The University of Leeds

EXPLAINING DEVELOPMENTS IN COMMUTING PATTERNS TO CENTRAL LONDON DURING THE 1980's

by

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

ABSTRACT

The main objective of this thesis is to identify and understand the key factors involved in the changing patterns of commuting into Central London during the period 1981-89, in particular through a case study of Kent. The questions addressed here are threefold: (i) what changes in the temporal and spatial patterns of work-trips can be identified and related to changes in the employment structure of Central London, population and employment relocation, and change in the rail attributes; (ii) to what extent the attributes of the transport system, the location of people and jobs, and the specialisation of the Central London market have contributed to the changes in Central London commuting during the 80's; (iii) which other factors, apart from the ones listed above, might be identified as playing a role in the patterns of work-travel to Central London.

This thesis initially addresses the qualitative aspect of the changes in the commuting patterns, in which a descriptive examination of the data set is carried out. This first analysis aims to provide the necessary background to investigate the interaction between the demand for rail commuting and the distribution of jobs and population. The second part of the work is comprised of a quantitative analysis carried out through a model which aims to explain the level and the spatial distribution of commuters.

The framework developed here proved to be powerful enough to shed some light on the understanding of the changes in the patterns of commuting between Kent and London during the 1980's. The results given by the model showed that it can be an useful tool to explain the long run effects of population and jobs location on the commuting patterns from Kent. Contrary to the conventional wisdom, the rail demand from particular zones was found to be very elastic with respect to improvements in services to those zones, disregarding the compensating changes elsewhere and allowing for long run population and job changes. Another important finding was that Mid-Kent presented significant levels of commuting to Central London alongside the expansion of the local economy in the area. This is explained by the overall migration of people in the metropolis according to life cycle, and the availability of employment opportunities provided by the relevant switch of jobs in Central London.

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ABBREVIATIONS

BR	British Rail
CBD	Central Business District
CGT	Car Generalised Time
CL	Central London
Cle	clerical
COBA	Cost Benefit Analysis
ED	Enumeration District
Else	elsewhere
EMU	Expected Maximum Utility
IL	Inner London
LILT	Leeds Integrated Land use Transport model
MATPAC	MATrix analysis PACkage
MASTER	Micro-Analytical Simulation of Transport Employment and Residence model
NOMIS	National On-line Manpower Information System
Man	manager or managerial
OLS	Ordinary Least Squares
OMA	Outer Metropolitan Area
OPCS	Office of Population Censuses and Surveys
Pro	professional
RGT	Rail Generalised Time
RIL	Rest of Inner London
ROSE	Rest Of South East
SEG	Socio-Economic Group
SIC	Standard Industry Classification
SWS	Special Workplace Statistics
WLS	Weighted Least Squares

CHAPTER 1

INTRODUCTION

1.1 - PRESENTATION OF THE PROBLEM

Understanding commuting behaviour is important when making investment planning for public transport. Understanding the behaviour of commuters to London is a complex challenge.

The nature and pattern of commuting play an important role in transport planning, when there is the need of a realistic forecast of how the demand for travel is likely to change. The understanding of the travel patterns is particularly relevant as regarding investment decisions, such as establishment of fares and service levels, the opening of new stations, introduction of new services, and terminal improvements.

Given the social and economic significance of the daily journey to work and its central place in planning, the commuting has attracted considerable interest in recent years. This is particularly true in London which has seen a remarkable increase in commuting trips using public transport. During the period 1981-1989, the overall public transport changed by 12% whereas the rail, which is the predominant mode of transport to the Central London market, has experienced a growth of 20%. Since then, the total number of commuters has decreased. From 1989 until 1991, a reduction of some 10% was observed in the rail mode, whereas the total flow was reduced of about 8.7 %.

A long trend in population decentralisation and a reverse in the declining economic activities of the city in the late 1980's, are likely to have attracted commuters to London from different parts of the South-East region. Until 1987, the level of employment in Central London had been falling, in parallel with the process of substitution of manufactures by financial and service establishments. With the continuous flourishing of the London market, the city was dependent on commuters who, because of high house prices in London and the concentration of London employers chose to live further out and travel long distances to work.

The effects of decentralisation on increasing distances between homes and jobs, expanding the outer area of employment centres, and lowering urban densities, are expected to favour car use. This is particularly true in work journeys within the urban areas or in suburban travel involving reasonably good conditions of road traffic and parking spaces. London, however, is a different case. Problems concerning congestion and parking limitations have restricted car use in the city, and encouraged the use of public transport by passengers.

In order to determine the role played by population and employment decentralisation on travel patterns, it is important to study the nature of both workplace and residential location. Also of interest is the effect of trip orientation on mode choices. In particular, there is the need to enhance and update the literature of commuting patterns into Central London, such that the phenomenon observed over the 1980's could be better understood.

The extent to which the changes in population and employment distribution, and the attributes of the trips influence travel behaviour, and are in turn influenced by it, are the core of this thesis.

1.2 - OBJECTIVES

The work aims to identify and understand the changes in the patterns of commuting to Central London over the period 1981-1989. The basic task is to understand the differences in commuting patterns from different zones in Kent, and to consider whether the changes in patterns and the increase in rail commuting have been related to non-metropolitan growth, employment distribution, and changes in the transport attributes.

The aim can be divided into two inter-dependent and complementary issues. The first concerns an investigation of the causal processes which led to changes in the patterns of commuting, as induced by the characteristics of the modes of transport available, as well as by population and employment changes. This issue is achieved by a descriptive analysis of the data set which is considered here.

The second is a model to explain the level and mode of commuting to Central London, taking into account the decision process over location and mode choice. There is the hope that the model could also be used as a forecasting tool.

1.3 - THE CASE STUDY

The job market in London has seen a long decline in the production sector whereas there has been a significant growth in specialised employment in the financial and service categories. In spite of the redistribution of jobs that has occurred in various parts of the South-East, London has maintained its dominant position of the most important job centre in the region. The number of commuting trips from the Southern Counties into Central London, and in particular the growth observed during the last decade, clearly reflect this situation.

But if London is the main focus of attraction, the origin of the commuting population is spread among the various Counties of the South-East, where the overspill population from the metropolis have been accomodated.

Since the spatial distribution of work travel is a representation of the relative distribution of homes and jobs, and since a considerable proportion of the Central London commuting comprises trips from outside the metropolis, the predominant commuting pattern is radially oriented towards the city centre.

Ideally, the analysis of the trips to work to Central London should be carried out for the whole catchment area. However, limitations of data set restricted the study area to only one county in the South of England.

The County of Kent was chosen particularly because of the availability of rail data. Very recent information concerning the attributes of the rail commuting to Central London, as well as the characteristics of the travellers was provided by the 1989 British Rail survey. This data base, complemented by other surveys and Census data, enabled the development of the framework adopted in this thesis. Additionally, the districts of Kent provide a great variety of working trip flows, as well as a quite large range of distances to London. Some desirable variability among the zones might be expected.

The study area is shown in figure 1.1. The zones delimited with dashed lines represent the districts Dartford, Gravesham and Rochester that were excluded from the analysis due to the data limitations explained in chapter 4. The remaining 11 out of 14 districts of Kent were considered in the analysis. In the next section, some characteristics of Kent and Central London are reported.

Fig 1.1 - Study area

1.3.1 GEOGRAPHY OF THE AREA AND REGIONAL ECONOMY

Kent is the second largest non metropolitan county of England, with a population of about 1.5 million. The North area from the Medway towns through to Sheerness-on-Sea, Queensborough and Thanet towns is largely urbanised, however, during the last decade population growth drifted toward the central districts of Canterbury and Ashford.The main concentration of commuters to Central London are from the districts along the border of the London conurbation, the Medway Cities, as well as the hinterland area which comprises of Tonbridge, Maidstone and Tonbridge Wells.

Focal points of attraction of local travel are mainly observed in the Mid and North Kent, eg. the retail sector is particularly strong in Maidstone and Gillingham, while the provision of office and shopping centres are dominant in Maidstone, Ashford and Tunbridge Wells.

Another source of flows within Kent are the economic activities concerning the port and ferry developments, which are located along the Eastern coast, in particular Dover, Folkestone, and Ramsgate.

Tourists and visitors to the county are mainly attracted to Canterbury, Sandwich, Tenterden, Tunbridge Wells and Maidstone. According to the Kent County Council (1987), traditional holiday resorts on the eastern and southern coasts, eg. Margate, Ramsgate, Broadstairs, Deal and Folkestone have gradually seen a change in demand from long stay to day trips. Such a change might have increased the number of daily travel to these towns as well as the demand for movements within them.

Regarding Central London, one may say that there are two major employment nodes: the City and Westminster. The former is characterized by very high employment density (1079 jobs per hectare in 1981 and 989 in 1989), but low residential density. Although the largest absolute number of jobs of Central

London is in the western part of the city, a much less density of jobs is found there (216 jobs by hectare in 1981 and 227 in 1989). The figures in brackets were derived from the 1981 Census of Population, and 1989 Census of Employment.

London has higher wage levels than the surrounding regions. According to the Department of Employment (1992), the 1989 average gross weekly pay to a full time male working in Greater London was £348.8, whereas in the rest of South East (ROSE), the corresponding payment was £281.4. This fact partially reflects higher actual wage rates, but mainly its extreme concentration of high income occupations. The scale of employment is another factor setting Central London apart from the other cities in the South East, as well as in England.

For the purpose of this study, the area denominated by Central London comprises 69 small wards of the districts City of London, City of Westminster, Camden, Hackney, Islington, Kensington and Chelsea, Lambeth, Southwark, and Tower Hamlets. The list of wards and enumeration districts by borough are given in appendix 1.1

1.3.2 - TRANSPORT NETWORK

The proximity of Kent to London results in a high demand for daily travel by rail, car and coach. The coach market is particularly concentrated in North Kent and in Maidstone, whereas dense networks of roads and trains are widely available in the County.

In 1981, the coach commuting from Kent was practically nonexistent. However, a great boost in this market was provided by the 1980 Transport Act. According to the Kent County Council (1987), a survey carried out in May 1985 showed that the coach was used by more than 5000 people in daily travels to Central London. This represented more than 4000 more travellers than the level given by the 1981 Census of Population. However, there is evidence that the number of coach passengers has remained approximately static since 1986 (Stavely (1989)).

Let us now turn to the rail commuting. Over the period 1981-1989, there was a 21% increase in the number of trips between Kent and Central London against an increase of 20% from all areas in the South of England (see tables 7.5 and 2.1). Since the train is the predominant mode of commuting to Central London, such statistics make the choice of the study area even more advantageous and attractive.

A comprehensive network of rail services comprising of 106 stations is provided by the Network South East sector of the British Rail. The main road links to London are through the A2, M2, A20, M20, but there are many inter-connected trunk roads, primary and secondary routes.

Kent is related to a historical fact in the creation of the railway season ticket. In the Canterbury West station, there is plaque with the following saying: "Near here was the terminus of the Canterbury and Whitstable Railway, 1830. George Stephenson engineer. The world's first railway season ticket issued here in 1834".

A particular characteristic of the season ticket is that it is largely used by commuters. For instance, the London season ticket holders residents in Kent account for 35% of the 46 million annual journeys on trains in Kent (Kent County Council (1987)). Given its importance in the travel to work, one can consider the year 1834 as the bench mark of the "creation" of the commuter, who since then has multiplied, caused many concerns, and even led to the study carried out in this thesis.

1.4 - THESIS STRUCTURE

The thesis is broadly divided into three major sectors. The first part contains an overview of the tasks. It introduces the basic principles of the location theory, and identifies the links between changes in patterns and some major explanatory factors such as changes in employment, population, and attributes of travel.

In the second section, a broad descriptive analysis of the data set is carried out. The characteristics of the data base are given in chapter 5, while analyses of the data trends are dealt with in chapters 6 and 7. Chapter 6 includes the historical trends in population and employment, and chapter 7 contains both the trends in work travels and the assessment of the role of population and job decentralisation on the changes of the commuting patterns.

The last part of the thesis is devoted to modelling. Chapter 8 concentrates on the model definition and estimation, and chapter 9 on the empirical work of testing the general applicability of the model, as well as forecasting. Eventually, the main findings of the descriptive analysis and the modelling are drawn together in chapter 10.

CHAPTER 2

AN OVERVIEW OF COMMUTING IN LONDON

2.1 INTRODUCTION

An overall picture of the London commuter market is required to give the necessary background. Therefore, initially this chapter reports the historical patterns and trends of the work journeys into Central London. Subsequently, the general policies concerning fares and subsidies, as well as their effects on the level of commuting to Central London are presented.

2.2 PATTERNS AND TRENDS IN THE COMMUTING TO CENTRAL LONDON

The patterns of employment and traffic into Central London have generally followed similar trends. However, a reverse in the process was observed in the early 1980's, when increases in commuting occurred even when job opportunities felt. Table 2.1 depicts a time series flows of Central London commuting by mode, and shows that there was a definite rise in demand.

Apart from a general decrease (experienced by all modes) in 1990, the number of rail passengers has increased since 1983. The figures show that the rail mode has a very predominant position in the market of commuting trips to Central London, followed by the underground.

Table 2.1 - People entering Central London 7-10 am [(a)] (x1000)

year	BR	LT rail	coach minibus	LT bus	car	mcycle pcycle	total private	total public	all
1976	401	-	10	-	165	22	187	868	1065
1977	400	320	10	139	170	21	192	860	1062
1978	410	325	10	133	176	24	200	867	1077
1979	421	347	10	112	173	22	195	880	1085
1980	412	305	10	103	184	27	211	830	1041
1981	394	336	16	105	173	26	199	851	1050
1982	390	283	22	99	197	39	236	794	1030
1983	384	323	24	97	180	33	213	828	1041
1984	386	350	25	94	180	26	206	855	1061
1985	401	364	26	94	171	26	197	885	1082
1986	421	381	25	91	166	21	187	918	1105
1987	449	401	21	79	161	19	180	950	1130
1988	468	411	21	80	160	17	177	980	1157
1989	473	390	23	73	161	23	184	958	1142
1990	458	368	20	70	158	20	178	916	1094
1991	426	347	20	74	155	21	175	867	1042
Percentage changed over 1981-1989:									
	20.0	16.0	43.8	-30.5	- 6.9	-11.5	- 7.5	12.2	8.8

(a) some journeys are through Central London rather than terminating

Sources: Serplan (1990) and the Department of Transport (1992)

In 1989, rail commuting increased despite a decrease of 1.3% in the total traffic of passengers into Central London. The reduction in the total traffic has been mainly attributed to the decline by 5% of passengers taking the underground (see Department of Transport (1991).

The light railway system, which was opened in inner east London as part of the Docklands redevelopment in 1987, is running at capacity (see Bayliss (1991)). The coach experienced significant growth after the 1980 Transport Act, however, since 1987 the coach commuting has been approximately steady.

By 1970, the growth in rail speed and capacity had allowed middle-income users to commute ever greater distances. A reverse in the growth of long-distance commuting came about 1976, when fares increased in real terms, and the market became more price-sensitive.

Data from the 1971 and 1981 Censuses showed that the decline in commuting was almost the same as the decline in the number of jobs in Central London, and while car ownership was increasing and population was decreasing there was a clear outward movement of people to the areas furthest from the city. For the period 1971-1981, Preston (1986b) identified a decrease by 11% in rail commuting (including London Transport Underground) to Central London, and concluded that this was due mainly to the decline in usage from within Greater London, as longer distance rail commuting from the outer South-East increased. Indeed, till 1987 the level of employment in Central London was falling and so the city was dependent on those long distance commuters who, most probably, worked in organisations that could not decentralise and so had to choose housing further out in order to get reasonably priced housing. Since then, rail trips into Central London are growing as employment grows, in spite of the increase in car ownership.

Some other determinant factors of commuter journey lengths are fare gradients and the relative house prices at different distances. These issues will arise in further chapters of this thesis.

Table 2.2 shows an apparent net outward movement of jobs, in which Central London presents a less steep decline than Inner and Greater London. The comparison between tables 2.1 and 2.2 shows that in the 1980s, the employment and the flow of passengers in the central area followed opposite trends.

Table 2.2 also shows that the decline in employment was particularly pronounced to Inner London, and that the South-East England experienced smaller reductions than the national level.

Table 2.2 - Jobs in London, SE and Great Britain 1971- 86 (x1000)

London	1971	1976	1981	1986	71-81 (%)
Central	1,241	1,186	1,134	1,084	- 8.6
Inner	2,448	2,250	2,071	1,909	-15.4
Greater	3,940	.	3,489	3,450	-11.5
SE	7,353	.	7,263[a]	.	- 1.2
GB	21,648[a]	.	21,362[a]	.	- 1.3

[a] base sic 68
Sources : Mackett R (1985), OPCS (1982b), and Department of Employment (1985)

One possible reason for the significant increase in commuting observed over the period 1984-1987, was the rapid expansion of the financial and business services, which almost offset the decline in the other sectors of the economy of Central London. Such a change in job mix resulted in an increase in commuting to the central area where the specialized jobs flourished.

Between 1975 and 1980, the coach share of the long-distance travel market remained quite stable at around 10 % of all modes of transport, and about 20-25 % of the public transport market. A slight upturn in coach use came as a consequence of the 1980 Transport Act, which allowed operators to run services of over 30 miles without licence restrictions. Some coach traffic was diverted from British Rail, particularly due to the two rail strikes in 1982.

According to Robbin and White (1987), the operators put more vehicles to attend to the extra traffic, which eventually was partially retained by the coaches. The authors also say that in May 1984, the largest market was from North Kent, given that nearly four out of ten of all commuter coaches were operating along the A2/M2 corridor, in the links mainly with Maidstone, Gravesend and the Medway towns.

However, a reverse in this trend came in 1986. A possible reason for the reduction in the coach traffic is given by Stavely (1989). The author suggested that the commuter population had acquired different routes or modes to work due to changes in workplaces and/or housing location during the 4 to 5 years after the 1982 rail strike. Moreover, he speculated about the saturation of the coach market.

Apart from North Kent and Maidstone, the coach commuting from other areas of the county has been poorly provided, and even nonexistent.

Despite the oil crises of the 1970s, a car boom was observed during the 1980s. The growth of car availability is likely to have a greater affect in the use of bus for local journeys to work and leisure purposes than in the commuting to Central London itself. Policies to control the car use in London came as a consequence of congestion in the inner areas, and various other side effects caused by car use, eg. pollution, accidents. Although private commuting has declined since 1984, the average traffic speed in Central London has decreased, reflecting a situation of congestion. The actual traffic speed is only about 3 mph higher than the speed in 1912, when the vehicles were very slow and the road infrastructure was poor.

There are evidences of the close link between the decision to commute by rail and changes in job or home location. The study on commuting to Central London by Johnson and Nash (1982) showed a relatively high level of home mobility amongst rail commuters, as well as higher job mobility among secretarial workers than managers. As expected, they also found that families tend to live long periods in the same home, whereas single people and couples have more mobility. Since the category of transport workers have benefited from fare subsidy, they usually moved further out than other non subsidised commuters. Therefore, the authors confirmed the belief that travel cost is an important factor in determining location of residences.

The Hertfordshire household interviews used in the study by Preston and Nash (1986) showed that changes in home location were mainly due to life cycle. They also observed a strong relationship between changes in the mode of transport for the journey to work and changes in job or home location. Improvements in the rail system, eg. electrification and parking facilities, were pointed out as attractions of the users to the public transport.

The positive reaction of commuters to improvements in current services was also confirmed by W.S. Atkins Planning Consultants (1990), in the report concerning the proposed Mid-Kent Parkway station. According to the study, commuters to Central London favoured fast journey times on high quality trains, which were less crowded and more frequent than the existing ones. A less significant response for the completely new service proposed by the Mid-kent Parkway to Kings Cross was also detected. Actually, the destination suggested seems to be inappropriate for existing commuters of Mid-Kent, who mainly use Victoria and Cannon Street stations. Despite its importance, the analysis of this potential market is not in the scope of this thesis.

2.3 EFFECTS OF FARES, TICKETS AND SUBSIDIES

During the last decade, the public transport scenario of London has changed. Policies implemented by operators of public transport have greatly influenced the process, eg. level of fares and type of ticket.

There are no doubts about the positive effects of the fares and tickets policies on the use of the public transport system in London. Car ownership has probably had negative effects until 1984, when car commuting was increasing. Since then, car use into Central London has decreased, partially due to the contribution of restrictive policies regarding the traffic and parking in the central area.

A major change in policy, called 'fares fair policy', was seen in 1981. It comprised an average reduction of 30 % on bus and underground fares, and the replacement of the distance-based fare by the zonal fare structure. Four zones with a corresponding zonal fare-scale were created for the bus system. For the Underground, the central area comprised of two zones with different prices, but outside this region the distance graduated fare was kept as before.

During this period, local governments were supposed to decide the level of revenue that should be allocated to support public transport. The 'fares fair policy' was a consequence of this belief, and the reduction in fare was financed by a supplementary rate levelled on the London Boroughs. However, the Conservative-controlled London Borough of Bromley challenged the legality of this policy adopted by the Labour-controlled Greater London Council. The House of Lords concluded that the Greater London Council had no legal power to adopt a policy which was known a priori to be loss-making in the London Transport operation and it reaffirmed that subsidies should be permitted only in the cases where deficits were unavoidable (see Mackie (1987)). As a result of this, in March 1982 average fares were doubled and there was a consequent reduction of 15 % in London Transport traffic. According to Bayliss (1987) such a drop in traffic was accompanied by a "substantial diversion of 'core' long-distance Underground traffic to British Rail and commuter coaches, with corresponding increase in car and two-wheel traffic, leading to increased traffic ongestion".

In addition, the 'just the ticket' policy was introduced in 1983 and fares were reduced by nearly 25 %. As a result, fares stayed in a position midway before and after the 'fares fair'. Around this time the full zonal system, comprising areas of 5 concentric rings was introduced, as well as integrated zonal travelcards for bus/underground. As a consequence, increases of about 16 % in passenger miles and of 11 % in passenger journeys were observed, with a bigger proportion of increase in underground compared to buses.

During the following two years, no other alteration was made to the system, and the increases in traffic continued for the period 1983 to 1985 with growths of 10% and 24% for bus and Underground respectively. In a study about traffic trends in London, Fairhurst et al. (1987) observed that the increase in bus and Underground traffic could be partially attributed to the introduction of travelcards and zonal fares, because passenger miles and passenger journeys had presented growth rates larger than the revenues obtained.

Then, in 1985 fares were increased once more in order to recover the real level prevailing in 1983. Other kinds of ticket were introduced : 'off-peak ticket', 'one day ticket', and the so called 'capitalcard', which permitted the mutual use of British Rail and the London Regional Transport (Underground). In 1988, the average increase of 9.5 % in fares was in excess of the current inflation, however since 1984 fare increases have kept in line with inflation and below the growth in earnings. A policy of full integration came in January 1989, when the capitalcard was replaced by a new 'travelcard', which could be used in any of the three modes of public transport of London (bus, underground and rail).

The gains in the public transport have been retained and continue to increase over time. (see Terzis(1988) and Fairhurst et al. (1987)). However, slight decreases in the number of people entering Central London by public transport were observed in 1989 and 1990. This basically reflects the decrease experienced by the underground, which was found to be very sensitive to the BR and bus fares (Fairhurst (1981).

Glaister (1991) concluded that "contrary to general public perception, the average rate paid per mile travelled has fallen markedly over the decades as a proportion of average earnings". This was based on the fact that during the period 1948-89, income of the travelling public had an approximately constant real growth rate of 3% pa, considering weekly earnings of men in work in the London and South East area, and ignoring increases in the level of unemployment. Using this measure the author found that the Londoners are 2.2 times more wealthy in real terms now than they were in 1963.

This supports the hypothesis that the increase in average distance travelled by commuters to Central London is related to the fact that people can afford to live further out and commute longer distances. Furthermore, that travel costs play an important role on the decision about residential location. These issues are fully discussed in chapter 7.

Glaister (1991) illustrated this effect using a time series of the average fares paid as a proportion of earnings, which is depicted in figure 2.2. It shows a continuous decline in the percentage of weekly earnings required to purchase 100 passenger miles.

In fact, fares have generally risen in real terms, that is after correcting for inflation by applying the index of retail price. This is clearly shown in figure 2.1, which depicts the real average fares paid over 1963 to 1990. Some reductions were observed in this period, but of significance were the falls in 1982 and 1983, particularly in the underground.

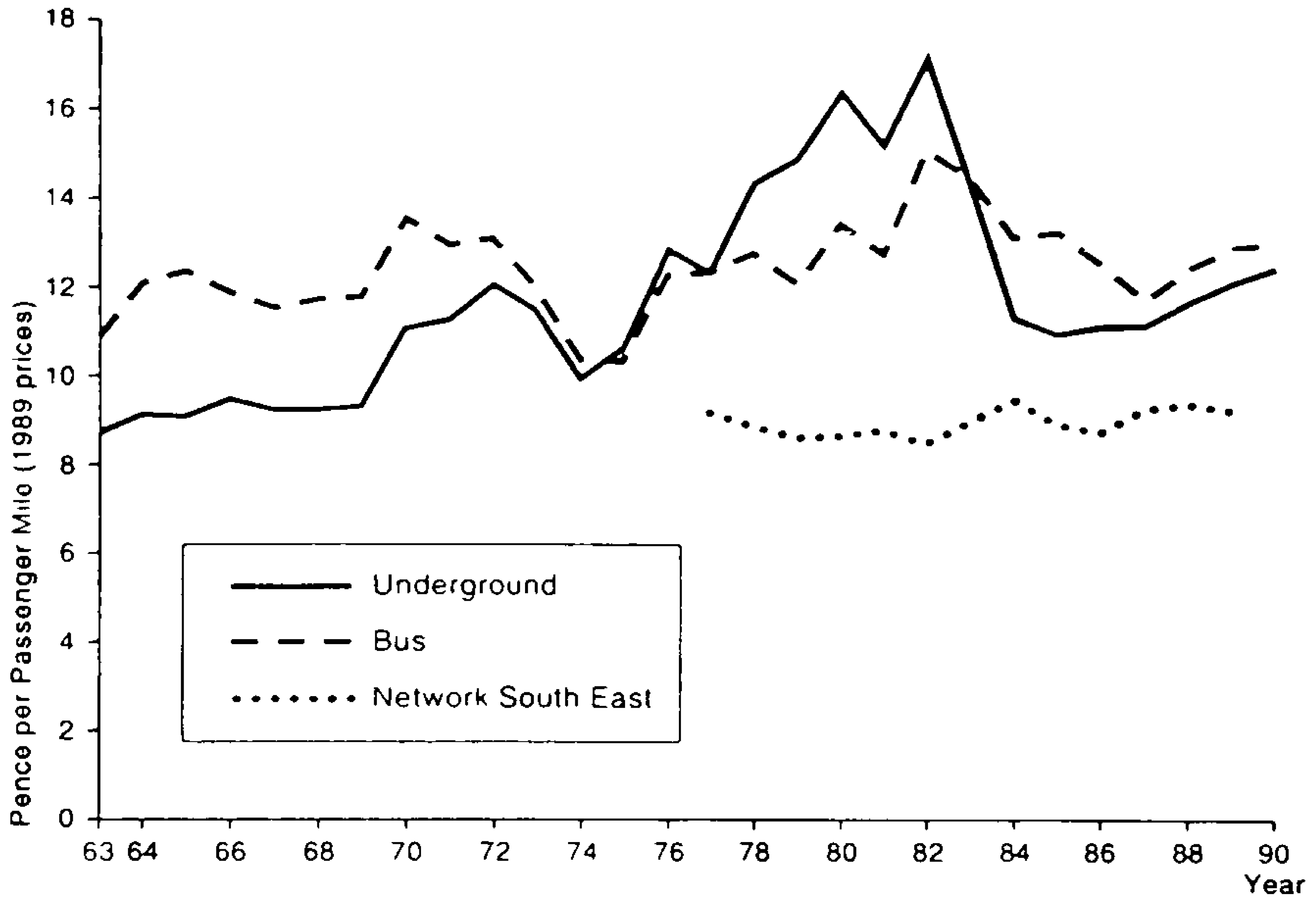


Figure 2.1 - Real average fares paid
Source : Glaister (1991)

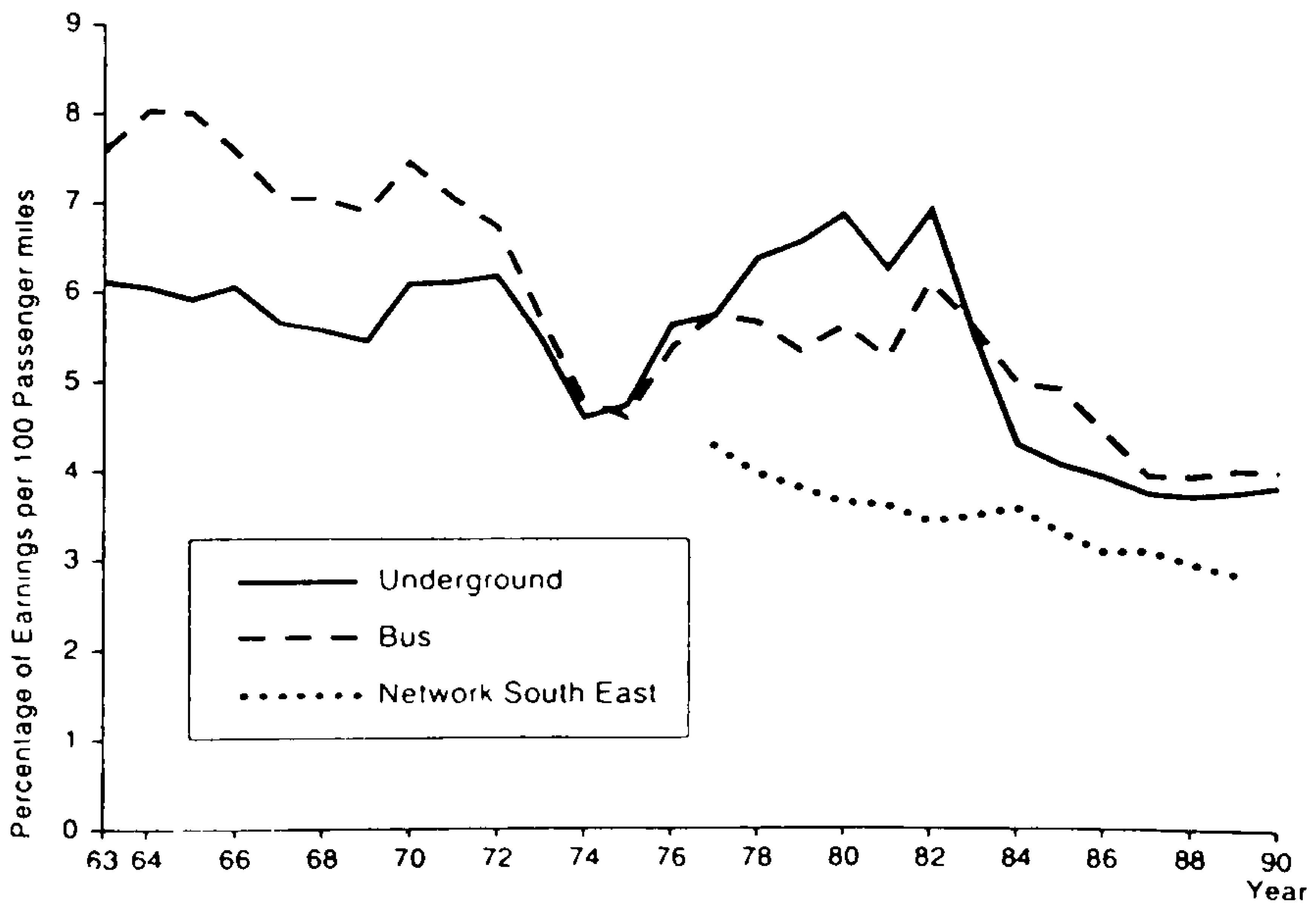


Figure 2.2 - Average fares paid as a proportion of earnings
Source : Glaister (1991)

Since the Network South-East assumes the short-term elasticity of -0.3, for the commuter traffic, and for other travels -0.7, commuter traffic is not considered to be very responsive to the level of fares (see The Monopolies and Mergers Commission (1987)). The fares structure generally follows a standard price by distance travelled, though proportionately more for very short distances. However, as far as the quarterly and second class season ticket is concerned, the travelcard seems to slightly favour short trips. This is shown in table 2.3, which depicts changes in the average real fares at different range of distances over the period 1981-89. The 1989 level of fares of the stations near the border of London, eg. Sevenoaks, Swanley, Otford, Bat & Ball, and Shoreham, were smaller than the majority of the Kent stations, which have not benefited by such a type of ticket. The ratios stand for the relation between the average fare figures of two sequential distance bands. The last column shows the percentage changes during the period 1981-90. The 1981 and 1989 British Rail survey data, which is described in chapter 5, were used in the computation of the figures depicted in table 2.3.

Table 2.3 - Average quarterly fare by range of distance to Central London (£)

distance (miles)	1981		1989		1981-89
	real 89 prices	ratio	fare	ratio	%
<= 30	257.21	-	324.57	-	26.2
(30 - 50]	319.04	1.24	409.19	1.26	28.3
> 50	391.43	1.23	483.00	1.18	23.4

Concerning the zonal ticket for both Network South East and London Regional Transport, the Monopolies and Mergers Commission(1987) stated that "The weekly season is thus priced at 80 to 85 per cent of ten single fares for short trips tapering to 50 per cent or less for journeys of 50 miles or more. The monthly season ticket is priced at a 4 per cent discount on four weekly tickets and the annual at the price of 40 weekly tickets. The effective discount, after the calendar month adjustment, on a monthly ticket is, currently, 11 per cent compared with the weekly rate."

Car use in London has certainly been favoured by company subsidies. According to the Greater London Council (1985), around 19% of the cars used for commuting into Inner London, and 16% of those to Outer London were company subsided. Moreover, 45% of cars terminating in Central London were company cars, and 77% of them had subsidy for motoring costs. For the latter, a significant proportion of 54% reported to have assistance of free parking space. The Greater London Council study also concluded that a great transfer to public transport would be expected for commuting into Central London if company car subsidies were eliminated. In 1985, the modal split for commuters benefited with company car was 60% by car and 40% by public transport, whereas the exact inverse proportion for those with access to private car. A relation of 5% by car to 95% by public transport was found for commuters with no access to cars.

A study by the National Economic Development Council (1990) pinpointed evidence that in the U.K. the company car is being used as a form of income. As such, company cars are associated with employee's personal status, with the implications of high engine size and petrol consumption. The analysis also highlighted the higher mileage driven presented in the U.K. and Scandinavia when compared with other countries in Europe. Increases in car mileage could not be corroborated by the road data investigated in this thesis, however strong evidences of increase in commuting distances were found and are presented in chapter 7.

Regarding rail subsidies, Sly (1986) found that 34% of BR commuters received loans from their employers to purchase season tickets. A proportion of 30% were related to journeys to Central London within 10 mile distances, whereas 52% in journey distances between 20 and 50 miles.

It seems that car subsidies overwhelm the rail ones, particularly if one considers the additional help concerning parking and services.

2.4 - SUMMARY

This chapter reported an overview of the patterns of commuting into London, and highlighted the relevance and dominance of the rail mode in the travels from the suburbs and beyond the metropolis.

The real average fares have generally risen, but the average rate paid per mile travelled has fallen as a proportion of average earnings. This certainly has favoured the long distance commuting, who could afford living out the city.

The relative benefits of travelcards might have had positive consequences on the level and distribution of commuting during the 1980's. As a matter of speculation, it is likely that short distance commuting would be promoted at the expense of the long distance.

The growth in commuting over the 1980's, even when the London economy was badly affected by a shift of jobs, is a striking issue. The combination of factors such as long trend population decentralisation, specialisation of the London job market, and the changes in the relative housing prices at different distances have certainly played an important role on the decisions of living further out and commuting long distances.

Questions concerned with the influence of location decisions and other elements related to the travel system and attributes on the work trips to Central London will be tackled in further chapters.

CHAPTER 3

BASIC CONCEPTS IN THE THEORY OF RESIDENTIAL AND JOB LOCATION

3.1 OVERVIEW

In the ideal hypothetical situation of transport and urban systems, people live in close proximity to their employment. Actually, this situation cannot be easily achieved, particularly in big cities where the majority of jobs are concentrated in the central area. In such cases, competition for space close to the workplace causes a rise in housing and land prices. As a direct result, residential densities decline from the centre.

A similar analysis can be applied to the location of firms, since the wages paid to their employees working downtown are usually high and varies according to the size of the city and the location of jobs in relation to the centre area. Some other diseconomies are higher land prices, congestion and pollution. This, in turn, leads to increases in costs for the firms and for their employees, despite the external economies that come from the central location, eg. transference of information from firm to firm, and the agglomeration effect which consists of the advantage of the increase in the size of the market for supply firms that may then provide goods and services more cheaply.

This chapter aims to provide the basic theoretical background in urban economy that is necessary for both identification of the relevant elements relating location and transport issues, and the definition of the methodology to be used in this thesis. The question of population and work places distributions as well as the interaction between urban structure and transport systems are initially presented. Then, the basic theory of residential and job search and the importance of accessibility in the analysis of travel demand are highlighted.

3.2 - ISSUES IN URBAN ECONOMY

Traditionally, cities have originated from a nucleus of co-existing jobs and residences. The urban structure has continuously changed, and along this process, population has experienced a long term decentralisation, followed by employment redistribution.

Three basic economic structures may be identified for the cities. Initially, they were primarily trading centres, then became manufacturing centres and now are urban centres of administration. Most of the establishments in the later stage comprise of banks, insurance, finance, and marketing companies, which benefit from external economies due to their central location.

However, improvements in telecommunications has allowed both the decentralisation of goods handling and centralisation of dealing, and most of the routine activities do not necessarily have to be located in the central area. Also increased car ownership make the workforce more flexible in terms of job location. In spite of these facilities, which favour job decentralisation, the cities are still very attractive. This is the typical case of London, which has presented growth in commuting over the last decade. Changes in the urban economy, and consequently on the patterns of work travel, have contributed to such a phenomenon. Indeed, as a consequence of the shift of job categories in the city, its catchment area has changed for specialised labour.

If only the costs of travel and housing were considered, the optimal location choice would be one where the household was able to minimise its total expenditure on housing and location, ie. the household would chose a location away from the centre where the saving in housing costs were greater than or equal to the increase in travel costs to that location.

But the location choices of individuals do not usually follow the trade-off between the housing costs which can be saved and the extra travel costs which are incurred. The characteristics of the town and its population are some of the elements responsible for the pattern of location.

Evans (1985) argued that the trade off theory is useful in explaining the pattern of location in very large cities with a dominant city centre, where travel costs are high and journey times to the destinations are long. However, if the differences in housing costs and travel costs are small (as they will be in small towns), then factors such as the past pattern of development and the ownership of land, environmental attributes, the social preferences of the population, and local government services will help to explain the general pattern of location. According to the author, the limited applicability of the trade-off theory is due to the restrictive assumptions on which it is based, such as single central business district to which all workers commute, uniform travel costs, no topographical features, costless adaption of housing, and no externalities.

Residential density, social agglomeration, and local government services are some of the factors which influence people in their choice of residential location. Householders are sensitive to variations in residential density, and in particular the higher-income group willing to pay more for a better residential area. Individuals also prefer to interact with others who are socially similar to themselves. In other words, people of the same class tend to live closer to each other, thus creating sectors differentiated by household income/social class. There is also some responsiveness to locations according to the quality of the public goods and taxes levied by the local government.

Some other factors which drive households to different location choices are level of education, life-cycle changes, historical mobility behaviour, income and changes in the level of jobs provided. The level of education can be related to mobility in a sense that educated people are better informed about cultural and economic opportunities. High incomes may imply a higher demand for space radiating out from the city centre. On the other hand, high income may also increase the time cost of commuting, leading to a need for locations closer to inner areas. But there is also a question of life-cycle, as younger and single people tend to live in high-priced houses near the city centre whilst families usually choose places further away. The combination of all these factors are likely to be important in this study.

In the U.K., there is a tendency, which is almost generalised, of richer people living further away from the centre than the poor. This is a characteristic of households with high income elasticities of demand for space. For those wealthy people with low income elasticities, the districts in the inner areas are preferred. The relative location of different income groups depend not only on the income elasticity of demand for space, but also on the cost and speed of transport, and other geographic and socio-economic factors.

To a certain extent, the decisions made to locate roads, railways, ports and airports have had an influence on people's life pattern and mode of transport. The transport systems shape the distribution of activities and interfere in the proportions that each zone contributes to the total traffic. Transport investments like a general increase in the comfort of travelling, might increase people's willingness to travel further, and changes in transport cost and time might affect the pattern of location of households relative to each other as well as in relation to the centre.

An increase in the speed of travel, which reduces journey times, has a much bigger effect on the reduction of travel cost of the high income people than on the costs of the lower income group. This is due to the higher value of travel time of wealthy people in relation to the other classes. Consequently, increases in travel speed favours the decentralisation of high-income groups.

On the contrary, a direct decrease in the transport costs causes a reduction of travel costs for the lower income groups that is more proportional than the amount perceived by the higher income groups. Therefore, it may lead to an outward movement of low-income households relative to high-income households.

Based on the previous argument, Evans (1985) concluded that a slow, cheap and uncomfortable transport system would result in a compact city with wealthy classes living close to the centre. On the other hand, the opposite effect would be seen with a fast, expensive, and comfortable transport system.

A brief recapitulation of the urban centres economy shows the effects of transport investment on the location of economic activities. In the nineteenth century, the short distance transport of goods using horses and carts was very inefficient as regarding cost and time. Therefore, the industries were usually located close to each other, and particularly in ports where the raw material could be easily accessed. Moreover, they tended to be concentrated in the city where the distribution was facilitated. However, the growth of cheaper, faster road haulage, and the reduction in transport cost since then have allowed the decentralisation of manufacturing from the large cities. In spite of the external economies obtained with the agglomeration of industries, the costs of concentration (eg. high land costs, high labour costs, congestion and pollution), have favoured the dispersal of the production sectors of the economy from the metropolis.

But in addition to decentralisation, the manufacturing industry has also been affected by a national economic crisis which has caused a drastic reduction in this sector.

The chapter now turns to a more specific issue that is the linking element between the city activities and the transport system. A basic concept of accessibility and some evidence of its relevance in determining the uses of the land are discussed in the following section.

3.3 - ACCESSIBILITY

Mobility and access are important for the economic well being of the city and the quality of life of the population as a whole. Due to easy accessibility, the city centre has been chosen for the location of specialised operations of both retail distributors and office activities. In most cities, the demand for central spaces has maintained high rent and land values, leading to a sharp fall in employment densities beyond the central business district (CBD), and then to gradual changes according to the inverse relation of the distance from the city centre. This is the typical case of London, whose annular job density, defined as the number of jobs in each two kilometres annular band from the centre, falls from around 600 in the central area to 100 within the first four kilometres (Dasgupta et al.(1990b)). The authors also found some other cities in Britain which have peripheral job locations, but still present low densities when compared with the CBD.

Improvements in accessibility to urban centres have played an important role in the increase of commuting to Central London. The process led to the incorporation of urban areas to the extended metropolis, and the link of former remote areas to the centre of economic activities. As a consequence, the overflow population of the metropolis could keep their activities in the central area.

Accessibility has been traditionally associated with the spatial economy of the cities as concerning urban rents, densities, and land use. However, more recently emphasis has been put on the effects of changes in accessibility on travel demand, due to urban transport investments. This is the concept that is used in this thesis.

Martinez (1991) explained accessibility in terms of spatial distribution of activities and the transport costs involved. Since individuals perceive trips and activities differently according to their taste and/or income, one might expect different accessibility valuations amonst them. This is clearly explained by an example given by the author in which the accessibility level in the city CBD is perceived differently according to the spatial distribution of the activities even if the transport costs are kept the same : ... accessibility for the activity "doing business during working hours" is normally the highest in the city while for the activity "attending school" it is usually very poor. The author concluded that accessibility should be represented by a collection of measures, and not by just an overall measure for a particular location. His proposed accessibility measure deals with the interaction between transport and urban rent, and consequently is of little application in this present work.

The study by Dalvi and Martin (1976) accounted not only for travel impedance but also considered location attraction as perceived by residents of the area analysed. One of their conclusions was that the accessibility pattern of the private transport in the Inner London area was very sensitive to the choice of the attractor variable considered (total employment, retail employment, households or population). If total employment was the attractor variable, then the central areas were more accessible than any other in Inner London. On the contrary, if household on employment were used, then the accessibility differentials would not be so pronounced.

Other measures of accessibility were proposed by Williams (1977), under the concept of composite costs, and by Ben-Akiva and Lerman (1979), as the expected maximum utility. Both concepts are compatible with the underpinning of the methodology considered in this thesis, which is based on random utility theory. Since this theory has been successfully applied in the spatial distribution analysis and modelling, a measure of accessibility given by a generalised cost function is proposed here. The basic concept underlying this theory is presented and is fully discussed in chapter 8.

3.4 - RESIDENTIAL AND JOB SEARCH

In the current literature, decisions concerning job and house location have been frequently described as interdependent rather than simultaneous. Decisions on home and job location are interrelated and, among other factors, dependent on the spatial separation between home and work place.

The decision to change residence may be associated with an increase for example in the number of children, or the wish to have a more comfortable house in a better environment. It might be the case that the residential change is not a consequence of any decision concerning job change. This happens when a household wants to keep the same job but decides to move to a bigger house due to life cycle effects, for instance. If the household works and lives in London, the relocation might possibly take place outside the conurbation due to constraints of the housing market in London. Then, as a consequence of housing location, the household may find it easier to change the work place, eg. to work closer to the new residence. Such an attitude would result in a structure of interdependence between job and house location, in which the work place would change consequent upon a change of house.

Similar analysis may be drawn for a change in work place. The decision to change job may happen completely independent of housing location, eg. a resident in Kent who works in London may decide to choose another job, either in London or elsewhere, without taking any decision about house location. However, it might also be the case that consequent upon a change in job, the home location also changes. This is a typical example applied to those who retire from Central London jobs and decide to change home. Most of them tend to relocate elsewhere in the South-East, where better housing condition might be easily achieved.

The above explanation clearly shows the complex links between the structure of location and the patterns of the various activities carried out by the household. The dynamic of this process is also illustrated by those who retire and have their vacancies filled by new entrants to the labour market. In this case, a change in commuting patterns may arise without anyone changing home location.

The simultaneous relocation of both job and home places is possible, but it is rather unusual. Changes in the location of both household's residence and its worker's workplaces usually happen close in time to one another. Imperfections in both the housing and labour markets, and time lags in decision-making are pointed out by Weinberg (1979) as factors which lead one to believe that simultaneous moves are not likely to occur in metropolitan areas.

An additional complexity in location matters concerns transitional relationships between home and job places. This case applies when a person has to start a job in a different place but can not buy a house before starting that job. This implies a conditional relationship that the home location might be expected to change as a consequence of a change in job. In the interim, for example, a lengthy, disequilibrium commute may be required.

A definitional question arises with the relationship of a temporary 'home base' which is arranged during the working week (eg. a guest house or pied a terre). The work journey would be the movement to/from the main residence, if the beginning and end of the working week is considered. During the working week, journeys to/from the temporary home would then be undertaken. Given the different cycle of regularity between journeys involving permanent (weekly or monthly) and temporary (daily) homes, they are usually modelled separately (see Kirby (1979)).

Another complication may arise when more than one of the above home-work relationships apply to the members of a household. This is exactly the case of a family member who takes a new job in a far away location, changing consequently the residence. If the other member(s) also had a job in the old place, then change(s) in employment location could happen as a consequence of the change in house.

Studies on migration and mobility analyses generally consider the relocation process divided into household's aspirations, decision-making and the actual search stages. The first two stages involve the decision to move from the previous residence or job, whereas the search stage comprises the screening of a particular search area and the selection of availabilities in the market, usually announced by the media and estate agents.

The understanding of the patterns of mobility requires the identification of factors which affect the complex interaction of job and residential movements, and definition of the relative importance of these variables as regards location decisions. A general view of the influence of some variables on mobility behaviour was previously presented in sections 3.2 and 3.3 of this chapter. Although most studies do not make a clear distinction between factors influencing the search area from those influencing home/job location, this section attempts to give emphasis to the search process.

Raji (1987) concluded that accessibility to work and transport-related variables are the most important factors in search-area decisions. His finding is supported by several studies on the role of transport and accessibility in residential location decisions. For the earlier stages of the relocation decision, ie. household's aspirations and decision-making, factors usually related to the decision to move are:
(i) dissatisfaction with the standard of living (housing conditions, neighbourhood quality, costs of living); and
(ii) life cycle (retirement, family size, composition and age).

Alternatively, the most frequent reasons associated to the decision to change job are redundancy and the decision to quit; the latter due to dissatisfaction with the job duties and activities, office environment, wage, and desire of a better position.

Miron (1978) quotes and questions Sjaastad's (1962) argument that migration tends to occur whenever there are differences in the standard of living between regions that are sufficient to exceed the costs of migration. According to Miron (1978), such a consideration would require perfect information by the potential migrant about the disequilibrium among regions. Therefore, this is a condition hardly to be found in practice.

Lyon and Wood (1977) observed that real-life decisions are subject to psychological constraints not present in laboratories or hypothetical situations. The authors found that house owners are not very systematic in their searching and evaluating process of choosing a house. Their finding was corroborated by Barrett (1976), who concluded that search behaviour in residential relocation is not a thorough process.

Barrett (1976) attempted to quantify search areas by studying the distances between the vacancies actually considered by a group of movers. The author developed three indices to measure search behaviour, which showed that spatially, the intensity of search was a random distribution; and that the areal extent of search was limited. The evidence found in his study indicated that the behaviour of most people is to buy a house after a very short search which covers only a few houses in a small area. Actually, only about two per cent of the trial group of movers considered had search clusters of more than five miles.

Kirby and Raji (1992) argue with these results on the basis that "the vacancies were of those *actually* inspected, which might therefore define a smaller (and possibly biased) area compared with that defined by the vacancies that one could inspect (ie. those in the 'search space' of Moore and Brown)". Moreover, the authors quote Davey's (1978) research in which 35 percent of the respondents considered areas beyond five miles from their chosen house. According to Kirby and Raji (1992), all the areas considered by the respondents were taken into account in the latter study.

The limited extent of the area of search is also supported by Brown and Moore (1970), who supposed that the migrant's knowledge of the possibilities was the principal constraint on the search pattern. Their study indicated that the density of information per unit area of the housing market tends to decrease with the household's location as the centre of the density surface. Moreover, the space of direct contact, provided by the day-to day activities undertaken by the household, was oriented along the major transport arteries to the city centre.

For transport planning, and in particular for the formulation of a destination choice model, Kirby and Raji (1992) suggest a choice process, which basically involves the range of house prices that an individual is willing to consider, and the geographic extent of the area of search. The authors agreed that the definition of a search space for a home or for a job is the main factor affecting the pattern of journeys between home and work; moreover, that the individual's choice of home (of a given type) within this area is random distributed.

Kirby (1979) considered different shapes of the search area assuming single and multi foci points. Given that most migrants will be unfamiliar with the area, for inter urban or labour migrants he suggested a monocentric area whose reference is the site of work. The case of more than one focus (eg.actual home and job) was considered for intra-urban migrants, who would probably have a more detailed knowledge of the search area.

3.5 - SUMMARY

This chapter reported basic concepts of the theory of residential and job locations and highlighted the interaction between transport and urban structure. It was shown that improvements in transport, and particularly in accessibility, play important roles on the location of firms and on the pattern of residential location. The interaction between urban structure and transport system comprises an important task as concerns the aims of this thesis.

It was also pinpointed that the spatial distribution of population, together with the relative distribution of jobs are important determinants of the choices concerning journeys to work. Moreover, that the socio-economic classes are related to travel distances, as the non manual workers travel longer distances than manual workers.

Factors which affect the optimal household location were pinpointed. Some external economies which favour firms to locate in the central area were presented, as well as the changing trend of the core of the large cities from manufacturing to a specialised office centre.

Various relationships involving location decisions of home and work place were presented. The relocation behaviour was associated to three different stages: household's aspirations, decision making and the actual search process. Dissatisfaction with the standard of living and life cycle were pointed out as the main factors related to the earlier stages of the relocation decision.

The review of the literature on migration and mobility suggested that the impact of accessibility is more pronounced in the search area than in the stage of the residential location which involves the decision to move to a new house.

CHAPTER 4

THE APPROACH ADOPTED

4.1 INTRODUCTION

The previous chapters have discussed the objectives of this thesis and the main elements of urban economy in relation to the location of residences and jobs. Here, this chapter turns to the study's methodology.

The method followed has two main interdependent stages. The first is to construct a model which estimates the effects of changes in the generalised time of the transport system and the levels of local employment opportunities and population on the probability of choice for the modes and destinations available. The second is comprised of a general descriptive investigation of the data base, which aims to identify possible trends related to the changes of the pattern of commuting from Kent to Central London, during the 1980's. There is the hope that the integration of both approaches sheds some light on the understanding of the response of London's commuters to changes in travel attributes and relocation of jobs and residences.

The roles played by population distribution and job decentralization in the changes of the travel patterns and the need to understand temporal and spatial trends in commuting are covered in the section 4.2. Then, in section 4.3 a brief review of past studies in the demand of the rail commuting to Central London introduces the necessary background for the model definition. In the same section, a range of modelling approaches is suggested for analysis, although this is a stage strictly dependent on data availability, which will be explored in chapter 5.

4.2 DESCRIPTIVE ANALYSIS

A general descriptive analysis of the data aims to identify and provide a better understanding of the determinants of changes in the patterns of work journeys.

One part of the analysis concerns the effects of the spatial and temporal distribution of residences and employments on the complex patterns of commuting. The other examines the attributes of the transport services as well as the socio economic aspects of the commuters.

4.2.1 THE ROLE OF POPULATION DISTRIBUTION IN THE CHANGES OF THE PATTERNS OF COMMUTING

It was shown in chapter 3 that factors such as income, level of education, and life-cycle play an important role in residence location. Moreover, that changes in transport attributes are perceived differently by people of different socio-economic levels. Consequently, increases/decreases in transport costs, speed, and comfort lead to dissimilar urban structures, and therefore different patterns of commuting.

The location of residences relative to jobs is also of relevance as regarding the choice of the transport mode for work journeys, eg. foot is generally considered the main accessible mode to work places where the location of both homes and jobs are centralised. On the contrary, if the distribution of employment is centralised and population is decentralised, then travel patterns are oriented to the city centre, and the journeys are preferably made by public transport. This is due to deterrent factors to the use of cars in central areas, such as traffic congestion and parking constraints. The car mode is generally selected in situations of decentralised distribution of employment, when the trip patterns tend to be orbital rather than radial.

Cross (1988) found evidence of the link between increase in suburban population and commuting. The author concluded that population growth in rural non-metropolitan areas observed during the period 1971-81 was related to the increased flexibility of residential location caused by improvements in the public transport, and raise in car ownership levels. Such an improvement in mobility, plus the housing demand, price differential, and quality and cycle of life encouraged long distance commuting.

A comprehensive analysis of the 1981 Census of Population data may provide useful information concerning the level of population distribution by socio economic characteristics and zone. Fruitful insights might be given by an analysis of the changes in population and commuting during the period 1981-1989. An attempt to identify any possible relationship between changes in population and local employment is also proposed.

4.2.2 THE SPATIAL DISTRIBUTION OF EMPLOYMENT AND ITS EFFECT ON TRAVEL PATTERNS

The level of decentralization of jobs and its relative distribution to homes help to explain the changes in trip patterns. During the last decade, a simultaneous process of concentration of specialized jobs in the city centres, and decentralization of manufacturing jobs was seen. As a result, non manual workforce has been attracted from a wide catchment, whereas labour catchment areas tend to become more localized for manual workers. This is corroborated by Dasgupta et al. (1990c), who concluded that non manual workers tend to travel longer distances than manual workers.

Such a conclusion applies to the study area proposed in this thesis. The city of London is comprised of a specialized central business district with high central employment density, while Kent contains a set of places of relative local attraction, in which the job opportunities tend to be less specialised.

This gives an idea of the interrelation between spatial and temporal distribution of employment and the travel patterns. A cross analysis of the commuting and job data is proposed in order to determine the role of employment distribution in the changes of the patterns of commuting over the last decade. This descriptive analysis also attempts to identify possible trends in the local job market of Kent.

4.2.3 TEMPORAL AND SPATIAL TRENDS IN COMMUTING

As previously reported in section 2.2, it was observed that in the early 1980's, there was a steady decline in the demand for public transport in London. This fact was partially a result of the policy of decentralisation of cities as a means of post-war reconstruction, but also due to the extraordinary growth in car ownership over the 1970's.

However, this situation was changed during the 1980's. British Rail and the underground have shown substantial increases in patronage. The mode split of passenger traffic of these modes have also increased, mainly at the expense of a fall in bus usage.

The relevance of the analysis of the historical trend in commuting has already been pinpointed in this thesis. British Rail surveys data are valuable sources of information, in particular the last one (see section 5.2) which holds data on the accessibility to and from stations. It is important to highlight that the last survey data has not previously been analysed.

The cross analysis of the 1981 and 1989 data set might give relevant information concerning the changes in distribution of commuting among the zones in Kent, the socio-economic characteristics of the traveller, and the response of the commuters to changes in their travel attributes.

4.3 MODEL OF COMMUTING CHOICES

A vast number of studies have been carried out concerning rail commuting into Central London. One of the earliest analyse involving this particular segment of the passenger demand was conducted by Foster & Beesley (1963), who accessed the social benefit of constructing an underground railway in London. The authors attempted to explain the number of Central London commuters from different boroughs using regression analysis and the combination of journey time, social class composition and size of population.

Some studies were aimed to evaluate the effect of different policies on the public transport demand of the urban area of London, see eg. Fairhurst et al (1984), Terzis (1988). Some others were concerned with the inter-city rail travel in the UK, which usually included the analysis of time series ticket sales data of London-based flows (Tyler and Hassard (1973), Jones and Nichols (1983), Fowkes et al (1985), Owen and Phillips (1987)). The inter-city service covers the principal trunk routes of the British Rail network, and therefore has different characteristics of the sector that deals specifically with the London commuters services, provided by the Network South East. In spite of their importance as concerning the passenger demand in London, these studies are not directly focused on the commuting side.

Amongst others, the suburban rail travel to work regarding local authority areas of various distances from London were considered by Wabe (1969) and Hepburn (1977). Both studies used a regression analysis technique based on the Census of Population data. Wabe (1969) identified the social class composition of the borough as the crucial factor influencing the proportions of male commuters to Central London, followed by journey time, accessibility to two or three stations, and the availability of employment within the borough. Hepburn (1977) attempted to examine the effect of changes in the rail service (variables fares, frequency and journey time) on the patronage. Unfortunately his study was not very conclusive about fare elasticities, and there was strong evidence that factors other than the level of the rail service analysed affected the travel pattern of commuters.

One of the few applications of the logit model was by Glaister (1983), who analysed the market share of different ticket types, for short to medium rail journeys to work into Central London.

Mackett (1985) modelled the impact of the cost of rail journeys between London and Hertforshire, and considered an extended version of the residential and employment sub model of the Leeds Integrated Land Use Transport model (LILT). The changes in the total number of residents working in London was assumed to be dependent on the allocation of workers to jobs plus their residential location and mode of travel. The author concluded that the decline in long-distance commuting to Central London would happen even if rail fares remained constant over the period 1981-86. Moreover, the number of relatively short trips by rail would increase to attend to the demand of commuters into London who would choose housing locations near their work places. Clearly, the forecasts were effected by decentralisation of jobs and population, as well as the increase in car-ownership over the period analysed. Consequently, the results of his study were not confirmed over the period 1981-1986, when the level of rail commuting from Hertfordshire to London had increased by 2% (see Hertforshire County Council (1990)). His conclusions about the effects of fare increases into Central London were corroborated by another study (see Mackett and Bird (1989)) using the same model but an area expanded to the South East Economic Planning Region. The latter study suggested that a large proportion of people would take into account revised fares in the process of changing home and work, and that the relocation of population in the South East has a simultaneous inward and outward movement. The former motion concerns people working in the city centre, whereas the latter follows the tendency of life-cycle.

Mackett and Nash (1991) pinpointed two particular problems concerning the analysis of the commuting market of London. The first regards the cross-elasticity effect between rail routes, and the second is the need of a forecasting model which considers not only the transport system variables but also the location and land use issues. The latter is based on the fact that changes in the number of jobs in the city and the location of the commuters who travel to Central London play an important role on the changes of commuting. Moreover, the authors also consider that changes in travel attributes would affect the land-use variables.

The limitations of time and data imposed the use of a much simpler model than the strategic models LILT (Leeds Integrated Land-use Transport) and MASTER (Micro-Analytical Simulation of Transport Employment and Residence) developed by Mackett. Moreover, since this thesis comprises a specific case study, which is to identify and understand the changes in the patterns of commuting to Central London, a less ambitious methodology tailored to give the solution of this particular problem seemed to be more appropriate.

The proposed method might have an underpinning to shed some light on the response of the commuters to the changes in both the transport attributes and the level of local jobs by population. There is the hope that such a model could be used as a predictive tool of policies involving the opening of stations, new parking areas, and new jobs.

Due to the performance of probabilistic models applied to transport (Ben-Akiva et al. (1985), Copley et al (1988)), the logit model was chosen for the analysis. The proposed model is supposed to explain the level and mode of commuting to Central London, taking into account the decision process over location and mode choice. The concept of the logit model is given in chapter 8.

A usual question in modelling demand concerns the choice process. The sequential choice structure occurs when at each decision level, the choice is assumed to be conditioned on the previous choice, whereas the simultaneous process assumes that the ratio of any two probability choices is independent of the characteristics of a third one. There is a certain consensus about the conditional structure being more realistic, however there is a compromise between its complexity and the level of practical requirements from the results.

The proposed approach involves both decision structures. As the data limitation permits, an initial investigation may regard the hierarchical structure of mode and destination choices. Other forms of the multinomial logit are also recommended for analysis.

Based on the data limitations pointed out in chapter 5, the estimation of the parameters of the model will be based on the 1981 data, while the validation will comprise a forward projection using the 1989 data set. A complete discussion concerning the modelling approach is given in chapter 8.

The proposed methodology is likely to explain some issues which could not be completely explored in some other studies. The main contrasts between the present research and most of the predecessor studies, are the following :

(i) The period - Wabe (1969) spanned the 10 year period 1951-1961, Hepburn (1977) related to the years 1966-1971, and Glaister (1983) the range of 1972-1977. Mackett (1985) used survey data (carried out in 1975 and 1976) and the 1981 Census of Population. The specific phenomenon concerning the commuting into central London that was observed during the 1980's has not yet been analysed at the depth proposed here.

(ii) Analytical technique - regression analysis was used by Wabe (1969) and Hepburn (1977). The association of method with variables adopted in both studies were not powerful enough either to explain the spatial context or to cope with the problems of autocorrelation and multicollinearity so frequent in multiple regression. In spite of using a flexible and appropriate model based on the utility maximisation theory, Glaister's (1983) approach was not concerned with the relation between trip rates and location changes. Despite its popularity, there is still a gap in the literature concerning the application of the logit model to explain the pattern of suburban commuting to Central London.

(iii) The scale of the study area - Wabe's analysis was related only to areas within 30 miles of Central London. Significant contribution of zones further out, including remote and rural areas which are actually in the catchment of the commuting to London were excluded. Glaister (1983) limited his analysis to two flows from 32 and 50 miles from London. Hepburn (1977) spanned a wide study area comprising 65 local authorities, however he did not consider rural districts. Moreover, the previous studies considered a higher level of aggregation than the proposed in this thesis.

(iv) Local attraction - the degree to which the employment situation in one area has repercussions on surrounding areas has not been satisfactorily specified. Wabe (1969) considered the total employment available within the area's boundary, while Hepburn the number of economically active people in a local authority. Shepherd (1974), in a study carried out in Australia, used the ratio of the labour force employed in a certain zone divided by the total labour force resident in that zone. None of the studies showed reasonable results for the proxy variables which accounted for the local focus of attraction. In this thesis, a specific zone of influence was determined on the basis of the relevance of the local flows from each ward, such that the local attraction was given by the number of jobs by the population within that zone.

(v) accessibility - a variety of measures have been applied in previous studies. In Wabe' study (1969), many variables were supposed to account for accessibility, such as fares, journey time, and dummies concerning access to routes and modes. As mentioned above, his results were argued on the light of the substantial multicollinearity found in the model. In addition to fares and journey time, Hepburn (1977), also considered the train frequencies and the availability of the car. Again, his results were not strong, and the author concluded that only the level of rail service was not enough to explain the changes in patronage. The present work also regards commuter accessibility as the monetary cost of the journey plus the value placed on the time spent travelling. However, the significant contributions given by access and egress time on the generalised time of the trips represent an important departure from the other analyses.

Since the previous studies have provided the foundations on which this research was laid, it is worth noting that, rather than only differences, there are also some similarities shared by them.

4.4 SUMMARY

The methodology was suggested in the light of the nature of the problem to be analysed in this thesis, and the evidence of previous studies.

The importance of the spatial distribution of population and the relative distribution of jobs on the choices concerning journeys to work, were highlighted. Moreover, the socio-economic characteristics of the commuting population influence travel distances, as the non manual workers travel longer distances than manual workers.

Given the need to identify and understand the complex interaction of the factors which affect the travel patterns, a descriptive analysis of population and job distribution, plus the examination of the spatial and temporal changes in commuting from Kent were proposed. As concerns the quantification of these effects, the investigation of the hierarchical and multinomial structures of the logit model was suggested.

The approach proposed is particularly appealing because it involves a powerful model structure and the use of existing data set which in a great deal has not yet been explored.

CHAPTER 5

DATA SET

5.1 DATA REQUIREMENTS

The achievement of the objectives of this research leads to a methodology which requires extensive use of data. To a certain extent, the information applied in the modelling procedure is more demanding than the one used in the descriptive analysis. The former constrains the data to a specific format, and requires compatibility of scale and unit, whereas the latter is more flexible and combines information at various levels of aggregation and detail.

Ideally, the analysis should be carried out at as disaggregate a level as possible, since differences amongst areas, as well as amongst individuals are likely to exist. However, there is a compromise between disaggregate level and the complexity of the model. As concluded in this chapter, the availability of data leads to a zonal analysis, in which the minimum level of aggregation is the ward.

One relevant characteristic of this thesis is the emphasis placed on the use of existing data. It is very common to face a situation in which there is considerable quantity of data which does not directly fulfill the needs of the analysis in question, eg. the available data is incomplete, has different levels of accuracy and format. This is particular true when the resource limitations necessitate the use of old data, usually collected for previous or even different applications and purposes. This practice inevitably involves some compromises, that have to be negotiated in the light of cost, precision and quality of the results.

A comprehensive view of the data requirements, as well as certain skills to cope with the gathering, and implementation of the existing data are necessary to make the various pieces of information suitable for the specific use. This tough task was pursued in this thesis, and comprises an important part as regards the merit of this study.

The two major sources of data used in this thesis are the 1981 Census of Population and the 1981 and 1989 British Rail origin and destination surveys. The Kent County Council provided survey data regarding the road mode, while the 1989 Census of Employment gave confidential data concerning job opportunities. Some additional information were obtained in the literature of previous studies as well as in periodicals which contain economic indices of the British economy.

The next section of this chapter describes the various sources of data analysed. Then, the main features of the data and its limitations are reported, such that the basic determinants of the methodology and model selection may be better understood.

5.2 DATA SOURCES

5.2.1 RAIL DATA

The large majority of the rail data analysed comprises journeys from stations of the County of Kent, which are part of the information given by the surveys of rail travel in London and the South-East, carried out every 10 years. This data provided information at the individual level. Some engineering data , eg. in-vehicle time, distance, and cost, were obtained in other different sources.

The questionnaires used in both the 1981 and 1989 surveys, comprised two main sections: (i) information about the trip attributes, and
(ii) general questions concerning travellers and tickets.

Regarding the trip attributes, both surveys contained similar questions about the rail journey itself, and the journey before and after taking the train. The questions were concerned with journey purpose, mode of travel to access the BR stations, destination station, interchange stations, schedule train times, mode of transport used to continue the journey onwards from the final BR station, and origin address.

The two surveys differ in the information regarding access time to stations. This variable is only available in the 1989 survey. Another characteristic of the 1989 data regards the origin addresses directly given by postcodes. Such facility allows the relation between postcodes and the Office of Population Censuses and Surveys (OPCS) areas to be straightforwardly obtained by using the special package POSTZON, run by the Manchester Computing Centre.

Unfortunately, the postcodes were not a very precise piece of information. In addition to the usual high number of missing information, the decoding of the questionnairies involved serious mistakes regarding the postcodes formats. Consequently, a large number of addresses could not be identified and properly matched to wards.

Due to the aggregate characteristics of the information applied in the model, it is unlikely that the reduction in sample size had significant consequences in the precision of the estimators obtained. In spite of its reduction, average figures could still be obtained for 246 out of the 304 wards included in the area analysed.

An additional difficulty to be reported concerns the change in ward codes introduced in the actual version of the POSTZON file. The new ward codes are inconsistent with the ones given by the OPCS, therefore the old 1981 file, which is off-line in Newcastle University, had to be used instead. Since the

1981 and 1989 postcodes are expected to be similar, it is unlikely that such an alternative has introduced errors in the data set.

In chapter 9, the aggregate analysis regarding the temporal transferability of the model was undertaken at the level of district. Therefore, the updated version of the POSTZON provided by the Manchester Computer Centre was used to match postcodes to districts. At the level of district, only 1% of the commuter's postcodes was mismatched.

One of the peculiarities of the 1981 survey concerns the coding of origin addresses. Codes were associated to a particular zoning system which has no relationship with the zones given by the postcodes. They also do not match the OPCS zoning at the level of enumeration districts (EDs), parishes, or wards. The zones were coded by numbers of 6 digits: the first four digits identify the districts, and the following two represent the zones themselves. Kent was covered by 322 zones which codes, given by the 'External Zone Gazetteer - Decode', vary from 980201 to 982724. Some of the zone's names listed in the Gazetteer coincide with the OPCS wards, however there is no guarantee that they exactly correspond to wards either in location or size. Therefore, any comparison between the 1981 and 1989 data sets had to be based on the district level. Unfortunately, a copy of the 1981 Travel survey map was not available, and even an inaccurate visual comparison of zones to wards could not be make.

There are some questions regarding trip attributes, which are not necessarily included in every card, eg. egress time to the final destination after leaving the last BR train, frequency of trip, return journey, number of people in party, and number of nights away.

The other major section of the questionnaires concerns general questions about age, sex, occupation, and car availability of the travellers, as well as information about the class and type of ticket used.

In the 1981 survey, four types of card were used. However, for coding purposes, the cards with serial numbers 'A' and 'T' were identical, as well as 'B' and 'V'. Three versions of the questionnaire were used in the 1989 survey: morning flows, afternoon flows, and weekends. In view of the aims of this thesis, only the cards returned in the morning survey were considered.

The estimation of the total population commuting by rail was obtained by the expansion of the sample data using weight factors provided by British Rail. The issue of the questionnaires was consistent with the stations passenger counts.

Concerning the range of weight factors applied to the station samples, different approaches were used in the 81 and 89 British Rail surveys. The 1989 data gave figures that varied within the wide range of 1.0 to 19.1. The large majority of the weights of the 1981 data was 4.0, although a few cases of figures 8.0 were also observed. This clearly shows that most of the 1981 samples extracted for processing and analysis comprised 25% of the population, whereas samples of a variety of population proportions were considered in the 1989 survey.

A nuisance in the analysis of the 1989 survey was caused by the introduction of additional codes for Victoria and London Bridge stations. The new extra codes were supposed to split up the South Eastern Division and Central Division flows of each mentioned Central London station. However, the two new codes were not published in the list of station codes provided by the British Rail, and this led to confusing and delay until the missing codes were discovered.

Figure 5.1 depicts the 67 stations that simultaneously presented journey to work data in Central London, in the 1981 and 1989 surveys. The relation of the stations is given in appendix 5.1.

Fig 5.1 - Rail stations analysed

As shown in the figure 5.1, some important rail lines in Kent were not covered by the 1989 survey, in particular the segment which comprises the main stations of Dartford, Gravesham, and Rochester, at the time at which the data set was acquired. By coincidence, the excluded districts have significant coach commuting flows to Central London (Preston (1986a), Staveley (1989)). The lack of rail data in these three North Kent districts not only led to the decision concerning a reduction in the area of analysis but also acted as one of the determinants of the exclusion of coach as a mode alternative to be considered.

5.2.2 CENSUS DATA

a- Census of Population

The Census is a comprehensive and reliable source of information. It comprises data in two main divisions: Small Area Statistics (SAS) and Special Workplace Statistics (SWS). The former represents a collection of over 4000 variables derived from the completed census questionnaires applied to approximately 130,000 enumeration districts of Great Britain. Most of them are based on a 100% sample of Census returns, however variables such as socio-economic groups are given at the level of 10% sample. The 100% and 10% SAS are available as separate SASPAC system files, which are accessible through the University of Manchester Regional Computer Centre.

The Special Workplace Statistics (SWS) is a specialized ward-level data set. It is derived from the 10% sample of Census returns, and provides detailed statistics of the employed population of the country. It is subdivided into three separate sections (A, B, and C). The first two sections have similar structure to the Small Area Statistics, and were included in the SASPAC. The SWS part C comprises origin-destination (o/d) flow matrices, and can only be accessed via MATPAC (MATrix analysis PACkage). This specifically designed software was released by the University of Manchester Computing Centre only in November 1989.

The packages to access the Census information share some similarities in terms of syntax, however their structure are completly different. Since the data required in this thesis demanded the use of both packages, the understanding and practice of each of them represented an additional work to be carried out.

The Census of Population provided data concerning origin and destination flows by mode, sex and social classes, employment opportunities, and population. Data concerning the usual residence population in wards was obtained in table 2, of the Small Area Statistics, 100% sample, by using the SASPAC software. Ideally, one should consider the economically active population, however, this data was not available for 1989. To achieve compatibility between the 1981 and the 1989 information, the analysis of the total population was considered.

This package also provided information concerning the number of local jobs, at the 10% sample. The data needed was obtained in the following two tables of the SASPAC-W :

Table 8 B3 (DT8317U), persons working in the zone by occupation orders and sex, and
Table table 9 B4 (DT8318U), persons working in the zone by industry division and sex.

Regarding the origin-destination data accessed through the MATPAC, three of the tables of the SWS-C were contemplated:

Table 1 (DT 8323U) - persons in workplace and/or residence in zone by mode of transport and sex;
Table 3 (DT 8327U) - persons in workplace and/or residence in zone by occupation orders and sex, and
Table 4 (DT 8328U) - persons in workplace and/or residence in zone by industry divisions and sex.

Since the SWS-C does not provide cross tabulation information, the analysis of flows simultaneously by modes and socio classes could not be undertaken.

Due to the aim of this study, the 17 occupation orders defined by the OPCS (1981) were aggregated in new orders as shown in table 5.1 .

Table 5.1 - Occupation orders

occupation	denomination
professional	professional and related supporting management, senior national and local government managers; professional and related in education, welfare, and health; professional and related in science, engineering, technology, and similar; literary, artitistic, and sports
manager	managerial
clerical	clerical and related
others	selling; security and protective service; catering, cleaning, hair-dressing, and other personal service; materials processing : making and repairing; painting,repetitive assembling, product inspecting, packing; construction, mining; transport operating, materials moving and storing; farming, fishing and miscelaneous; inadequately described and not stated

Unfortunately, the results of the 1991 Census were not released on time to be considered in this thesis. Therefore, the 1981 Census was cross analysed with a 1989 data set, which was gathered from different sources, and presented various formats and levels of precision. In the light of this problem, the model was estimated using the more reliable 1981 data set.

b - Census of Employment

The data base NOMIS (National On-line Manpower Information System) provided the estimate number of persons employed in each ward of the County of Kent, in 1989. This information was based on the 1989 Census of Employment, and was released under an non-disclosure agreement with the Department of Employment.

The data was related to the 10 industry divisions classified by the OPCS. Since this kind of classification amalgamates jobs of different socio classes, it was not possible to identify specialized segments of the job market that are highly concentrated in Central London. An alternative solution was to merge the industry divisions 8 and 9, which together comprise banking, finance, insurance, leasing, and other services.

This information was given in paper printouts, and transfered to the main frame computer via scanning. In spite of the excellent quality of the output, this procedure required extra checking for the correction of some optical reading errors.

5.2.3 - ROAD DATA

The data provided by the Kent County Council was limited to matrices of time and distance regarding the links of the Kent road network. The timings were obtained from traffic of all kinds and not only cars.

Since the perceived costs were unavailable, an estimate of car cost was obtained using the recommendations of the COBA manual[1], versions 1979 and 1988. One should bear in mind that the computation of costs by this method comprised an additional source of imprecision to the already inadequate road data set. The implications of this assumption are fully explored in chapter 8.

[1] COBA is a program for the cost-benefit analysis of trunk roads used in the U.K.

The road data was provided according to a particular zoning system, which does not match the OPCS ward classification. In order to relate them, a manual matching was carried out by plotting the grid coordinates of the wards in the Kent zonning map. Then, it was assumed that the road data of the ward and zone matched were the same. This procedure has certainly involved some errors, particularly when a unique zone comprised more than one ward, or when the ward's centre was placed near the border of two or more zones, and the matching was based on merely good sense.

This data set was provided in paper printouts, and was edited into a data file of the main frame.

5.2.4 - OTHER SOURCES OF DATA

Some additional information, eg. the value of time, retail price index, personal disposable income and consumption, were obtained either in the literature of previous studies (MVA Consultancy et al. (1987), Fowkes (1986)) or in periodicals published by the Government (Employment Gazette, Economic Trends).

The value of time was based on a sample survey carried out in 1983, in North Kent, amongst commuters into Central London who faced the choice between train and coach. Due to the unavailability of another index to express the car users' perception of time, a single value of time (Fowkes (1986)), properly inflated by the personal disposable income and consumption index, was generally assumed in this thesis. Unfortunately, this is another source of imprecision of the car data. However, there is the hope that such an average figure will not have greatly interfered in the results of the analysis.

5.3- DATA CONSTRAINTS

Some of the required information could not be obtained, eg. cost of car parking in Central London. One might expect that both company car and free parking space affect the mode choices to Central London. This assumption is confirmed by Copley et al. (1988), and by the Greater London Council (1985), who found that few of the car trips to Central London involved car parking costs. The latter study pointed out that 58% of company car drivers and 42% of private car drivers commuting into Central London receive some form of assistance with parking charges. Since no information could be obtained about motoring subsidies, this important factor was not taken into consideration in the model.

However, the most crucial lack of data is the perceived cost and time of trips within the County of Kent. The job accessibiliy was then represented as jobs within a given distance band, which was fortunately found to be significant in the modelling of binary choices between trips to Central London and to local places within Kent. This issue is fully discussed in section 8.3.

Another minor implication due to data limitation is the exclusion of the districts Dartford, Gravesham and Rochester from the study area. Of particular interest in this area is the high proportion of residents of the clerical class going to work in Inner London, as well as the significant flow of coach commuting to Central London. In spite of the reduction in area, suitable conditions for the analysis of the patterns of commuting to Central London were found. There was a great variety of working trips flows, as well as a quite large range of distances to London.

Another possible source of data-related errors regards the changes in wards boundaries, mainly done after 1983. The districts affected by such changes were Gillingham, Canterbury, Faversham, Folkestone, Maidstone and Swale.

As already mentioned in the item 5.1, some other problems were mismatch of ward and postcode, lack of information concerning rail waiting time, 1981 rail access time, and perceived car cost and time.

Regarding the modelling procedure, one should be aware of incompatibilities of sample sizes among data from the various sources, eg. compatibility of the 1981 Census of Population, given at the level of ward, with the 1989 British Rail survey, provided at the individual level and related to stations rather than wards.

5.4 - DATA MANIPULATION

The amount of data manipulated and extracted from the 1981 Census of Population and 1981 and 1989 British Rail surveys was huge. For such a size of data base, a 100 Mb disk was permanently available at the main frame of the Leeds University Computer Area. The information obtained from the other sources was generally more compact and easly operated.

Most of the programs used in the preparation, analysis, and modelling of the data set were written in SAS, but there were a few cases in which the FORTRAN language was also used. As concerns the extraction and manipulation of the 1981 Census of Population, the special packages SASPAC and MATPAC were used.

5.5 SUMMARY

From the above exposition, one may conclude that the data limitations comprised the bottle-neck of this thesis. The arduous gathering and the complex manipulation of a huge data base comprised of various sources and formats represented a challenge to be overcome.

Of relevance is the fact that the framework proposed allowed such a comprehensive analysis to be carried out on existing data. Moreover, it is very motivating to unveil the details of some of the data undertaken, which has not yet been explored elsewhere.

The minimum level of disaggregation obtained, the ward, is likely to allow a reasonable analysis and modelling. One might hope that the data related errors would be small compared with the changes that took over the period analysed.

CHAPTER 6

POPULATION AND ECONOMIC TRENDS IN SOUTH-EAST ENGLAND

6.1 BACKGROUND

Population and jobs are factors which play important roles in the analysis of the patterns of commuting. With the influence of many other elements, the patterns are basically determined by the intrinsically entangled spatial distribution of residences and places of economic activities. These factors are also relevant in the analysis concerning mode choices for work journeys. For example, the centralisation of jobs in London leads to radial trip patterns that favours the use of public transport, whereas the decentralisation of jobs in Kent favours the use of the car mode in journeys which usually have orbital patterns.

An open question is to which degree the growth in job in any other possible location rather than in London affects the commuting patterns. This is an hypothesis to be tested in the later chapters, when the effects of the role of population growth and the employment changes, assessed in this chapter, will be better understood.

There are so many historic facts involved in the location of people and jobs in London and South-East, that their trends over time are worth recalling. Such recapitulation might shed some light on the understanding of the changes in the patterns of commuting during the 1980s.

This chapter reports a small piece of the English history, by giving the flavour of the urban economy of the 19th century London. Then comes some comments on the mid twentieth century, when regional planning was implemented and became fashionable. A general analysis based on aggregate data highlights some historic trends in job and population locations. For the period 1981-1989, a more specific descriptive and comparative analysis of such trends is shown, and the role of the population growth in the job changes is then considered. Finally some preliminary conclusions are presented.

6.2 HISTORICAL TRENDS

6.2.1 LAND USE AND REGIONAL PLANNING

Since the nineteen century, a progressive redevelopment has been observed in London. Houses have been replaced by modern business offices, and sometimes homes have been just converted into work activities. This process seems to have started at the core of the area, in the City of London, where most of the jobs were placed.

By 1850, the competition for space and the rise in property price was already forcing the decentralization of the population to the outer areas of the city. However, the lack of proper housing and transport infrastructure inhibited the expansion of the city to its out-skirt areas. By 1861, the population of approximately 2 million people was confined within an area of 3 miles radius, and only a small number of commuters initially travelled on foot or by horsebus to the city of London (Clout(1987)).

Transport facilities have played a big role in the development and decentralization of London, which was initially characterized by gradual and short-distance movements outward from the central area. By the beginning of this century, London had already implemented a reasonable network of railways, tramcars, and buses. A network of horse trams was developed in 1855, and expanded to the suburbs in the 1870s, whereas the first line of the underground railway was opened in 1863. However, the main determinant of

London's growth was electric traction, that came after 1890. The old trains had some operational limitations, eg. the slow acceleration of the steam trains demanded large distances between stations, whose sizes of the catchment areas were limited by poor accessibility conditions. With the electric trains, the suburbs could be progressively linked together into a continuous stream, creating the nucleus of what came to be known as the London metropolis.

The suburbanization process mainly occurred during the flourishing of industry in Victorian London, when increases in demand for travels to work were a direct consequence of the transport facilities, and changes in population and economic activities of the inner area.

Since the government did not have concerns either for urban developments nor city's dimensions, the growth of the cities was uncontrolled and therefore disorganised.

According to Buck et al. (1986), the need for planning concerning housing and industrial development for the metropolitan London was firstly recognised in the 1920s. However, the establishment of policies concerning this issue only came as a consequence of the war, when concentration of cities proved to be strategically undesirable.

The first signs of market specialisation in London appeared with the reconstruction of the city, after the World War II. Areas occupied by warehousing, industrial premises, housing and even shops were gradually transformed into offices, such that this process reached a peak by 1962.

From the post-war period until 1979, strategic planning has restrained the decentralization of population and employment of the English cities. Such policy was reversed by the conservative government of the 1980s, when urban planning was reduced in scope, and the forces of commercial development were set free.

Based on the same principles of decentralization, three major strategic plans were developed for London (see Buck et al. (1986)). The first one was proposed for the County of London in 1943, followed by the plan for Greater London, in 1944, and another for the City of London, in 1951. Worthy to be pointed out is the plan designed by Abercombie for Greater London. It comprised the establishment of the Green Belt, and the new towns and major growth centres outside the Greater London area. The latter were supposed to receive the overspill population and industry from the city.

The initial proposition of the Green Belt was an area of almost 1,200 square miles, which was expanded to around 2,200 square miles during the 1960s and early 1970s. Since its official creation in 1955, such containment area has been preserved, despite the conflicts of interest between regional planners and developers and commercial agents.

The main purpose of the Green Belt was to prevent the continuous development of London. It would also increase the commuting time to the city, making it less attractive, and consequently enforcing the 'self-containment' characteristic of the new towns proposed.

However, the containment of London and the development of the new towns were not undertaken at the plannned extent. According to Buck et al. (1986), only about 13% of the population decentralized from Greater London moved to the new towns of the South-East, and much more went to those already existing towns of the Outer Metropolitan area.

To a certain degree, the government has regulated the establishment of new activities in the inner area, by restricting the issues of Industrial Development Certificate - IDC. However, Buck et al. (1986) estimated that only half of all office jobs decentralizing from Central London were officially controlled by the government. Hall (1989) argued that certificates were given to many growing firms to relocate in the M4 corridor, instead of in the Development Areas proposed. According to the author, this fact has most probably contributed for the good performance of that corridor during the 1970s and early 1980s.

It is not very clear whether people were not confident in moving to the new towns because they were not very attractive. One might expect that the program of reconstruction of cities implemented after the World War II, would have favoured the decentralisation of population. As part of this program, a large contingent of domiciles were built up, making the guidance of people to new areas of development easier.

Since the mid-1950s, the effects of the decentralisation have been seriously taken into consideration and questions concerning the changes in distribution of population, activities, and employment have arisen. Such issues are discussed in the following sections, which initially presents the problems concerning population, followed by employment.

6.2.2 CHANGES IN POPULATION DISTRIBUTION

If the moving out of jobs was not initially disciplined by government planning, the decentralization of population was even more uncontrolled and carried out in a complex and widespread pattern within the South-East.

For the period 1951-1981, there was a continuous decrease in the population of both Inner and Outer London, whereas the opposite tendency occurred in the Rest of South East. According to Hall (1989) in the 1950s, the ring of maximum population growth was between 15-30 miles around London, whereas it lay in the range 30-50 miles in the following decade. By the 1970's and 1980's, the largest growth in population was observed in separate areas at various distances within 80 miles and 110 miles around the core respectively.

Table 6.1 depicts the trends in the population of England, Central London, Inner London, and Greater London since 1801. The columns % stand for the growth rates between two subsequent years. In the analysis of this table, one should take into account the changes in the geography and size of the areas comprising London. Boundaries and parish names have been changed, and the dimension of the rings have increased/decreased by the aggregation/disagregation of new areas. The appendix 1.1 gives the list of enumeration districts and wards which comprises Central London, according to the 1981 Census of Population.

Despite the 1967 recession, a general increase in employment and individual prosperity was observed in the country in the 1960s. During such period, the public sector strongly invested in housing, and the expansion of the motorways and trunk road construction. Substantial immigration from overseas was also detected during the 60s, which coincided with the peak of the birth rate in England. Consequently, by the begining of the 70s the demand for housing space has boosted the demand for larger dwelling in lower-density premises.

Table 6.1 - Population of England and London during 1801-1981(x1000)

	England		London					
			central		inner		Greater	
year	pop	%	pop	%	pop	%	pop	%
1801	8305	.			959			
1811	9490	14.3			1139	18.8		
1821	11206	18.1			1379	21.1		
1831	12992	15.9			1655	20.0		
1841	14868	14.4			1949	17.7		
1851	16764	12.7			2363	21.2		
1861	18779	12.0	1521	.	2808	106.	3223	.
1871	21299	13.4	1520	0.0	3261	16.1	3886	20.6
1881	24402	14.6	1499	-1.4	3830	17.4	4766	22.6
1891	27231	11.6	1437	-4.1	4488	17.2	5572	16.9
1901	30514	12.1	1387	-3.5	4859	8.3	6506	16.8
1911	33650	10.3			4998	2.8	7160	10.1
1921	35230	4.7			4973	- 0.0	7387	3.2
1931	37359	6.1			4893	- 1.6	8110	9.8
1939	38994	4.4			3364	-31.2	8615	6.2
1951	41159	5.6			3679	9.4	8197	-4.9
1961	43461	5.6			3493	- 5.1	7992	-2.5
1971	46018	5.9			3032	-13.2	7452	-6.7
1981	46363	0.7			2498	-17.6	6713	-0.0

N.B. blank spaces stand for either unavailability of data or incompatibility of area boundaries

Sources : OPCS(1901), OPCS(1951), OPCS(1982a) and OPCS(1982b)

The trend in population decentralization has been observed since 1911, therefore even before the Abercombie's planning. It is likely that urban plans have just contributed to the acceleration of the process that eventually came to a peak in the 1970's. Gilje (1985) shows that most probably the Londoners would have moved out without the help of the planner. According to the author, " The population fall due to migration reached a peak around 1970 with a net loss between 1970 and 1971 of some 110 thousand, but this figure has been halved in the last decade (to 55 thousand in 1980-1981)". Similar trend was expected for the last decade, however this assertion cannot be corroborated due to the unvailability of migration information in the preliminary results of the 1991 Census of population.

Although the decreasing trends during the 1970's were significant, in the early 1980's, some rural districts were still experiencing annual growth rates above the national average. In a study which comprised the period 1971-1986, Cross (1988) investigated the effect of non-metropolitan population growth. He detected the presence of local level overspill from regional population cores, in parallel to the major decentralisation within and from the South-East. In his study, there was some evidence of the strong and widespread decentralisation tendencies among the south-eastern districts, and extending to the peripheral regions. The author concluded that this was probably related to the retirement migration of the most affluent members of the society. The development of such retirement areas, which generally coincide with rural and remote parts of the country, generates a certain level of local employment opportunities, and consequently some population growth in the rural districts.

Due to the housing surplus in the mid 1970's, a decrease in the moving out of people for housing reasons in the following decade was expected. It seems that such process was accelerated by the long period of high interest rates that culminated with another crisis in the housing market, in the late 80s. The following extract of the article by Michael Ignatieff, in the Observer Sunday, of 19 May 1991,(Trapped in the big city wilderness) express such stagnation of the housing system in London: "In London, most people I know can't move house, because they can't either sell or afford to buy; they'd leave town altogether, but they're tied to their work; they can't get around because the transport system is such a mess; ..."

The evidence of the decline in the decentralisation of population are given by table 6.2, which shows the comparison between yearly natural changes and net migration in London and in England and Wales, during the period 1971-1984.

Table 6.2 - Population changes 1971-1984 (per 1000 people/year)

area	natural change		net migration	
	71-78	78-84	71-78	78-84
Greater London	1.0	2.0	-12.0	-6.5
Inner London	0.7	2.2	-19.5	-11.6
Outer London	1.2	1.8	-7.0	-3.4
England-Wales	1.0	1.0	-0.2	0.0

Source: Champion (1989)

The figures in table 6.2 give a clear idea of the process of moving out of population from London. In the various parts of the metropolis, the number of new borns were remarkably smaller than the figures shown by the net migration. This effect was particularly significant in the inner area, whose losses over the period 1971-78 were approximately 27 times bigger than the overall gains. Despite the much reduced figures given over the years 1978 to 1984, Inner London kept a high level of population decentralization, showing a net migration about 5 times superior to the natural growth.

Champion (1989) concluded that the shift has involved all ages in fairly equal proportions. He also pinpointed that the growth areas were not essentially dormitory settlements, since the decentralization phenomenon has been associated with a substantial shift in the location of job opportunities. To a certain extent, this explain the levels of commuting to London during the

1980s. It significantly increased, while a similar trend was also observed in the trips between suburbs. This is an issue investigated in the next chapter.

Despite the apparent importance of migration in the analysis of peoples' location and travel patterns, Cross (1988) concluded that the growth in non-metropolitan population was more related to longer distance commuting to urban employment centres than to a shift through the decomposition of job and population towards a post-industrial pattern of distribution.

The cross analysis concerning the changes in population, jobs and commuting by area might give a sound base for the investigation of the commuting patterns proposed in this thesis. The sections 6.3 and 6.4 of this chapter, regard respectively the patterns of Kent employment and population during the period 1981-1989. The role of the commuting growth in the changes of population and employment remains the task of the next chapter.

6.2.3 JOB DECENTRALISATION

By the 1960s, the out migration of population to the growing towns beyond the Green Belt was so fast that it caused concerns about the imbalances that could emerge in the demand and supply of labour. However, a substantial fall in the level of London industrial jobs came in the late 1960s, leading the London Council to challenge the long standing regional policies for the deconcentration of the metropolis.

According to Lomas (1973) the revisions of the Greater London Development Plan have argued that the larger losses of the professional and management resident groups could have serious socioeconomic effects for London. As a consequence of the socially polarized population, the city would stay with the onus of the old, the less skilled, the poor, and the disadvantaged, whereas the growing towns with the young, skilled, well educated people, families with young children, and workers with good prospect and rising income. It seems that his predictions are very close to the actual picture of London, particularly at the western side of the city.

An early study of the outward movements of industry was that of Keeble (1968). He found that 32 % of the factories in the area of North-West London between the M1 and the Thames had moved out during the period 1940-1964. As a consequence, 30 % of the jobs in that zone in the 1960s were lost. Nearly 40 % of such jobs went to the Outer Metropolitan Area, within 15 and 40 miles from London, where space was still available and reasonable affordable. Actually, shortage of space, followed by shortage of labour and government control were the main reasons of the outward movement of firms pointed out by Keeble's study.

Due to the 1960's prosperity, consumer demand was high, and the factories were searching for suitable places for their expansion. A different scenario was presented by the economy of the following decade, when the deindustrialization process was mainly undertaken. Changes in demand were particularly harmful to Inner London manufacturing, which used to be market oriented of specialized products. According to Buck et al.(1986), standardization, mechanization, and economies of scale were not applied in the inner-city industries because of the uncertain demand for such goods. Due to these limitations, and the competition for space, most of the firms located in the central area employed a relatively small number of people. Such small-scale industries were more sensitive to fluctuations in demand, and consequently have greatly suffered the effects caused by the unemployment which has occurred in the area as a whole. The figures shown in table 2.2 corroborate the argument by Buck et al.(1986) about the effect of the 1970's crisis, particularly in Inner London.

While the losses in employment in manufacturing, construction, distribution, and trade have contributed at a large extent to the decrease of the 1970's

London economy, a small but important increase was observed in the professional and scientific services. If the growth in the financial and the public services are also considered, it is likely that losses and gains were approximately offset in Central London (see Hall et al. (1987)). According to these authors, the same is not valid for the other areas of London, where jobs in services have also fallen.

Table 6.3 shows that in the 1970's and early 1980s, the South-East experienced a relative prosperity in relation to either London or the rest of the country. However, it is worthy noting that Hall et al. (1987) concluded that the high technology industries have not significantly contributed to the South-East success, as commonly accepted by popular opinion. In fact, the authors suggested that this success should be attributed mainly to the good performance of manufacturing outside London, and the almost general growth of the service sector. Such trends are obtained by comparing the changes over the period 1971-1981 presented by both Outer Metropolitan Area (OMA) and Outer South-East (OSE) with those shown by either Great Britain, Inner London, or Outer London. Table 6.3 shows the job changes over the period 1971-81, for segments of the industry of London, South-East, and the Great Britain. The appendix 6.1 gives the list of counties and districts which comprises OMA and OSE.

Table 6.3 - Employment changes during 1971-1981 (%)

	manufacturing	services	total
Inner London	- 40.6	- 6.1	- 13.9
Outer London	- 32.6	10.2	- 5.8
OMA	- 18.4	25.0	6.3
OSE	- 3.5	23.9	13.6
South-East	- 23.9	10.0	- 1.3
Great Britain	- 24.9	14.5	- 2.3

Source : Hall et al. (1987)

According to the figures given by table 6.3, the losses in the London manufacturing were significantly higher than the ones in Great Britain. Worthy to be highlighted are the changes in service experienced by the outer areas of London, and in particular the differential increases presented by Outer London in relation to Inner London.

6.3 PATTERNS OF EMPLOYMENT IN THE 1980's

In the previous section, the historic view of the job market in Kent and the South-East England was considered, and information regarding economic activities was given at the aggregate level. This section turns towards the structure of the workforce in Kent and Central London, over the years 1981 and 1989. The disaggregation of the data for the various segments of the labour market are taken into consideration.

The Census of Population allocates occupied persons either to one of the ten standard industry divisions, or to one of the seventeen standard socio economic groups (SEG). However, the information given by the Census of Employment is based only on the standard industry divisions. Therefore, for the purpose of this analysis, the classification given by the industry divisions was adopted. Due to the cumbersome character of such classification, the amalgamation of some classes is a common practice that was also adopted here.

Table 6.4 depicts the 5 broad groups considered in this study, and shows the five main production sectors grouped into a single class called sic05.

Table 6.4 - Industry divisions

group	industry division
sic05	0 agriculture, forestry and fishing
	1 energy and water supply industries
	2 extraction of minerals, ores. etc
	3 metal goods,engineering and vehicles industry
	4 other manufacturing industries
	5 construction
sic6	6 distribution
sic7	7 transport and communication
sic8	8 banking, finance, etc
sic9	9 other services

6.3.1- STRUCTURE OF JOBS IN KENT OVER THE PERIOD 1981-89

According to the data investigated, the number of job opportunities by industry divisions varied quite significantly among the 11 districts of Kent considered in this study. Table 6.5 depicts the absolute number of employments in each district of Kent, and the county as a whole. In this table, the totals do not match due to rounding. The percentages corresponding the jobs by divisions in each area are presented in table 6.6, whereas the percentages relative to the totals in Kent by category are given in table 6.7.

Table 6.5 - Jobs in Kent, 1981-89 (x 100)

area	sic05 manufactur.		sic6 distribut.		sic7 transport		sic8 finance		sic9 services		total	
	81	89	81	89	81	89	81	89	81	89	81	89
Sevenoaks	103.3	83.0	74.6	96.0	17.5	16.2	30.4	56.0	89.0	92.5	315	344
Gillingham	44.5	50.8	24.8	42.0	1.8	4.6	10.4	7.1	22.0	28.0	104	133
Swale	146.7	138.9	71.4	76.1	31.0	37.4	15.2	22.7	58.5	75.7	323	351
Tonbridge	172.0	161.3	69.7	103.1	22.0	41.9	24.8	32.9	78.4	96.1	367	435
Maidstone	140.3	153.9	115.2	124.2	26.9	27.9	48.5	85.1	146.3	249.3	477	640
Canterbury	94.4	76.1	95.3	107.5	26.2	31.9	31.5	41.9	125.1	176.9	372	434
Tunbridge W.	89.7	95.6	86.9	96.6	27.2	30.3	48.1	69.0	107.9	141.1	360	433
Ashford	109.7	106.7	43.5	61.5	22.6	29.2	20.2	33.8	69.2	78.7	265	310
Thanet	77.6	66.2	61.8	59.1	18.0	23.0	14.7	16.1	69.5	81.9	242	245
Dover	70.8	44.8	27.3	24.6	33.9	29.0	5.5	9.2	56.6	66.7	194	174
Shepway	78.5	73.6	42.5	42.7	8.4	8.9	17.3	15.4	54.6	63.6	201	204
all	1127.5	1050.9	713.0	832.4	235.5	280.1	266.6	389.2	877.1	1150.4	3220	3703

Sources : 1981 Census of Population and 1989 Census of Employment

Table 6.6 - Percentage of jobs by area and sic groups

area	sic05 manufactur.		sic6 distribut.		sic7 transport		sic8 finance		sic9 services		
	81	89	81	89	81	89	81	89	81	89	
Sevenoaks	32.8	24.1	23.7	27.9	5.6	4.7	9.7	16.3	28.2	26.9	
Gillingham	43.0	38.4	24.0	31.7	1.8	3.5	10.0	5.4	21.3	21.1	
Swale	45.4	39.6	22.1	21.7	9.6	10.7	4.7	6.5	18.1	21.6	
Tonbridge	46.9	37.1	19.0	23.7	6.0	9.6	6.7	7.6	21.4	22.0	
Maidstone	29.4	24.0	24.1	19.4	5.6	4.4	10.2	13.3	30.6	38.9	
Canterbury	25.3	17.5	25.6	24.8	7.0	7.3	8.5	9.6	33.6	40.7	100%
Tunbridge W.	24.9	22.1	24.2	22.3	7.6	7.0	13.4	15.9	30.0	32.1	
Ashford	41.4	34.4	16.4	19.8	8.5	9.4	7.6	10.9	26.1	25.4	
Thanet	32.1	27.0	25.6	23.7	7.5	9.4	6.1	6.5	28.8	33.4	
Dover	36.5	25.7	14.0	14.1	17.5	16.6	2.8	5.3	29.2	38.2	
Shepway	39.0	36.1	21.1	20.9	4.2	4.4	8.6	7.6	27.1	31.1	
all	35.0	28.4	22.1	22.5	7.3	7.5	8.3	10.5	27.2	31.1	

Sources : 1981 Census of Population and 1989 Census of Employment

Table 6.7 - Percentage of the total jobs in Kent by sic groups

area	sic05 manufactur.		sic6 distribut.		sic7 transport		sic8 finance		sic9 services		all	
	81	89	81	89	81	89	81	89	81	89	81	89
Sevenoaks	9.2	7.9	10.5	11.5	7.4	5.8	11.4	14.4	10.1	8.0	9.8	9.3
Gillingham	3.9	4.8	3.5	5.0	0.8	1.6	3.9	1.8	2.5	2.4	3.2	3.6
Swale	13.0	13.2	10.0	9.1	13.2	13.4	5.7	5.8	6.7	6.6	10.0	9.5
Tonbridge	15.3	15.3	9.8	12.4	9.3	14.9	9.3	8.4	8.9	8.3	11.4	11.7
Maidstone	12.4	14.6	16.2	14.9	11.4	9.9	18.2	21.8	16.7	21.7	14.8	17.3
Canterbury	8.4	7.2	13.4	12.9	11.1	11.4	11.8	10.7	14.3	15.4	11.5	11.7
Tunbridge W.	8.0	9.1	12.2	11.6	11.5	10.8	18.0	17.7	12.3	12.2	11.1	11.7
Ashford	9.7	10.2	6.1	7.4	9.6	10.4	7.6	8.7	7.9	6.8	8.2	8.4
Thanet	6.9	6.3	8.6	7.1	7.6	8.2	5.5	4.1	7.9	7.1	7.5	6.6
Dover	6.3	4.2	3.8	3.0	14.4	10.5	2.1	2.3	6.4	5.8	6.0	4.7
Shepway	6.9	7.0	5.9	5.1	3.5	3.2	6.5	3.9	6.2	5.5	6.2	5.5

|---------------------- 100% ----------------------|

Sources : 1981 Census of Population and 1989 Census of Employment

During the period 1981-89, Kent had an absolute increase of some 48300 jobs, which represents the significant growth of 15%. Maidstone presented the largest increase with 16330 additional employment opportunities in 1989, followed by Tunbridge Wells (7270), and Tonbridge (6830). Apart from Dover, which suffered the reduction of about 2000 employments, the eastern districts of Kent had minor job changes.

According to the figures given by tables 6.5 and 6.6, the bulk of the economic resurgence was in Mid-Kent, although the districts of Ashford and Canterbury also had shown some signs of revival.

The percentages shown in table 6.6 clearly suggest a shift in the shares of the job market in kent. In 1981, a proportion of 35% of all employments in the county was provided by the manufacturing sector, whereas in 1989 the largest share belonged to the service class (31.1%).

The disaggregated analysis by jobs classes provides some fruitful insights. For both years, the largest concentration of jobs of the production sector (sic05) was in Tonbridge, followed by Maidstone. In 1981 and 1989, the Tonbridge's wards which had the most substantial number of jobs of the production sector coincided. On the contrary, different job patterns by year were given by the wards of Maidstone. During the period 1981-89, the ward Harrietsham and Lenham increased the number of jobs related to the production industry, while new poles of such industry group appeared in Boughton Monchelsea and North.

As expected, Maidstone has been the absolute major market of employment of Kent. According to table 6.7, this district has presented the largest figures concerning jobs of the classes distribution, banking and finance, and other services. Regarding the sector of transport and communication, Dover showed the largest number of jobs in 1981, but had a steep decline in 1989, with losses of 1986 jobs. In 1989, this sector of the economy was mainly developed in Tonbridge.

Regarding the distribution industry, Dover and Thanet experienced reduction in the number of jobs, whereas Tonbridge showed the largest growth with an addition of about 3340 employment opportunities.

The only industry segment to present a general pattern of growth was the service sector, whose main concentration of jobs was once more in Mid-Kent.

Table 6.7, which shows the percentages of the industry groups in each district of Kent, provides information concerning the level of specialisation of the local job markets. Over the period 1981-89, there was a general trend of specialisation in the financial sector of almost all districts of Kent. For instance, the composition of jobs shown by Sevenoaks, Tunbridge, and Maidstone in 1989, highlights their specialisation in the sector of banking and finances among the other districts. Worthy to be pinpointed is the reduction in the percentage of jobs of of the financial sector experienced by Gillingham, and the more than proportional increase in the distribution industry. As concerns the latter, the major growth was shown by the ward Hempstead and Wigmore.

The manufacturing sector was most probably the determinant factor of the decreases in the relative proportion of jobs of the group sic05, experienced by almost all districts of Kent. In spite of the lack of data, one would expect similar trend for the Medway Towns, whose depression, particularly on the shipbuilding industry, is well known.

In 1981, 45.4% of the total jobs of Swale were classified as sic05, and only 4.7% and 18.1% of them comprised the divisions finances and services respectively. In 1989, an average decrease of 5.8% was observed in the production sector of Swale. However, in spite of the losses, Swale maintained the highest proportion of such category of jobs, among the districts of Kent.

The comparison between tables 6.5 and 6.6, gives information about the trends followed by the districts in the various sectors of their economy. For instance, the absolute increases in the industries of banking and finances, and services of Maidstone and Tunbridge Wells were more than proportional to the changes shown by other segments of the economy of the respective districts. Consequently, in spite of the average increases experienced by the production, distribution and transport and communication industries, their relative percentages were reduced in 1989. Similar analysis applied to the other districts of Kent, shows that Gillingham, Canterbury, and Ashford also had a clear tendency of market specialisation, highlighted by their strong financial sectors. As concerns the other districts, marginal effects were detected, which suggests a kind of equilibrium between losses and gains, without any substantial preponderance of one sector over the others.

According to table 6.6, the average reduction of 6.6% of jobs of the production sector in the whole County of Kent was approximately offset by the increases observed in the sectors of bank, finances and other services (6.1%). If compared to the other sector, the overall change in the banking and finances of Kent was relatively small.

6.3.2 - STRUCTURE OF JOBS IN CENTRAL LONDON OVER THE PERIOD 1981-89.

Table 6.8 depicts the absolute number of jobs by industry divisions in Central London, and the corresponding percentages changed over the period 1981-89. The figures in brackets stand for the corresponding percentages relative to the total in each year.

Table 6.8 - Jobs in Central London 1981-89

sic	1981	1989	change %
sic05 manuf.	105180 (13.8)	56990 (7.4)	- 45.8
sic6 distri.	122560 (16.1)	134520 (17.4)	9.8
sic7 transp.	84590 (11.1)	51010 (6.6)	- 37.9
sic8 finance	268260 (35.6)	351850 (45.6)	31.2
sic9 service	180280 (23.7)	176810 (22.9)	- 1.9
total	760900 (100)	771200 (100)	1.35

Sources : 1981 Census of Population and
1989 Census of Employment

A total change of some 10300 jobs were shown in Central London, in 1989. Given the insignificant growth of only about 1%, the level of jobs in Central London can be considered as approximately constant. Worth to be highlighted is the specialization tendency, and the remarkable switch of jobs experienced by this market during the period analysed. The economic changes experienced by Central London were mainly comprised of reductions in the production groups sic05 and sic7, which were approximately offset by the significant 10% increase in the market share of specialized jobs of the division sic8.

The manufacturing industry, followed by transport, experienced reductions of 48190 and 33580 jobs respectively. The gains, which were mainly observed in finances, represented 83590 new jobs over the period 1981-89. The percentage distribution of jobs by standard industry classification shown by each year are quite different. In 1981, the market share of finance and services were respectively 35.6% and 23.7%, while the percentages shown by the other groups were approximately similar. On the contrary, the 1989 market share was highly concentrated on finance activities, which comprised almost 50% of the job market in Central London.

The changes in the Central London market are expected to have important implications for the patterns of commuting. Given the level of specialization of the jobs in the central area, the socio-economic characteristics of the commuters might have changed, as well as the patterns of work-travel. The role played by the specialization of the Central London market in the commuting patterns will be tackled in chapter 7.

6.3.3 - SPATIAL DISTRIBUTION OF JOBS BY OCCUPATIONS

This section attempts to identify possible correlations between concentration of jobs by classes and their spatial position within the county, as well as in relation to Central London.

According to table 6.5 the largest concentration of jobs has been in Mid-Kent, particularly in Maidstone. In 1981, Canterbury was in the second position in the rank of total employments by district of Kent. However, in 1989 its status was interchanged with Tonbridge, which was previously the third, but experienced an increase of 669 jobs more the one presented by Canterbury. As regards the other districts, their relative position in the rank were preserved.

Concerning the spatial distribution of jobs, table 6.9 depicts the total number of jobs in Kent by industry divisions and range of distances to Central London. Table 6.10 depicts the corresponding average changes in job opportunities for ranges of distance between wards' centre and Central London.

Table 6.9- Job distribution in Kent by distances to Central London(x 10)

distance (km)	jobs by group and year											
	sic05		sic6		sic7		sic8		sic9		total	
	81	89	81	89	81	89	81	89	81	89	81	89
0 - 30	29.5	20.8	23.3	27.9	5.7	5.0	5.9	10.9	20.6	16.7	850	812
30 - 40	82.3	75.6	55.4	73.3	13.0	11.7	25.5	46.7	67.3	76.1	2435	2834
40 - 50	258.1	236.4	128.1	181.0	44.3	65.1	66.5	86.7	168.4	248.1	6654	8173
50 - 60	179.9	204.6	154.7	173.9	29.4	36.4	62.0	105.4	172.7	249.5	5987	7699
60 - 70	127.4	123.5	63.6	64.1	27.0	34.7	15.1	17.4	63.1	87.8	2962	3274
70 - 80	96.3	101.8	56.3	74.7	18.3	32.8	21.6	38.5	52.2	53.5	2447	3013
80 - 90	126.3	102.1	99.5	111.3	37.5	33.6	32.2	42.6	151.5	205.3	4470	4949
90 - 100	75.1	74.7	34.3	36.1	7.9	10.3	7.7	10.0	42.6	40.4	1676	1715
> 110	152.6	111.5	97.8	90.2	52.4	50.7	30.1	30.9	138.7	173.0	4716	4563

totals do not match due to rounding

Sources : 1981 Census of Population and 1989 Census of Employment

Table 6.10 - Average job change in Kent by distance, 1981-89

distance (km)	total	sic05 manuf.	sic6 distr.	sic7 transp.	sic8 finance	sic9 service
<= 30	- 383	- 871	455	- 71	499	- 395
30 - 40	3988	- 667	1787	- 135	2120	883
40 - 50	15193	-2171	5290	2082	2023	7969
50 - 60	17117	2469	1919	705	4344	7680
60 - 70	3122	- 394	51	766	226	2473
70 - 80	5663	550	1840	1451	1695	127
80 - 90	4787	-2424	1181	-387	1037	5380
90 -100	389	- 44	175	243	231	-216
> 100	-1527	-4111	- 760	-173	84	3433

Source : 1981 Census of Population and
1989 Census of Employment

A clear pattern of concentration of jobs exists within the ranges of 40-60 km and 80-90 km distances. In the latter set of distances, which basically comprises wards of Canterbury and Ashford, the industry divisions were mainly related to production, distribution, financial, and other services. However, the figures show that the bulk of the job market in Kent was within 40-60 km distances to Central London. The wards of Maidstone, Gillingham, Tonbridge, and some of the wards of Sevenoaks and Tunbridge Wells, are included in this range of distances.

The overall reduction in employment occurred in wards situated both at distances of 30 km and above 110 km from Central London. Apart from the range of 80 km, the industry group sic05 presented negative changes for all distance rings. As expected, the financial and business category given by sic8, was the only sector of the economy to show positive changes in each range of distances.

6.4 PATTERNS OF POPULATION DISTRIBUTION IN THE 1980's

During the period 1981-89, an average increase of 6.3% of the population was observed in Kent. Canterbury experienced the largest increased of 15.4%, followed by Ashford (12.3%) and Thanet(9.6%). Sevenoaks was the only district of the study area to show reduction in its population, presenting about 2000 less residents in 1989 than in 1981.

Table 6.11 shows the changes in population in the districts of Kent, over the period 81-89. The population density, expressed by number of people by hectare, is also given.

Table 6.11 - Population and population density by hectare, 1981 and 1989

district	population 1981	population 1989*	change %	density pop 1981	density pop 1989*
Sevenoaks	109340	107460	- 1.72	2.95	2.89
Gilling.	92920	95300	2.56	28.73	29.47
Maidstone	129280	136200	5.35	3.28	3.45
Tonbridge	96200	101200	5.20	4.00	4.21
Tunbridge	95250	99300	4.25	2.88	3.00
Swale	109010	115350	5.82	2.95	3.13
Ashford	84710	95200	12.38	1.46	1.64
Canterb.	114300	131950	15.44	3.68	4.25
Shepway	84550	87600	3.61	2.37	2.46
Thanet	118330	129700	9.61	11.50	12.57
Dover	99410	106300	6.93	3.19	3.41
total	1,133,290	1,205,610	6.30	3.33	3.54

* estimate figures
Source: 1981 Census of Population and
Kent County Council estimates

Sevenoaks, the district near the border of Lon don, showed negative change, while the areas further out had increases in population. This might be associated with the increases in commuting distances to Central London, during the last decade.

A better view of the distribution of population according to the relative distance of wards'centre to Central London is given by table 6.12. For ranges of distances given in kilometres, the number of residents and the changes occurred over the period 1981-89 are depicted.

Table 6.12- Distribution of population in Kent by distance

distance (km)	population 1981	population 1989	changes 81-89 abs	changes 81-89 %	total change %
<= 30	36645	38000	1355	(3.7)	1.9
30 - 40	78725	75860	-2865	(-3.6)	-3.9
40 - 50	223575	233050	9475	(4.2)	13.1
50 - 60	178000	186350	8350	(4.7)	11.5
60 - 70	95284	102900	7616	(7.9)	10.5
70 - 80	87416	95500	8084	(9.2)	11.2
80 - 90	122715	140950	18235	(14.8)	25.2
90 - 100	87307	92800	5493	(6.3)	7.6
> 100	223626	240200	16574	(7.4)	22.9
all	1133293	1205610	72317		100

Source : 1981 Census of Population and estimates of the Kent County Planning Department

The band of 80-90 km presented the largest proportion change in population, followed by the range of 70-80 km distances. If the total growth is considered, then the range of 80-90 km distances had an increase of 25.2%, whereas the areas further than 100 km had the second largest increase of 22.9%. This clearly shows that the population location has been further out from London.

There was a slight increase in the Kent population within the radium of 30 km from Central London, whereas a reduction of about 2800 people in the range of 30-40 km distances.

A survey carried out in Mid Kent (Maidstone/Tonbridge, Medway Towns and Sittingbourne) in 1989, showed that 22% of the heads of household interviewed had been in the local area for less than two years, whereas 54 % of them for more than ten years (see W S Atkins Planning Consultants (1990)). The study concluded that 41% of the moves during the two years before the survey were from outside Kent, and that 22% of the total household sample were relocated from London. According to the survey, a proportion of 70% of London migrants to Kent justified their moving due to housing reasons, while 48% of the households interviewed pointed out the search for better housing/affordable/more dwelling space as the main reason for relocating. Only 19% of all moves into Mid Kent was associated with job purpose.

A clear relationship between workplace and previous residence is given by the 38% of heads of households who have moved from London to Mid-Kent, and kept their jobs in London.

6.5 - THE ROLE OF POPULATION GROWTH IN THE CHANGE OF LOCAL JOBS

In the sections 6.3 and 6.4, the trends in population and employment were respectively discussed. The present section attempts an assessment of the role of population growth in the change of local jobs using the results of the analysis previously carried out in this chapter.

A preview of the inter-relation between this two factor may be provided by the simultaneous analysis of the figures depicted in tables 6.13 and 6.14. The former shows the relationship between jobs and population of the districts of Kent, while the latter gives the percentages of changes in both population and jobs during the period 1981-89. Figures 6.1 and 6.2. give the illustration of the spatial changes in both population and employment during the same period.

Concerning the three eastern districts whose changes in job by population were negative, Dover was the only one which experienced a reduction of some 10% in the local employment opportunites. Thanet and Shepway presented slight increases in local jobs. The former had a relevant change in population whereas the population growth showed by the latter district was not so accentuated. Maidstone, which had the largest absolute changes in local jobs, was the most prosperous district, whereas the highest ratio between job and population was given by Tunbridge Wells.

The figures in table 6.14 show that Kent experienced a much higher proportion of change in employment than in population. Dover presented losses of 2000 jobs and gains of some 6900 new residents, while the contrary was observed in Sevenoaks which had an increase of 2900 in jobs and lost 1900 residents.

Different patterns for the growth in population and employment were observed. The largest job changes were identified in Mid-Kent, particularly in Maidstone, Tonbridge, and Tunbridge Wells, whereas the major increases in population were in the Eastern districts Canterbury, Ashford and Thanet.

Table 6.13 - Ratio jobs to thousands of population in the districts of Kent

district	1981	1989	change %
Sevenoaks	288	320	11.1
Gillingham	112	139	24.1
Tonbridge	249	258	3.6
Maidstone	381	429	12.6
Tunbridge W.	501	645	28.7
Swale	341	376	10.3
Canterbury	425	455	7.1
Ashford	232	235	1.3
Thanet	286	279	- 2.4
Dover	164	134	-18.3
Shepway	202	192	- 4.9
total	284	307	8.1

Table 6.14 - Average job and population changes by district (%)

district	jobs	pop.
Sevenoaks	9.2	- 1.8
Gillingham	27.9	2.6
Tonbridge	18.5	5.3
Maidstone	34.2	5.2
Tunbridge W.	20.3	4.2
Swale	8.7	5.8
Canterbury	16.7	15.4
Ashford	16.9	12.3
Thanet	1.2	9.6
Dover	-10.3	6.9
Shepway	1.5	3.6
total	15.0	6.3

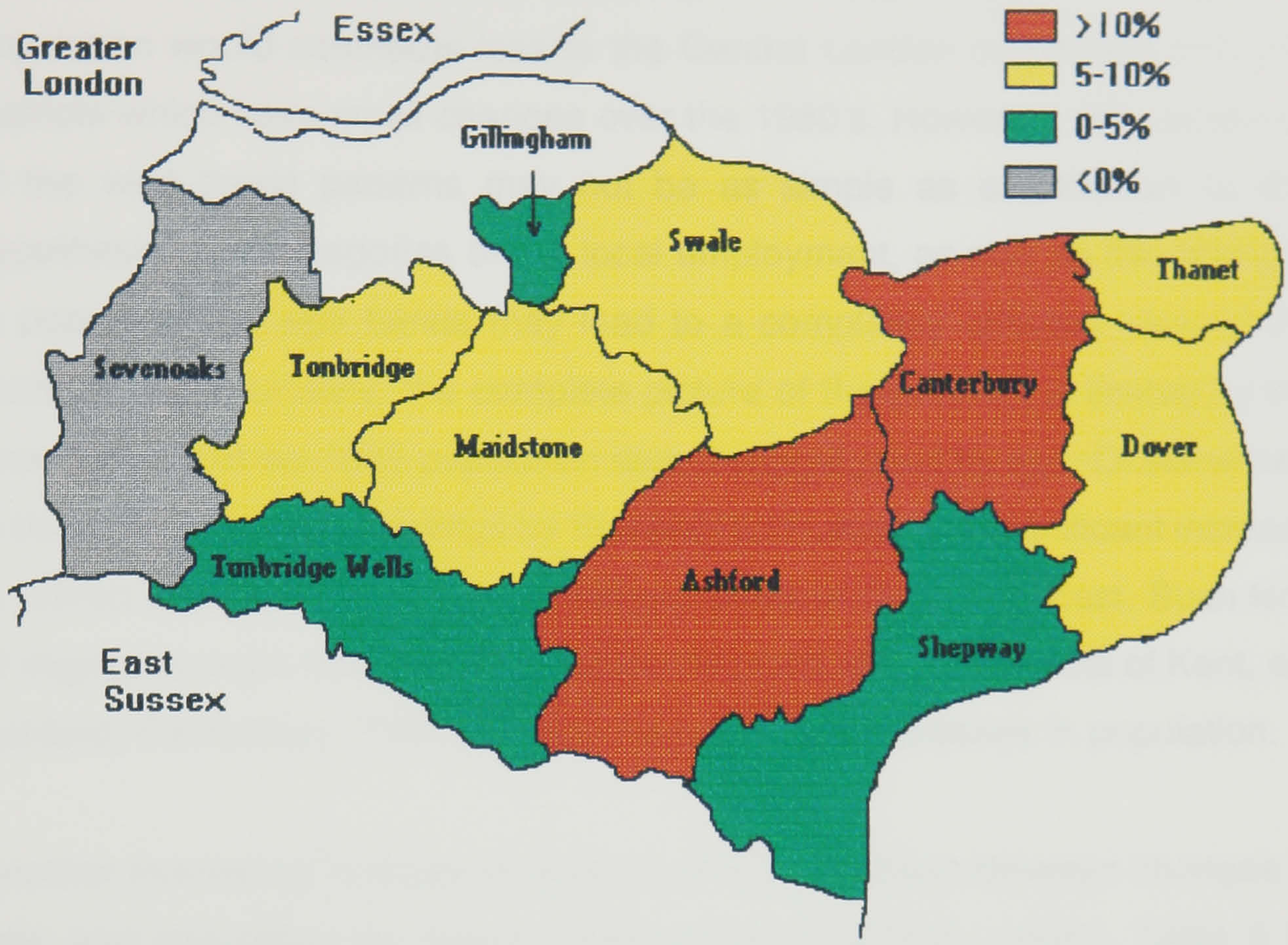


Fig 6.1 Change in Population by district, 1981-1989

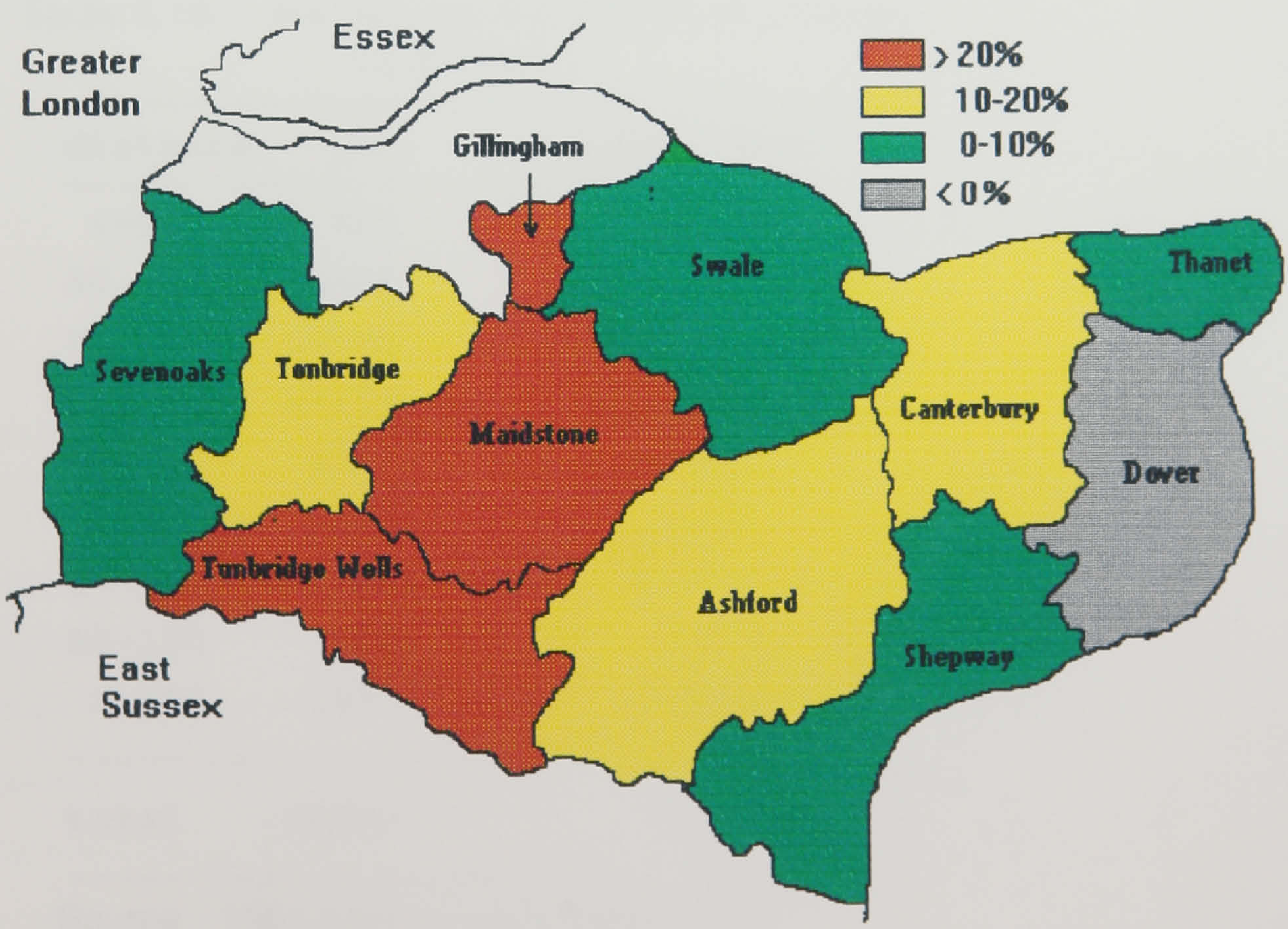


Fig. 6.2 Change in employment by district, 1981-1989

One would expect that areas which have increased the ratio of jobs to population would contribute less to the Central London commuting than the districts which have small changes over the 1980's. However, the complexity of the work-travel patterns may not be as simple as established by this hypothesis. The categories of the local employment, as well as the changes in population by age bands may lead to a completely different view of the problem. Unfortunately, the complete picture of the problem is limited by the unavailability of the 1989 population data disaggregated by age. Of some help in this analysis are the findings by Stavely(1989) about the significant increase in retired population on rural and remote areas of the South-East. Such kind of migration might have happened in some of the eastern districts of Kent, eg. Ashford, Canterbury, Thanet, which had relevant increases in population.

Another interesting analysis is given by the comparison between changes in jobs and population by range of distances to Central London. Table 6.15 shows these changes by distances given in kilometres.

Table 6.15 - Average job and population changes by distance

distance	job	population
<=30	- 383	1355
30-40	3988	-2865
40-50	15193	9475
50-60	17117	8348
60-70	3122	7616
70-80	5663	8084
80-90	4787	18235
90-100	389	5493
> 100	-1527	16574
total	48349	72315

Source : 1981 Census of Population and 1989 Census of Employment

The figures depicted in table 6.15 clearly show that the locations of people and jobs have followed completely different patterns.

In the analysis of the differentials between job and residents by range of distances, one should bear in mind the fact that the growth in population comprises, among other segments of the society, non working people, and those who commute to places outside Kent. Given that, a first issue to pinpoint regards the difference between changes in population and employment at the range of distances between 40-60 km of Central London. At this band, the absolute change in population was less than half the job growth. On the other hand, the contrary happens at 80-90 km distances, where the number of new jobs was one third the change in population.

The different tendencies followed by population and employment growth by zone have implications in the patterns of work-travels. The increase in job opportunites at medium distance relative to population is expected to reduce commuting. However, a major expansion of population relative to jobs at long distance, is likely to increase commuting. Given the importance of this issue as concerns the aims of this work, the role of population and job location on the commuting patterns will be fully explored in the next chapter.

6.6 PRELIMINARY CONCLUSIONS

The historic view of the urban planning in London showed a long trend in decentralization of population. Since the peak of the trend in the 1970's, the urban decreases have continued at a slow pace. Actually, the pattern of centrifugal movement is beyond the ring of the conurbation towards the remote and rural areas. The deconcentration patterns clearly reflect a cyclic behaviour in the urban-rural shifts.

The London job market has been approximately steady, and a relevant switch of jobs has been undertaken. Losses in the production sector were approximately offset by gains in specialized employment opportunities. As a consequence of the structural change in the level of specialisation of the Central London market, the socio-economic characteristcs of the commuters as well as their work travel patterns changed.

Kent has seen an average increase in jobs. However, the reduction experienced by the manufacturing sector was much smaller than the increase in the banking and finance jobs. In 1981, the production was the dominant sector of the Kent economy, whereas in 1989 the service industry had the largest market share.

It is evident that employment trends have tended to follow the urban-rural shift in population. The absolute growth in the whole population of Kent was bigger than the increase in job opportunities, however there was a much higher proportion of increase in jobs than in population.

The locations of new jobs do not exactly coincide with the places of largest population increases. To a certain extent, this suggests that the increases in population/relocation of people are not necessarily correlated to the growth in job opportunities for the location in question.

Of relevance, are the effects of the different tendencies in population and job locations on the commuting patterns. The major expansion of jobs at medium distance relative to population is likely to reduce commuting. On the contrary, the major expansion of population at long distance is supposed to increase commuting. The implications of population and job locations on the temporal and spatial changes of commuting are left to be explored in chapter 7.

CHAPTER 7

DESCRIPTIVE ANALYSIS OF COMMUTING TRENDS

7.1 OVERVIEW

This chapter turns to the analysis of patterns of travel to work from Kent. The task here is to identify factors which possibly explain the trends in commuting over the period 1981-89.

Generally, one might expect that zones which presented a large growth in population would have had some contribution to the growth in commuting within Kent and/or to Central London. On the other hand, if a zone had a large increase in employment opportunities, it is likely that a substantial part of the local residents would have filled these jobs and a lesser proportion would commute to London.

However, the actual mechanism is not as simple as that. For instance, factors such as composition of the growing population and level of specialisation of the new jobs are expected to play a role in this process. Indeed, there is evidence of some significant increase in population of rural and remote areas due to retirement (Cross (1988)), which would have no effect on the patterns of work at all. Another factor to consider is the predominance of the London commuting by specialised socio-economic classes. One might expect that additional local jobs in the production sector of Kent will not greatly affect the work trips to London.

In this chapter, the 1981 commuting by mode of transport and socio-economic classes, as given by the Census of Population, are initially discussed. Then a descriptive and comparative analysis of the 1981 and 1989 British Rail surveys data attempts to identify and explain the specific characteristics of the growth in rail commuting. The attributes of the transport services as well as the socio economic aspects of the rail commuters are explored. The results of the analysis of commuting trends undertaken in this chapter plus the main findings concerning the role of non-metropolitan population growth on the decentralisation of employment carried out in chapter 6 are drawn together in a preliminary conclusion regarding the 1980's patterns of commuting to Central London. Here, the role of changes in the transport system, as well as decentralisation of jobs and population on the growth of commuting to Central London is assessed.

7.2 - COMMUTING FROM KENT IN 1981

7.2.1- TOTAL FLOW BY DISTRICT

Table 7.1 contains the total number of commuting trips from each district of Kent, the flows destined to Central London (CL), rest of Inner London (RIL) and Outer London (OL), the local working trips within each district (local), and flows to elsewhere. The figures given in the column 'major' comprise the flow to a major destination within Kent. Workplaces not stated, not fixed, inadequately described, outside the U.K., or on oil rigs were grouped together under the heading 'undefined'. The 'undefined' group was disregarded in the column total, which concerns only flows with defined destinations, as well as in the percentages, shown in brackets.

One should be aware of the fact that the OPCS tables, which give journey-to-work flows at the district level, treat the irregular cases called 'undefined' as if the workplace was located in the same district as place of usual residence. Hence, the figures given by the published OPCS tables and the ones obtained through the Special Workplace Statistics, part C, may differ. (see MATPAC User's Manual (1989)).

Table 7.1 - Total flow by district of Kent (10% sample)

District	total	CL	RIL	OL	local	elsewhere	major	undefined
Sevenoaks	4531	760(17)	301(7)	821(18)	1988(44)	661(14)	Dar 238(5)	462
Tonbridge	3776	349(9)	113(3)	195(5)	1989(53)	1130(30)	Mai 331(9)	436
Gillingham	3672	382(10)	128(3)	105(3)	1398(38)	1659(45)	Roc 1124(31)	425
Maidstone	5276	247(5)	107(2)	145(3)	3475(66)	1302(25)	Ton 620(12)	551
Tunbridge W.	3776	326(9)	95(3)	93(2)	2563(68)	699(19)	Ton 261(7)	436
Swale	4019	227(6)	71(2)	77(2)	2881(72)	763(19)	Roc 209(5)	462
Ashford	3185	117(4)	38(1)	46(1)	2425(76)	559(18)	Mai 174(5)	420
Canterbury	4027	165(4)	43(1)	56(1)	3171(79)	592(15)	Dov 134(3)	520
Shepway	2856	52(1)	13(1)	17(1)	2275(80)	449(16)	Dov 191(7)	389
Thanet	3695	56(2)	41(1)	31(1)	2996(81)	571(15)	Dov 295(8)	458
Dover	3688	22(1)	16(1)	8(0)	3155(85)	487(13)	She 165(4)	425
Totals	42499	2713(6)	956(2)	1594(4)	28316(67)	8872(21)		4984

Source : 1981 Census of population

As expected, there is an inverse relation between travel distances and the level of flow to London. Table 7.1 shows that the proportions declined from the peripheral district, Sevenoaks, to those more outward. The opposite is valid to local flows within the districts, since the proportion of trips increased approximately in line with the district distance to London.

Apart from Sevenoaks, all districts of Kent had larger flows to Central London than to any other part of London. On the other hand, there were larger flows to places in Kent than to either the rest of Inner London or Outer London. For instance, the number of commuting trips from Gillingham to Rochester was almost the same as the one within the district of Gillingham, but more than eight times the flow to the rest of Inner London. The significant proportion of 31% of the flow generated in Gillingham was to the single destination Rochester, whilst 38% had local destinations.

The largest contribution of journey to work flows to destinations other than London and the district itself was given by Gillingham, whose flows to elsewhere represented a proportion of 45% of the total flow generated in the district. This figure sounds reasonable in the light of the information given in table 6.7, which shows the reduced share of the job market of Kent experienced by this district. Since Gillingham had the smallest proportion of the job market in Kent (3.2%), it is very likely that its working population commute to areas more attractive. All these features associate Gillingham with a dormitory district.

Maidstone had a high number of commuting to elsewhere, however it also had the largest proportion of jobs of the County of Kent, and consequently a significant influx of commuters from the surrounding areas. Therefore, the same analysis does not apply any more. Possible reasons for the high level of in and out flows in Maidstone are the geographical position of the district in Mid Kent and its relative accessibility to other areas, as well as the relatively good housing and other urban facilities that exist in the district.

Once the level of commuting from the different places of Kent was presented, interesting views come from the analysis concerning the modes of transport used. This is explored in the following section.

7.2.2 - FLOWS BY MODE

Table 7.2 relates the total flow by mode between the districts of Kent and London, as well as the local flow within the districts. The modes of transport underground, motor and pedal cycle, and foot were grouped together in the class called others, as well as the reported cases of people working at home. The figures in brackets stand for the corresponding percentages, which are computed for the totals excluding the undefined flows.

Table 7.2 - Flows by mode (10% sample)

From	\ to	BR	car	bus[a]	others	undefined
Sevenoaks	CL	627 (83)	112 (15)	2 (0)	17 (2)	2
	RIL	76 (26)	200 (67)	2 (1)	19 (6)	4
	OL	80 (10)	643 (79)	46 (6)	41 (5)	11
	local	13 (1)	881 (45)	122 (6)	951 (48)	21
Tonbridge	CL	279 (80)	51 (15)	9 (3)	6 (2)	5
	RIL	36 (32)	67 (60)	5 (4)	3 (3)	1
	OL	21 (11)	169 (88)	0 (0)	2 (1)	3
	local	22 (1)	959 (49)	155 (8)	837 (42)	16
Gillingham	CL	306 (81)	40 (10)	26 (7)	9 (2)	1
	RIL	62 (49)	47 (37)	13 (10)	5 (4)	1
	OL	31 (30)	70 (68)	1 (1)	1 (1)	1
	local	16 (1)	583 (42)	117 (8)	676 (49)	6
Maidstone	CL	191 (80)	41 (17)	6 (2)	3 (1)	6
	RIL	47 (44)	52 (49)	2 (1)	6 (6)	0
	OL	19 (13)	120 (84)	1 (1)	3 (2)	2
	local	29 (1)	1646 (48)	519 (15)	1254 (36)	27
Tunbridge Wells	CL	290 (89)	30 (9)	2 (1)	3 (1)	1
	RIL	58 (61)	35 (37)	1 (1)	1 (1)	0
	OL	8 (9)	82 (88)	1 (1)	2 (1)	0
	local	12 (0)	1108 (44)	258 (10)	1156 (46)	29
Swale	CL	183 (83)	24 (11)	12 (5)	2 (1)	1
	RIL	49 (65)	25 (33)	0 (0)	2 (2)	0
	OL	21 (28)	54 (70)	1 (1)	1 (1)	0
	local	71 (2)	1392 (49)	127 (5)	1253 (44)	38
Ashford	CL	105 (87)	9 (8)	1 (1)	5 (4)	1
	RIL	24 (71)	10 (29)	0 (0)	0 (0)	0
	OL	20 (44)	23 (50)	1 (2)	2 (4)	0
	local	31 (1)	1137 (47)	184 (8)	1054 (44)	19
Canterbury	CL	138 (84)	19 (12)	4 (2)	3 (2)	2
	RIL	27 (64)	13 (32)	1 (2)	1 (2)	1
	OL	18 (32)	35 (63)	1 (2)	2 (3)	0
	local	28 (1)	1632 (52)	273 (9)	1209 (38)	29
Shepway	CL	42 (81)	5 (10)	1 (2)	4 (7)	0
	RIL	6 (46)	6 (46)	0 (0)	1 (8)	0
	OL	3 (18)	12 (70)	1 (6)	1 (6)	0
	local	6 (0)	1113 (49)	246 (11)	888 (40)	22
Thanet	CL	43 (75)	8 (14)	0 (0)	6 (11)	3
	RIL	11 (34)	12 (36)	1 (3)	9 (27)	4
	OL	6 (21)	16 (55)	3 (10)	4 (14)	2
	local	25 (1)	1468 (49)	302 (11)	1170 (39)	31
Dover	CL	15 (68)	5 (23)	0 (0)	2 (9)	3
	RIL	3 (20)	10 (26)	0 (0)	2 ( )	1
	OL	0 (0)	8 (100)	0 (0)	0 (0)	0
	local	57 (2)	1420 (45)	431 (14)	1229 (39)	18

[a] includes bus, minibus, and coach (public or private)

Source : 1981 Census of Population

As far as the modes are concerned, the train had the largest proportion of the market of commuting trips to Central and the rest of Inner London, followed by car and bus. Flows by train in the Northern, Mid and Western districts were larger than the ones in the Eastern region. As expected, the use of rail to local trips was almost insignificant.

The largest number of coach trips to Central and Inner London came from the Northern districts of Gillingham and Swale, although Tonbridge, located in the West of Kent, also had a significant coach use. As regards the flows by coach to Outer London, the peripheral district, Sevenoaks, presented the largest figure. For the local travels within Kent, bus was the second most used mode of transport, showing the largest figures in Maidstone, followed by the eastern districts Dover and Thanet.

The car commuting was mainly observed in Sevenoaks, Tonbridge and Maidstone. It was the mode of transport most used in trips to Outer London, whilst the number of trips by train was far smaller than the ones to both Central and Inner London. A similar trend was observed in local trips within districts of Kent where the average mode share of car and rail was 47% to 1%.

Given the fact that the sequential order of the districts showns in table 7.2 is compatible with their position according to the distances to Central London, a relationship exists between the distances to London and the flows by train and car. For these two modes, table 7.4 shows figures that decrease according to the distance to London, although for the other modes no similar analysis could be done.

As expected, local trips were mainly undertaken by private transport, whereas the public mode, in particular rail, was chosen for the destinations in London.

An important factor to complement the cross-analysis of the patterns of commuting to both Central London and local areas of Kent, concerns the social classes of the travellers. This is an issue explored in the next section.

7.2.3 - FLOWS BY OCCUPATION ORDERS

Table 7.3 depicts the total flows by occupation orders from the districts of Kent to Central London, Inner and Outer London, and the local working trips within each district. The percentage of the flows by district is presented in brackets. As a matter of simplification, the classes selling, security, material processing, and farming were grouped into a single class called others. The abbreviations prof, man, and cle stand for professional, manager, and clerical respectively.

As far as the flow shares by district and occupations are concerned, most of the commuting trips to any part of London were done by people of the professional category. According to table 7.3, the only exception was Gillingham, whose clerical class presented a proportion of 52% of the total flow to Central London.

The largest flows of professionals and managerial to London were mainly from Sevenoaks, Tunbridge Wells and Tonbridge.

On the contrary, smaller proportions of the professional and managerial categories were given by the local flows of the 11 districts of Kent. In almost all of them, more than 50 % of the total commuting were related to the other social classes. This is compatible with the job categories depicted in table 6.5. In 1981, only 35% of the jobs in Kent were of the financial and service sectors, what means that some 65% comprised non specialised activities likely to be filled by the local population.

The figures in table 7.3 clearly show district trends concerning the work trips to London and to local places in Kent. The former mainly involves the specialized social classes and clerical, whereas the latter a wider range of categories of the production sector.

In spite of not being the major class of local flows, professional presented significant proportions in relation to the total commuting. If tables 7.3 and 6.6 are compared, one may observe that the largest concentration of the local flows by professionals was mainly in Canterbury (19%), which also had a high level of local jobs of the financial and services sector in 1981.

Table 7.3 - Flows by occupation orders (10% sample)

From \ to		prof	man	cle	others	undefined
Sevenoaks	CL	274(36)	97(13)	257(34)	130(17)	2
	RIL	98(33)	48(16)	51(17)	104(35)	2
	OL	243(30)	111(13)	146(18)	316(39)	5
	local	335(17)	227(11)	394(20)	1026(52)	8
Tonbridge	CL	133(38)	45(13)	118(34)	52(15)	1
	RIL	39(35)	23(20)	14(12)	37(33)	0
	OL	72(37)	38(19)	23(12)	62(32)	2
	local	301(15)	199(10)	388(20)	1094(55)	7
Gillingham	CL	90(24)	28(7)	200(52)	64(17)	0
	RIL	35(27)	16(13)	33(26)	43(34)	1
	OL	30(29)	15(14)	17(16)	43(41)	0
	local	182(13)	142(10)	216(16)	855(61)	3
Maidstone	CL	97(39)	30(12)	83(34)	37(15)	0
	RIL	35(33)	22(21)	17(16)	33(31)	0
	OL	55(38)	29(20)	11(8)	50(34)	0
	local	566(15)	394(11)	788(23)	1718(49)	9
Tunbridge Wells	CL	148(45)	49(15)	91(28)	38(12)	0
	RIL	38(40)	23(24)	19(20)	15(16)	0
	OL	38(41)	21(23)	13(14)	21(22)	0
	local	441(17)	266(10)	577(23)	1266(50)	13
Swale	CL	84(37)	28(12)	83(37)	30(14)	2
	RIL	19(27)	15(21)	14(20)	22(32)	1
	OL	19(25)	17(22)	7(9)	34(44)	0
	local	350(12)	278(10)	415(14)	1824(64)	14
Ashford	CL	43(37)	19(16)	36(31)	19(16)	0
	RIL	15(39)	6(16)	9(24)	8(21)	0
	OL	18(39)	6(14)	6(14)	15(33)	0
	local	354(14)	262(11)	387(16)	1416(59)	6
Canterbury	CL	73(44)	26(16)	38(23)	28(17)	0
	RIL	17(40)	10(23)	9(21)	7(16)	0
	OL	24(44)	9(16)	3(5)	20(35)	0
	local	589(19)	379(12)	568(18)	1597(51)	19
Shepway	CL	27(52)	5 10)	13(25)	7(13)	0
	RIL	4(31)	2(15)	1(8)	6(46)	0
	OL	5(29)	4(24)	0(0)	8(47)	0
	local	314(14)	283(12)	429(19)	1236(55)	13
Thanet	CL	18(32)	8(14)	17(31)	13(23)	0
	RIL	12(29)	8(20)	6(15)	15(36)	0
	OL	11(35)	5(16)	5(16)	10(33)	0
	local	454(16)	390(13)	476(16)	1654(55)	22
Dover	CL	14(64)	1(5)	2(9)	5(22)	0
	RIL	8(50)	2(12)	0(0)	6(38)	0
	OL	2(25)	1(12)	0(0)	5(63)	0
	local	383(12)	293(9)	516(17)	1944(62)	19

Source : 1981 Census of population

7.2.4 LOCAL COMMUTING BY DISTANCE

Another interesting analysis comprises the local commuting trips within Kent. The figures given in table 7.4 show that some 67% of the 1981 local work trips in Kent was in the range of 5 km distance from the ward's centre, while the majority of 82.2% of the flows were within 10 km distance.

Table 7.4 - Local commuting by distance

Distance (km)	frequency	%
0 - 5	27304	67.1
5 - 10	5319	15.1
10 - 15	2801	7.9
15 - 20	1376	3.9
20 - 30	1259	3.6
30 - 40	474	1.3
40 - 50	183	0.5
50 - 60	106	0.3
> 70	119	0.3

Source : 1981 Census of Population

The band of 10km distance from the ward's centre is therefore a reasonable verification of the local employment catchment area.

7.3 - DESCRIPTIVE ANALYSIS OF RAIL COMMUTING TO CENTRAL LONDON

This section attempts to analyse the origin and destination data provided by the 1981 and 1989 British Rail surveys. The data set comprises journeys only from stations of the County of Kent, and is part of the information given by the surveys of rail travel in London and the South-East, carried out every 10 years. The attributes of travel and the social class composition of the commuting population are combined in a descriptive and comparative analysis of the data.

As explained in chapter 5, the station's samples were grossed up by using the weight factors provided by British Rail. The resulting figures, which will be simply called 'estimates', are supposed to represent the population commuting by rail.

Despite the various differences between the 1981 and 1989 origin and destination surveys, the data analysis provided relevant information on accessibility to stations, inter-change of trains, location of commuters by distance to Central London, and socio-economic characteristic of travellers. Such issues are treated in this section, which initially presents the level of commuting to the main destination stations of Central London, followed by the flow changes according to ranges of travel distances. The growth in commuting by station and origin district are also presented. Some attributes of travel related to the period 1981-1989 are in the scope of section 7.3.3 which shows the average travel time and cost of commuting to Central London, train inter-changes, the access time to local stations of Kent, the egress time to the final destination in Central London, and some modifications undertaken in the transport network. Section 7.3.4 deals with the influence of the Outer London stations on the commuting of the boundary area of Kent, and section 7.3.5 presents an analysis of the socio-economic characteristics of the commuters.

7.3.1- CENTRAL LONDON STATIONS

The figure 5.1 showed that some important rail lines in Kent were not covered by the 1989 survey, in particular the section which comprises the main stations of Dartford and Gravesend. Therefore, the districts Dartford, Rochester and Gravesham were excluded from the analysis.

During the period 1981-89, as seen in chapters 2 and 6, increases in the number of commuting trips from Kent to Central London were expected. For the set of stations surveyed in both years, the estimated number of rail commuters to Central London was 20756 in 1981 and 25186 in 1989, an increase of 21% (see table 7.5). This increase was very slightly faster than the 20% average growth of the flows entering Central London by rail from all destinations (see table 2.1). Growth from Kent was also higher than growth in the flows on the South-East sub-sector of Network South-East as a whole. According to the figures shown by the Department of Transport (1990), the total flow from that sub-sector increased from 119,000 in 1981 to 139,000 in 1989, that is by 16.8%. Overall, therefore, we conclude that the stations studied here experienced growth in central London commuting which was typical of that from all destinations, and higher than the rest of the South-East sub-sector.

Flow changes experienced by Kent were higher than British Rail forecasts for Network South-East as a whole. According to the report on rail passengers in the South-East of England, by the Monopolies and Mergers Commission (1987), "the growth of traffic between 1984-85 and 1986-87 exceeds that previously forecast for the entire period of the 1985 Corporate Plan". The report explains that "The 1985 Corporate Plan was based on a stable commuting market and increased leisure travel expected to result from marketing initiatives, producing a two percent increase in passenger miles over the five years as a whole".

In general, the stations of Kent presented growth in flows. However some few stations either kept about the same level of commuting or even reduced it. Significant increases were observed for the stations Sevenoaks, Gillingham, and Ashford. To a certain extent one may say that the largest growth of commuting to Central London occurred along the rail lines Tonbridge-Ashford and Faversham-Rochester, whereas the decreases were scattered in various places of Kent.

The destination Central London considered in this analysis comprises any of the following six major stations: Cannon St., Charing Cross, Holborn, London Bridge, Waterloo, and London Victoria.

Table 7.5 shows the 1981 and 1989 flows of commuting to the Central London stations, for the same set of Kent stations mutually surveyed in each year.

Table 7.5- Frequency of commuting to Central London stations (am peak)

	1981	1989	change
stations	freq (%)	freq (%)	freq (%)
Victoria	6766 (32.6)	8690 (34.5)	1924 (43.4)
Cannon St.	7493 (36.1)	8428 (33.5)	935 (21.1)
Charing Cross	3923 (18.9)	4843 (19.2)	920 (20.8)
Holborn	1412 (6.8)	1176 (4.6)	- 236 (-5.3)
London Bridge	498 (2.4)	1073 (4.3)	575 (13.0)
Waterloo	664 (3.2)	976 (3.9)	312 (7.0)
total :	20756 (100)	25186 (100)	4430 (100)

The changes in the distribution of flows are clearly shown by the figures of table 7.5. During the period 1981-1989, there were reductions in the proportions of flow to both Holborn and Cannon St. stations, but increases in the flows to the stations Victoria, London Bridge, Charing Cross and Waterloo.

To test whether the change in the percentage distribution of flows between 1981 and 1989 is significant, a hypothesis test of the difference between the proportions given by both years was carried out. The explicit hypothesis formulated is that the proportion of passengers going to western stations of London (Victoria station, Charing Cross, and Waterloo) increased during the period 1981-89. One may then test the null hypothesis that there was no change in the percentage distributions, against the alternative hypothesis that the distributions were different.

In 1981 and 1989, the flows given by the three selected stations together are 11353 and 14509, and the proportions going to western stations 54.7% (p_1) and 57.6% (p_2) respectively. The pooled estimated proportion is then computed as

$$p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$$

$$p = 0.5629$$

where n_1 and n_2 are the total samples in 1981 and 1989 respectively, given by table 7.5.

and

$$z = \frac{p_1 - p_2}{\sqrt{p(1-p)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

$$z = -6.236$$

Given the large sample sizes, z will approximates a normal distribution. The probability in each tail is less than 0.001, and a combined probability of less than 0.002 in both tails. At the 5% level of significance, the result is highly significant. The null hypothesis is then rejected, and one may conclude that the 1989 proportion is significantly different from the 1981 proportion.

Evidence of the decentralization of jobs within the central area is given by the location of the latter stations which are situated at the western side of the city, where the office area is not so concentrated. As regards the flow decline showed by Holborn station, it is attributed to diversion of trains to some other stations.

The reduction in the proportion of commuting using Cannon St. reflects the fall in employment (-16%) in the City of London, over the period 1981-90. On the other hand, the 17% increase in job occurred in Kensington and Chelsea is consistent with the higher proportions shown by the stations Victoria, Charing Cross and Waterloo.

7.3.2 - ZONAL CHANGES

a - Commuting by distance

A clear picture of increases in commuting distances is given by the analysis regarding the level of rail users of local stations. In 1981, about 39% of the total flow was originated in stations within 30 miles from Central London, whereas in 1989, the reduced proportion of approximately 36% was observed at the same range of distances. However, for distances above 40 miles, the figures given by the 1989 rail data are generally higher than the 1981 ones. This means that during the 1980's there was a tendency of rail users to live further out London.

Such trends are corroborated by table 7.6, which depicts the proportion of rail commuting by distance, for data given by the 1981 and 1989 British Rail surveys.

Table 7.6- Flows by distances between local and CL stations

range distance (miles)	1981 frequency (%)	1989 frequency (%)	change frequency (%)
<= 20	1136 (5.5)	1210 (4.8)	74 (1.6)
20 - 30	7043 (33.9)	7760 (30.8)	717 (16.2)
30 - 40	6179 (29.8)	7723 (30.7)	1544 (34.9)
40 - 50	2903 (14.0)	3674 (14.6)	771 (17.4)
50 - 60	1824 (8.8)	2826 (11.2)	1002 (22.6)
60 - 70	1167 (5.6)	1407 (5.6)	240 (5.4)
70 - 80	437 (2.1)	497 (2.0)	60 (1.4)
80 - 90	67 (0.3)	89 (0.4)	22 (0.5)
total :	20756 (100)	25186 (100)	4430 (100)

According to the frequencies given by both surveys, a large majority of the commuting trips was within the range of 20-40 miles. Worthy to be highlighted are the flow changes from both ranges of 30-40 and 50-60 miles distance.

b - Changes in commuting by stations

The investigation of the distribution of flows by station and district is shown by table 7.7. The frequencies stands for the total flows from the station or stations located in a particular district.

Table 7. 7 - Flows by stations in districts of Kent

district	1981 frequency (%)	1989 frequency (%)	change frequency (%)
Swale	1919 (9.2)	3064 (12.2)	1145 (25.8)
Canterbury	1456 (7.0)	1644 (6.5)	188 (4.2)
Dover	205 (1.0)	259 (1.2)	54 (1.2)
Thanet	502 (2.4)	540 (2.1)	38 (0.9)
Maidstone	2084 (10.1)	2500 (9.9)	416 (9.4)
Tunbridge Wells	776 (3.7)	1004 (4.0)	228 (5.1)
Ashford	925 (4.5)	1540 (6.1)	615 (13.9)
Shepway	398 (1.9)	479 (1.9)	81 (1.8)
Sevenoaks	5241 (25.3)	5836 (23.2)	595 (13.4)
Tonbridge	3704 (17.8)	4010 (15.8)	305 (6.9)
Gillingham	3544 (17.1)	4310 (17.1)	766 (17.3)
total :	20756 (100)	25186 (100)	4430 (100)

According to the figures depicted in the last column of table 7.7, the largest proportion changes in commuting were shown by Swale, Gillingham, Ashford, and Sevenoaks. Substantial increases were observed in the stations of Ashford (66%), Swale (60%), Tunbridge Wells (29%), and Dover (26%). Maidstone, Shepway, and Gillingham presented flow changes about the overall average commuting growth of 21%, whereas the remaining districts showed much lower figures. The electrification of the rail line Hasting-Tunbridge Wells-Tonbridge might have contributed to some of the growth in the commuting from Tunbridge Wells.

The increase in commuting from Ashford and the other districts of Mid-Kent corroborates the evidence of increase in trip lengths within 50 miles distance, discussed somewhere in this chapter.

c - Changes in commuting by origin addresses

One should be aware of the problems involved in the identification of the rail users' origin. The address codes given by both surveys were completely different. Additionally, the 1989 survey contained some cards with wrong and incomplete postcodes, as well as missing information about travellers addresses. These discrepancies made more difficult the task of an analysis of commuting by ward. However, at the district level a better view of the problem was given by the analysis of the raw data.

Due to incomplete postcode, a total of 2269 (9%) addresses were not properly matched to wards. However, 1997 of them could be associated to districts, and only 272 comprised missing information. Since the file provided by British Rail contained the data in a sequential order by stations surveyed, it was possible to guess the likely origin of the 272 missing postcodes by associating them with the other district or districts shown by that station. This adjustment in the 1989 estimated number of rail commuters to Central London allowed a compatible analysis of the 1981 and 1989 commuting changes to be undertaken. Given the small size of this adjustment, it is unlikely that significant errors were introduced in the flow distributions.

Table 7.8 depicts the distribution of flows by district in 1981 and 1989, as well as the changes occurred during this period. Figure 7.1 illustrates the changes in commuting flows by district over the period 1981-89.

Table 7. 8 - Flows by origins in Kent

district	1981 frequency (%)	1989 frequency (%)	change frequency (%)
Swale	2134 (10.3)	3207 (12.7)	1073 (24.1)
Canterbury	1534 (7.4)	1736 (6.9)	202 (4.6)
Dover	239 (1.1)	331 (1.3)	92 (2.1)
Thanet	528 (2.5)	535 (2.1)	7 (0.1)
Maidstone	2041 (9.8)	2196 (8.7)	155 (3.5)
Tunbridge Wells	1857 (8.9)	2099 (8.3)	242 (5.5)
Ashford	1082 (5.2)	1941 (7.7)	859 (19.3)
Shepway	447 (2.2)	540 (2.1)	93 (2.1)
Sevenoaks	4282 (20.6)	5282 (20.9)	1000 (22.6)
Tonbridge	2961 (14.3)	3484 (13.8)	523 (11.8)
Gillingham	3651 (17.6)	3835 (15.2)	184 (4.2)
total :	20756 (100)	25186 (100)	4430 (100)

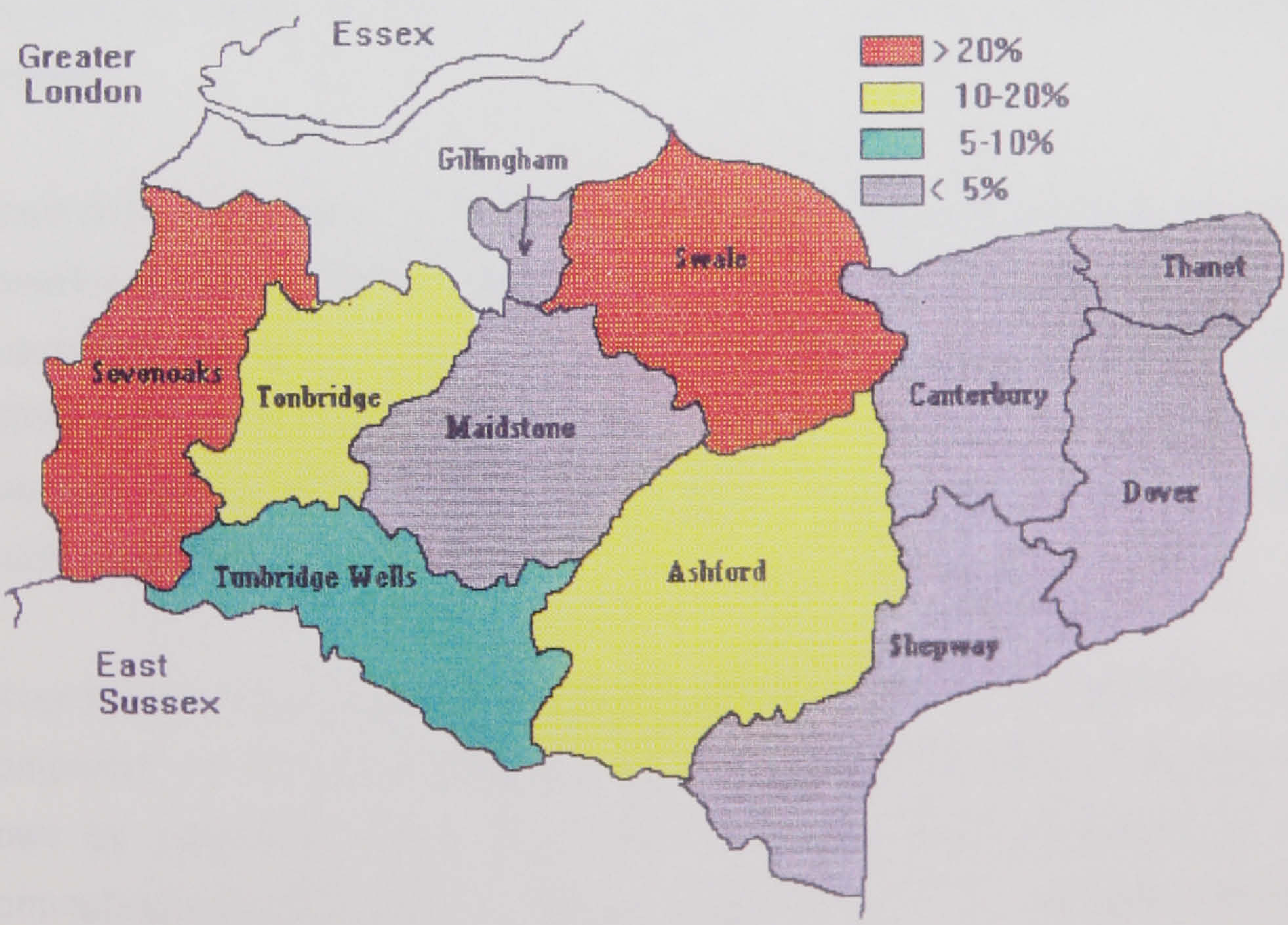


Fig. 7.1 Change in rail commuting by district, 1981-1989

As expected, there are some contrasts between the figures shown by tables 7.7 and 7.8. The comparison between them highlights the differences in the distribution of flows particularly shown by Tunbridge Wells, Sevenoaks and Tonbridge in both years. According to the figure given by table 7.7, the totals of 776 and 1004 commuters started their trips in any of the stations located in the Tunbridge Wells district, respectively in 1981 and 1989. However, table 7.8 shows that higher sample of 1857 and 2099 commuters had their postcodes identified to that district, in 1981 and 1989 respectively.

A probable reason for the discrepancies found in the 1989 flows from Tunbridge Wells is the fact that the main station in the district (Tunbridge station) was not covered by the British Rail survey, at the time the data analysed here was obtained. Another possible reason concerns commuters who initiate their trips in stations located in a district different from their origin addresses. As concerns the latter, the comparison of the flows shown by Maidstone and Sevenoaks in both tables suggest that a high number of non residents of these two areas initiate their commuting trips in stations of these districts.

Apart from Gillingham, both tables show that most of the changes in the commuting flows occurred in Sevenoaks, Swale and Ashford. Table 7.8 shows substantial increases in the flows from the districts Ashford (79%), Swale (50%), and Dover (38%). Shepway presented flow changes about the overall average commuting growth of 21%, whereas the remaining districts showed much lower figures.

Given the relative accuracy of the information provided by the origin addresses compared with the coarse approach used in the computation of the district flows by association with station flows, only the 1989 distribution of rail commuting shown by table 7.8 will be considered in the remainder of this thesis.

7.3.3 TRAVEL ATTRIBUTES

a - Accessibility to stations

The reported modes of access to the local stations were bus, car, cycle, taxi, and foot. Another option 'others' comprises the aggregation of the following modes: (a) Waterloo and city line, (b) sea or air, (c) underground/Dockland Light Rail, and (d) another BR train. The latter regards a situation of interchange of trains, whereas items (a) and (c) are likely to involve trips within the Greater London area.

Table 7.9 shows the distribution of access modes to the local stations of Kent.

Table 7.9 - Access mode to stations

access mode	1981 frequency (%)	1989 frequency (%)
car	9717 (46.9)	12557 (50.4)
foot	8895 (43.0)	10493 (42.2)
bus	1284 (6.2)	766 (3.1)
cycle	734 (3.6)	790 (3.2)
taxi	60 (0.3)	197 (0.8)
others	6 (0.0)	92 (0.3)
total :	20696 (100)	24896 (100)

The access mode car, followed by foot, is far more used in Kent. At the expense of almost all the other modes, and in particular buses and foot, the mode shares in 1989 highly favour the car.

Significant is the average 50% decline experienced by the bus mode, which were mainly observed at the stations Tonbridge (145), Longfield (68), Rainham (56) and Swanley (56). The figures in brackets stand for the absolute changes in the number of people using the bus mode to access the Kent stations.

In the majority of stations, the increases observed in the car mode were approximately proportional to the reductions in walk. However, the opposite was observed in the stations Folkestone West, Charing, Maidstone East, Dunton Green, Gillingham, Westgate-on-Sea, and Chestfield & Swalecliffe. The proportions of walk in relation to the other modes were substantial at the latter four stations, as well as at Bat & Ball, Teyham, and Eynsford.

In some other stations the increases in the access by car involved decreases in modes other than foot, eg. Dover Priory and East Malling. Stations which had increases in foot at the expense of reductions in modes other than car are Tonbridge, Sheerness-on-Sea, and Shoreham.

As expected, wards relatively far from rail stations tend to show a high percentage of car use. However, one cannot state that difficulties to access the station, eg. remote station, are the only reasons to led people to use the car as their access mode. There are some wards which presented reasonable high figures for the car mode even in cases of good accessibility to the stations.

b - Accessibility from stations

Foot, followed by underground, were the most used egress modes reported by the commuters from Kent. Foot experienced a decrease from 62%, in 1981, to 57.9% in 1989, mainly in favour of the underground which presented 27.7% of the modal share in 1981, and 30.1% in 1989.

The frequencies and proportions concerning the egress modes in the Central London stations are depicted in table 7.10.

Table 7.10 - Egress modes from Central London stations

egress mode	1981 frequency (%)		1989 frequency (%)	
foot	12810	(62.0)	14323	(57.9)
underground	5728	(27.7)	7584	(30.1)
bus/coach	1897	(9.2)	2369	(9.4)
others	212	(1.1)	424	(3.6)
total :	20647	(100)	24700	(100)

The use of buses/coaches as egress modes were approximately steady over the period 1981-89, but a slight increase was observed in the group called others, which is comprised of modes like taxi, cycle/motorcycle, and the Waterloo & City Line, as well as not stated information.

Three components of journey time were analysed: access time, egress time, and in-vehicle travel time. As a matter of simplification, in-vehicle time will be called travel time.

c - Access time

Unfortunately, the questionnaires used in the 1981 survey did not give any information concerning access time to the stations of Kent. Therefore, the variations that occurred over the period 81-89 could not be estimated.

Since some stations were used by commuters from various and relatively distant wards, a large variation of access times was found in 1989. For a range of 4 to 40 minutes, an average access time of about 11 minutes was obtained for Kent. The stations Deal, East Malling, Shoreham, Maidstone East and Tonbridge presented figures higher than the average, whereas lower times were given by Teynham, Newington, Bat & Ball, Westenhanger, and Wye.

d - Egress time in the Central London stations

Apart from egress mode and egress time, no other information concerning commuter's patterns in their final destination is available. The egress time variable, which is highly important as a component of the overall generalised time of travels, gives an indication of how far people go from the Central London rail termini to reach their job places. However, a better understanding of these patterns would be provided by the distribution of distances involved if the exact work place in London was known.

Given this data constraint, an aggregate analysis of the data from the simultaneous set of Kent stations surveyed in 1981 and 1989 results in the following average egress time depicted in table 7.11.

Table 7.11 - Egress time from Central London stations

station	1981		1989	
	freq	ET	freq	ET
Cannon St.	2114	12	3769	13.1
Charing Cross	1093	16	2159	16.5
Holborn	395	12	548	11.5
London Bridge	130	12	469	11.3
Waterloo	189	11	436	10.7
Victoria	1878	16	3353	16.7*

* if 180 observations of figures above 35 minutes are disregarded (otherwise et=17.4)

In spite of increases presented by some of the Central London stations, the figures given by both surveys are approximately in line with each other. The small increases observed might be attributed to congestion in the central area, and to the quite frequent delays in the overcrowded underground system. This is particularly true for the stations Victoria, Charing Cross, Cannon Street, and Waterloo, which have connections with the underground.

The egress time of the destination stations reinforces the conclusion about decentralization of employment in the central area. For both 1981 and 1989, Victoria station and Charing Cross had the largest egress times, whereas Waterloo presented the smallest figures. The former stations are located at the western side of the city, where the office density is relatively low.

One should bear in mind that a detailed analysis of the accessibility to work places in London would require much more disaggregate and complete information than the one examined here.

e - Travel time

Given the published timetable of trains related to the years 1981 and 1989, only a few changes in travel time were observed in Kent. An average increase of +0.8 minutes was computed for all stations of Kent, by taking into account the changes in travel time by station, which varied within the range of -5 to +6 minutes. Regarding morning trips, the largest reductions in time mainly occurred at the stations Charing(5), Harrietsham(5), Canterbury East(4), and Headcorn(4), whereas increases at the stations Farningham Road(6), Shepherds-Well(5), and Bearstead(5). The figures in brackets stand for the average travel time changes in minutes.

The range of rail travel times from Kent varied between 28 and 126 minutes. The differences in the figures of the revealed travel time, given by the 1989

British Rail survey, and the timetable of trains are within the range of -16.1 to 8.7 minutes, and represent a weighted average of 2.3 minutes. The same comparison for the 1981 data gives figures varying from -12.1 to 20.0 minutes, and an average of 3.3 minutes. This clearly shows an apparent improvement in the rail travel time as perceived by commuters.

Given the fact that travel time is an important element in location choices, the perceived improvement in speed seems to be a relevant factor in the analysis of the changes in the patterns of commuting.

f - Travel costs

The fare policies adopted by the British Railways used to favour long distance trips. However, since the introduction of the travelcard, some stations along the border of Greater London have had fare increases less than proportional to the other areas.

In real terms, the quarterly fares had a general average increase of some £86 corresponding to an approximately growth of 25% in the level of fares from Kent, during the period 1981-89. However, at the stations Otford, Shoreham, Swanley, Bat & Ball and Sevenoaks, the sum of the travelcard prices and season ticket fares to the Greater London boundary comes to less than the normal BR season ticket rates. Therefore, the BR season ticket was completely replaced by travelcard plus season ticket at these stations. For some of the main stations in Kent, including those benefitted by travelcards, table 7.12 depicts the actual 1989 quarterly fares, and the corresponding 1981 inflated figures to the 1989 prices using the retail price index. The resulting changes in the real level of fares (1989 prices) over the period 1981-89 is also shown.

Table 7.12 - Quarterly fares in the main stations of Kent (pounds)

district	inflated 81	1989	change 81-89
Swanley[a]	221	270	49
Shoreham[a]	259	319	60
Otford[a]	268	319	51
Bat & Ball[a]	276	319	43
Sevenoaks[a]	245	319	74
Maidstone East	318	410	92
Sittingbourne	325	412	87
Canterbury East	371	467	96
Ashford	353	449	96

[a] stations benefitted by travelcards

Given the great advantages of the travelcard, including the use free of charge of any transport mode in Central London, one may speculate about the role played by this special ticket on the significant growth in the commuting from Sevenoaks (23%) and Swanley (50%).

g - Inter-change of trains

Trips by direct trains avoid the inconvenience of inter-changes, and are usually more comfortable. They also tend to be faster, and consequently cost effective, due to the low generalised costs provided by the reduced travel time.

However, the service of direct lines to Central London is not available everywhere in Kent and inter-changes of trains in such cases are inevitable.

In the 1981 data set, a number of 1960(8.3%) commuters reported to inter-change trains at least once in their trips to Central London, whereas 156(0.7%) of them did it twice. For the 1989 data, the samples of 1302(4.3%) and 56(0.2%) observations were respectively obtained for single and multiple inter-changes.

In both years, the largest number of inter-changes was undertaken within London stations, eg. London Bridge, and Bromley South. Regarding the Kent stations, significant levels of inter-changes were observed in Sevenoaks, Sittingbourne, Faversham, and Ashford.

Another interesting analysis concerns the relation between number of inter-changes and origin stations. Table 7.13 depicts the frequencies and the largest proportions of single inter-change of trains by origin stations, for the 1981 and 1989 data set. The proportions, in brackets, are given by the number of inter-changes divided by the total flow originating from the station in question.

Since most of the stations depicted in table 7.13 presented growth in the commuting to Central London, the substantial decline of inter-changes over the period 1981-1989 might reflect improvements in the rail services in Kent. This is particularly true for the station Gillingham, which did not have any interchanged reported in 1989. The reductions in Canterbury East and Bat & Ball were also significant.

Due to the lack of direct trains from Sheerness-on-Sea and Queensborough to Central London, high proportions of commuters from these stations were supposed to inter-change. In fact, one would expect 100% of inter-changes in the flows from these stations; therefore the declines shown in 1989 were most probably caused by missing or wrong information obtained in the survey.

A possible reason for the high number of inter-changes observed in Bat & Ball are the very few direct trains destined only to Holborn, the less attractive station of Central London (see table 7.5).

On the other hand the final destination station in Central London does not seem to justify the high level of inter-changes shown by Canterbury East. However, the timetable of trains from Canterbury East facilitates the changes to faster trains in Faversham. Indeed, commuters from Canterbury East mainly inter-changed trains at Faversham, whereas Sittingbourne was the inter-change station chosen by the commuters from Sheerness-on-Sea and Queensborough.

There are only a few cases of multiple inter-changes and whenever they occur they are usually undertaken within the London area. Worthy of mention is the frequency shown by London Bridge in both surveys.

Due to the significant number of inter-changes presented by some stations, it seems reasonable to take them into account in the modelling of commuting choices, which is tackled in chapter 8.

Table 7.13 - Inter-change of trains

origin stations	1981 abs (%)	1989 abs (%)
Canterbury East	132(70)	62(20)
Sheerness-on-Sea	104(100)	74(34)
Otford	120(29)	72(15)
Queensborough	60(94)	78(46)
Bat & Ball	76(79)	90(82)
Rainham	112(5)	72(3)
Tonbridge	76(3)	28(1)
Ashford	56(7)	44(3)
Canterbury West	36(75)	45(42)
Wye	36(64)	16(49)
Eynsford	44(48)	22(26)
Shoreham	20(83)	14(60)
Swanley	64(5)	18(1)
Maidstone East	36(5)	18(2)
Sevenoaks	104(4)	38(1)
Borough Green	28(8)	14(3)
Gillingham	64(4)	0
Herne Bay	24(4)	30(6)
Newington	24(43)	16(14)
Sittingbourne	36(3)	57(3)
Teynham	48(48)	19(17)
Chelsfield & Swalec.	12(8)	43(30)
Headcorn	44(13)	24(4)
Paddock Wood	60(8)	60(6)
Stapplehurst	36(6)	23(3)
Hildenborough	60(13)	23(4)

i - Changes in the transport network

Apart from the electrification of the rail line Hasting-Tunbridge Wells, no other changes in the transport network of Kent seem to have had relevant effects to the access of commuting to Central London.

As concerns the improvements undertaken in the road network, worthy to highlight is the opening of the section of the motorway M25 from the A20 to the A21, in the link Swanley-Sevenoaks. A major benefit of such connection was to direct the traffic from South-West Kent into the M20, which leads to Central London. Given the lack of updated information concerning the level of commuting by private mode, the effects of the road improvements cannot be evaluated.

7.3.4 OUTER LONDON STATIONS

It is reasonable to suppose that Kent residents who live in the area along the border of Outer London may be attracted to stations across the border.

The increase in the use of Outer London stations was approximately in line with the average growth of 21% in the commuting from Kent. In 1981, 1084 commuters reported to initiate their commuting trips in one of the Outer London stations, whereas in 1989 the number was increased to 1352.

Table 7.14 relates some of the Outer London stations used by commuters from Kent, and gives the most significant frequencies observed in the 1981 and 1989 data set. Information concerning the origin of the flows is also given.

Table 7.14-Outer London stations used by commuters from Kent

OL station	origin	1981	1989
Bromley South	Sevenoaks	32	194
Chelsfield	Sevenoaks	4	121
Orpington	Sevenoaks	48	153
Knockholt	Sevenoaks	16	130

As expected, commuters from Sevenoaks district comprise the large majority of those who initiate their trips in Outer London stations. Some minor flows from Maidstone, Tonbridge and Tunbridge Wells were also reported. The significant increase in the number of Kent commuters using Outer London stations does not seem to be related either to the change in population of the wards close to the border, which generally decreased, or the use of cars to access the stations. In 1981, the main mode of transport used to access the Outer London stations was the car (96%), whereas in 1989 the car had only 62.8% of the mode share with buses (9.3%), cycle (0.9%) and others (27%).

7.3.5 SOCIO ECONOMIC CHARACTERISTICS OF THE RAIL COMMUTERS

In 1981, the largest proportion of the Kent commuters classified as professional originated in Sevenoaks (26.9%), whereas in 1989 the highest concentration of such category of commuters was in Swale (19.2%). The flows of non manual workers also presented different patterns. Gillingham (21.4%), followed by Sevenoaks (18.40%), had the largest proportion of commuters in 1981; while in 1989 the largest proportion of non manual workers was shown by Swale (24.7%) and Gillingham (24.2%). No change in patterns were presented by commuters classified as manual. The majority of the jobs of this category still originated in the districts Gillingham and Swale.

Table 7.15 depicts the proportions of the 1981 and 1989 rail commuting by socio economic class from Kent to Central London. The category of managers also comprises employers and professional. The non-manual class includes intermediate, junior and personal service workers, whereas the manual includes skilled, semi-skilled and unskilled jobs. Others contain members of armed forces, those inadequately described, school children, students, retired, and others not stated.

Table 7.15 Proportions total rail commuting in Kent by socio classes (%)

	managers		non-manual		manual		others	
	81	89	81	89	81	89	81	89
Gillingham	9.3	9.5	21.4	24.2	25.7	29.7	15.3	17.3
Swale	6.7	19.2	11.8	24.7	13.9	24.5	10.4	13.5
Canterbury	9.4	16.5	6.3	11.8	7.6	7.8	7.8	13.2
Dover	0.9	1.5	1.1	1.6	1.7	3.0	2.6	2.1
Thanet	2.8	3.3	2.0	3.3	5.9	4.2	3.7	2.4
Maidstone	11.1	11.1	9.6	5.2	8.4	3.6	6.3	7.9
Tunbridge	12.0	16.1	7.7	8.7	5.1	9.1	9.3	17.8
Ashford	4.7	2.6	5.3	1.5	6.3	0.8	6.0	2.3
Shepway	2.0	1.6	2.0	1.6	3.0	1.3	4.5	3.7
Sevenoaks	26.9	11.8	18.4	12.3	11.4	11.1	17.9	11.9
Tonbridge	14.2	6.7	14.4	5.0	11.0	4.8	16.0	7.8

|-------------------------- 100% ---------------------------|

Another interesting analysis concerns the socio classes of the commuters in each district. In every district of Kent, the largest proportions of rail commuters to Central London were given by the non-manual category. Worthy to highlight are the high proportions of non-manual commuters from Gillingham, in 1981 (72.1%) and in 1989 (72.2%). Concerning the professional category, different patterns were observed. In 1981, Tunbridge Wells (40.6%), followed by Sevenoaks (39.5%) and Canterbury (38.3%) showed the largest proportions, whereas in 1989, they were presented by Maidstone (45.0%), Tunbridge Wells (39.7%), and Canterbury (36.0%).

Unfortunately, the origin and destination information given by the 1981 Census is not split by mode of transport; therefore, the 1981 figures in table 7.15 may not be cross checked. Although not precise, a comparison with table 7.3, which regards the total population commuting by occupations, gives an idea of the distribution of people among the districts. The figures given by the columns of professional and manager in table 7.3, against the information of the column managers in table 7.15 show very close proportions. Since rail is the predominant mode of commuting to Central London, the similarity of flow proportions by categories given by the rail flow and the total flow to Central London was already expected.

Regarding flows by sex, the proportions of female in relation to male were respectively 27% to 73%, in 1981,and 33.2% to 66.8% in 1989. These figures confirm the increase in the female participation in the English economy during the 1980's. As concerns the analysis by individual districts, Gillingham kept the highest proportions of female commuting among the districts of Kent, in both years, whereas Shepway had the highest concentration of male in 1981, and in 1989 Tunbridge Wells, followed by Shepway. A clear pattern of increases in the male commuting distances was detected.

As concerns the number of cars available for the use of the family, the proportion of 14.2% of the total sample obtained in 1981 reported to have no cars, 63.8% had access to one car, and 21.9% to two or more. The 1989 sample showed the figures 8.1% for no cars, 54.2% for one car, and 37.7% for two or more cars. In 1981, the largest proportions of commuting with access to 2 or more cars were in Sevenoaks (19.9%), followed by Tonbridge (16.4%); whereas in Gillingham 30.1% were without cars at all, followed by Swale(13.5%). A completely different pattern appeared in 1989, since Swale(19.0%) and Tunbridge Wells (16.3%) had the largest proportions of commuting with 2 or more cars, while Swale (27.3%) and Gillingham (19.9%) maintained the highest figures for no cars.

Table 7.16 depicts the proportions of the commuting population to Central London according to the availability of car in the family.

Table 7.16 Proportions of rail commuters with access to car (%)

	1 car		2 or > cars		no car	
	81	89	81	89	81	89
Gillingham	18.2	22.3	7.7	13.8	30.1	19.9
Swale	11.1	21.5	6.1	19.0	13.5	27.3
Canterbury	7.3	14.1	6.1	10.8	9.3	13.3
Dover	1.0	2.0	1.0	1.5	2.0	1.8
Thanet	2.7	3.9	1.4	2.1	3.9	4.8
Maidstone	10.5	6.4	9.7	10.0	7.1	3.1
Tunbridge	8.6	10.3	13.7	16.3	3.3	7.2
Ashford	4.5	0.9	7.0	3.0	5.9	3.0
Shepway	1.7	1.9	2.1	1.5	3.9	3.4
Sevenoaks	19.9	11.8	28.8	13.3	11.2	15.0
Tonbridge	14.6	4.9	16.4	8.7	4.7	1.4

|------------------ 100% --------------------|

As previously mentioned in section 7.3.3, no relationship was found between the use of the car and the access time to stations. However, a definite pattern was presented by the relation between access mode by car and job category. The wards which had high percentage of car use also had relatively high figures of commuters who belong to the classes professional and manager. This is the confirmation of the fact that wealthy people use the car more frequently than the ones belonging to the other occupation classes.

Some other important insights are given by the changes in the age groups of the commuters during the period 1981-89. Table 7.17 depicts the percentages of the Kent commuting population by age groups, as given by the 1981 and 1989 British Rail data.

Table 7.17- Percentage of rail commuters by age

year	16 - 24	25 - 34	35 - 44	45 - 60	> 60
1981	16.7	28.1	23.5	27.8	3.9
1989	12.8	24.2	31.6	27.8	3.5

A notable feature shown in table 7.17 is the significant growth in the commuting population of 35 - 44 years of age. The decentralisation of population from London might have played an important role as concerns the changes observed in this age group. Given the evidence of a high number of immigrants from London who move out due to life cycle (see section 6.4), they probably comprise families aged 35-44.

In 1981, a much higher proportion of young used to commute to Central London. About 45% of the 1981 commuting population was at the range of 16 - 34, whereas in 1989 only 37% of the commuting was at the same age range. This fact might be associated with the inward and outward movement of the residential location of those working in the city centre, as explained by Mackett and Nash (1991). The authors suggest that the new entrants in the London market tended to live further in while those who move through the life-cycle tend to move out of the city.

Despite the differences in age bands, the comparison between the figures depicted in table 7.17 and the ones given by the 1991 Census of Population (see OPCS(1991)) shows that the growth in the rail commuting aged 35-44 is in line with the increase in the total population at this age in Kent.

Since the main characteristics of the rail commuting in Kent were presented, and some important issues regarding the changes in population and employment were already discussed, this chapter turns to a more specific discussion involving these three elements together.

7.4- THE ROLE OF POPULATION AND EMPLOYMENT CHANGES IN THE COMMUTING TRENDS

This section attempts to link the preliminary results individually obtained in the analysis of the rail commuting patterns, and population and job distribution, and to disentangle the role of these elements in the work to travel trends.

The effect of changes in population and employment in Kent are initially examined, followed by a discussion of the role played by the specialization of the Central London market in commuting patterns.

7.4.1-THE ROLE OF POPULATION AND EMPLOYMENT CHANGES IN KENT

A practical and easy way to relate these three factors is to compare their temporal and spatial changes. For the period 1981-89, table 7.18 shows the absolute changes and corresponding proportions in population, jobs and commuting flows by district of Kent. Here,jobs stand for the number of persons employed in the local area considered. As explained in section 7.3.2, the rail flows are given by the sample obtained by matching postcodes to districts.

The figures depicted in table 7.18 clearly show that the overall percentage changed in the rail commuting (21%) was bigger than the changes in both jobs (15%) and population (6%) in Kent. Also, the percentage changed in jobs was bigger than the relative change in population. It is worth noting that the rail commuting, in spite of comprising the major flow to Central London, is part of the total commuting that also involves other modes.

In the light of the expectations that increases in the local job market could lead to reductions in the Central London commuting, one might find striking some of the figures shown in table 7.18.

Table 7.18 - Population, job, and rail commuting changes

district	population		job		rail by origin	
	absolute	(%)	absolute	(%)	absolute	(%)
Swale	6340	(5.8)	2800	(8.7)	1073	(50.3)
Canterbury	17650	(15.4)	6200	(16.7)	202	(13.2)
Dover	6890	(6.9)	-2000	(-10.3)	92	(38.5)
Thanet	11370	(9.6)	300	(1.2)	7	(1.3)
Maidstone	6920	(5.2)	16300	(34.2)	155	(7.6)
Tunbridge Wells	4505	(4.2)	7300	(20.3)	242	(13.0)
Ashford	10490	(12.3)	4500	(16.9)	859	(79.4)
Shepway	3050	(3.6)	300	(1.5)	93	(20.8)
Sevenoaks	-1880	(-1.8)	2900	(9.2)	1000	(23.4)
Tonbridge	5000	(5.3)	6800	(18.5)	523	(17.7)
Gillingham	2380	(2.6)	2900	(27.9)	184	(5.0)
total :	72320	(6.3)	48300	(15)	4430	(21.3)

Canterbury was the only district to present similar trends as concerns the absolute proportions changed in population, jobs, and rail commuting. Apart from Canterbury and Thanet, the growth in population of all districts was much smaller than the growth in commuting. It is worth noting the negative correlation between changes in population and commuting shown by Sevenoaks. In spite of a decrease of about 2% in population, Sevenoaks presented a significant increase in commuting.

Since there was some increase in the specialised local jobs of Ashford and Swale, the high change in rail commuting shown by these districts might be related to a change in the socio-economic characteristics of its population, and a consequent increase in the demand for this kind of job. On the other hand, the decrease in jobs of the financial and service sectors experienced by Gillingham might explain the changes in the proportions of rail commuting to Central London. Apparently, the same reason does not explain the positive relation between increases in both jobs and commuting given by Tunbridge Wells.

Coherent are the figures presented by Dover, which had significant decreases in the local employment but presented increases in the relative proportions of work trips to Central London.

The explanation for the fact that there were prosperous areas of Kent which still presented high number of work trips to Central London may be related to the finding by Steinnes (1982) that jobs follow people. The author developed a methodology to detect if the causality is unidirectional running from one certain variable to another. Steinnes (1982) found that residential intra-urban location is exogenous and is a determinant of employment location, not vice-versa. This seems to justify the figures given by the quite urbanised Mid-Kent area. A large number of residents from these areas, still commute to Central London, in spite of the increases in the local employment market, which brought substantial number of jobs in specialised categories.

Some different features are presented by the estimate changes in economic active population, obtained through interpolation of the 1991 Census of Population data (see OPCS (1991)). Table 7.19 depicts the percentages of the growth in economic active population by district observed during the period 1981-89. Given the fact that the summary of the 1991 Census results were only very recently released (late September 1991), a comprehensive analysis of them could not be considered in the scope of this thesis.

Table 7.19 - Economic active population by district of Kent

district	1981	1989	change %
Swale	44810	48712	8.7
Canterbury	45450	48083	5.8
Dover	41140	42993	4.5
Thanet	41480	43918	5.9
Maidstone	58270	62800	7.8
Tunbridge Wells	42060	45050	7.1
Ashford	36050	40198	11.5
Shepway	32430	35553	9.6
Sevenoaks	49930	49537	- 0.8
Tonbridge	42120	47197	12.0
Gillingham	40910	42586	4.1
total	393150	425127	8.1

Overall, the total percentage changed in economic active population in Kent (about 8%) was higher than the changed that occurred in the total population during the period 1981-89. In spite of that, the growth in rail commuting was still much higher than the relative expansion of the economic active population in the county.

As expected, there are some differences between the distributions given by the total population and the economic active segment by district. As concerns the simultaneous analysis of changes in population, job opportunities and rail demand, are of importance the differences presented by Canterbury and Tonbridge. The comparison between the figures given in tables 7.20 and 7.18, shows that there is some correlation amongst these three factors if the active population in Tonbridge is considered. However, no coherent trend is shown in Tonbridge when the percentage changed in the total population is compared with the changes in both jobs and rail demand. Exactly the opposite analysis is valid for Canterbury, whose growth in active population is significantly smaller than the expansion of the total population, as well as the other three factors in question.

The figure 7.2 gives an illustration of the relationship between changes in both rail demand and economic active population by district of Kent during the period 1981-89. The changes in rail demand as function of the changes in the number of local employments during the same period is shown in figure 7.3.

The figure 7.2 shows an overall positive correlation between the changes in economic active population and rail commuting. In this figure, the lowest point represents Sevenoaks, which experienced an anomolous growth in commuting in despite of the decrease in population.

An overall positive correlation is also shown by figure 7.3. The largest change in local employment was given by Maidstone, which is the highest point in the figure.

Fig 7.2– Population & rail changes

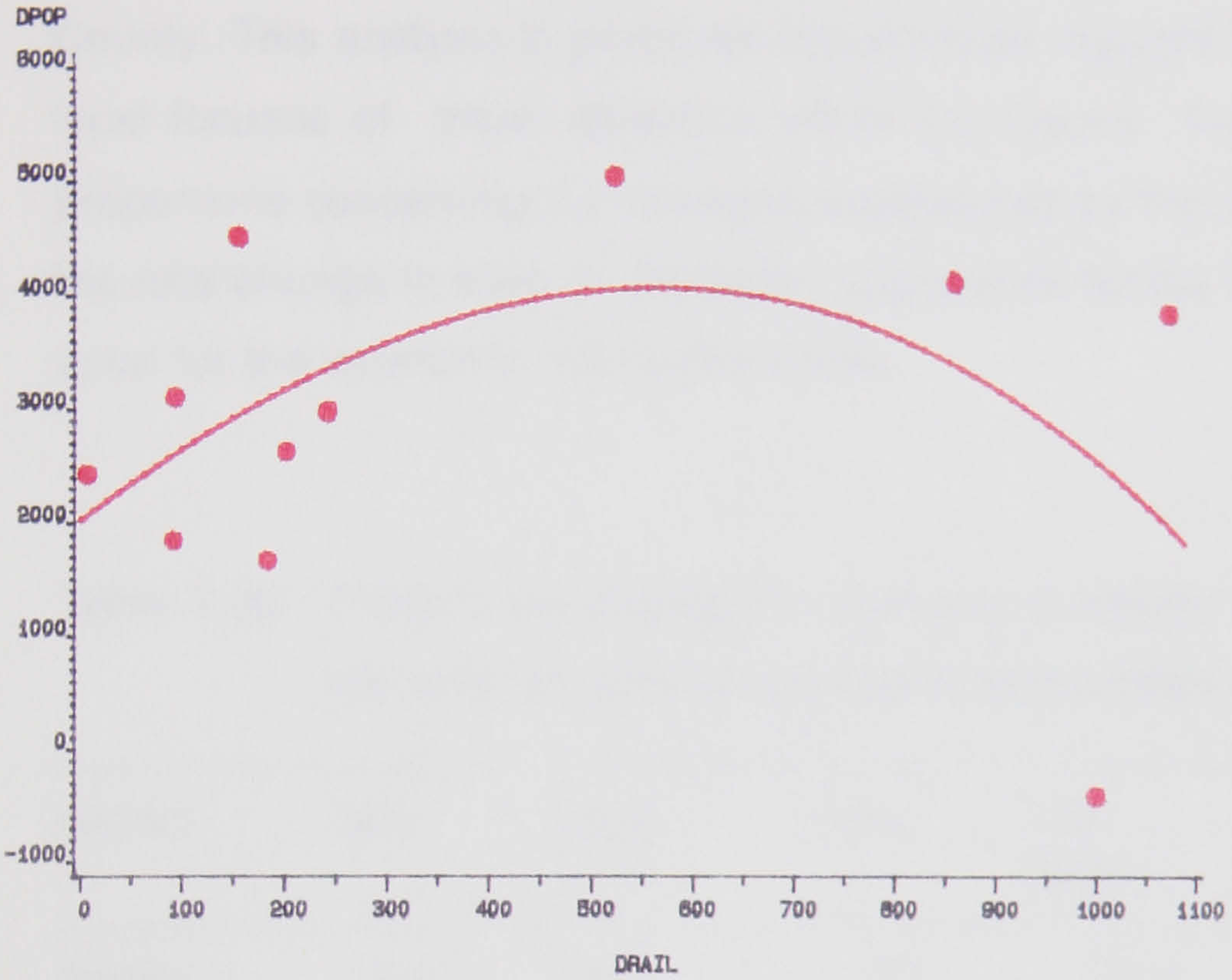
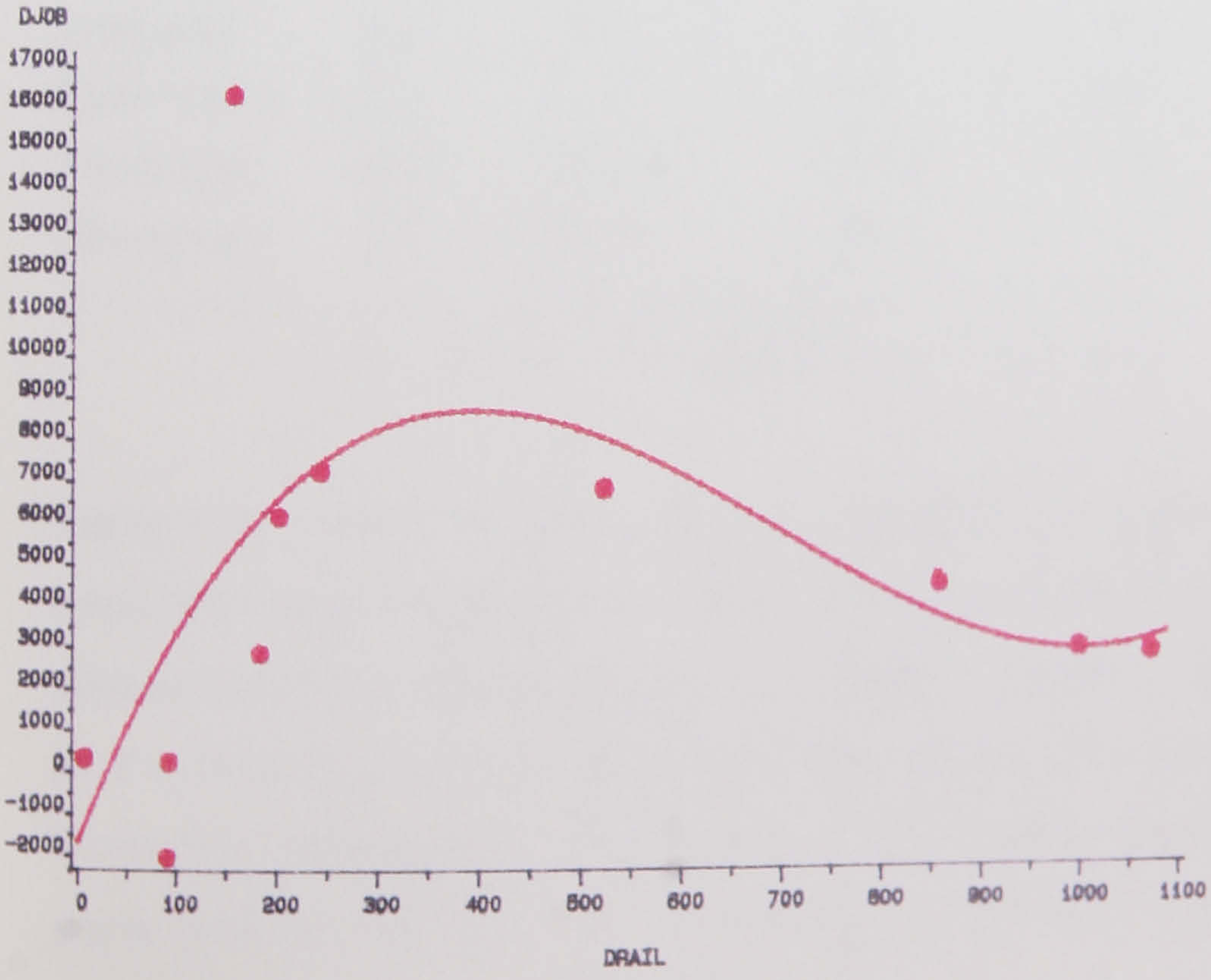


Fig 7.3– Job & rail changes,1981–89



Different insights are given by the district proportions related to the total in the County. This analysis is particular important on the light that there are some local focuses of travel attraction within the County. Table 7.20 shows the proportions concerning the changes experienced by the districts in relation to the total change in Kent. In the table, tpop stands for the total population, and epop for the economic active population.

Table 7.20 - Proportions changed in total and economic active population, job, and rail commuting, related to the totals changed in Kent (%)

district	tpop	epop	job	rail origin
Swale	8.7	12.2	5.8	21.1
Canterbury	24.4	8.2	12.8	5.2
Dover	9.5	5.8	-4.1	1.9
Thanet	15.7	7.6	0.6	0.7
Maidstone	9.5	14.2	33.7	4.9
Tunb. Wells	6.2	9.3	5.1	6.2
Ashford	14.5	13.0	9.3	16.2
Shepway	4.2	9.8	0.6	2.1
Sevenoaks	- 2.6	-1.2	6.0	22.1
Tonbridge	6.9	15.9	14.1	12.4
Gillingham	3.3	5.2	6.0	7.1
	100 %	100 %	100 %	100 %

Table 7.20 shows completely different patterns in the changes of commuting, population, and employment in Kent. The largest growth in the total population was shown by remote areas, eg. Canterbury, Ashford, and Thanet. The bulk of the expansion in the economic active population was mainly observed in Tonbridge, Maidstone, and Ashford. The increases in the number of local jobs were mainly observed in traditionally urbanised zones, like Maidstone,

Tunbridge Wells, and Tonbridge, whereas the commuting in distinct districts, eg. in the border of Outer London (Sevenoaks), in Mid-Kent (Tunbridge Wells, and Swale), and the rural and remote areas of Ashford.

7.4.2 - THE ROLE OF EMPLOYMENT CHANGES IN LONDON

According to the Department of Transport (1989), employment in Central London fell from a peak in the early 1960's until 1984, when it showed a sharp upward trend mainly caused by the rise in Docklands jobs. The statistics show that this development area, which is located in Inner London, experienced an increase of employment by 45 % to 65,000 between 1984 and 1987. The recovery of the job market in London as a whole was earlier, in 1981, however it was not so abrupt as in Central London.

The major issue concerning employment changes in London is the expansion of specialized sectors of the market, which experienced an increase of 83590 new jobs in 1989. Losses in the production sector, particularly shown by manufacturing and transport industries were approximately offset by gains in banking and finance activities. Such a switch in the London economy is coherent with the composition of the commuting to Central London, which is mainly comprised of professionals, managers and clerical.

The analysis of rail commuting by age suggests an expansion of the mature group of travellers at the range of 35-44, in 1989. This age group clearly indicates the effect of life cycle on people's decisions to move out of the conurbation and commute to London. Indeed, the study by W S Atkins Planning Consultants (1990) showed that 70% of London migrants to Kent justified their moving due to housing reasons, while only 19% of all moves into Mid-Kent was associated with job purpose. The study also concluded that 38% of heads of households interviewed have moved from London to Mid-Kent and kept their job in London. Given the fact that the most specialized activities are particularly developed in the headquarters of the big establishments, one could expect a significant proportion of captivity of the London market during the 1980's.

Both the socio-economic composition of the commuting and the growth in the commuting population of 35-44 years of age give clear evidence that the specialization in the Central London job market has lead to increases in the Central London commuting. A coarse sign of this trend is given by the overall growth of some 17% in the Central London arrivals from the South-East division of the Network South-East, and the significant 10% increase in the market share of specialized jobs of the finance industry, during the period 1981-89.

7.5 MAIN FINDINGS

In 1981, the train was by far the most popular choice for work-trips to any part of London; whereas the car was mainly used in the local commuting within districts. This is a tendency which is expected to have continued over the 1980's.

The 1981 Census data showed that rail and car commuting were related to the distance from London. Given the concentration of flows in two major origins in Kent, a similar conclusion could not be reached for the bus mode. The flows by bus to Inner London mainly came from the North corridor, whereas to Outer London from the districts located on the West border of Kent.

Some districts had larger flows to places within the County than to either Inner or Outer London. These trips were usually destined to neighbouring districts, although a few cases of longer distances were also observed. The analysis of the local commuting by distance showed that 82% of the overall local flow was within 10km distance from the ward's centre. This range of distance seams to be an appropriate measurement of the local employment catchment area.

Clear evidence of the decentralisation of the Central London market is given by the growth in traffic observed in the westerns stations of the central area. The increases in egress time, as well as the fall in foot to access the final destination in London also corroborate the dispersion of the central employment area.

The user's perception of rail travel time clearly reflect improvements occurred in the transport system. The analysis of the 1989 data suggests an average difference of about 2 minutes between the travel time revealed by the commuters and the figures given by the British Rail timetables. Similar analysis for the 1981 data gives a higher figures of some 3 minutes.

Improvements in accessibility may also be associated to the location of rail commuters to increasing distances, as well as the overall reduction in train inter-changes occurred during the period analysed. As concerns the former, the 1981 rail data showed that the majority of the commuters classified as managers and professionals were originated in Sevenoaks, whereas in 1989 they mainly came from Swale.

An important feature of the study area concerns the expansion of commuting occurred during the period 1981-89. Overall, the stations studied here experienced growth in Central London commuting which was typical of that from all destinations, and higher than the rest of the Sout-East sub-sector.

The overall percentage changed in rail commuting between Kent and Central London was much bigger than the increase in both local jobs and total population. Also, the percentage changed in job opportunities was more than double the expansion in population.

A striking feature was given by the completely different spatial changes in jobs, population and rail commuting to Central London. The major expansion in population occurred at the range of 80-90 km distances from Central London, whereas the local economy mainly flourished in the Mid-Kent districts, at the range of 40-60km distances. Surprisingly, the major expansion of the rail commuting was observed at distances of 50-60 km, where most of the local jobs were also shown.

In 1981, the rail commuters were younger than in 1989. About 45% of the 1981 commuting population was at the range of 15-34, whereas in 1989 only 37% of the comuting was at the same age range. Clearly, the inward and outward movement of the residential location of those working in the city centre play an important role in the observed age changes. The expansion of the commuting of 35-44 years of age, reinforces the relation between the life cycle effect and the decentralisation of population from London.

CHAPTER 8

MODELLING OF COMMUTING CHOICES

8.1 APPROACH USED

This chapter deals with the quantitative part of the proposed methodology. It aims to assess the effect of the changes in travel attributes and in the level of local employment and population on the commuting decisions.

The journey to work involves three basic decisions : where to work, where to live, and how to get there. As concerns location decisions, the process which involves a choice for either home or work is considered to be more realistic than the simultaneous choice for both places. Kirby and Raji (1992) suggest that the location changes might happen close in time to one another, but that one or other will always be chosen first.

Although typical journeys to work involve different types of location and complex search processes, eg. households which contain more than one worker, the approach adopted in this chapter considers only the choices of a new job given a certain home location.

A dynamic framework would be necessary to satisfy both home and job constraints simultaneously, which would increase the difficulties of the already complex analysis of trip distribution and modal split tackled here. Moreover, such a model would require data on changes in home and job location over time, rather than a single cross-section. Therefore, a more appropriate model of job and home location decisions could not be built. Use of a single cross-section forced the definition of a framework in which we either model the choise of job location taking home location as fixed, or vice versa. We chose the former as the more realistic.

The model expresses the demand between two zones in terms of the generalised time of travel between the two zones compared with the generalised time of travelling to any other competing zone. The proposed form leads to a classical distribution model of trip ends, which is singly constrained by the number of trip origins in the zones. The number of trips generated in each zone is assumed to be fixed, whereas there is no constraint to the number of journeys to be attracted to a zone.

If the number of trips attracted to each destination were subject to constraints, the number of trips attracted and originated from each zone would be fixed and the necessary condition to develop a doubly-constrained model would be provided. However, what is available is only the total number of journeys to work from Kent. The model then distributes these trips as a function of travel cost and the relative strengths of the attraction in the destination zones given by job opportunities.

No allowance can be made within the model for exogenous influences on the number of jobs in Central London such as economic growth or restructuring of the London economy leading to changes in the job mix. One may then expect under/over predicted figures for future years as a result of the implicit assumption of an unchanged attraction of the destination Central London over time. The way we propose to deal with this problem is to scale the predictions up/down to adjust to the total flow from Kent attracted to the destination London.

However, in the light of the model's purpose and application, the apparently restrictive assumptions used do not invalidate the methodology suggested. The model structure is adequate for use with the exogenous information of the total number of commuters estimated through the forecasts of the number of jobs in Central London carried out by British Rail. Given the forecasts, then the remaining task is to define the trip distribution for the various zones. The formulation proposed here attempts to develop a model able to provide this flow distribution.

Basically the model should be used to predict where a certain number of commuters will come from, given forecasts of jobs in Central London and population by zones of Kent. An useful application of the proposed methodology is to constrain the forecasts to provide the location of commuters given a fixed number of rail commuters from Kent to London.

Given this framework, a model, based on the 'homo economicus' assumption and random utility is considered. In this kind of model, individuals are assumed to choose the alternative that yields the highest utility.

Among other postulates, rational behaviour implies that a commuter, facing the same circumstances, will repeat the same choice. An open question is whether the choice process is characterised by a simultaneous or a sequential choice structure. The latter occurs when at each decision level, the choice is assumed to be conditioned on the previous choice. A kind of feedback effect is incorporated in such formulation. On the other hand, simultaneous choice implies independence across the choices, such that the ratio of any two probabilities is independent of the characteristics of a third choice. In this case, the axiom of independence of irrelevant alternatives (IIA) applies.

The conditional structure is generally considered more realistic, therefore it was thought that a model with recursive structure should be initially investigated. Due to the well known applicability of probabilistic models in dealing with utility maximisation, the hierarchical logit model was initially chosen. However, such complex structure proved to be inappropriate for the kind of data analysed, and alternative forms of the multinomial logit were adopted instead.

The combination of data base and methodology lead to the development of a zonal model, whose level of aggregation is the ward. Given some limitation of the data available and its possible consequences on the desirable accuracy of the analysis, the estimation of the parameters were undertaken by using the 1981 data set. The validation comprised a forward projection using the 1989 data.

This chapter is concerned with the model specification and estimation. The basic concept of the logit model is initially presented. Then, the structure and formulation of a binomial model is followed by the definition of variables and the corresponding assumptions undertaken due to the zonal characteristic of the model. A multinomial model comprised of three alternatives, and a hierarchical model of destination and mode choice alternatives are also explored. Then, the method of estimation and the results are shown, and the performance of the models are fully discussed.

8.2 SPECIFICATION OF THE MODEL

8.2.1 The logit model

The traditional passenger travel demand analysis comprises the sequential stages of trip generation, trip distribution, model split and route choice. Models of such a kind of approach usually assume that the number of trips made is independent of the performance of the transport system, and thus that changes in the transport attributes can only influence the split of a fixed number of trips among destinations, modes or routes.

By contrast, economic demand models permit the volume of travel and its distribution to be adjusted as any transport characteristic is changed. This is an important tool for the investigation of the consequences of simulated policies on trip-making behaviour.

The logit model, suggested here, belongs to the category of econometric models and can be also used in the four stage studies. It has been extensively applied in travel demand analysis (Ben-Akiva and Lerman (1985), Copley et al (1988)), not only due to its theoretical underpinning, which is compatible with economic theory, but also because of its flexibility and good performance in dealing with choice investigation.

Aldrich and Nelson (1984) quoted McFadden (1973) as placing the logit formulation in an econometric framework, while Luce and Suppes (1965) as the founders of a formal, rational choice perspective on behaviour, on which the logit model is based. The model has been frequently associated with discrete choice analysis, however, the application of the logit to a continuous range of proportions is equally valid, and will be considered in this thesis.

The random utility theory has two basic principles :

i - individuals, when faced with a number of mutually exclusive alternatives, are perfectly rational, and are able to compute the utility of each option, such that the alternative with the biggest utility are chosen; and

ii- due to differences in perceptions and tastes, individuals perceive the utility of a given alternative differently.

As a simplified approach, one may assume that the utility of alternative i can be expressed by the following linear expression :

$$U_i = \sum_j \theta_j x_j \tag{8.1}$$

where x_j is a set of attributes j of the alternative i, and θ_j is a set of parameters.

The specification of the utility formula involve the attributes of the alternative as perceived by the users, together with the unobserved factor which are neither recognised nor measured. Thus, the most popular and widely used expression for utility of alternative i can be given by :

$$U_i = V_i + \varepsilon_i \tag{8.2}$$

where V_i is the representative utility as seen by the modeller, and ε_i is the error term which introduces a stochastic element into the utility function.

If the set of ε_i is assumed to be independent and identically distributed with a standardized Gumbel distribution, whose standard deviation is $\pi/\sqrt{6}$, then the well known multinomial logit model is obtained. In such a kind of model, the probability of a randomly selected user choosing alternative i (approximately equal to the proportion of users which will choose it over the total population) has the form :

$$P_i = \frac{\exp\ (V_i)}{\sum_j \exp\ (V_j)} \tag{8.3}$$

where

P_i is the probability that an individual will make a certain choice i out of all the available alternatives j.

The assumption that the error terms for each alternative is independent and identical is restrictive in a sense that it implies equality in the variances of the disturbances components of the utilities. As a consequence of the mutually independent assumption, the independence of irrelevant alternatives (IIA) property of a multinomial model is contradicted. This is well known in the literature as the red bus/blue bus paradox (see Ben-Akiva & Lerman (1985)).

The lack of ability to deal with correlated alternatives is the main criticism of the multinomial logit model. This problems does not occur in the particular case of binary choices, since it is possible to specify the model in such a way to represent the differences between the utilities, rather than their absolute values. An alternative way to deal with multiple correlated alternatives is the use of the nested or hierarchical logit model (see Williams (1977)), which will be explored in section 8.2.3.

Since the dependent variable P_i is non linear in relation to the attributes of the alternative i, the direct application of the ordinary least squares method in the estimation of the model is, at a first glance, impossible.

However, a linearised and tractable form of the equation 8.3 is the so called logit transformation, which is given by

$$\log\left(\frac{p_i}{1 - p_i}\right) = a + bX_i \tag{8.4}$$

The dependent variable of the transformed logit is the logarithm of the ratio of the probability that a particular choice will be made to the probability that it will not be chosen. The discrete choice directly implied in this formulation, apparently departures from the aggregated character of the data used in this thesis. However, one very important characteristic of this form of the logit is that it transforms the problem of predicting probabilities within a (0,1) range to the problem of predicting the odds of an event's occurring within the interval of real numbers.

Since the probability of an event (P_i) is the limit of the relative frequency (P^*) as the sample size becomes infinitely large, for large samples P^*_i is a reasonable good estimate of P_i. Therefore,

$$\log\left(\frac{P_i}{1 - P_i}\right) \approx \log\left(\frac{P^*_i}{1 - P^*_i}\right) = a^* + b^*X_i + \varepsilon_i \tag{8.5}$$

where

ε is the error term

a^* and b^* are parameters

X_i represents the set of explanatory variables of the choice i .

Equation 8.5 is linear not only in the explanatory variables but also in the parameters, thus the ordinary least squares estimators will be consistent[1], when applied to large samples. The need for a large number of observations is due to the fact that the dependent variable is not normally distributed for small samples, but only approximates the normal distribution when the sample size is large.

In such case, one assumes that the frequency of a certain choice obeys the binomial probability distribution, for which the mean frequency of occurrences is given by Pi. The estimated dependent variable is also assumed to be approximately normally distributed, with mean zero and variance v_i given by

$$v_i = \frac{n_i}{r_i\,(n_i - r_i)} \tag{8.6}$$

where

r_i is the number of observations that corresponds the chosen alternative, and
n_i is the total number of observations of the choices set

This characteristic of the logit suits the kind of zonal data considered in this thesis. For each zone, the proposed dependent variable is the number of rail trips made by users of certain characteristics as a proportion of the total population which commutes and has the same characteristics in that zone.

$P^{c}_{rd} = r_i / n_i$ = probability that a person with certain characteristics 'c' travel by rail 'r' to destination 'd'

$$P^{c}_{rd} = \frac{\text{commuting to destination 'd' by individual of characteristics 'c'}}{\text{total commuting population with the same characteristics 'c' in the zone}}$$

[1]An estimator is consistent if the probability distribution of the estimator collapses to the true value of the parameter as the sample size gets arbitrarily large.

The probabilities given by the observed relative frequencies are subject to random variation. Therefore, the error terms do not have the same variance, and are heteroscedastic.

In the presence of heteroscedasticity, the ordinary least squares (OLS) estimators are unbiased but inefficient. In other words, the estimators do not have minimum variance. According to Pindyck and Rubinfeld(1976), the heteroscedasticity causes the ordinary least squares estimation to put too much weight on the observations which have large error variances. A way to overcome this problem is the estimation of the model by using the weigthed least squares method (WLS), which consists of the multiplication of each observation by the weight $1/\sqrt{v_i}$, where v_i is the variance given by equation 8.6. A clear idea of the weight strategy is given by Gujarati (1988) "... to give more weight to observations that are closely clustered around their (population) mean than those that are widely scattered about".

The least squares approximation gives poor estimators when the frequency of a choice (r_i / n_i) is close to either 0 or 1. This is clearly shown in Equation 8.6, whose expression for variance becomes arbitrarily large for such values. In other words, the dependent variable of the transformed logit model given by the logarithm of the relative frequencies, tend to be undefined when the frequency of choices approximates to either 0 or 1.

Considering the three different model structures (binomial, multinomial, and hierarchical) explored in this chapter, this undesirable situation is unlikely to be significant in the choice probabilities of the binomial model proposed. As will be shown in section 8.3.1, the relative frequencies presented in almost all wards are not so close to the limits of the logistic function. On the contrary, the same does not apply to both the multinomial and the hierarchical models, in particular for the mode choices involving Central London. There were many wards in which 100% of the commuting was undertaken by the rail mode, causing the logarithm of the relative frequencies with any other mode to be undefined. Therefore, such observations were automatically excluded from the data set. This explains the reduced number of observations in the multinomial and hierarchical models in relation to the binomial model. Moreover, it might have contributed for the poor performance of them, as explained in the sections 8.3.2 and 8.3.3.

Unfortunately, it was not possible to use any other alternative procedure to minimise this problem. The maximum likelihood method available in the statistical package SAS is not able to deal with the kind of dependent variable proposed (relative frequencies). Therefore, the parameters of the models were estimated by using weighted least squares, and the statistical package SAS.

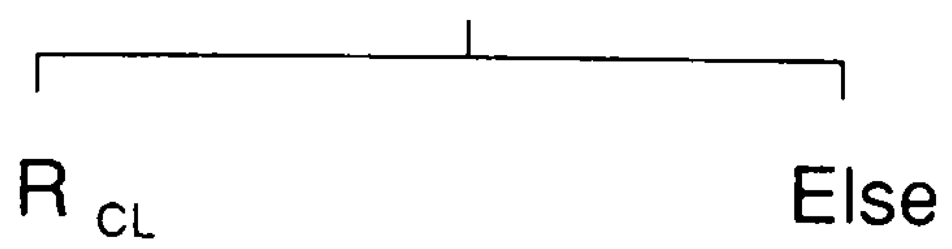
The structure specifications, formulations, and definition of variables of the various models considered are in the scope of the following sections.

8.2.2 THE BINOMIAL MODEL

The choices components of the binomial model proposed are limited to two: where to work and how to travel there. Thus, the model intends to estimate the probability that an individual with certain characteristics chooses rail in a work trip to Central London, according to the characteristics of the transport system available and the level of employment opportunities in the area in question.

For the individuals in a certain zone, two alternative work travel choices are considered: to travel to Central London by rail (R_{CL}) or go to a local work using any mode of transport (Else). Diagram 8.1 depicts the structure of the binomial model considered.

Diagram 8.1 - Structure of the binomial model



According to table 2.1, the assumption of a single modal choice in the estimation of long distances commuting to Central London sounds realistic. That table showed that 69.5% of the 1981 morning trips to Central London was undertaken by rail, whereas an even bigger proportion of 76% was observed in 1989. This trend has been seen in the commuting trips from Kent. In 1981, about 82% of the trips were undertaken by rail, while the figures depicted in table 7.6 suggest that this high proportion be maintained.

The coach alternative was disregarded for two basic reasons. Firstly, according to the 1981 Census of Population, the proportion of coach trips between Central London and the 11 districts of Kent considered in this study (2.3 %) was almost insignificant if compared to the other main modes, rail (81.8 %) and car (12.7 %). By 1981, the coach operation in Kent was not widespread, and even non existent in Thanet and Dover. Insignificant flows were observed in the Eastern districts Shepway and Ashford, as well as in Dartford, Sevenoaks, and Tunbridge Wells. The most significant number of commuting flows to Central London by coach were from the North districts Gillingham and Rochester, followed by the Mid-Kent districts of Swale, Tonbridge and Maidstone. In 1981, the market share of coach was about 4.0% in the area comprised by the 4 districts of North Kent (Dartford, Gravesham, Rochester and Gillingham), whereas only 1.7% in the three districts of Mid-Kent.

Secondly, the available 1989 coach data [2] is aggregated by corridors, and is completely incompatible with the level of aggregation of wards provided by the

[2] Stavely, P(1989) Role of commuter coach services in London. MSc thesis. Polytechnic of Central London.

other modes data. One should also consider the unreliability of this data due to the fact that it was collected in the day immediately after a British Rail strike of July 1989. As a consequence, some customers might have thought that the road congestion would have been bad, and probably took unusual decisions related to their commuting trips.

Given the market share between rail and coach has already been analysed at a disaggregated level in the study by Fowkes (1986), it did not seem to be appropriate to include coaches in the suggested zonal model.

The model also restrict the number of employment location choices to two : the main job market of London, and the local zone within Kent. In spite of some potential areas of local attraction, the analysis of the 1981 Census of Population data showed that about 67.1 % of the local commuting trips within Kent was in the range of 5 km distance from the ward's centre (see table 7.4). This basically comprises the central business area of the wards. Therefore, one may assume that the individuals face only the two relevant destination alternatives, either to go to Central London or elsewhere within the County of Kent.

a - Formulation of the binomial model

For the binary choices considered, the utilities are given by

$$U_{rCl} = V_{rCL} + \varepsilon_{rCL} \qquad (8.7)$$
$$U_e = V_e + \varepsilon_e$$

where V_{rCL} and V_e are the systematic components of the utility and ε_e and ε_{rCL} are the random error terms, which correspond to the alternatives rail to Central London and any mode to elsewhere, respectively. As a question of simplicity, the index rail to Central London (rCL) will be represented solely by 'r'.

The guidelines of a suitable functional form of the utilities, are basically twofold: (i) to reflect the actual influence of the explanatory variables on the utility, and (ii) to have such computational properties to make the estimation of the parameter easier.

To cope with this requirements, the form of linear in parameters for variables has been successfully applied (MVA Consultancy et al.(1987), Ben-Akiva & Lerman, 1985). The linear utility has not only the advantage of easy computation, but according to Bruzelius (1981) "... necessary and sufficient conditions for expressing travel demand in terms of generalised cost are that this cost, when measured in monetary units, is linear, and that the time variable is weighted by a constant marginal value of time". The evidence found in the vast literature of travel demand models, support the adoption of the generalised time or generalised cost functions (MVA Consultancy et al.(1987), Ben-Akiva & Lerman, (1985)). These functions differ only in the units they represent, and consequently in the variable to weight with the value of time.

The binary model is specified in such a way to represent the differences between the utilities rather than their absolute values. Its functional form is shown by the following equation.

$$\frac{P_r}{P_e} = \frac{\exp\ (V_r)}{\exp\ (V_e)} \qquad (8.8)$$

where:

P_r - the relative frequency of observed trips by rail to Central London

P_e - the relative frequency of observed trips to elsewhere

V_r - the utility of rail trips to Central London

V_e - the utility of trips to elsewhere in Kent

The utilities are represented by

V_r = rgt = rail generalised time

rgt = rivt + rat + ret + rac/vot + rc /vot

V_e = egt = jobs / pop

where:

rivt - rail in-vehicle time

rat - rail access time

ret - rail egress time

rac - rail access cost

vot - value of time

rc - rail fare

jobs - jobs within 10 km radius of the ward's centre

pop - population of the ward in question

The following section contains the definition of the variables considered in the binomial model.

b - Definition of variables of the binomial model

Some difficulties appeared in the definition of aggregated variables by wards. Despite the fact that most of the data related problems were already presented in chapter 4, the incompatibilities in formats and level of aggregations caused by the different sources of data analysed are worth recalling. For instance, the rail data was disaggregated by individual observations, and related to stations instead of wards. Consequently, there was the need to associate stations to wards, such that average values for the rail variables could be computed.

The crux of the matter was to define a generalised time function for the aggregated destination elsewhere. The elsewhere alternative was assumed to comprise a choice for any mode of transport to a destination in Kent. Therefore, it represents an aggregation of areas, with different trip attributes, eg. travel time, and travel cost. However, the elsewhere utility should be defined and valued in such a way that it could generally represent the attributes of any of the places within the considered area. Additionally, any such destination should have a geographical location able to represent a potential choice for the Central London alternative. One might expect that wards situated beyond a certain distance range will not be relevant in the choice process. Therefore, it is important to know how far people commute to places rather than to Central London.

The figures depicted in table 7.4 corroborate the assumption of a single conglomerated area for the elsewhere destination. The table showed that 82.1% of the travel-to-work flow to places in Kent, comprised trips within 10 km distances from the centre of each ward, while about 67% travelled in the 5 km distance. Consequently, the investigation of a proxy variable for the generalised time of elsewhere destination was initially based on the number of jobs in the ranges of 0-5 km and 0-10 km distances. Both sets were tested, however a variable defined for the range of 0-5 km gave the most significant results in the estimation of the model, and therefore was chosen. This issue is in the scope of the section 8.3.

Another relevant factor to be considered is the trade-off between trips to Central London and to elsewhere area. Since job opportunities are an attraction for travel, and since the main concentration of employments is in the central business district of London, there is the need to identify the job categories of the people who commute to Central London. Due to the high number of white collar jobs in Central London, there are certain job categories which may be insignificant in the trade-off process of destination alternatives. Therefore, they should not be accounted in the determination of a proxy variable for the utility of elsewhere.

The proportions by occupational category of travel to Central London are depicted in table 7.4. As expected, the largest average figures were given by professionals (36.9%), followed by clerical (34.9%) and managerial (12.4%). Therefore, it is assumed that only the jobs concerning this three main classes will be included in the elsewhere utility. Indeed, the application of this assumption in the model calibration showed slight better results than if all occupation categories were included (see section 8.3).

Dependent variable of the binomial model

The dependent variable is represented by the logarithm of the ratio between the relative frequency of daily commuting trips to Central London and elsewhere.

Information about the dependent variable was given by the 1981 Census of Population, Special Workplace Statistics, section C, table 1 - mode of transport by sex. Since the Census output is at the level of ward, no additional manipulation of data was required.

Explanatory variables of the binomial model

jobs -

One of the dilemmas caused by the various data sources concerns the kind of job classification to be used. In spite of the more understandable 17 occupation orders, given by the 1981 Census of Population, the industry classification was used as a standard category in both calibration and validation of the model. Unfortunately, this was imposed by the validation data, provided by the 1989 Census of Employment, which only relates jobs to industry divisions. Consequently, a group comprised by the amalgamation of the categories banking, financial, and other services were considered to approximately represent the class of professionals and managerials. As foregoing discussed, this segment of the job market is highly concentrated in Central London, justifying its specific inclusion in the decision process for trips destinations.

population -

The variable population, which was obtained through the small area statistics of the 1981 Census of Population, concerns the 100 % sample of all residents by ward.

For the validation process, estimate data of population by ward was provided by the Kent County Council Planning Department.

rail in-vehicle-time -

Rail in-vehicle time, is given by the average travel between the origin station in Kent and one of the Central London stations considered. This information was obtained in the British Rail timetable of trains, assuming the commuters' preference for direct trains, shortest travel time, and constraint of arrival time between 7:00 and 10:00 am. The unit of time considered is the minute.

Individual's observations were initially related to origin wards, and then wards to stations, such that the trip attributes concerning a station could be considered as generally perceived by the individuals of the ward in question. There were no information about user's ward, but only their origin post-code addresses. Therefore, the post-codes of rail users were matched to wards using the special package POSTZON, recently released by the Manchester Computing Centre.

A difficulty that appeared was to relate stations to wards, particularly when more than one station was used by people from the same origin. Thus, commuters of that ward would face different trip attributes that should be averaged to satisfy the requirements of the aggregate level of the model.

This procedure initially involved the cross relation of travel's address and origin stations, such that it was possible to identify the stations used by people of each ward. Then, the frequencies were used as a kind of weight to select the most relevant stations for each ward. In other words, if from a single ward, a large and a comparatively small samples of commuters used different stations, then the station which presented insignificant flow was disregarded. On the contrary, if both stations had equally high or low flows, the trip attributes of the stations were weighted according to their corresponding frequencies. This process was arbitrary and based on good sense, but was demanded by the aggregate characteristic of the model.

rail access time and rail egress time -
Since the 1981 British Rail O/D survey does not provide information concerning access time to stations, and since the access and egress conditions of the wards and Central London respectively have not significantly changed, average figures given by the 1989 rail data set were used instead. The identification of stations to wards followed the same process explained above. As a question of compatibility, the unit of time used was minute.

Rail access cost -

The need for a variable to account for the effect of access costs was given by the analysis of the rail data set carried out in chapter 7. The 1989 average figures showed that more than 50% of the commuters used private transport to access the stations in Kent, while an increasing tendency for the use of the car was detected. Since car is the mode far more used to access stations, an estimate of this cost was computed by using the perceived costs given by the COBA manual of May 1981. The behavioural vehicle operating cost parameters provided by this manual are based on average 1979 prices, thus the corresponding retail price indices were applied to compute the 1981 figures. Assuming the average speed of 40 km/h for the local motorized flow, an inflated factor of 2.12 pence/minute was computed. To obtain the rail access cost, in pence, this factor was then multiplied by the average access time to stations.

Rail cost -

This variable represents the single fare, in pence, transformed from the quarterly second class season ticket, by applying the factor 1/1.2. This figure was obtained considering 120[4] single journeys in a quarterly ticket, and then transforming pounds into pence. A factor of 1/1.38 was assumed by Wabe (1969), who considered a single journey as one forty-sixth of the monthly season ticket rate. A week of 5 working days seems to be more realistic, particularly for those commuting to Central London.

[4] 3 months x 4 weeks x 5 days x 2 trips (return) = 120

Value of time -

The value of time considered in this thesis was obtained as part of the research project MVA Consultancy et al. (1987), carried out for the Department of Transport. It was given by a sample survey conducted from 12th to 27 July 1983, in the North Kent, amongst regular commuters into Central London who faced a choice between train and coach. Fowkes (1986) summarised the values of time obtained for the three different modelling methods applied to the whole sample of that survey. As a matter of compatibility with the data base described in chapter 5, the figure given by the revealed preference modelling method for the main vehicle time (3.18 p/min) was adopted.

Since the value of time was based on 1983 prices, the 1981 and 1989 figures were computed by deflating and inflating 3.18 p/min according to the respective personal disposable income and consumption indices given in the Economic Trends (1992).

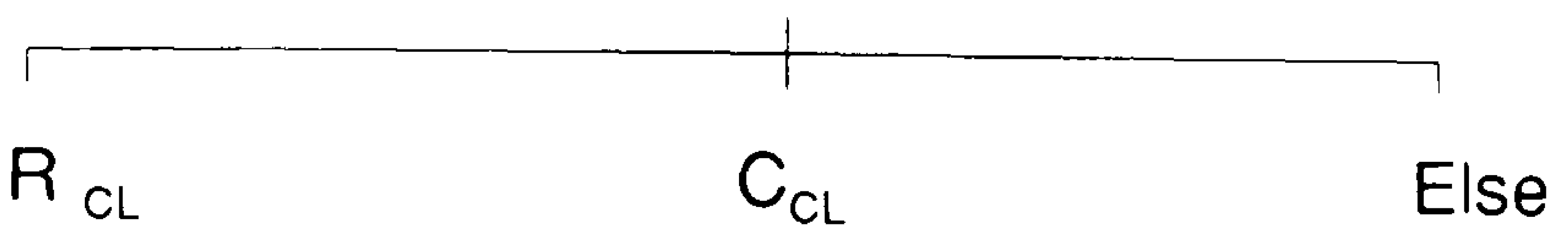
Inter-change of trains -

Given the significant number of inter-change of trains reported in the BR surveys and depicted in table 7.13, a dummy variable to account for the effects of interchanges was also included in the model. It would take the value of 1 if there was any case of inter-change trains in the ward, and 0 otherwise.

8.2.3 - THE MULTINOMIAL MODEL

In order to identify the effect of car use in the commuting to Central London, a multinomial model involving three choices is proposed. The structure comprises the shares rail to Central London, car to Central London and any mode to elsewhere. The alternative coach was disregarded due to the reasons already presented in section 8.2.2. Diagram 8.3 shows the structure of the multinomial proposed.

Diagram 8.3 - Structure of the multinomial model



where:

R_{CL} - rail to Central London

C_{CL} - car to Central London

Else - elsewhere

In the probabilistic choice theory, the choice probabilities from a subset of alternatives is dependent only on the alternatives included in this subset and is independent of any other alternative that may exist. This means that one or more alternatives removed from a choice set will not cause any change in the relative choice probabilities from the reduced choice set.

In order to prevent violations in the IIA, there is the need to specify distinct alternatives in the choice set of the multinomial model. The choices in the multinomial model proposed are dissimilar, with the high dominance of rail over car in the trip alternatives to Central London. The only problem likely to appear concerns the very common correlation that exists between modes, in particular between car cost and rail fares, since both are based on the travel distances.

a - **Formulation of the multinomial model**

The formulation of the multinomial model is similar to the binomial presented in section 8.2.2. Its functional form is given by

$$P_r = \frac{\exp(V_r)}{\exp(V_r) + \exp(V_c) + \exp(V_e)} \tag{8.9}$$

where:

P_r - the relative frequency of observed trips by rail to Central London

V_r - the utility of rail trips to Central London

V_c - the utility of car trips to Central London

V_e - the utility of trips to elsewhere in Kent

The utilities are represented by

V_r = rgt = rail generalised time

rgt = rivt + rat + ret + rac/vot + rc /vot

V_c = cgt = car generalised time

cgt = civt + cc/vot

V_e = egt = jobs / pop

where:

rivt - rail in-vehicle time

rat - rail access time

ret - rail egress time

rac - rail access cost

vot - value of time

rc - rail fare

civt - car in-vehicle time

cc - car cost

jobs - jobs within 10 km radius of the ward's centre

pop - population of the ward in question

Pindyck and Rubinfeld (1976) suggested that the estimation of the parameters of such a kind of model can be done by regressing the following linearised set of equations, involving pairs of choices:

$$\ln\left(\frac{P_r}{P_c}\right) = V_r - V_c$$

$$\ln\left(\frac{P_r}{P_e}\right) = V_r - V_e \qquad (8.9)$$

$$\ln\left(\frac{P_c}{P_e}\right) = V_c - V_e$$

The simultaneous linear regression procedure PROC SYSLIN provided by the statistical package SAS, was used to estimate the parameters of the multinomial logit.

b - Definition of variables of the multinomial model

Most of the variables of the multinomial model are the same already defined for the binomial model. The remaining variables to explain are the following:

<u>Dependent variables of the multinomial model</u>

The three dependent variables shown in the set of equations 8.9 represent the logarithm of the ratio between the relative frequencies of daily commuting trips by rail and car to Central London; rail to Central London and any mode to elsewhere; and car to Central London and any mode to elsewhere respectively. This information was given by the 1981 Census of Population, Special Workplace Statistics, section C, table 1, mode of transport by sex.

Explanatory variables of the multinomial model

The components of the rail generalised time are the same as previously explained in the binomial model. In spite of the importance of waiting time in mode choice decisions, this factor was not taken into account because the required information could not be obtained.

The variables car-in-vehicle time and cost were concerned with the road flow in the Kent network, and provided by the Kent County Council. To scale the cost variable of the car generalised time function, the value of time given by the North Kent survey (see Fowkes (1986)) was used. In spite of being based on the rail and coach data, this value of time was applied to the car mode due to the lack of a proper value. Also due to lack of information, no account of the car egress time in Central London, as well as parking costs, were undertaken.

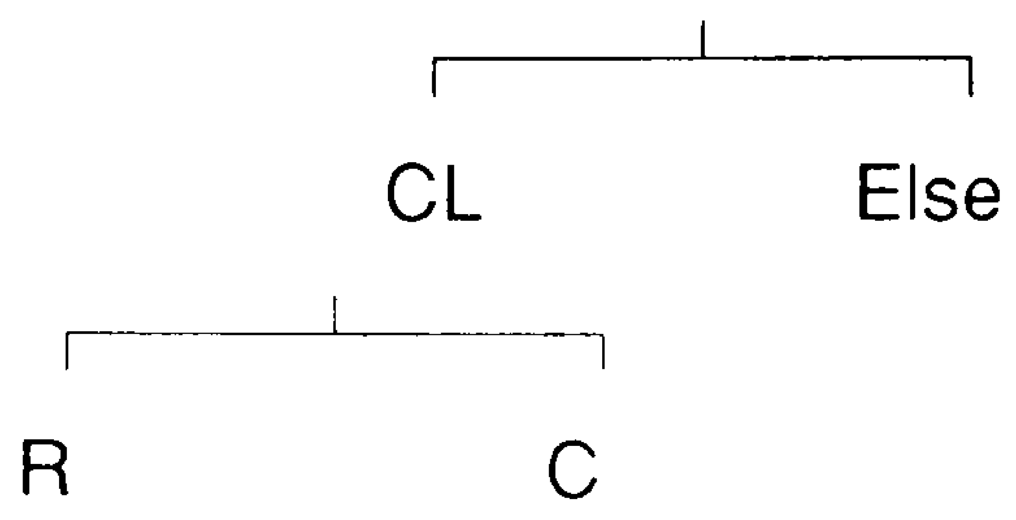
Concerning the alternative elsewhere, the same assumptions undertaken in the definition of the elsewhere utility of the binomial model are valid. Thus the proxy variable representing jobs of the financial and services classes within 5 and also 10 km distance of the ward's centre divided by the local population was used.

8.2.4 THE HIERARCHICAL MODEL

In the formulation of multidimensional logit models, a question that usually arises regards the structure of the tree and the sequence of the nests. There is no theoretical basis for assuming a priory any specific structure order. The confirmation of the tree structure in only obtained after the model calibration, through comparison of scale parameters of adjacent levels. According to Williams (1977), a condition for an internally consistent model is that the scale parameter of the lower nest is greater than or equal to the upper one. Actually, bigger scale factors imply smaller standard deviation of the error term, and consequently will correspond to more similar or correlated alternatives. In this case, such alternatives should be accommodated in the lowest nest.

The most commonly hierarchical structure used is that in which destination choice precedes modal choice. Thus, the following hierarchical logit structure of mode conditional to destination depicted in diagram 8.3 was initially investigated.

Diagram 8.3 - The structure of the nested model



where:

CL = Central London

Else = elsewhere

R = rail

C = car

Due to the relatively small proportion of flows to Central London presented by other private modes, the alternative private transport comprises only the car mode. As regards the alternative coach, it was disregarded due to the same reasons previously pinpointed in section 8.2.2.

a - Formulation of the hierarchical model

For the structure defined in diagram 8.3, the nested logit choice probability of a nest of destination (d) and a nest of mode (m) can be expressed as a product of marginal and conditional choice probabilities by

$$P(d\ m) = P(m/d).P(d) \tag{8.10}$$

The marginal probability that destination d is chosen is given by :

$$P(d) = \frac{\exp\,(V_d + \nabla_d)\,\beta_d}{\sum_{d \in D} \exp\,(V_d + \nabla_d)\,\beta_d} \tag{8.11}$$

and the conditional probability by :

$$P(m/d) = \frac{\exp\,(V_m\,\beta_m)}{\sum_{m \in M} \exp\,(V_m\,\beta_m)} \tag{8.12}$$

where ∇_d is a composite utility, defined as

$$\nabla = \frac{1}{\beta_m} \ln \sum_{m \in M} \exp\,(V_m\,\beta_m) \tag{8.13}$$

and

V_d = utility corresponding to the destination d, of the choice set D

V_m= utility corresponding to the mode m, of the choice set M

β_d, β_m = scale factors of the nests destination and mode respectively

A particular feature of the hierarchical model is the composite utility, also called logsum, which equals the expected maximum utility when there are no common attributes among the alternatives of the same nest. Such factor aims to preserve the utility previously computed in the lower nest to the upper level of decisions.

Apart from the composite utility, the formulation of the mode and destination sub-models follows the same structure of the binomial model presented in section 8.2.2.

The functional form of the mode sub-model is given by

$$\frac{P_r}{P_c} = \frac{\exp\ (\ V_r\ \beta_m\ )}{\exp\ (\ V_c\ \beta_m\ )} \qquad (8.14)$$

where:

P_r - the relative frequency of observed trips by rail to Central London

P_c - the relative frequency of observed trips by car to Central London

V_r - the utility of rail trips to Central London

V_c - the utility of car trips to Central London

β_m - scale factor of the mode nest

As a question of simplicity, the index CL for destinations Central London is disregarded.

The utilities are represented by generalised times, and are given by

V_r = rgt = rail generalised time

rgt = rivt + rat + ret + rac/vot + rc /vot

V_c = cgt = car generalised time

cgt = civt + cc/vot

where:

rivt - rail in-vehicle time

rat - rail access time

ret - rail egress time

rac - rail access cost

vot - value of time

rc - rail fare

civt - car in-vehicle time

cc - car cost

The linearised form of the equation 8.14 is represented by

$$\ln\left(\frac{P_r}{P_c}\right) = (V_r - V_c)\,\beta_m \qquad (8.15)$$

substituting the utilities by the corresponding generalised time,

$$\ln\left(\frac{P_r}{P_c}\right) = \beta_m a_1 + \beta_m a_2\, rgt - \beta_m a_3\, cgt \qquad (8.16)$$

$$\ln\left(\frac{P_r}{P_c}\right) = a^*_1 + a^*_2\, rgt - a^*_3\, cgt \qquad (8.17)$$

where a^*_1, a^*_2, and a^*_3 are the estimate parameters of the mode choice model, and β_m is the scale factor of the mode nest.

For the destination nest, the functional form is given by

$$\frac{P_{cl}}{P_e} = \frac{\exp\ (\ V_{cl} + \nabla_{cl}\ )}{\exp\ (\ V_e\ )} \qquad (8.18)$$

Which linear form is

$$\ln\left(\frac{P_{cl}}{P_e}\right) = \beta_d\, b_0 + \beta_d\, b_1\, V_{cl} + \beta_d\, b_2\, \nabla_{cl} - \beta_d\, b_3\, V_e \qquad (8.19)$$

$$\ln\left(\frac{P_{cl}}{P_e}\right) = b^*_1 + b^*_2 \nabla_c - b^*_3 V_e \qquad (8.20)$$

where:

P_{cl} - the relative frequency of observed trips to Central London

P_e - the relative frequency of observed trips to elsewhere

V_{cl} - the utility of trips to Central London

∇_{cl} - composite utility related to the nest of modal choices

V_e - the utility of trips to elsewhere

b^*_1, b^*_2, b^*_3 - parameter to be estimated

β_d - scale factor of the destination sub-model

The utilities are represented by

V_e = utility of elsewhere = jobs in elsewhere/pop

V_{cl} = utility of Central London= (jobs/pop)

Since the number of jobs in Central London is constant for all wards in a particular year, the variable V_{cl} is not included in the model. It is supposed to be accounted by the intercept, without interfering in the estimators of the model.

b - Definition of variables of the hierarchical model

Most of variables of the hierarchical model are the same already defined for the binomial and multinomial models. The remaining variables to explain are presented in the following two sections.

dependent variable of the hierarchical model

The dependent variable of the destination nest is given by the relation between the flows to Central London and to elsewhere. The input data used in both sub-models was given by the 1981 Census of Population, Special Workplace Statistics, section C, table 1 - mode of transport by sex.

explanatory variables of the destination choices sub-model

Concerning the alternative elsewhere, the same assumptions undertaken in the definition of the elsewhere utility of the binomial model are valid. Thus, the proxy variable representing jobs of the financial and business classes within the ranges of 0-5 km and 0-10 km distances of the ward's centre divided by the local population were tested.

The utility of Central London is taken to be a constant, represented by another proxy variable given by the local jobs in the city. However, the number of jobs in the City is constant in a cross section for a particular year, and therefore would have no influence in the estimation of the parameters.

The composite mode utility, also called expected maximum utility, concerns the mean value of the distribution of a maximum utility corresponding to the mode node. Thus, the composite cost is computed as a separate and independent variable, using the parameters obtained in the mode choice model.

8.3 - ESTIMATION OF THE MODELS

The models were estimated using the SAS package and weighted least square regression. The basic assumption of the least square regression method consists in choosing the values of the unknown parameters such that the residual sum of squares is as small as possible. Weighted observations were considered due to the problem of heteroscedasticity, which is implicity introduced in the linear transformation of the logit model (see Gujarati (1988)). For the analysis of correlation among the variables, the matrix of Pearson pair-wise correlation coefficients was considered, whilst the multicollinearity of parameters was examined by the variance-covariance matrix.

To measure how well the regression line fits the data set, the multiple coefficient of determination R^2 was used. This coefficient measures how much variation in the dependent variable can be accounted for by the explanatory variables of the model. The range of values of R^2 lies between 0 and 1, which means that the fitted regression line explains the variation of the dependent variable within 0% to 100 %.

However, to check if R^2 is significantly different from zero, another test called the F statistic was applied. It was used to test the overall significance of the multiple regression. The F value provides a test of the null hypothesis that the true slope coefficients are simultaneously zero. If the computed value exceeds the tabulated critical value, for a given level of significance, the hypothesis test is rejected; otherwise, it is accepted. Given the 95 % confidence interval and a model with 120 degrees of freedom, the critical tabulated F equals 3.07, while F=3.0 for the same level of significance and an infinity number of observations. This is the range of critical values that covers the sample sizes analysed.

Since the coefficients of the independent variables must be also significantly different from zero, the value of R^2 by itself is not sufficient to guarantee the quality of a good model. A hypothesis testing about individual partial regression coefficients was used. It is called student t-test, and measures the significance of the individual parameter estimates for different degrees of confidence. One may accept that the estimated partial regression coefficient is statistically significant if the computed t value exceeds the critical t value. For a number of degrees of freedom superior to 120, and a confidence interval of 95%, the tabulated t value is inferior to1.658.

Another test applied was the Cook's D statistic (see Cook D (1977)). This test measures the influence of each observation on the parameter estimates. In other words, it measures the change to the estimates that results from deleting each observation. The computed D value is compared with the value given by a certain probability point of the central F-distribution.

The statistical tests previously mentioned were of great assistance to check and understand the results of the models, however a large dose of good-sense was vital to judge and select the 'best' models. The following sections attempt to approach the analyses concerning the results of the models.

8.3.1 DISCUSSION OF THE RESULTS OF THE BINOMIAL MODEL

Since all wards of Kent presented local commuting trips, the sample size used in the estimation of the binomial model was dependent solely on the number of wards which have flows to Central London. This is due to the fact that the number of observations used in the calibration is concerned with the logarithm of the relative frequencies between the two alternatives. Therefore, the model was only defined for those wards which have flows simultaneously attached to both choices.

Various combination of variables were tried, eg. else variable comprised only of the jobs of the financial, banking and service sectors, as well as all job classes; and the segmentation of the sample according to ranges of distances to Central London. Some of the variables tried did not improve the results of the model, eg. rail distance, and are not reported here.

Table 8.1 depicts the results of the binomial model for the cases when the else variable comprised the jobs of the financial and banking sectors, as well as all categories of jobs within the local 5km distance of the ward's centre. The statistics for the models which include a dummy variable to account for the effects of rail inter-changes are also presented.

Table 8.1 - Results of the binomial model for local jobs within 5km distance

a) jobs of the financial and service sectors

sample	F	R^2	variable	t	parameter
246	157	56			
			intercept	4.8	1.0436
			rgt	- 17.4	-0.0242
			else	- 3.6	- 0.1833
246	108	57			
			intercept	3.8	0.8692
			rgt	- 17.4	-0.0240
			else	- 3.1	- 0.1600
			inter-change	2.2	0.1987

b) all categories of jobs

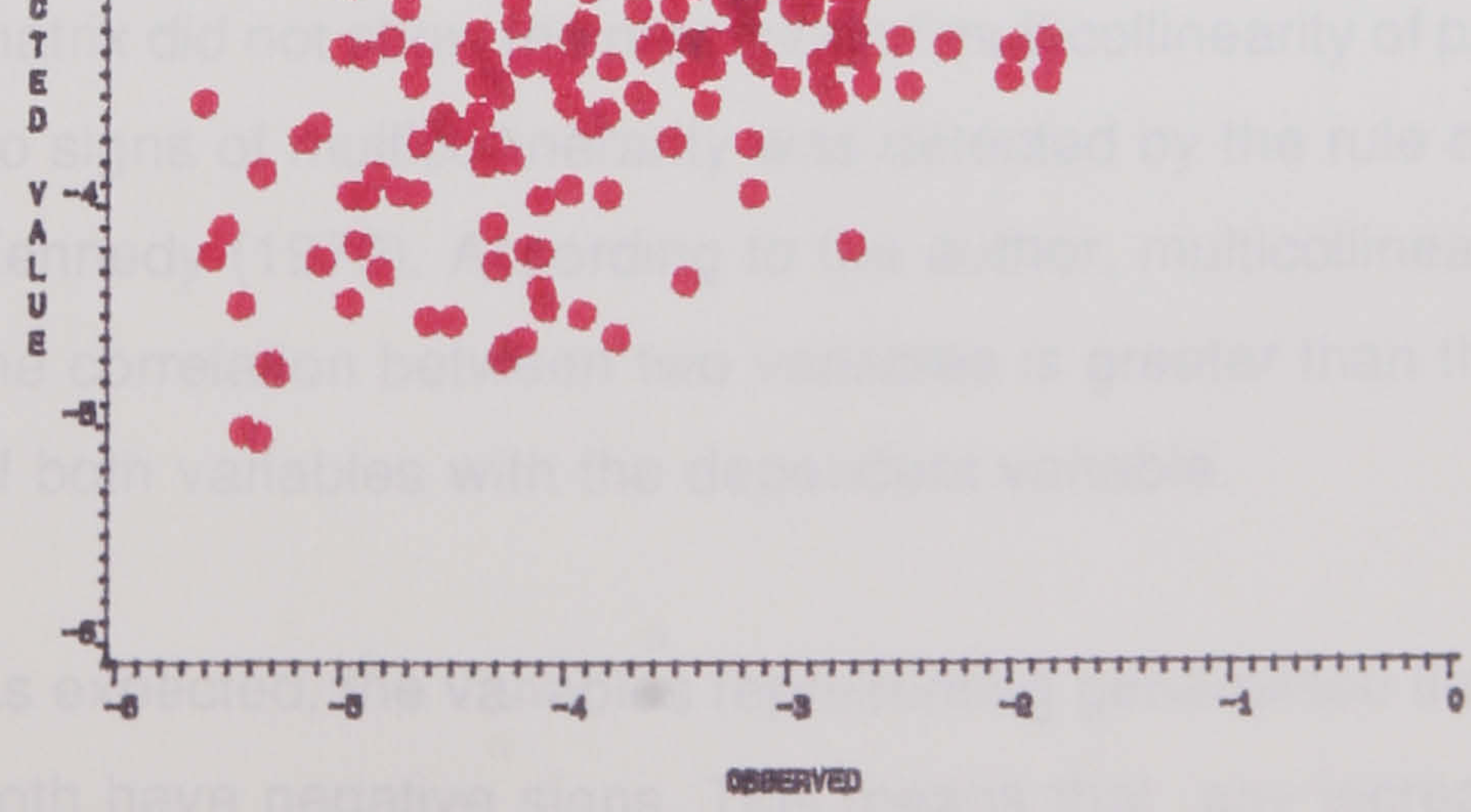
sample	F	R^2	variable	t	parameter
246	155	56			
			intercept	4.7	1.0009
			rgt	- 17.1	- 0.0239
			else	- 3.4	- 0.0672
246	107	57			
			intercept	3.6	0.8283
			rgt	- 17.1	- 0.0239
			else	- 2.9	- 0.0576
			inter-change	2.2	0.2003

According to the coefficients of determination R^2, the models can account for some 56% of variation in the explanatory variables. Since the critical F value is 3.0, and the F estimated by the models are much bigger, the values of F are significant for the 95% degree of confidence, and the sample size of 246 observations. Thus, one may conclude that the multiple regression coefficients R^2 are also significant.

Given the values of 't' statistic, the independent variables are well accounted by the model, and the parameters are statistically significant. The Cook's D statistics, showed that all observations were acceptable, and therefore no one should be rejected. Concerning the other statistics analysed, the standardised residual and the 95% interval of lower and upper prediction also gave acceptable results. A total of 231 actual flows (out of 243) were within the 95% confidence limits of the model predictions.

Figure 8.1, which depicts the estimates against the observed trips to Central London, illustrates the overall adequacy of the sub-model (a) in the base year (1981).

FIG 8.1 – PREDICTIONS x OBSERVED



Considering the same sub-model (a), table 8.2 shows the sum of the numbers of observed and estimated trips to Central London, for both the year of calibration (1981) and the year of prediction (1989).

Table 8.2 - Total observed and predicted trips to Central London

year	observed	predicted
1981	20840	21285
1989	25186[a]	23320

[a] estimate figure

In 1981, the model slightly overpredicts the number of trips to Central London, whereas it underestimates the 1989 flows. A possible reason to explain the underprediction of the 1989 rail commuting is the inability of the model to account for the changes over time in the distribution and structure of employments in London. Factors such as the uncertainty of the 1989 observed flows, the relative changes in fares and in the value of time during the period analysed, and some other assumptions undertaken in the modelling might have also interfered in the results presented in table 8.2. These issues are left to be discussed in chapter 9, which presents a general investigation of the applications and restrictions of the model regarding the predictions of the flow distribution in Kent.

The low figures given by the Pearson correlation coefficients matrix assured the absence of correlation among regressors, and the variance-covariance matrix did not show the presence of multicollinearity of parameters. In addition, no signs of multicollinerarity was detected by the rule of thumb suggested by Kennedy (1979). According to the author, multicollinearity is likely to occur if the correlation between two variables is greater than the correlation of either of both variables with the dependent variable.

As expected, the variables representing generalised time and jobs/population both have negative signs. This means that any increase in the ratio jobs to population in the local area will cause a decrease in the rail to Central London share, while any rail fare or journey time increase will cause the rail to Central London market share to fall.

The comparisons between the parameters of the variable else in the binomial models given in table 8.1 show the importance of the local financial and business jobs in the choices of the commuting from Kent. This is a relevant finding that corroborates the assumption regarding the significance of the white collar jobs in the trade-off between trips to Central London and elsewhere, initially undertaken in section 8.2.2.

Train inter-changes are supposed to have a negative effect on rail demand. Contrary to the expectations, the model gives a positive sign to the dummy variable. The inclusion of a dummy for train inter-changes does not affect the rail generalised time variable. However, it generally causes slight reductions in the intercept as well as in the explanatory power of the elsewhere variable. This might reflect the lack of other variables in the model.

The analysis of the residuals did not show any particular tendency that could be related to unidentified features. Only 12 actual observations out of 243 were out of 95% confidence limits of the model predictions. For the sub-model (a) including the dummy variable, the figures 8.2, 8.3, and 8.4 depict the residuals versus the model estimates, and the variables rail generalised time and utility elsewhere, respectively.

FIG 8.2 – RESIDUALS x PREDICTIONS

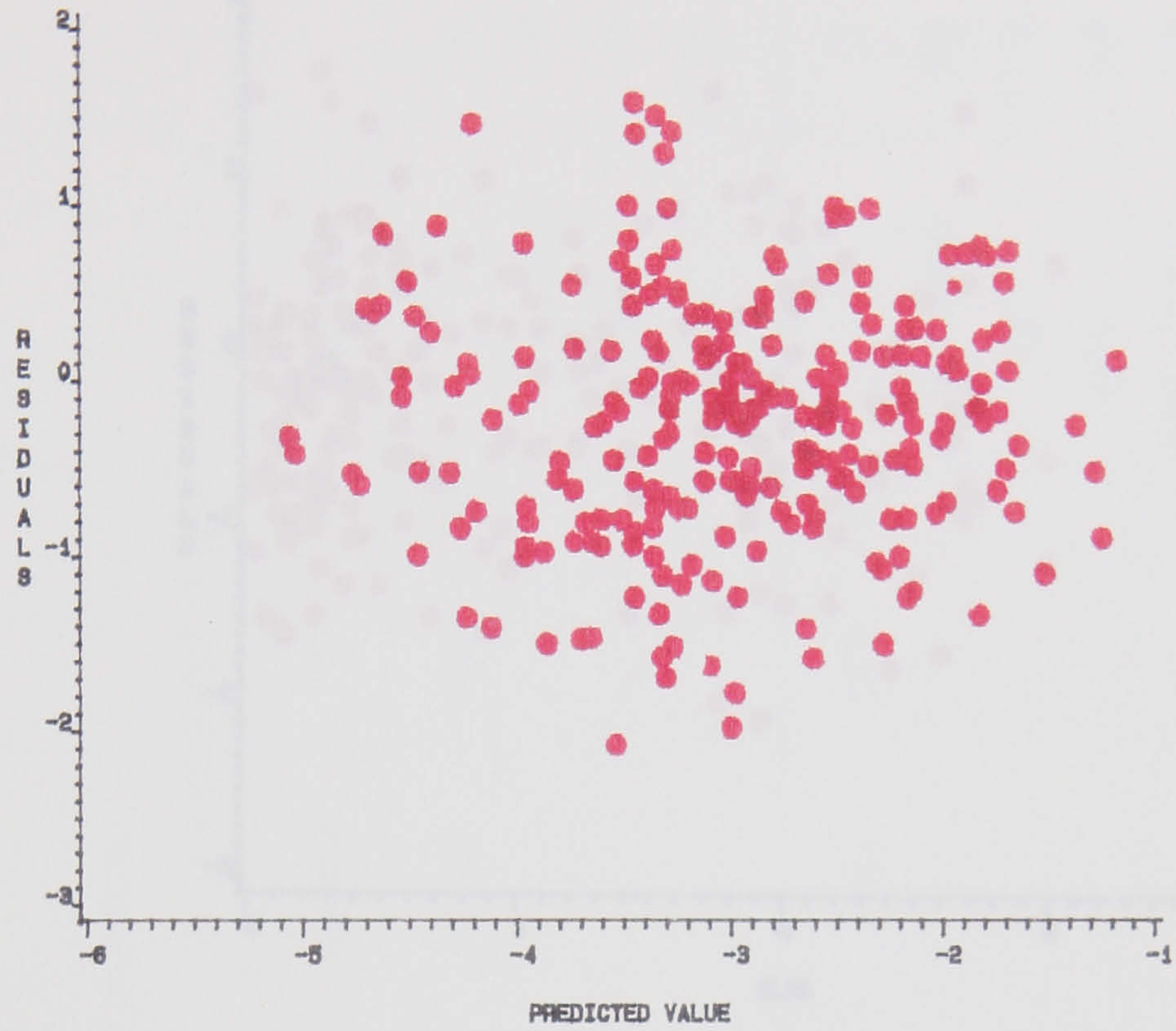


FIG 8.3 – RESIDUALS x RGT

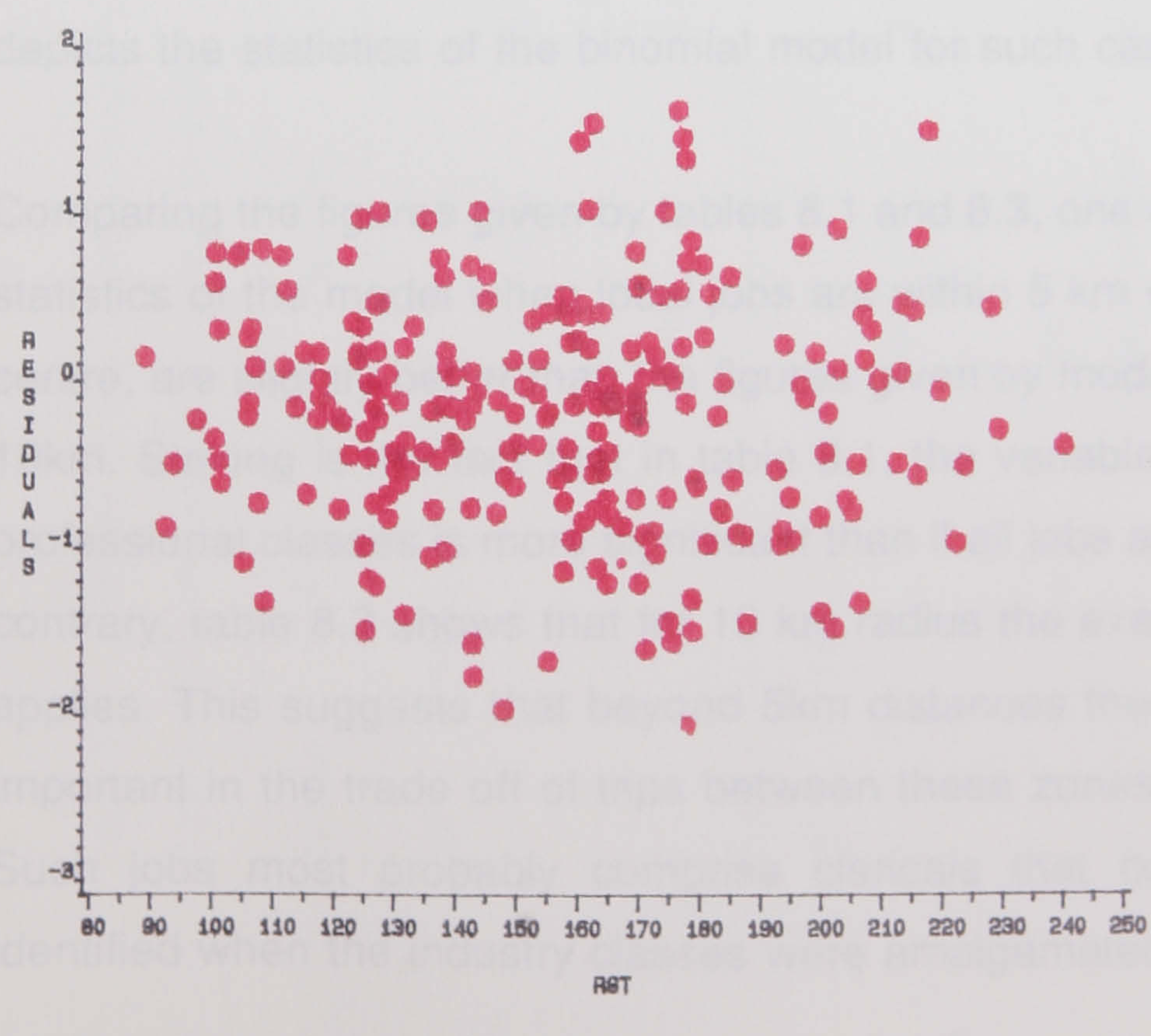
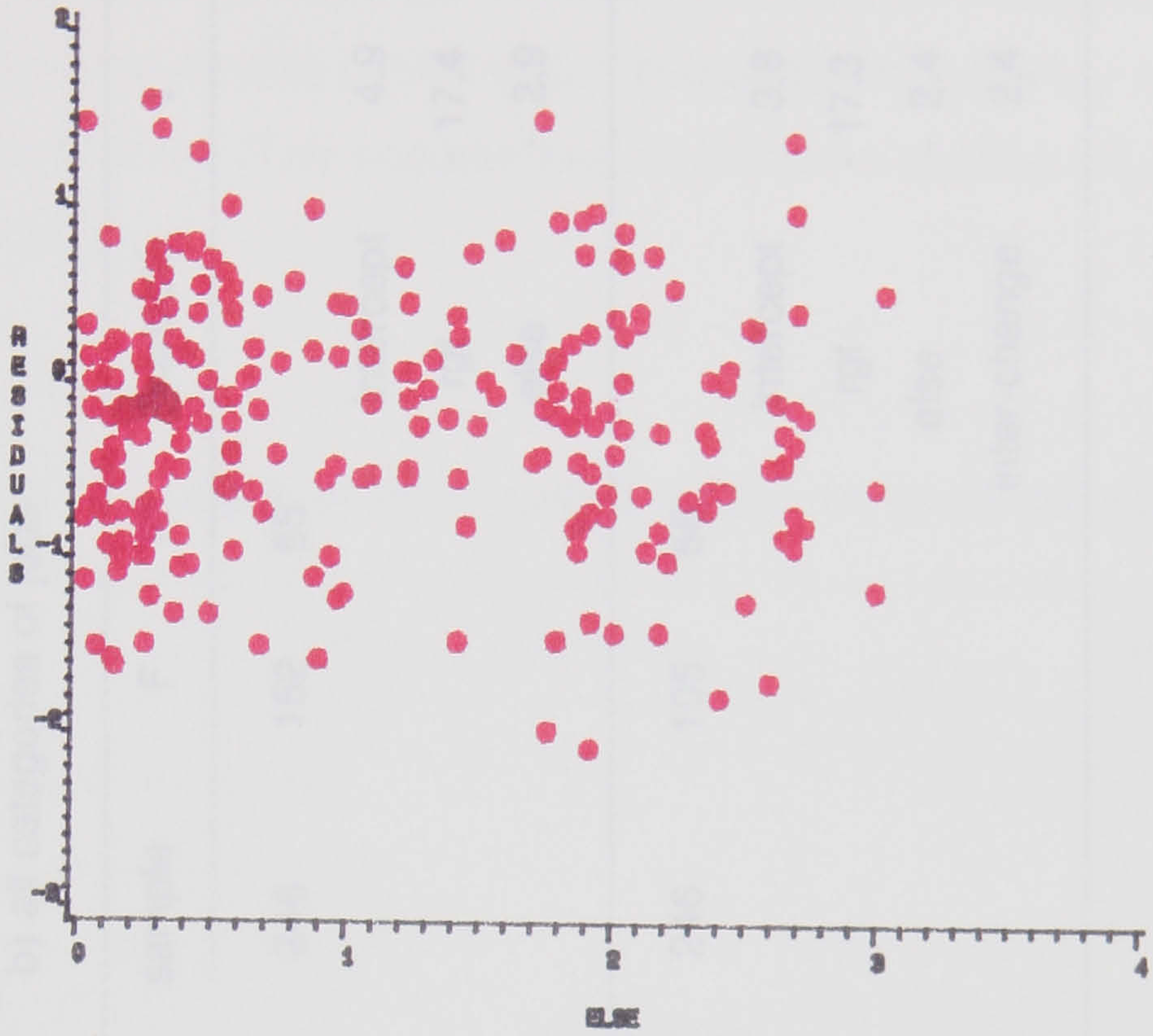


FIG 8.4 – RESIDUALS x ELSE UTILITY



Similar analysis can be done for the model which considers the elsewhere variable for the radius of 10 km distance from the ward's centre. Table 8.3 depicts the statistics of the binomial model for such case.

Comparing the figures given by tables 8.1 and 8.3, one may conclude that the statistics of the model when local jobs are within 5 km distance of the ward's centre, are slightly better than the figures given by model when distances are 10km. Striking is the fact that in table 8.1, the variable else comprising only professional classes is more significant than if all jobs are considered. On the contrary, table 8.3 shows that for 10 km radius the exact vice-versa analysis applies. This suggests that beyond 5km distances there are jobs which are important in the trade off of trips between these zones and Central London. Such jobs most probably comprise clericals that could not be properly identified when the industry classes were amalgamated (see section 6.4).

Table 8.3 - Results of the binomial model for local jobs within 10 km distance

a) jobs of the financial and service sectors

sample	F	R^2	variable	t	parameter
246	149	55			
			intercept	4.6	1.1549
			rgt	- 17.2	-0.0247
			else	- 2.4	- 0.0980
246	103	56			
			intercept	3.5	0.9283
			rgt	- 17.2	- 0.0244
			else	- 1.9	- 0.0796
			inter-change	2.5	0.2237

b) all categories of jobs

sample	F	R^2	variable	t	parameter
246	152	55			
			intercept	4.9	1.2141
			rgt	- 17.4	- 0.0246
			else	- 2.9	- 0.0451
246	105	56			
			intercept	3.8	0.9943
			rgt	- 17.3	0.0243
			else	- 2.4	- 0.0378
			inter-change	2.4	0.2126

Some other interesting insights resulted from the segmentation of the sample by travel distances. Table 8.4 depicts the results obtained in the models for the following three ranges of distances: below 30 km, between 30 km and 50km, and above 50 km. The variable else concerns distances within 5 km from the ward's centre.

Table 8.4 - Results of the binomial model for distance bands

sample	F	R^2	variable	t	parameter
a) distances <= 30 km					
61	9	20			
			intercept	1.2	0.7646
			rgt	- 4.2	- 0.0235
			else	0.4	0.0367
b) 30 km < distances <= 50 km					
75	12	30			
			intercept	0.4	0.3495
			rgt	- 3.7	- 0.0196
			else	- 3.4	- 0.2994
c) distances > 50 km					
108	28	34			
			intercept	2.4	1.9293
			rgt	- 6.6	- 0.0281
			else	- 3.8	- 0.3049

The influence of the Outer London border is clearly seem in the results of the model using segmentation of the sample by travel distances. For distances below 30 km, the F and R^2 tests corroborate the overall significance of the multiple regression, however the variable elsewhere, which represents the relation between local jobs and population, was not significant. The low figure given by the 't' statistics and the unexpected sign of this variable show that it is an irrelevant variable in the decision process between trips either to Central London or elsewhere. A probable reason for this fact is the close proximity of this area to the border of London. At this range of distances, the attraction of jobs elsewhere in Greater London might be stronger than any other local alternative available, what explains the insignificant parameter for the local destination obtained.

For the other two ranges of distances considered (30-50 km and above 50 km), the results were significant, in particularly for the model involving the longest distances, which presented the best statistics of all.

The analysis of residuals shows that almost all actual flows were within the 95% confidence interval of the three sub-model predictions.

Very small marginal changes in the results were obtained in some other tests involving all classes of jobs in the else variable, the introduction of rail distance and a dummy variable to account for the rail inter-changes.

8.3.2 DISCUSSION OF THE RESULTS OF THE MULTINOMIAL MODEL

Table 8.5 depicts the results obtained for the multinomial model, whose estimation involved the set of equations given in (8.9). It was assumed that the else variable comprised only jobs of the financial and service sectors.

The sub-model rail-car to Central London can account only for about 14% of variation of the data set. In spite of the low figures of F and R^2 statistics, they are still significant. As expected, the variables rail and car generalised time have opposite signs. This means that if the attributes of rail mode are kept the same, any increase in the car attributes will cause an increase in the rail/car share.

The lack of data concerning the perceived cost of the car mode, as well as the method used to compute the variable car cost are likely to have influenced the results of the car variable in the mode split model to Central London. This variable is just significant in the model which includes a dummy variable to detect the effects of train inter-changes. The dummy spreads the variation among the coefficients and consequently improves the performance of the car generalised time variable. However, one would expect a negative effect of inter-changes in the number of commuters by rail to Central London, which is not confirmed by the sign of this variable. Given the high 't' statistics of the dummy variable, one may suspect that it captures the effect of some other relevant variables not included in the model.

Regarding the size of the parameters, one may conclude that people are much more sensitive to a change in the rail time or cost than to a change in the car attributes.

Table 8.5 - Results of the multinomial model

a) $\ln (P_r / P_c) = V_r - V_c$

sample	F	R^2	variable	t	parameter
156	14	14			
			intercept	8.8	2.7844
			rgt	-3.4	-0.0159
			cgt	1.3	0.0045
156	12	18			
			intercept	8.2	2.6121
			rgt	- 3.9	-0.0179
			cgt	1.7	0.0062
			interchange	2.7	0.3472

b) $\ln (P_r / P_e) = V_r - V_e$

sample	F	R^2	variable	t	parameter
156	79	50			
			intercept	3.1	0.8531
			rgt	-12.5	-0.0229
			else	-2.2	-0.1396
156	56	52			
			intercept	2.3	0.6655
			rgt	-12.7	-0.0230
			else	-1.7	-0.1118
			interchange	2.5	0.2708

c) $\ln (P_c / P_e) = V_c - V_e$

sample	F	R^2	variable	t	parameter
156	36	31			
			intercept	-10.0	-2.1303
			cgt	-7.6	-0.0105
			else	-3.3	-0.2249

rgt=rail generalised time cgt=car generalised time else=utility elsewhere inter change= dummy for train inter-changes

Multicollinearity was clearly detected by the high figures shown in the matrix of Pearson correlation coefficients, particularly between the variables rail and car generalised time, which presented a correlation of 0.89. This is a relatively common problem in model split models, and the literature shows that similar results have been found in the commuting to Central London (see Wabe (1969)). Given that both the rail costs and the engineering method used to compute the car costs were related to the travel distances, high correlation was expected in the mode split model.

Good results are given by the sub-model rail to Central London and any mode to elsewhere. For both combinations of variables, the model accounts for at least 50% of variation in the explanatory variables. The else variable is still significant, in spite of the reduction in the explanatory power of the variable local jobs by population caused by the inclusion of the dummy variable train inter-change.

The F and R^2 statistics given by the rail-elsewhere sub-model are worse than the ones presented by the sub-model car-elsewhere, but much better than the figures shown by the sub-model rail-car to Central London. All variables of the sub-model (c) in table 8.5 are significant, and the signs are the expected ones.

Generally, one may say that the results of the multinomial model for the alternative in Kent are relatively good, but that they are poor as concerns the choices for Central London. The previously mentioned weakness of the car variable has certainly played an important part in this finding, however the cultural tradition concerning the train use as well as the high proportion of rail choices relative to car in work trips to Central London might have contributed for the performance of the multinomial model.

Overall, the performance of the multinomial model was unsatisfactory. This is because of the insignificant 't' statistics of the variable car generalised time, high correlation between mode split variables, and the low level of variation in the dependent variable given by the explanatory variables of the sub-model rail-car to Central London. On the basis of these statistical tests, the multinomial model is rejected in favour of the binomial model, whose results are significantly better.

8.3.3 DISCUSSION OF THE RESULTS OF THE HIERARCHICAL MODEL

The sub-models of the hierarchical structure were estimated in two sequential stages, using weighted least squares regression. Since the parameters of the mode split model are used in the composite utility of the upper level of the structure, the unbiased but inefficient estimates given by ordinary least squares method could not be applied.

The level of aggregation of the model led the sample size to be dependent on the number of wards which have flows to Central London. However, the linearisation of the logit model and the estimation method used are likely to reduce even more the number of observations considered in the models. This happens when 100% of the trips from a particular ward is by a single mode, or to a unique destination, and the logarithm of the proportions tend to limits which cannot be determined. Unfortunately, this was observed in many wards of the data set used in the mode split model. Consequently, the number of observations used in this sub-model of the hierarchical model (156) is significantly smaller than the one used in the estimation of the binomial model (246).

Table 8.6 depicts the statistical tests obtained for the mode split and the destination models, considering different combinations of variables.

Table 8.6 - Results of the hierarchical model for local jobs within 5 km distance

modal split model						destination model					
obs	F	R^2	variable	t	parameter	obs	F	R^2	variable	t	parameter
156	12	18				156	52	50			
			intercept	8.2	2.6121				intercept	-3.4	-2.9069
			rgt	-3.9	- 0.0179				EMU	2.6	1.3962
			cgt	1.7	0.0062				else	-2.1	-1.1241
			interchange	2.7	0.3472				rd	-12.2	- 0.0411
156	14	14				156	30	27			
			intercept	8.8	2.7844				intercept	-10.9	-6.9903
			rgt	-3.4	-0.0159				EMU	7.6	0.5447
			cgt	1.3	0.0045				else	-2.3	-0.1621

where:

rgt=rail generalised time cgt=car generalised time rd= rail distance EMU=expected maximum utility else= utility elsewhere

Although R^2 of the mode-split models are low, the values of F-statistic are significant, and one may accept that the models can still fit the dependent variable data. Insignificant parameter is obtained for the alternative car to Central London, when only the rail and car generalised time are considered. In spite of the unexpected positive sign of the dummy variable train interchanges, its inclusion improves the performance of the mode choice model. The size of the parameter shown by the dummy suggests that relevant and unidentified variables might be missing in the model.

As expected, the variables rail and car generalised time have opposite signs. One would presume that increases in travel distance would not stimulate more commuting to Central London, therefore the negative sign for the variable rail distance was also expected. Since increases in the attributes of both rail and car travels to Central London are not supposed to encourage the commuting trips, a negative sign for the variable EMU was expected.

An unexpected result comes from the comparison between the scale parameters of the nests. The ratio of scaling parameters at adjacent levels of the hierarchy is much larger than unity, and the order of choice initially suggested is not acceptable (Williams(1977)). Such test provides the information that the structural order of the tree is wrong, and there is the need to investigate a structure in which mode choice model precedes distribution. Williams and Senior (1977) demonstrated that the sequence of models does not generally affect the forecasts, provided that the composite costs are properly defined. In the light of the scale of the parameters, it seems advisable to explore the inverted structure of the hierarchy of choices. It seems also important to recall the London destination and mode choice model developed by Copley et al. (1988). For the kind of hierarchical model developed, it was found that the most acceptable structure order was the one in which the choice between public and private mode preceded distribution, followed by the modal choice between bus and rail. Therefore, the Copley et al. (1988)

conclusion concerning the inversion of the structure of the model for London is similar to the one obtained here.

However, further tests involving the inversion of the hierarchical structure proposed are not worthy pursuing. First, the results of the mode split model were not significant and very high correlation between the alternatives rail and car was detected. Although similar levels of correlation have been previously found in models of the commuting trips to Central London (Wabe(1969)), no immediate and practical solution was found to overcome such a problem. Second, there was no guarantee about the performance of the proxy variable for the generalised time of elsewhere in the lower nest of the tree. Given the transference of information, and consequently of errors, from the lower to the upper level of the tree, a good precision in the lowest nest is desirable. Moreover, the coefficient of the logsum is bigger than one, suggesting that the hierarchical structure is not appropriate for the kind of analysis proposed.

Models considering some other variables and forms were run, but no improvements in the test of significance were obtained. On the light of the actual lack of data, and the impracticability to cope with the problem presented by the proposed hierarchical structure, any further exploration of this model does not seem to be very recommended.

Given the disadvantages shown by the hierarchical model both in the structural order and in the statistic significance, and given the considerably better performance presented by the binomial model, the hierarchical structure is then rejected.

8.4 - CONCLUSIONS FROM THE MODEL

This chapter described and presented the results of a simple and traditional distribution model to forecast trip ends. Given the assumptions adopted, the main aim of the model is to predict where a given number of commuters will come from.

Two main restrictions were identified in the modelling framework. One regards the fact that the model presumes that all commuters are choosing a job, having already got a home in Kent. The other limitation is that there is no provision for the model to reflect any changes in the distribution and structure of jobs in London.

The effect due to the limitation of the choice process to the search of jobs was not clearly identified in the results obtained. However, the inability of the methodology to deal with changes in the distribution or structure of jobs in Central London might have affected the estimates given by the models. In the base year, the estimates of the binomial model were slightly above the actual commuting flows, whereas in 1989 the total number of trips were underestimated.

The assumptions underpinning the methodology did not inhibit the achievement of the main purpose of the analysis, which is to predict the flow distribution of the commuting from Kent. The underpredicted figures resulting from the model may be scaled up according to the total number of trips forecasted, such that the flow could be properly distributed among the various origins. Consequently, the underestimated results obtained do not invalidate the method proposed.

Some fruitful results were obtained from the quantitative analysis carried out. The hypothesis concerning the importance of the social composition of the commuting in the trade-off of trips both to Central London and elsewhere within the county of Kent was confirmed. Models including all classes of jobs gave results less significant than if only the specialised local jobs of the financial and service categories were considered. Unfortunately, the disaggregation of trips simultaneously by mode and social classes, was not possible, and the results were concerned only with the total population commuting.

Also corroborated was the postulate that the influential area of the local employment is about 5-10 km within the ward's centre. Results slightly less significant were obtained when the local area of employment was augmented to 10km radius. However, the statistics given by the model suggest that beyond 5 km distances there are jobs which are important in the trade off of trips between the local area and Central London. Clearly, the results might have been affected by misidentification of job categories, particularly the clerical, caused by the aggregation of industry classes.

Three different structures of the logit model were analysed: binomial, multinomial, and hierarchical. The overall explanatory power of the binomial model rail to Central London-elsewhere is good. The statistics shows that the variables rail generalised time, local jobs by population, and a dummy variable to account for train inter-changes are significant. Apart from the dummy, which has an unexpected positive effect on the rail demand, the other variables had the expected signs.

The segmentation of the sample by travel distance highlighted the attraction of the Greater London market. For short distances, the variable which represents local jobs was insignificant, in spite of the overall fit of the multiple regression shown by the multiple coefficient of determination. The performance of the model for medium and long distances was good, and the model involving the longest distances presented the best statistics of all.

The other two more sophisticated structures analysed gave less relevant results. Both models involved the alternatives car to Central London, which was under represented by a car generalised time variable. The main weaknesses of this variable comprised the lack of the perceived costs of the car commuting, as well as information concerning the effects of car company and subsidies on costs.

Mackett and Nash (1991) suggested that the changes in the volume of rail commuting are less associated with the changes in mode split than with the changes in the number of jobs in Central London and in the corresponding location of its employees. The poor results of the mode split model corroborate their suggestion.

The structural order of the hierarchical model initially tested was not adequate, and the size of the logsum coefficient suggested that this kind of sequential choice structure was not appropriate for the kind of analysis proposed.

Statistical tests showed the inadequacy of both the multinomial and hierarchical models. On the grounds of the support of the statistical analysis, the two mentioned structures were rejected in favour of the binomial model, whose performance is adequate to the suggested framework. Therefore, analysis of the elasticities, as well as the capability of the model for forecasting rail demand, which are in the scope of chapter 9, will only be undertaken for the binomial model.

CHAPTER 9
USES OF THE MODEL

9.1 - INTRODUCTION

In chapter 8, the calibration and goodness of fit measures of various models were presented. Given the significance of the results of the model concerning the choices rail to Central London and any mode to elsewhere, this chapter examines the general applications and restrictions of this model. Some of the issues raised by the work in the previous chapter are here contemplated. Initially, the elasticities are discussed. In the light of the implications of assumptions undertaken in the model construction, the ability of the model to estimate the distribution of the commuting flows in Kent is investigated in section 9.3. The model responsiveness to policy changes concerning the effects of improvements in the quality of the rail service, and increase in local job opportunities is examined in section 9.4. Then, the main findings concerning the applicability of the model are summarised in section 9.5.

It is important to highlight that the emphasis of this work is on the practical rather than the theoretical aspects of modelling. All efforts were made to make the most efficient use of existing data sources, even though these data sets may have different accuracies.

9.2 ELASTICITIES

Elasticity is a measure used to express the responsiveness of demand to changes in the factors determining the level of demand. By definition, elasticity is the change in the relative frequencies due to a relative change in any of the independent variables. In terms of the probability model, it is the percentage change in the probability of choosing a given alternative due to a 1% change in one of the variables in the utility function of that particular alternative.

Since the elasticities vary with the size of the independent variables, they are calculated at the mean values of the variables for each zone. For the binary logit considered, the direct elasticity (E) of a given attribute (z) of the rail mode (r) is derived as :

$$E_{z_r} = \frac{\partial P_r}{\partial x} \frac{\partial x}{\partial V_r} \frac{\partial V_r}{\partial z_r} \frac{z_r}{P_r} \tag{9.1}$$

where

$$P_r = \frac{\exp x}{1 + \exp x} \tag{9.2}$$

$$x = V_r - V_e \tag{9.3}$$

P_r - relative frequency of trips by rail to Central London

V_r - utility of rail trips to Central London

V_e - utility of trips to elsewhere

z_r - attribute of the rail mode

Due to the non linearity of the logit model, aggregation bias arises when disaggregate data are used to obtain aggregate results, which are based on average attribute values. A solution for the problem of aggregation across the zones is similar to the one given by Ben-Akiva and Lerman (1985) for aggregation across individuals. The weighted average of the ward elasticities considering the flows as weights is used. Thus, the aggregate elasticity weights the ward elasticities according to the level of flows concerning a particular mode of transport. For the rail mode, the direct elasticity is given by:

$$E_{z_r} = \frac{\sum_n R\,(\,1 - P_r\,)\,a_r\,z_r}{\sum_n R} \tag{9.4}$$

where :

P_r - relative frequency of trips by rail to Central London
R - rail flow to Central London
a_r - parameter of the rail generalised time
z_r - attribute of the rail mode
n - number of zones (wards)

Since the probability of choosing one alternative is a function of the utility of each of the other alternatives, then it is possible to define cross elasticity as the percentage change in the probability of choosing a given alternative resulting from a 1% change in one of the variables in the utility function of a second alternative. By similarity, the elasticity of rail to Central London related to the number of jobs in the surrounding areas is given by :

$$E_e = \frac{\partial P_r}{\partial x} \frac{\partial x}{\partial e} \frac{\partial e}{\partial z_e} \frac{z_e}{P_r}$$

$$E_e = \frac{\sum_n R \, a_e \, z_e \, (P_e)}{\sum_n R} \tag{9.5}$$

where:

R - rail flow to Central London

P_e - relative frequency of trips to elsewhere

a_e - parameter of else variable

z_e - attribute of elsewhere trips (job/population)

n - number of zones (wards)

The analysis of elasticities carried out in this chapter is regarding the binomial model rail to Central London-elsewhere, given by additive generalised times. The binary models for ranges of distances are also considered.

One would a priori expect that trips are negatively related to increases in rail generalised time to Central London and increases in the number of local jobs in Kent. This is supposed to hold for the model of the full rank of distances, whose parameters were significant (see table 8.1). However, one should be aware that the estimated elasticity of trips within 30 km distances may be misleading, due to the fact that the coefficient on the attraction of trips elsewhere was not significant at the 5% level of confidence (see table 8.3).

Table 9.1 depicts aggregate elasticities by district, for the binomial model concerning the full sample. Journey time comprises in-vehicle time plus access and egress times, and else stands for the elasticity of rail in relation of jobs elsewhere.

Table 9.1 - Elasticities

districts	fare	ivt	journey time	rgt	else
Ashford	-1.48	-1.59	-2.19	-3.86	-0.24
Canterbury	-1.54	-1.98	-2.52	-4.20	-0.07
Dover	-1.79	-2.40	-2.91	-4.93	-0.13
Gillingham	-1.24	-1.23	-1.78	-3.19	-0.12
Maidstone	-1.29	-1.34	-1.82	-3.30	-0.23
Sevenoaks	-0.88	-0.68	-1.09	-2.14	-0.15
Shepway	-1.60	-1.83	-2.41	-4.22	-0.15
Swale	-1.36	-1.54	-2.10	-3.64	-0.06
Thanet	-1.74	-2.48	-3.02	-4.91	-0.25
Tonbridge	-1.10	-0.86	-1.42	-2.71	-0.13
Tunbridge Wells	-1.16	-0.91	-1.49	-2.85	-0.22

Table 9.1 shows that the estimated elasticities of the rail demand are very high. A reduction of 10% in the rail travel time will cause an increase of 13.4% in the rail commuting from Maidstone to Central London, if the travel times from all other zones are held constant. This is particularly striking because of the predominance of the rail mode in the market share of trips to London. In addition, the elasticities are concerned with the commuting trips in the peak

period, which are supposed to be less elastic than off-peak trips for purposes other than to work.

Given the functional form of elasticity (equation 9.4), it is inevitable that the higher the current generalised time, the higher the elasticity. In other words, the elasticity of demand is greater at higher fares and longer journeys. Therefore, the far-eastern areas, eg. Thanet, Dover and Shepway, presented the highest rail elasticities, whereas zones close to the border of Outer London showed much smaller figures. The figures are compatible with the fact that remote areas, which have only a few people commuting to Central London, might have scope for expansion of their market, and therefore have high elasticities. The opposite applies to the areas close to the border, where one would expect lower elasticities figures.

There are two major reasons for the relatively high figures shown in table 9.1. Firstly, the elasticities considered here measure the effect on rail demand caused by improvements in service to each particular zone of Kent, holding service levels to all other zones constant. The elasticities represent a percentage change in the forecast ratio of commuting for London versus the alternative destinations assuming prices (or times) from the other places constant. Secondly, they have no constraints or time lags; they are long-term elasticities which allow for long run population and employment changes. Mackett and Nash (1991), who stressed the crucial importance of locational interactions in forecasting aggregate demand, have shown that substantially higher long-run elasticity is obtained when these changes are allowed for. These two characteristics represent a significant departure from most of the previous studies. Therefore, one should be aware of the fact that the specific features of the model may lead to results which are different from the ones obtained in most published works.

Thus it is not surprising that the elasticities of the rail demand obtained are higher than the ones usually considered by British Rail for commuting into

Central London. The Monopolies and Mergers Commission report (1987) reports the figure of -0.3 for the elasticity of rail demand in the South East England, and suggests that there is no reliable estimate of longer-term elasticity taking into account the effect on residential and job location that might result from larger increase in fares.

Since the model developed here attempts to catch the long run effects of population and job locations, and since the raising in generalised time is from a single origin, and not simultaneously for all districts of Kent, the estimate accepted by British Rail may not be simply compared with the results obtained in this thesis. They could neither be compared with previous studies carried out by Hepburn (1977), Wabe (1969), Glaister (1983), and Mackett and Nash (1991). Table 9.2 depicts some of the results found by those authors.

Table 9.2 - Point elasticities given by previous studies

study	fare	journey time
Wabe	- 0.54	- 0.30
	- 0.37	- 0.41
Hepburn	-	- 0.9(>40km)
		- 0.5(<40km)
Glaister	-0.77 to -0.9	-
Mackett & Nash	- 0.15	- 0.34[a] to
		- 1.29

[a] the lowest figure excludes the net transfer between corridors

The previous studies listed in table 9.2 have looked at the effects of raising all fares simultaneously. The only exception was the study by Mackett and Nash (1991), who compared the elasticities for the South-East sector with the elasticities for the specific Chiltern line within that sector. An important finding of the study by Mackett and Nash (1991) was that considerably smaller figures were found if the transfer between corridors were disregarded. For instance, the travel time elasticity for trips to Central London was -1.29 for the Chiltern line and -0.50 for the South-East sector. Their work suggested that the high elasticity figures measured represent not only mode switches or a reallocation of demand to routes where rail fares have not increased, but mainly reflect a wholesale reallocation of jobs and homes.

According to Mackett and Nash (1991) relatively small changes in residential and employment patterns at an aggregate level can mask large changes in the spatial linkages at the individual level, and consequently can affect the level of demand for the various modes. The authors found high travel time elasticities for rail trips from zones on the Chiltern Line, calculated from changing travel time along the corridor, and ignoring any change elsewhere in the study area. As a result of disregarding compensating effects elsewhere, they found elasticities values which lead to an overestimation of the overall growth in rail patronage of up to 50% in the isolated corridor. This gain was partially due to people locating so that they could take advantage of the improved accessibility.

Traditional elasticity and mode choice models do not usually consider the effects of changes in rail attributes of one corridor in isolation. However, one should bear in mind the crucial importance of this kind of information in the evaluation of the impact caused by individual projects, ie. a high speed train implemented in Mid-Kent.

Clearly, the high figures found in the present thesis are compatible with the findings by Mackett and Nash (1991). Given the scale of the figures for the Chiltern line when compared with the elasticities for the whole South-East sector, high elasticities would be expected if single origins were considered, other variables being held constant. This is specifically the case examined here, when individual districts were considered.

A question that may arise concerns collinearity between the variables time and cost, and how this would affect the elasticities estimates. Since the elasticities were estimated from a model using a single variable for generalised time, any multicollinearity likely to exist between cost and time variables is not relevant to that process. What matters are both the value of time used to scale the cost component of rail generalised time, and the estimated parameter of the generalised time variable. The value of time was borrowed from the North Kent study of commuting to Central London, in which rail was the dominant mode. Given that the data analysed in the North Kent study was obtained in a survey designed to avoid biases, the value of time used should give reliable results. Regarding the rail generalised time parameter, statistical tests carried out in the item 8.3.1 showed that the estimators of the binomial model were significant, and no signs of collinearity between the variables rgt and else were found.

Given the credibility of the value of time used, and the significance of the rail generalised time estimator, one may say that collinearity is unlikely to have affected the estimated elasticities of the rail demand.

As far as the cross elasticities of the rail demand in relation to local jobs are concerned, relatively low figures were found. Since the attribute of elsewhere trips that is shown in equation 9.5, represents the ratio of jobs to population, the interpretation of the cross elasticities is not so simple. The ratios between these two variables, which are given in table 6.12, do not show any relationship with the figures shown in table 9.1.

Models considering segmentation of the sample by distances to Central London, stress even more these spatial differences in elasticities. The fare elasticities for models involving ranges of distances of 30 miles, between 30 miles and 50 miles, and above 50 miles are depicted in table 9.3.

Table 9.3 - Fare elasticities for range of distances (miles)

districts	<=30	(30-50]	>50
Ashford		-1.25	-1.76
Canterbury			-1.82
Dover			-2.12
Gillingham		-1.13	
Maidstone		-1.18	
Sevenoaks	-0.77		
Shepway			-1.89
Swale		-1.21	-1.69
Thanet			-2.06
Tonbridge	-0.94	-1.11	
Tunbridge Well	-0.98	-1.08	

The comparison between tables 9.1 and 9.3 shows that lower average figures by district are obtained for the ranges of distances. This was expected, particularly for those districts which have wards in more than one of the ranges of distance considered. However, one should take into account the fact that the model for short distances (<30miles) could represent only a very small proportion of the variation of the data, and may give misleading figures.

It is generally accepted that short distance journeys by rail are more sensitive to changes in access and less sensitive to variations in fares and journey times. The explanation for this fact is that for short journeys, the access time forms a greater proportion of the total generalised time, than for longer journeys. Therefore, one might expect lower rail fare and in-vehicle time elasticities for short distance journeys. The figures depicted in table 9.2 corroborated this supposition.

9.3 - MODELLING TESTS

Considering the implications of some basic assumptions undertaken in the modelling construction, a general discussion concerning the ability of the model to estimate the location of the commuters amongst the various zones in Kent is here carried out.

Table 9.4 shows that the model represents the observed flows reasonably well. The figures in table 9.4 are the ratios of model predictions to observed values given by the relative frequency of the rail commuting to Central London in 1981 and 1989. The predictions were given by the model which considers only jobs of the financial and service categories in the utility of elsewhere.

Table 9.4- Ratios of predicted to actual frequencies of rail commuting to Central London

District	1981	1989
Sevenoaks	0.97	0.93
Gillingham	0.67	0.43
Maidstone	1.40	1.17
Tonbridge	1.22	1.05
Tunb. Wells	0.95	1.26
Swale	1.03	0.61
Canterbury	0.77	0.61
Ashford	0.91	0.64
Dover	1.88	1.40
Thanet	0.86	0.83
Shepway	1.21	1.37

Overall, the model slightly overpredicts the relative frequency of rail flows in 1981, whereas it underpredicts the 1989 flows. The 1981 estimates have a residual mean square error (rmse) of 0.019, and an absolute deviation (ad) of 0.16. The same statistics for the 1989 are rmse =0.024 and ad =0.27.

The residual mean square error and the deviation were computed using the following equations:

$$rmse = \sqrt{\frac{\sum_{n} (P - A)^2}{n}}$$

$$ad = \frac{\sum_{n} |(P - A)|}{\sum_{n} A} \tag{9.6}$$

where:

A - actual or observed values

P - predictions by the model

n - number of observations

Apart from Dover, whose average relative rail frequencies are overpredicted by a factor of 1.88, and Gillingham, whose overall estimated flow frequencies are 0.67 their actual value, the other districts presented similar predicted and observed figures in the 1981 model.

Despite the general characteristic of underestimation presented by the model applied to the 1989 data, the overall results are reasonable. The overprediction tendency presented by Maidstone, Tonbridge, Dover, and Shepway in 1989 is also shown in 1981. The overprediction tendency shown by Swale in 1981 is not followed in 1989. On the contrary, the 1989 relative frequencies from Sevenoaks and Tunbridge Wells are overestimated, whereas they are underestimated in the 1981 results.

Since this work aims to understand the commuter patterns from Kent, rather than to use the model as a tool to measure the absolute level of flows, it is certainly more appropriate to extract from the model useful information concerning the patterns of commuting. In the view of this, table 9.5 shows the percentages of the rail commuting flow from Kent by district, given by the observed data and the model predictions for 1981 and 1989.

Table 9.5 - Proportions of the observed and predicted rail flows by district

districts	1981 (%)		1989 (%)	
	observed[a]	predicted	observed	predicted
Sevenoaks	24.0	23.5	20.9	23.0
Gillingham	16.3	11.3	15.2	7.8
Maidstone	6.5	9.2	8.7	12.0
Tonbridge	13.5	15.9	13.8	17.2
Tunb.Wells	12.1	12.3	8.3	12.3
Swale	7.0	8.2	12.7	9.1
Ashford	6.1	5.7	7.7	5.8
Canterbury	6.3	4.6	6.9	5.0
Dover	1.5	2.8	1.3	2.2
Thanet	2.5	2.2	2.1	2.1
Shepway	4.1	4.2	2.1	3.4
Kent	100	100	100	100

[a] given by the 1981 Census of Population

Apart from Sevenoaks and Swale, the results shown by the other districts follow the same overprediction or underprediction in both years. In 1981, the model slightly overpredicts the flows from Swale, whereas in 1989 the total flows from this district are underestimated. The contrary occurs for Sevenoaks, whose 1989 estimate is significantly higher than the observed figure in that year.

Apart from Maidstone, the comparison between the 1981 and 1989 figures shows a general tendency of flow underprediction in the eastern Mid-Kent districts. Overprediction was mainly shown in the areas near London (Sevenoaks, Tonbridge, and Maidstone). Clearly, the model is over representing the striking effect of growth in commuting simultaneously to the expansion of the local economy, previously detected in chapter 7.

It is important to recall some possible sources of imprecision in the computations of the model estimations. One of them is related to the fact that the 1989 observed level of commuting from Kent, and more precisely the shares between the flows to Central London and elsewhere, are not provided by the data set available. The only available information concerns the flows by rail to Central London. However the exact proportion of the rail flows in relation to the total commuting from Kent is unknown. Therefore, the 'observed' 1989 flows of commuting are assumed to be approximately equal to the 1981 total flow increased in proportion with the increase in the level of economically active population in Kent from 1981 to 1989. The 1989 economically active population was computed by simple interpolation of the figures given by the summary of the 1991 Census of Population, table F in OPCS (1991).

Another important issue to recall regards the differences in precision of the observed flows for both years. The 1981 figures were solely based on the Census of Population data, and are expected to be accurate. On the contrary, the 1989 results involved data of different sources, and therefore different accuracy. An illustration of this problem is given by the difference in flow distributions given by the Census and the 1981 BR survey. The 1981 actual proportions depicted in table 9.5 were given by the Census of Population data, and might differ from those in table 7.8, which were obtained through the 1981 British Rail survey data. Also, the adjustments undertaken in the 1989 British Rail data (see section 7.3.2) due to the lack of some postcode information might have contributed to the results shown in table 9.4.

Three possible reasons arise to explain the underprediction of the 1989 rail commuting to Central London, in relation to the base run. The first is the overall increase in rail generalised time, particularly due to the increase in real fares (about 25%) relatively to the real change in value of time (15.2%). The second concerns the significant growth in local jobs by population in some areas of Kent. And the third possible reason is the inability of the model to capture the effect of the changes over time in job opportunities of the Central London market.

The third reason is concerned with the direct application of the parameters estimated with the 1981 data set in the 1989 model. More precisely, one might argue whether the model constant obtained in 1981 holds in 1989. Since Central London is considered as a single destination, the number of jobs in this market is a constant for any ward of Kent. As explained in chapter 8, the alternative specific constant would then account for the attraction of the jobs in Central London. Since the changes over time in the level of employment in Central London are not regarded by the model, a possible consequence of the use of the parameter obtained in the 1981 calibration is under-represented 1989 estimations.

As concerns the other two reasons, a better view of their effects on the results of the model is given by figures 9.1 and 9.2, which respectively depict the rail generalised time and the elsewhere utility for each district of Kent.

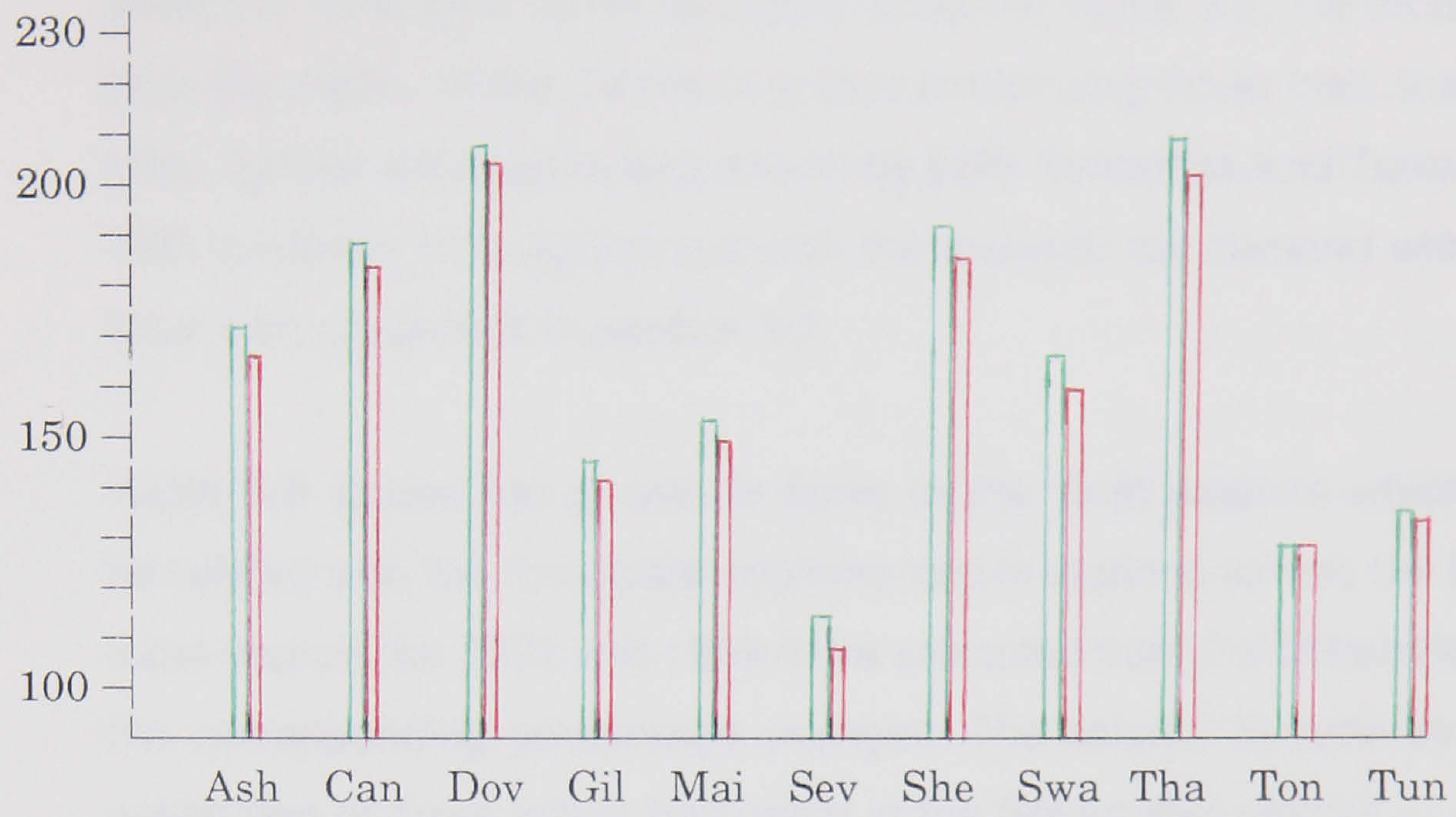


Fig 9.1 - Rail utility, 1981 and 1989

Fig 9.2 - Utility elsewhere, 1981 and 1989

A striking feature is presented by Maidstone. In spite of its extraordinary growth in local jobs, which is clearly shown in figure 9.2, the model still gives high estimates of the Central London commuting flows from the Maidstone area. Similar situation is also shown by both Tonbridge and Tunbridge Wells. This tendency is in agreement with the inelastic rail demand with respect to local jobs presented in section 9.2.

Table 9.6 shows the growth in flows in the Kent stations which may have benefitted with the travelcard implemented in stations across the border. This table depicts the 1981 and 1989 flows extracted from the British Rail data, and the corresponding percentage changes. The column % local stands for the proportion of flows which has origin in the Sevenoaks district.

Table 9.6 - Flows in stations served by travelcard

station	1981	1989	change %	% local[a] 1981	1989
Sevenoaks	2452	3151	28.5	91	95
Swanley	1172	1337	14.1	15	7
Otford	412	468	13.6	98	98
Bat & Ball	96	111	15.6	100	100
Shoreham	24	24	0	100	100

[a] approximate figures

The flow percentages shown the Swanley station are anomalously low. Since this station is near the borders of both Dartford and Outer London, the contribution of flows from Sevenoaks is probably small compared to the flows from other districts in the Swanley catchment area.

The evaluation of the effect of the travelcard on the level of commuting requires a detailed analysis, which goes beyond the simple examination of the changes in flows. It is also important to know the origin of the commuters who generated such changes. It might be the case that commuters from districts other than Sevenoaks prefer to take the train from one of the Kent, or even Outer London stations, which benefited from the travelcard.

The examination of the figures depicted in the last column of table 9.6 does not corroborate this hypothesis. Apart from the station Swanley, whose proportion of commuters originated outside Sevenoaks increased by 8%, all the other stations kept a high percentage of local users.

This simple analysis does not provide any strong evidence of the effects of travelcards in the level of commuting to Central London. However, this is a complex issue which deserves a detailed analysis, and much more time than is possible within the framework of this thesis.

Since the appropriateness of the model for the analysis of the relative flow distribution, and the main implications of some assumptions of the model on the results estimated were discussed, the present section turns to the applicability of the model as concerns its responsiveness to policy changes.

9.4 - EFFECTS OF POLICY CHANGES ON RAIL DEMAND

In order to evaluate the ability of the binomial model in forecasting the demand of rail passengers to Central London, two different hypothetical scenarios were considered:

(i) a reduction of 50% in rail in-vehicle time; and

(ii) an increase of 10% in the local job market.

The impact of halving in-vehicle time is shown in table 9.7, which gives the changes in the level of rail commuting from each district of Kent, and the corresponding in-vehicle time and journey time elasticities.

Table 9.7 - Predictions of the binomial model if halving in-vehicle time

districts	change demand	%	elasticities ivt	elasticities journey time
Sevenoaks	2111	12.3	- 0.31	- 0.70
Gillingham	1286	7.5	- 0.57	- 1.09
Maidstone	2429	14.2	- 0.63	- 1.08
Tonbridge	1837	10.7	- 0.40	- 0.93
Tunbridge Wells	1600	9.4	- 0.43	- 0.99
Swale	2205	12.9	- 0.72	- 1.25
Canterbury	1900	11.1	- 0.94	- 1.44
Ashford	1210	7.1	- 0.76	- 1.34
Dover	687	4.0	- 1.16	- 1.65
Thanet	898	5.3	- 1.20	- 1.72
Shepway	955	5.6	- 0.87	- 1.43

Given the functional form of the elasticity the higher the current generalised time, the higher the elasticity, and consequently the higher the relative responsiveness of the demand to travel time changes.

The elasticities computed at current levels (see table 9.1) showed that demand was very sensitive to changes in rail services. Apart from Sevenoaks and Tonbridge, the journey time elasticities depicted in table 9.7 reveal that the demand remains elastic even if halving in-vehicle time. Table 9.1 showed that a reduction of 10% in the journey time would cause an increase of 18.2% in the rail commuting from Maidstone to Central London, holding the travel time from all other zones constant. Similar analysis considering the figures depicted in table 9.7 shows an increase of about 11% in the commuting from Maidstone.

In the light of some studies quoted in the literature of the commuting to Central London, the figures depicted in table 9.7 might seem high. However, one should consider the fact that the model developed in this thesis is concerned with long term decisions on location, which represents an important deviation from most of previous work. Given a different number of commuters placed at different locations, the model shows the effects of the improvements in the transport services in a particular zone, in relation to the others. In the light of the characteristics of the approach used, the size of the elasticities found are appropriate.

This finding is particularly important in the view of the Mid-Kent Parkway proposal. Since Mid-Kent has a large concentration of commuters, and since the rail demand with respect to changes in journey times in each individual district is very elastic, any improvement in rail speed would certainly favour the long distance commuting of the area. In spite of the probable increases in access cost to the Parkway station, the reduction in travel time seems to be the main achievement of that project.

There is no intention to carry out a discussion concerning the merit of the Mid-Kent Parkway proposal. However, given the limitations of this work, the figures depicted in table 9.7 provide a strong evidence of the sensitivity of the rail demand from the Mid-Kent area for improvements in speed. The highest level of responsiveness was shown by Maidstone, but a large area comprised of Swale, Canterbury, and Tonbridge also gave high changes in demand. For the former two districts, a reduction by 50% in in-vehicle time still give journey time elasticities higher than unit.

The model seems to be an adequate tool to the examination of the catchment area of the proposed Mid-Kent Parkway station. Unfortunately, limitations of time and resources restrict any further exploration of this interesting issue.

The model was also used to measure the effects of an increase of 10% in the number of local jobs in Kent. Table 9.8, which gives the results of this policy, shows the consequent changes in the rail flows, their corresponding percentage in relation to the total flow change in Kent, and the cross elasticities of the rail demand with respect to job increases.

The largest losses would occur in the districts near London, where the bulk of the commuting is mainly located. Maidstone and Tunbridge Wells presented significant proportions of the total level of jobs in Kent, as well as high changes in employment opportunities during the period 1981-89. Considering the inelastic rail demand with respect to jobs, Sevenoaks and the two previously mentioned districts, were relatively more sensitive to a job change than the others. Rail demand is insensitive to jobs at current levels and remains so even if a 10% increase occurs.

Table 9.8 - Predictions of the binomial model if increasing local jobs by 10%

districts	change rail demand	%	else elasticity
Sevenoaks	- 69	21.3	- 0.16
Gillingham	- 21	6.3	- 0.13
Maidstone	- 59	18.0	- 0.25
Tonbridge	- 45	14.0	- 0.14
Tunbridge Wells	- 59	18.0	- 0.25
Swale	- 12	3.6	- 0.07
Canterbury	- 14	4.4	- 0.08
Ashford	- 25	7.6	- 0.27
Dover	- 5	1.4	- 0.15
Thanet	- 9	2.7	- 0.27
Shepway	- 9	2.7	- 0.16

9.5- MAIN FINDINGS

This chapter highlighted some useful applications of the binomial model, and supported some findings concerning the trends in the commuting previously obtained in this thesis.

The model showed a reasonable accuracy to estimate the rail frequencies in both years. In 1989, the model underpredicts about 7% of the overall rail flows from Kent, while in 1981 the overprediction tendency gives a figure of only 2%.

In the temporal transferability to 1989, an overall tendency of underprediction was detected in most of the eastern Mid-Kent districts, whereas a pattern of flow overestimation was mainly shown at the short commuting distances. In spite of the significant expansion of the local economy, the model still overestimate the flows from Maidstone.

The increase in flows associated to the decrease in population observed in the Sevenoaks district, suggests that the travelcards might have played a role on the commuting changes. However, in the light of the limited examination of the changes in flows in the Sevenoaks stations beneffited by travelcards, as well as in those across the border of Outer London, no conclusive results can be drawn.

Some fruitful results were obtained in the elasticity analysis. Given the functional form, the elasticities vary amongst the residential location of the commuters, and differ according to the levels of commuting in the origin zones. As expected, commuters from the districts near the border of Outer London were much less responsive to changes in the rail attributes, whereas high elasticities were shown in long distance areas with relatively small number of commuters.

The size of the elasticities are higher than the figures generally obtained in the literature of the rail commuting to Central London. However, they are compatible with the fact that they measure the growth in rail demand due to improvements in services on particular zones of Kent, disregarding the compensating change elsewhere, and allowing for long run population and job changes. Given the fact that the model developed here represents an important diversion from most of the previous works, the direct comparison of elasticities between them might be misleading.

The model was also assessed in its responsiveness to policy changes. It is evident that at reduced journey times, the rail demand is still elastic with respect to speed. The elasticities indicated that there is a significant potential for improving patronage by journey time reductions.

This is an important finding in the view of the Mid-Kent Parkway project station. In the Mid-Kent districts, the rail demand is still elastic even with the reduction of 50% in travel time.

The effects of increases in the local employment opportunities on the level of commuting are not so accentuated. The rail elasticities due to increases in local jobs are inelastic, and remained so even with an expansion of 10% in the local market. Reductions in journey time would have a larger effect on the patronage than the resulting from increases in local jobs.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

10.1 INTRODUCTION

The purpose of this work was to identify and understand the key factors involved in the changing patterns of commuting into Central London during the period 1981-89, in particular through a case study of Kent.

The fundamental postulate underlying this study is that the changes in patterns of commuting were caused, among other factors, by the combined effects of the following main elements:
(i) relocation of population and jobs;
(ii) specialisation of the Central London job market; and
(iii) changes in travel attributes.

It was shown that population and jobs have followed a long trend to decentralisation. In Kent, both socio economic factors presented different tendencies as concerns their distribution by zones over the period analysed.

Simultaneously during the 1980's, the Central London job market experienced a significant structural change within an approximately constant total. Losses in the production sector were nearly offset by gains in specialised jobs. The manufacturing and transport sectors were the most seriously hit, while an enormous expansion in financial activities was observed.

As a consequence of the switch in the Central London economy, and the relocation of people and jobs in Kent, the socio economic composition of the commuters and their work-trips patterns changed. Some changes in accessibility likely to affect the commuter's decisions were also identified.

This chapter seeks to draw together and summarise the principal aspects which have emerged in the foregoing work. A qualitative and quantitative reconsideration of the main findings is presented, followed by some recommendations for further research.

10.2 SUMMARY OF THE FINDINGS

It became clear that the general process of job decentralisation also occurred within Central London. Over the period 1981-89, employment density of the City of London felt whereas it increased in the Westminster borough. This fact was also corroborated by the relative growth in traffic presented by the western stations of the central area. Victoria station received 41.4% of the total change in commuting from Kent, while 23.5% was observed in Cannon Street, and 20.5% in Charing Cross.

Given the low concentration of offices in the western side of the central area, slight increases in the egress time spent from most of the British Rail stations to the final destination in London were found. Also, the walk mode used in the access to the final destination in London fell by some 5% mainly in favour of the underground.

The changes in the patterns of access mode to stations in Kent are consistent with the growth in car ownership during the 1980's. At the expense of almost all the other modes, and in particular buses and foot, the mode shares in 1989 highly favoured the car use.

In Kent, employment and population have followed different location tendencies during the last decade. The largest growth in population was mainly observed at the range of 80-90 km distances from Central London. Canterbury experienced the largest increase followed by Ashford. The bulk of the job changes was seen at the 40-60 km distance band from Central London. The most prosperous districts were Maidstone, Tunbridge Wells, Tonbridge and Canterbury.

The different tendencies presented by the patterns of population and job distributions were expected to have opposing effects on the level of commuting from Kent. The major expansion of job opportunities at medium distance relative to population location in Kent was expected to reduce the level of commuting. On the contrary, the expansion of population relative to jobs at long distance was likely to increase commuting. However, a striking feature arises when the trends in commuting are confronted with the previous two postulates.

There is a strong evidence concerned with the tendency of the rail commuters to live further out. During the period 1981-89, the proportion of commuters within 50 km distance from Central London felt by some 4%. The major expansion of the total change in commuting was observed within the band of 50-60 km distance from Central London.

Clearly the largest growth in commuting did not occur in the same places which had the expansion of population. What is notable is the fact that there were areas in which the growth in employment opportunities occurred simultaneously to increase in commuting. This is particularly the case of Tonbridge, Tunbridge Wells, and also Canterbury.

In the light of this striking pattern, it is important to highlight the fact that apart from manufacturing, all the other sectors of the local market in Kent expanded. Overall, the changes in jobs related to financial and service activities were higher than the growth observed in the production sectors. Since the major composition of the commuting to Central London is comprised of professional, managers and clerical, one would expect a significant diversion at least of these three segments of the long distance commuting to the local job market. Clearly, the expected reduction in commuting from the areas of expanded local economy did not happen in Kent. One may speculate that the most specialised activities, which are particularly developed in the headquarters of the big establishments, remained captive to the Central London market during the 1980's.

Evidence of a high number of immigrants to Mid-Kent who kept their jobs in Central London supports the postulate that employees in Central London moved to Kent mainly due to life cycle and better housing. Since this group of people did not primarily intend to change jobs, they moved with the presupposition of commuting to the central area.

The notable expansion of the commuting population of 35-44 years of age, which was partially caused by immigration to Kent, reinforces the conclusion that life cycle is a relevant element in the decentralisation of population from London, and in the changes of the commuting patterns.

Improvements in accessibility might have played a part in the decision process of relocation. Evidence of the reduction of some 4% in train inter-changes in commuting trips to Central London were shown, particularly in some of the long distance journeys. The perception of the quality of the services, as given by the marginal difference between the average travel time reported by the users and the actual time provided by the British Rail timetable, can be pinpointed as another possible factor considered in the decision process of moving out and commuting to the city.

Improvements in accessibility are also corroborated by the location of rail commuters of higher classes, and therefore with expected high valuation of time, at increasing distances in Kent. In 1981, the large proportion of the commuters classified as professional and managers originated in Sevenoaks, whereas in 1989, a reduced but still the highest concentration of this segment of the commuting population was in Swale.

Overall, there was a real increase in rail fares of some 25% that might have been off-set by the increase in wealth of the commuters. Some signs of the effect of travelcard on the commuting choices for stations, particularly those in Outer London across the boundaries, were detected. However, given the constraints of time and resources to carry out a fuller exploration of this issue, no conclusive remark of the effect of travelcard on the patterns of commuting into Central London may be stated.

A restriction identified in the modelling framework concerns the fact that the model presumes that all commuters are choosing a job, having already got a home in Kent. Also, no allowance can be made within the model for influences on the number of jobs in Central London, such as economic growth or restructuring of the London economy leading to changes in the job mix. The effect due to the former assumption was not clearly identified in the results obtained. However, the latter might have affected the model estimates, which were slightly above the actual commuting flows, in 1981, whereas in 1989 were underestimated. It is proposed that, in practice, the model should be used to forecast the distribution of a given number of commuters between origin zones rather than the absolute flow of commuters.

Fruitful results were obtained in the modelling of the choice process regarding the commuting alternatives rail to Central London and any mode to elsewhere. Investigation of the level of local flows showed that the local employment catchment area was within the radius of 5-10 km distance from the ward's centre. Better results for the catchment area of 5 km distance are given by the model which considers only specialised local jobs. However, the 10 km area is favoured if all categories of local employment are considered.

A notable feature of the model developed here concerns its ability to measure the long term effects of population and job locations. This characteristic represents a significant departure from most of the previous studies, which looked only at short run effects of these two socio economic aspects of the commuting.

Given this property of the model, the rail elasticities found are apparently higher than the current ones shown in the literature. For instance, a reduction of 10% in the travel time will cause an increase of 13.4% in the rail commuting from Maidstone to Central London, if the travel times from all other zones is held constant. The high figures are compatible with the fact that they measure the growth in rail demand due to improvements in services to particular zones of Kent, disregarding the compensating changes elsewhere and allowing for long run population and job changes.

Evidence given by Mackett and Nash (1991) confirm that a model which looks at long-term relocation effects will present higher elasticity values. Moreover, their study on the Chiltern line, considered in isolation of the rest of the South-East sector, gives support for the high elasticities found in this thesis.

When assessed in terms of its responsiveness to policy changes, the model showed that at reduced journey times, rail demand would still be elastic with respect to speed. The elasticities indicated that there is a significant potential for improving the level of flows by journey time reduction. However, given the similarities of both the Kent and the Chiltern case studies, one might be aware that the high elasticities obtained here reflect people relocating and taking advantage of the improved accessibility, when journey time from a particular zone is improved, and cannot be used to predict the effect of a general improvement for all zones.

Clearly, the model represents an important tool in the analysis of the relative distribution of commuters amongst the districts of Kent. It is particularly appealing as concerns the evaluation of the catchment area of new stations, and so might be useful for the analysis of the Mid-Kent Parkway station proposal.

Overall, this thesis has demonstrated that the simultaneous process of long term relocation of people and jobs, the switch of job categories in the London market, and the improvements occurred in the transport system explained some relevant changes in the commuting patterns observed during the 1980's. A striking and important finding was that Mid-Kent presented significant levels of commuting to Central London alongside the expansion of the local economy in the area. This is explained by the overall moving-in and out of people in the metropolis according to the life cycle, and the availability of employment opportunities provided by the relevant switch of jobs in Central London.

10.3 - SUGGESTIONS FOR FURTHER RESEARCH

In various parts of this thesis, many issues were claimed as requiring a more detailed examination. This section attempts to bring them together to provide a better picture of the missing elements that could possibly strength some of the suggestions and evidence found in this work, as well as unveil some other features that were not properly explained.

Two major areas for research may be identified. One involves the interchange of and between modes in the access to local stations, and is particularly concerned with the cases of origin stations outside the residential district of the commuter. This area comprises the overall effects of the 'park and ride' within Kent, and its particular implications concerning the Mid-Kent Parkway station project. A comprehensive analysis of the existing rail data will be required.

The 'park and ride' issue, which here stands for any mode of transport rather than only cars, clearly deserves more research. There were signs of a high number of commuters originated in one district who initiate their trips in stations located in another area. The connection of this matter with faster trains or the travelcard benefits were envisaged but not investigated. Also the application of the model developed in this thesis, in the investigation of the catchment area of the Mid-Kent Parkway station will be certainly fruitful.

Another related issue in this field is the implications of travelcards on the changes in the commuting patterns from Kent. Given the benefits provided by this special ticket and the observed growth of commuting from Sevenoaks, the diversion of the traffic to the stations of Sevenoaks or even across the border of Outer London needs to be better explored.

The other area, which involves the complex analysis of migration, attempt to shed some more light on the simultaneous and opposing expansion of local economy and commuting in Mid-Kent. Some insights to explain the expansion of the local economy in places of growing commuting might be provided by the analysis of migration in Kent. The investigation of the segment of the economic population rather than the total population might also be more appropriate. A comprehensive and accurate source of information for this kind of analysis is provided by the Census of Population, and particularly appropriate is the 1991 Census whose results are about to be released.

APPENDICES

Appendix 1.1

Wards and Enumeration Districts of Central London Boroughs

Borough	Wards (EDs)
City of London	Aldersgate, Aldgate, Bassishaw, Billingsgate, Bishopsgate, Bread Street, Bridge, Broad St., Candlewick, Castle Baynard, Cheap, Coleman St., Cordwainer, Cornhill, Cripplegate, Dowgate, Farringdon Within, Farringdon Without, Langbourn, Lime St., Portsoken, Queenhithe, Tower, Vintry, Walbrook.
Camden	Bloomsbury, Brunswick, Holborn, King's Cross, Regent's Park (EDs ABAW 26,29,30,33), St. Pancras (ED ABAY 20), Somers Town(EDs ABAZ 01, 06, 14-22).
Hackney	Moorfields (EDs ACAL 01, 02).
Islington	Barnsbury (ED AFAA 01-05), Bunhill, Clerkenwell, St.Mary (ES AFAR 03), St.Peter (ED AFAS 11), Thornhill (ED AFAU 03).
Kensington and Chelsea	Brompton (EDs AGAC 01, 02), Hans Town (EDs AGAL 1-10,31,32,35,36), Royal Hospital (EDs AGAU 01-04, 21).
Lambeth	Bishop's (ED AHAB 01-13, 24-29), Prince's (ED AHAL 20).
Southwark	Abbey (EDs ALAA 02, 20), Browning (EDs ALAF 01-03), Cathedral, Chauser (EDs ALAK 01-10), Newington (ED ALAT 01), Riverside (EDs ALAU 01-04, 06)
Tower Hamlets	St. Katherine's (EDs AMAP 22-24), Spitalfields (Eds AMAT 01-05, 24).
City of Westminster	Baker St., Belgrave, Bryanston, Cavendish, Churchill, Church St.(EDs APAG 16-24), Hyde Park, Knightsbridge (EDs APAL 02-20, 22, 23, 25, 26), Millbank, Regent's Park (Eds APAT 26, 27, 30-33), St. George's, St. James, Victoria, West End.

Sources: Preston, J. (1986) and OPCS (1981)

Appendix 5.1

Stations in Kent surveyed in 1981 and 1989

Adisham
Ashford
Aylesham
Barming
Bat & Ball
Bearstead
Beckesbourne
Borough Green & Wrotham
Broadstairs
Canterbury East
Canterbury West
Charing
Chartham
Chestfield & Swalecliffe
Chilham
Deal
Dover Priory
Dumpton Park
Dunton Green
East Malling
Eynsford
Farningham Road
Faversham
Folkestone Central
Folkestone West
Gillingham
Harrietsham
Headcorn
Hildenborough
Hollingbourne
Kemsley
Lenham
Kearsney
Kemsing
Longfield
Maidstone East
Marden
Margate
Martin Mill
Newington
Otford
Paddock Wood
Pluckley
Queensborough
Rainham
Ramsgate
Sandling
Sandwich
Selling
Sevenoaks
Shepherd's Well
Sheerness-on-Sea
Shoreham
Sittingbourne
Staplehurst
Sturry
Swanley
Teynham
Tonbridge
Walmer
West Malling
Westenhanger
Whitstable
Wye

Appendix 6.1

Counties and Districts of Outer Metropolitan and Outer South East Areas

County	Districts Outer Metropolitan	Districts Outer South East
Bedforshire	Luton, South Bedfordshire	Mid Bedfordshire, North Bedfordshire
Berkshire	Blackbell, Reading, Slough, Windsor & Maidenhead, Wokingham	Newbury
Buckinghamshire	Chiltern, South Buckinghamshire	Aylesbury Vale, Milton Keynes
Essex	Basildon, Brentwood, Castle Point, Chelmsford, Epping Forest, Harlow, Rochford, Southend-on-Sea, Thurrock	Braintree, Colchester, Maldon, Tendring, Uttesford
Kent	Dartford, Gillingham, Gravesham, Maidstone, Rochester, Sevenoaks, Tonbridge, Tunbridge Wells	Ashford, Canterbury, Dover, Shepway, Swale, Thanet
West Sussex	Crawley, Horsham, Mid Sussex	Adur, Arun, Chichester, Worthing
Hertfordshire	all	-
Surrey	all	-
East Sussex	-	all
Isle of Wight	-	all
Oxfordshire	-	all
Hampshire	Hart, Rushmcor	Basingstoke & Deane, East Hampshire, Eastleigh, Fareham, Gosport, Havant, New Forest, Portsmouth, Southampton, Test Valley, Winchester

REFERENCES

Aldrich J.H. and F.S.Nelson (1984) Linear probability, logit and probit models. Series:Quantitative applications in the social sciences. Series no.07-045. Sage Publications.

Angel S. & G.M.Hyman (1976) Urban field : a geometry of movement for regional science. Pion Ltd.

Bayliss D. (1991) Transport in London: the background. In S. Glaister (ed.) Transport options for London. Greater London Group, Greater London Papers, no. 18. ed.

Bayliss D. (1987) Transport subsidy costs and benefits:the case of London Transport. In A. Jarrison & J.Gretton (ed.) Policy Journals. Transport UK 1987: an economic, social and policy audit.

Ben-Akiva M. and S.R. Lerman (1985) Discrete choice analysis:theory and application to travel demand. The MIT Press, Cambridge.

Ben-Akiva M., A. Daly and H.Gunn (1987). Destination choice models : design and appraisal. PTRC. Summer annual meeting. Seminar C, pp 99-116

Ben-Akiva M. and S.R. Lerman (1979) Disaggregate travel and mobility-choice models and measures of accessibility. In D.A.Hensher and P.R.Stopher (eds) Behavioral Travel Modelling, Croom Helm, London.

Browns A.H. (1981) Commuter travel trends in London and South East 1966-79 : and associated factors. Department of Transports. London

Buck N., I.Gordon and K.Young (1986) The London Employment Problem. Clarendon Press. Oxford.

Bruzelius N.A. (1981) Microeconomic theory and generalised cost. Transportation, vol 10, pp 233-245.

Buchanan M., N.Bursey, K.Lewis and P.Mullen (1980) Transport planning for Greater London.Saxon House, Farnborough, Hants.

Champion A.G.(1989) United Kingdom:population deconcentration as a cyclic phenomenon. In A.G.Champion (ed.) Counterurbanization.

Clout H. and J.Burguess (1978) Central London. In Hugh Cout (ed.) Changing London. University Tutorial Press Ltd.

Cook R.D. (1977) Detection of influential observations in linear regression.Technometrics, 19, pp. 15-18.

Copley G., G.Hyman, A.H.Meechan and D.A Swain (1988) Distribution and mode choice modeling in London. 16th PTRC. Transportation Planning Methods, Seminar D, pp 123-142.

Cross D.F.W. (1988) Characteristics pf non-metropolitan population growth in England and Wales, 1971-1986. PhD Thesis. Politechnic of Central London. University of London

Dalvi M.Q. & K.M.Martin (1976) The measurement of accessibility:some preliminary results. Transportation no.5, pp 17-42.

Dasgupta M. (1991) Longer term issues in transport. In J.H.Rickard & J.Larkinson (eds.). Proceedings of a research conference sponsored by the Department of Transport.

Dasgupta M., M.Frost and N.Spence (1990a) Mode choice in travel to work in British cities 1971-1981. Research Paper. Department of Geography. London School of Economics.

Dasgupta M., M.Frost and N.Spence (1990b) Employment patterns and travel distances in British cities 1971-1981. Research Paper. Department of Geography. London School of Economics.

Dasgupta M., M.Frost and N.Spence (1990c) Journey to work trends in British cities 1971-1981. Research Paper. Department of Geography. London School of Economics.

Department of Employment (1985) Employment Gazette, issue May 1985, Government Statistical Office.

Department of Employment (1992) New Earnings Survey 1992, Government Statistical Office.

Department of Transports (1992) Transport Statistics Great Britain

Department of Transports (1991) Transport Statistics Report : Transport Statistics for Greater London

Department of Transports (1989) Transport Statistics Report for London. HMSO

Domencich T. and D.McFadden (1975) Urban Travel Demand-A Behavioral Analysis. Contributions to Economic Analysis, v.93. North-Holland Publishing Company, Amsterdam.

Economic Consultants Limited (1973) The Channel Tunnel:its economic and social impact on Kent. Report presented to the Secretary of State for the Environment

Economic Trends (1992) Annual Supplement. Central Statistical Office. Great Britain.

Evans A.W. (1985) Urban Economics:an introduction. Basil Blackwells. Oxford.

Evans A.W. (1973) The economics of residential location. Macmillan Ed.

Evans A.W. (1969) Intercity travel and the London Midland electrification. Journal of Transport Economics and Policy, vol 3 no.1

Fairhead R.D., R.L.Jackson and P.F.Watts (1983) Developments in long-distance commuter coaching following the Transport Act 1980. TRRL. Laboratory Report 1038. Crowthorne, Berkshire.

Fairhurst M.H., J.F. Lindsay and M.Sing (1987) Traffic trends since 1970: an analysis of London bus and underground travel trends (1970-85). Economic Research Report R266. Group Planning Office. London Transport Executive.

Fairhurst M.H. and J.F. Lindsay (1984) The London transport fares experience 1981-1983. Economic Research Report R259. Group Planning Office. London Transport Executive

Fairhurst M.H.(1981) Why Simplify? A case for simplified fares. Economic Research Report R244. Planning and Appraisal Division. Group Finance and Planning Department. London Transport Executive.

Foster C.D. and M.E.Beesley (1963) Estimating the social benefit of constructing an underground railway in London. Journal of the Royal Statistical Society, series A, v. 126, pp.46-92

Fowkes A.S. (1986) The UK Department of Transport value of time project. International Journal of Transport Economics. vol.XIII, no. 2.

Fowkes A.S., C. Nash and A.E.Whiteing (1985) Understanding trends in inter-city rail traffic in Great Britain. Transportation Planning and Technology, vol 10, pp 65-80.

Gilje E.K. (1985) The flight from the metropolis: the London experience. In Greater London Council (ed.) Metropolis 84. GLC papers, Review and Studies Series:no.24.

Glaister S. (1991) An economic historic of public transport in London in the last three decades. In S. Glaister (ed.) Transport Options for London. Greater London Group. Greater London Papers, no. 18 .

Glaister S. (1983) Some characateristics of rail commuter demand. Journal of Transport Economics and Policy, vol xvii, no.2, pp 115-132.

Greater London Council (1985) Company assisted motoring in London. Review and studies series:no.27.

Gujarati D.N. (1988) Basic Economitrics. McGraw-Hill International Editions. 2nd. ed.

Hall P. (1989) London 2001. Unwin Hyman. London.

Hall P. (1984) The world cities. 3rd. ed. Weidenfield and Nicholson, London.

Hall P., M.Breheny, R.McQuaid and D.Hart (1987) Western Sunrise. The genesis and growth of Britain's major high-tech corridor. London.

Hepburn D.R.C.(1977) Analysis of changes in rail commuting to Central London, 1966-71. Transport and Road Research Laboratory, Supplementary Report 268

Hertfordshire County Council (1990) Rail commuting from Hertfordshire, 1966-1986. Forward Planning Group, County Planning & States Department.

Johnson I. and C.Nash (1982) Transport and location decisions of rail commuters to Central London - some evidences. Institute for Transport Studies. The University of Leeds, TN101.

Jones I.S. and A. Nichols (1983) The demand for inter city rail travel in the United Kingdom:some evidence. Journal of the Transport Economics and Policy, vol xvii, no.2, pp 133-154.

Keeble D.E. (1968) Industrial decentralisation and the metropolis:the north-west London case. Transactions and papers, Institute of British Geographers, 44, 1-54

Kennedy P. (1979) A guide to econometrics. Martin Robertson. Oxford.

Kent County Council (1987) Transport Policies and Programme for Kent, 1987.

Kirby H.R. (1979) Is distance no object ? Location behaviour and the journey to work. Institute for Transport Studies. The University of Leeds, TN 22.

Kirby H.R. and Raji F.A.O. (1992) Location behaviour and the journey to work. 6th World Conference on Transport Research, paper no.352. Lyon.

Lomas G.(1973) Labour and life in London. In David Donnison and David Everly (eds.) London:urban patterns,problems, and policies. Heinemann. London.

Luce R.D. and P.Suppes (1965) Preference,utility, and subjective probability. In R.D.Luce,R.Bush, and E.Galander (eds.) Handbook of Mathematical Psychology, vol 3.New York:John Wiley.

Mackett R. and C.Nash (1991) Commuting. In T.Fowkes and C.Nash (eds.) Analysing demand for rail travel. Institute for Transport Studies, vol.4. Avebury.

Mackett R. (1985) Modelling the impact of rail fare increases. Transportation, vol. 12, pp293-312.

Mackett R. and J.Bird (1989) Commuting in South-East England. Report to the British Railways Board. University College London. Transport Studies Group.

Mackie P. (1987) Local transport under conservative. In A. Jarrison and J.Gretton (ed.) Policy Journals. Transport UK 1987 - an economic, social and policy audit.

McFadden D. (1973) Conditional logit analysis of qualitative choice behavior. In P.Zarembka (ed). Frontiers in Econometrics, New York:Academic Press.

Martinez F.J.(1991) The impact of urban transport investment on land development and land values. PhD thesis. School of Business and Economic Studies. The University of Leeds.

MATPAC User's Manual (1989) University of Manchester Regional Computer Centre. 1st ed.

Miron J.R. (1978) Job-search perspectives on migration behaviour. Environment and Planning A, vol 10, pp 519-535.

Monopolies and Mergers Commission (1987) British Railways Board : Network South East. A report on rail passenger services supplied by the Board in the South East of England. Cm 204, Bluebooks British, Commons.

MVA Consultancy, Institute for Transport Studies of the University of Leeds, and Transport Studies Unit of the University of Oxford (1987) The value of travel time savings. A report of research undertaken for the Department of Transport. Policy Journals, Newbury, Berkshire.

Nash C. (1991) Needs,sources and methods. In T.Fowkes and C.Nash (eds.) Analysing demand for rail travel. Institute for Transport Studies, vol.4. Avebury.

National Economic Development Council (1991) Company cars:an international perspective . Traffic Managment Systems. Working party. London.

Office of Population Censuses and Surveys (1991) County Monitor. 1991 Census. Kent. CEN 91 CM24. HMSO.

Office of Population Censuses and Surveys (1982a) Census 1981. County report Kent, part 1. CEN 81 CR 24. HMSO

Office of Population Censuses and Surveys (1982b) Census 1981. Historical tables 1801-1981, England and Wales. CEN 81 HT. HMSO

Office of Population Censuses and Surveys (1981) Definition. Great Britain. HMSO.

Office of Population Censuses and Surveys (1980) Classification of occupations. HMSO.

Office of Population Censuses and Surveys (1971) County Report:London. HMSO

Office of Population Censuses and Surveys (1951) Census of Population. Counties : London. HMSO

Office of Population Censuses and Surveys (1901) Census of Population. Counties : London. HMSO

Ortuzar J.D. and L.G.Willunsen (1990). Modelling Transport. Chichester:Wiley

Owen A. and G.D.Phillips (1987) The characteristics of railway passenger demand:an econometric investigation. Journal of Transport Economics and Policy.

Pindyck R.S. and Rubinfeld D.L. (1976). Econometric Models and Economic Forecasts. McGraw-Hill Book Company.

Preston J.M. (1986a) Analysis of coach and rail commuters in North Kent. Institute for Transport Studies. The University of Leeds, TN187.

Preston J.M. (1986b) Trends in commuting to Central London 1971-81:evidences from the 1981 Census. Institute for Transport Studies. The University of Leeds, TN188.

Preston J.M. and C.Nash (1986) Location and commuting. Further analysis of the Hertfordshire household interviews. Institute for Transport Studies. The University of Leeds, TN189.

Robbin D. and P. White (1985) Deregulation of express coach services : has the 1980 Act worked ?. In A. Jarrison & J.Gretton (ed.) Policy Journals. Transport UK 1985 - an economic, social and policy audit.

Serplan (1990) Public Transport in South-East England. A review of current trends and issues. South East Regional Monitor 1989-90. Technical Appendix. RPC 1733

Shepherd L. (1974) Choice of the mode of travel to work in Perth. Seminar in quatitative economics E 585. Department of Econometrics and Operations Research. Monash University. Australia.

Sly F. (1986) British Rail origin and destination survey:London and South-East 1981-1982. Statistics Bulletin 42. Department of Transport , Statistics Branch, RA Division.

Staveley P. (1989) The role of commuter coach services in London. MSc. in Transport Planning and Management. Polytechnic of Central London. Transport Studies Group.

Steinnes D.N. (1982) Do 'people follow jobs' or do 'jobs follow people'? A causality issue in urban economics. Urban Studies, vol.19, pp.187-192.

Terzis G.C. (1988) The longitudinal method: an application to public transport policies in London. Transport Studies Group, University College London.

Tyler J. and R. Hassard (1973) Gravity/elasticity models for the planning of inter-urban rail passenger business. PTRC Summer Annual Meeting, Brighton

Wabe J.S. (1969) Commuter travel into Central London. Journal of Transport Economics and Policy, vol.3, no.1.

Weinberg D.H. (1979) The determinants of intra-urban household mobility. Regional Science and Urban Economics, vol 9.

Williams H.C.W.L. (1977) On the formation of travel demand model and economic evaluation measures of user benefit. Environment and Planning, A, vol. 9, pp.285-344.

Williams H.C.W.L. and Senior (1977) Model-based transport policy assessment: 2. Removing fundamental inconsistences from the models. Traffic Engineering and Control, vol 18, pp 464-469

W S Atkins Planning Consultants (1990) Midway Parkay surveys components. Final Report. A report to Kent County Council and Ecotech Research and Consulting Ltd.