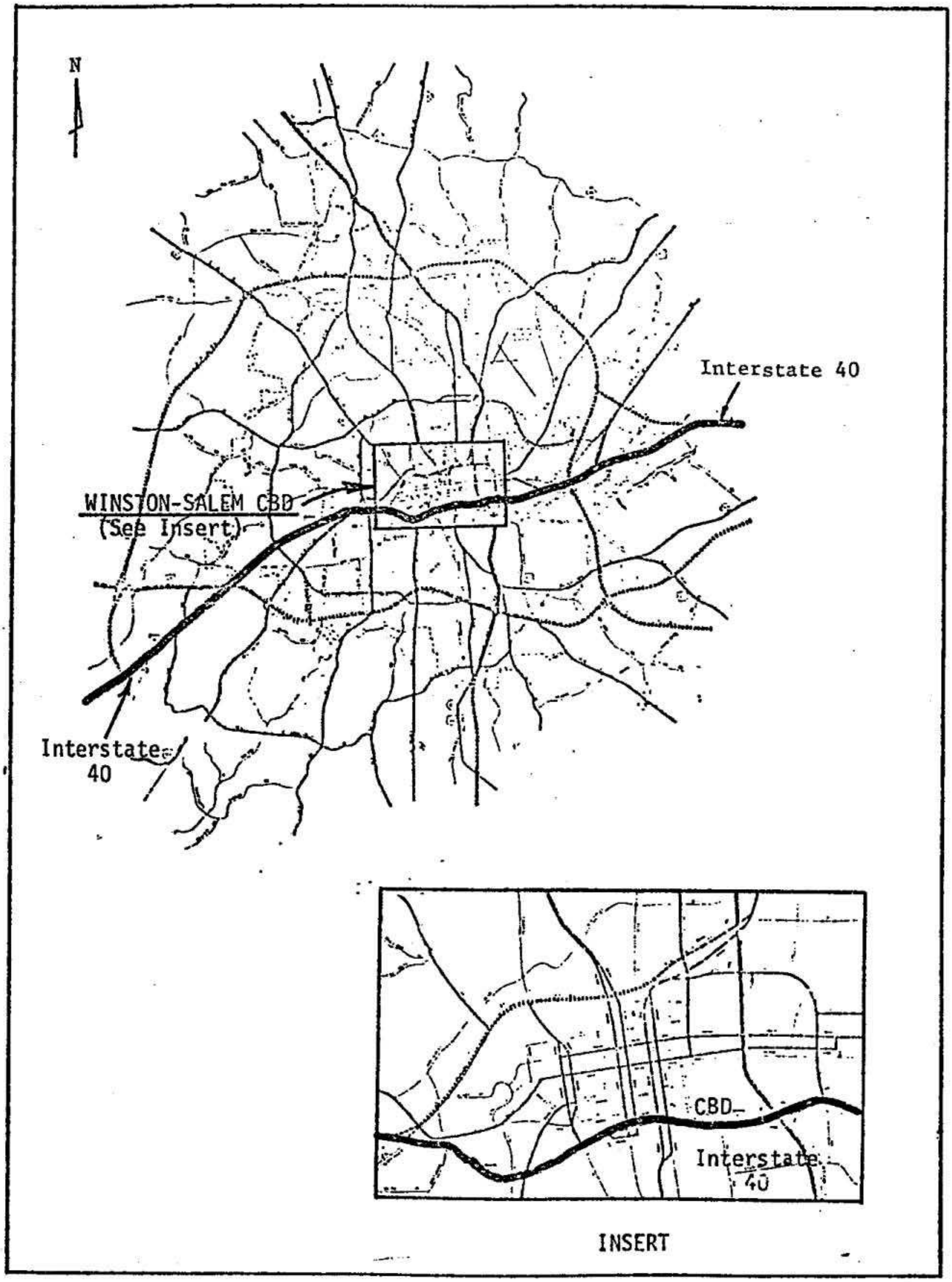


Figure 5. Winston-Salem Thoroughfare Plan

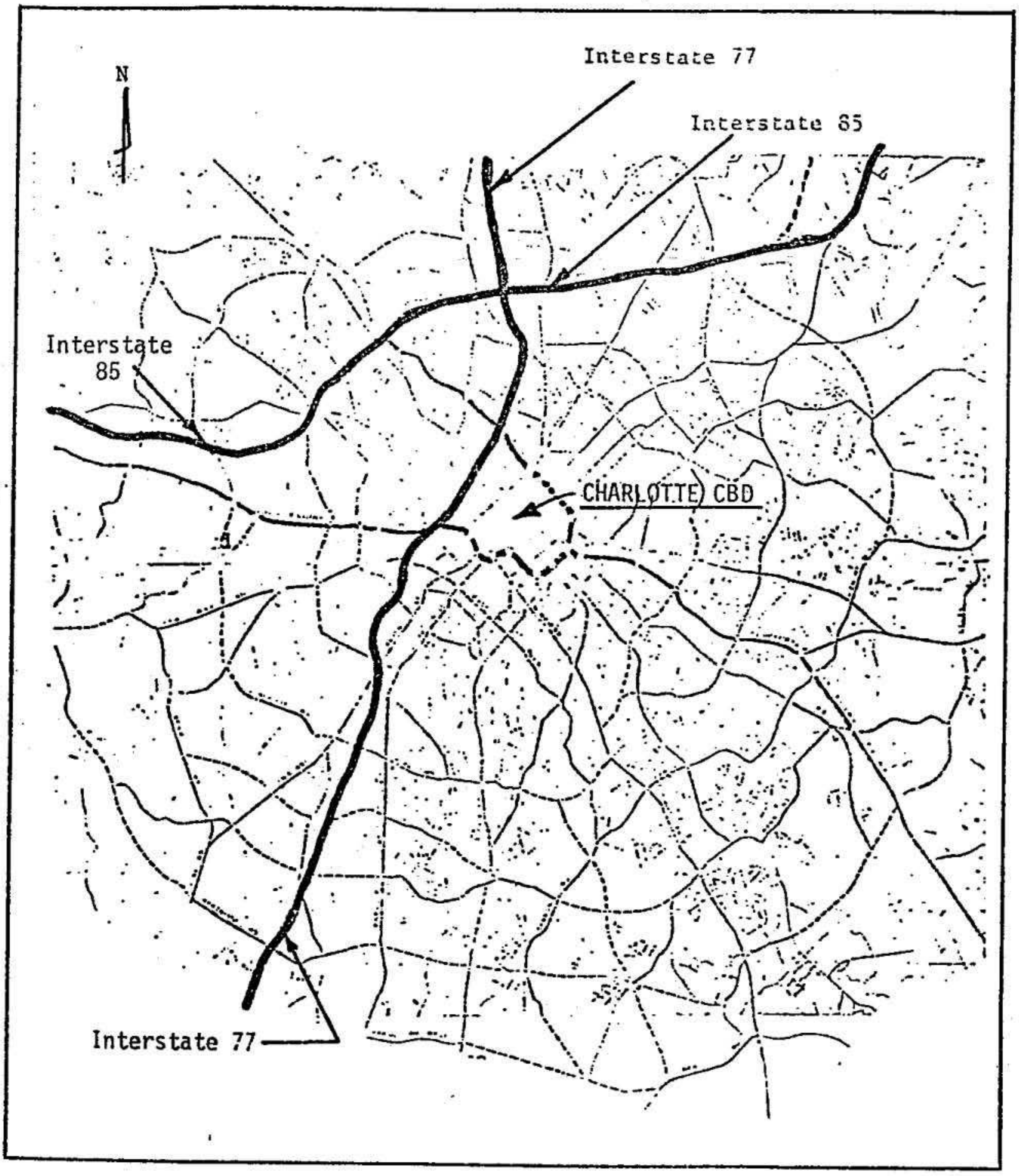


Figure 6. Charlotte Thoroughfare Plan

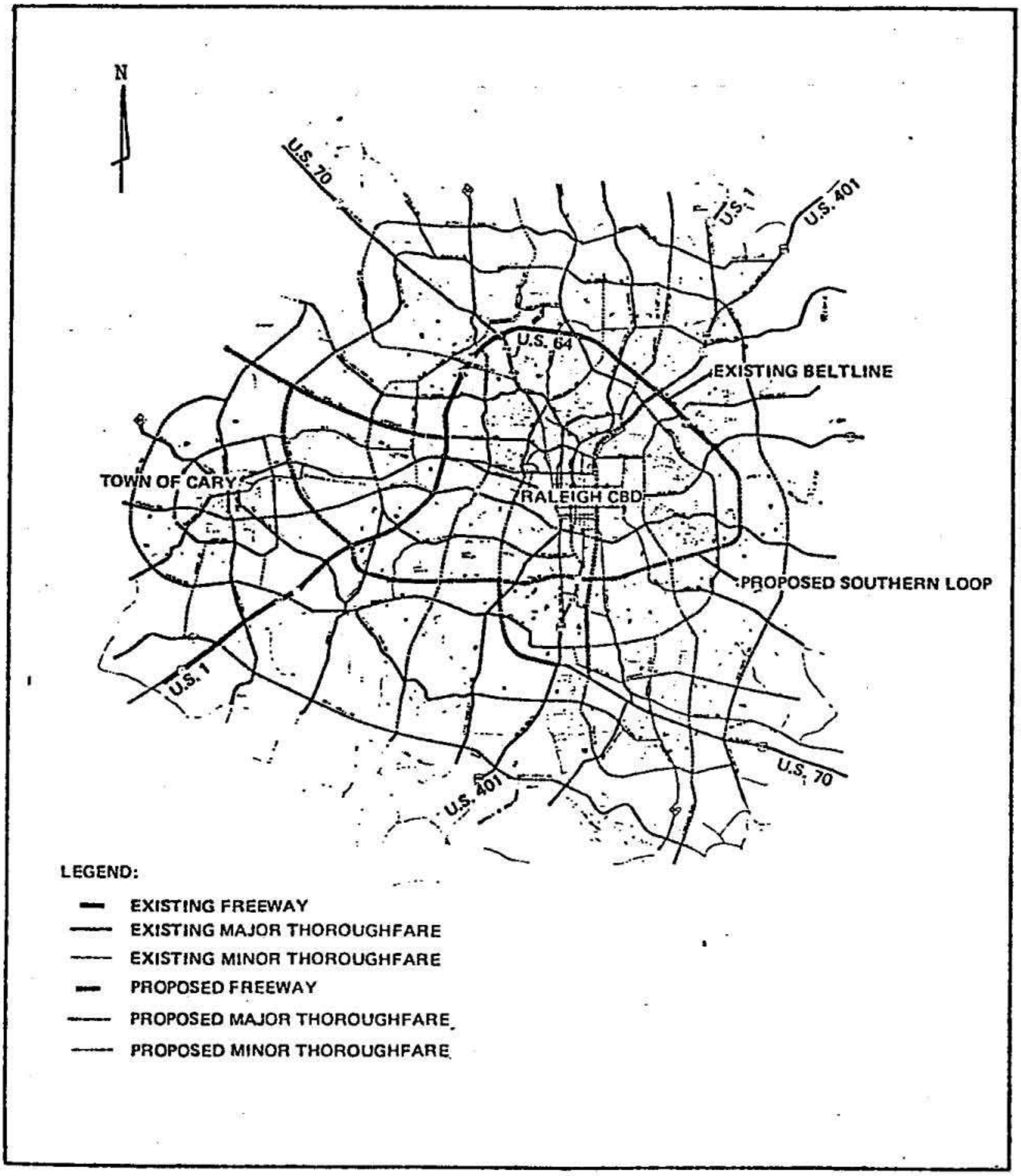


Figure 7. Raleigh Thoroughfare Plan

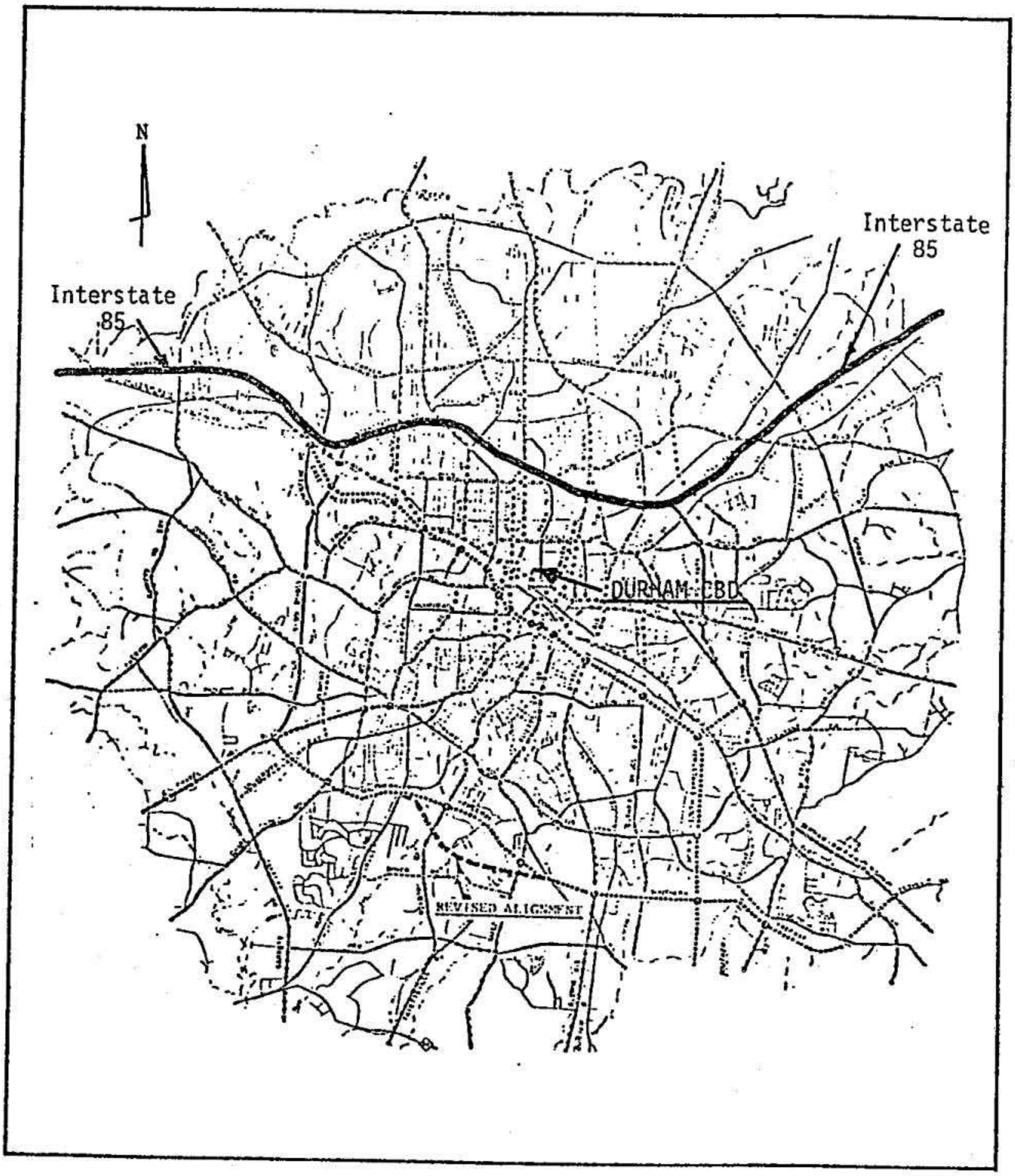


Figure 8. Durham Thoroughfare Plan