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The Adaptable City: The Use of Transit Investment and Congestion Pricing to Influence Travel and Location Decisions in London

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The Adaptable City:
The Use of Transit Investment and Congestion Pricing to Influence Travel and Location Decisions in London

by

Andrea Lynn Broaddus

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ABSTRACT

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This dissertation investigates two key transportation policies influencing travel behavior and location decisions in London towards sustainability: bus priority and congestion charging. Traffic congestion is a problem faced by cities worldwide, imposing time delays on travelers and decreasing economic efficiency. Congestion is increasing as cities are successful at attracting population and employment growth. This increasing urban density increases competition for urban road space, resulting in traffic congestion and forcing prioritization among road users. At the same time, sustainability goals increasingly set reduction targets for vehicle miles travelled (VMT). Transportation policy must both reduce congestion and VMT, while maintaining a fair distribution of costs and benefits among residents. London has navigated these challenges through pairing bus priority as a 'carrot' and congestion charging as a 'stick' policy. Beginning in the late 1990s with the introduction of a bus priority network, and continuing with the 2003 introduction of congestion charging in the central business district, London has achieved a decade-long trend of declining VMT and mode shift to transit and non-motorized modes. This research investigates the processes of how they were implemented, including consideration of the necessary politics, financing, and institutional authority. The synergistic impacts of these two policies over a decade is investigated in three dimensions: travel behavior, costs and benefits, and firm location decisions.

First, the role of bus priority in the successful implementation of congestion charging is explored. Built from 1994 to 2003, London's regional bus priority network was in place when congestion charging implemented in 2003. The development and scope of this bus priority network is discussed using previously unpublished data. It was found that approximately 15% of London's arterial road network was reallocated to create a 1,100 mile (1,800 km) regional network of dedicated bus lanes. An analysis of Census travel to work data before and after congestion charging showed that declines in driving and increases in bus ridership were highest along bus network corridors. It is argued that bus priority explains why car use and VMT began

to decline the London region in 1999, and then played a key role in preparing transport system capacity to absorb drivers switching to transit.

Secondly, the costs and benefits of London's congestion charging policy are evaluated over the decade since it was implemented in 2003. Due to the rare implementation of congestion charging, this study is the first longer-term evaluation of a congestion charging policy using empirical data. It is the first to consider impacts on Londoner's culture and attitudes, and reasons why the central charge zone was non-controversial while the western extension zone was removed. The research revealed congestion charging has had wider impacts on traffic levels beyond the charged zone, leading to travel time savings for vehicular traffic throughout Inner London. It had mixed results in meeting its stated goals of reducing traffic volumes, increasing vehicle travel speeds, improving public transit service, reducing vehicle emissions, and improving safety for bicycles and pedestrians. Traffic volumes entering the charged area fell immediately and remained stable, while transit ridership increased and has continued an upward trend. However, travel speeds increased in the short term but fell in the longer term, such that congestion levels today in the charged zone are approximately the same as they were before congestion charging. The study found that this is not considered a negative outcome by city officials. By clearing cars off the roads, congestion charging allowed for a 'capacity grab' where road space and travel time savings were reallocated to buses and pedestrians. Bus speeds and reliability have vastly improved, pedestrian fatality and serious injury rates have plummeted, bicycle use has more than doubled, and air quality has shown some small benefits. City officials assert these outcomes would not have been achievable without the network reconfigurations made possible by released capacity.

Thirdly, the longer-term impacts of the accessibility improvements realized in the central charged zone (CCZ) due to bus priority and congestion charging were investigated. It was hypothesized that improved accessibility in the congestion charging zone is being capitalized into higher land and rent costs. Firms valuing accessibility were expected to be the most likely to remain or to move in, in spite of rising rents. This hypothesis was tested using two panels of firms for the period 1997 to 2012 created with microdata from the UK Business Structure Database (BSD). One panel had only micro enterprises with ten or fewer employees, the other had larger firms with more than ten employees. Rent and accessibility data was added to each panel to explore the role of these factors. The study found the concentration of larger firms has been increasing inside the CCZ since 2004. Industry sectors that depend upon agglomeration economies have been concentrating there at the highest rate, especially 'knowledge' industries like Computers/Telecomm/Research & Development and Business Management Consulting. Evidence was found of increased churn, or rates of firm relocation into and out of the CCZ. For larger firms, the ratio of moves in to moves out increased from 1.02 in 1998-2002 to 1.14 in 2008-2012, indicating a preference for locating in the CCZ. Most firms that moved into the CCZ improved their transit accessibility by 20% to 40%. The net flow of jobs moving in to out also increased from .80 in 1998-2002 to 1.16 in 2008-2012. Retention of tourism sector firms increased in the CCZ, including Theatre & Cinema and Sports & Culture. Sectors vulnerable to rising rents and factor costs, including Retail and Restaurants, had increased odds of moving out of the CCZ. Rising rents were a statistically significant factor for firms moving out, and these firms were likely to have reduced accessibility after the move. The pull of accessibility on firms moving into the CCZ was stronger than the push of rising rents on those moving out.

The dissertation concludes with a discussion of the findings, policy implications, and next steps for research.

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Chapter 1. Introduction

This dissertation considers London as a bellwether, a modern global city that has successfully adapted its transport system to support a 21st century services-based economy where efficient flows of people and information determine success or failure.

Transportation planners in growing cities face three key challenges of urbanization: proliferation of vehicles, competition for road space, and the fair distribution of policy benefits and burdens. Increasing urban density increases competition for urban road space, resulting in traffic congestion and forcing prioritization among road users. Sustainability goals increasingly set reduction targets for vehicle miles travelled (VMT), setting the stage for unpopular policy measures aimed at getting people out of cars, such as congestion pricing. Planners must strive to be fair when responding to these pressures, and ensure that costs and benefits are distributed progressively among residents.

London offers a case study exemplifying the navigation of these challenges through the use of paired ‘carrot’ and ‘stick’ policies aimed at reducing private car travel. Beginning in the late 1990s with the introduction of a bus priority network, and continuing with the 2003 introduction of congestion charging in the central business district, London has enjoyed a decade-long trend of declining VMT and mode shift to transit and non-motorized modes. This achievement is especially significant given that London experienced strong economic and population growth during this timeframe, factors which typically drive VMT growth.

Figure 1.1 illustrates London’s success as reducing VMT, compared the national trend in the rest of England. It shows that VMT increased in London until about 1999, and then the trend reversed from growth to decline. Notably, VMT has been decreasing in both densely populated Inner and more suburban Outer London. A regional bus priority network was developed in earnest from 1997 to 2003, in preparation for congestion charging. VMT began to decline as bus services improved, and at an increased rate after congestion charging began in 2003.

The reason for VMT decline was people switching travel modes away from driving, to public transit and bicycling. Travel grew steadily over this timeframe, from 23 million daily journey stages in 1993 to 30.3 million in 2012, an increase of 32%. As shown in Figure 1.2, 47% of trips were made by car or taxi in 1993, but only 34% were in 2012. Meantime, bus travel grew from 13% of trips in 1993 to 21% in 2012, travel by rail transit grew from 9% to 12%, and travel by commuter rail grew from 6% to 9%. Bus travel accounted for 40% of the 7.3 million new trips added to the system over this timeframe, twice as much growth as travel by Underground (19%) or commuter rail (19%).

This dissertation investigates two key transportation policies behind these outcomes, bus priority and congestion charging, as well as how firm location patterns have evolved since they were implemented in London.

Figure 1.1 VMT trend for private cars in London compared to England (1993=100)

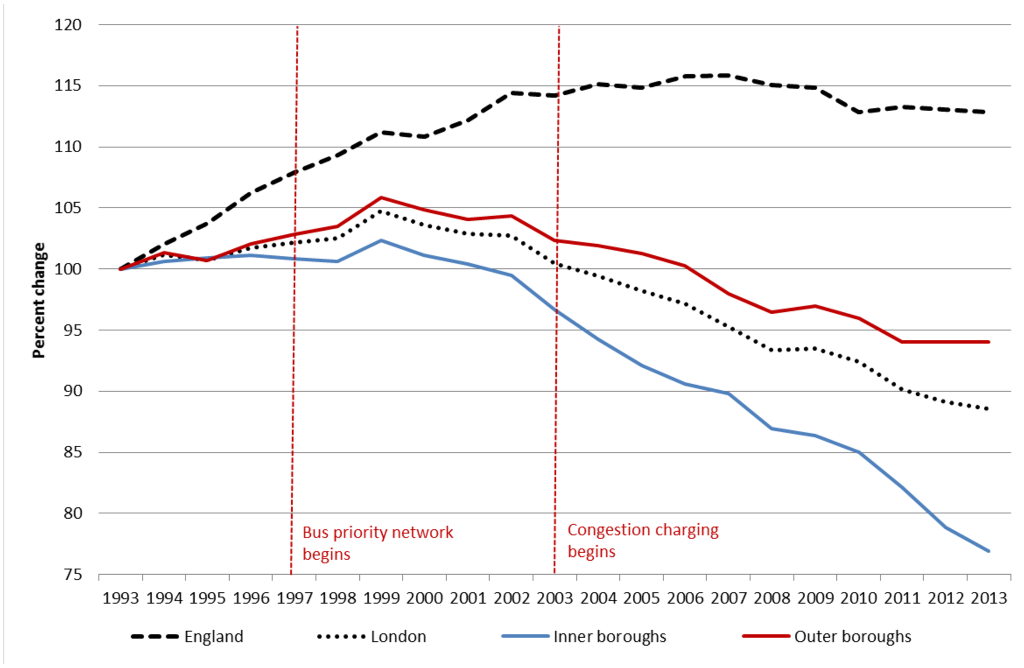
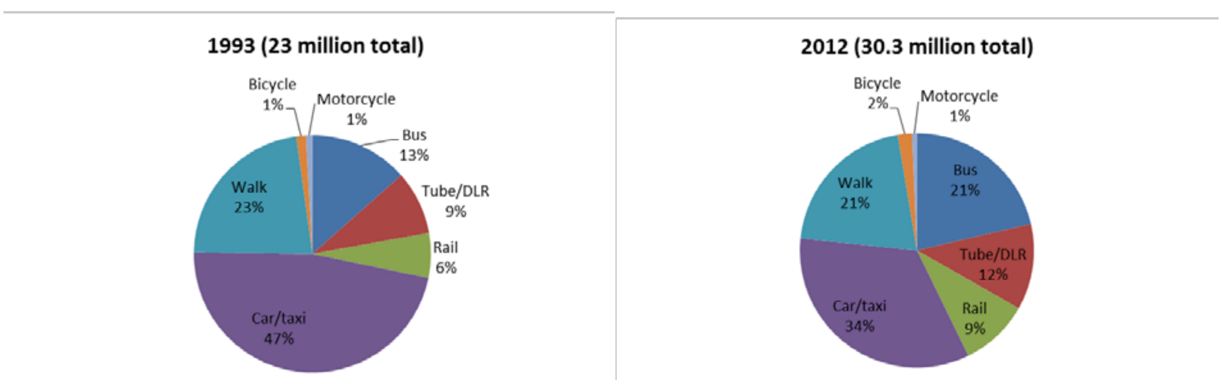


Figure 1.2 Mode split among total daily journey stages in Greater London



1.1 Research questions

This dissertation explores how London was able to achieve what many vehicle-clogged cities are striving for today: reduced traffic congestion and mode shift away from cars. It investigates how bus priority and congestion charging were implemented, with consideration of the necessary politics, financing, and institutional authority. The synergistic impacts of these paired policies over a decade is investigated in three dimensions: travel behavior, costs and benefits, and firm location decisions.

Three key questions about the London case are posed in this dissertation, across three main chapters which are intended to serve as stand-alone papers:

1. What was the role of bus priority in achieving mode shift and gaining public acceptance for congestion charging?
2. Have the initial traffic reduction benefits of congestion charging endured, has its financial performance improved, and were there any unexpected impacts, over the ten years since it was implemented? Why is the central zone non-controversial while the Western Extension zone was removed?
3. Has employment in the charged area tended to disperse or concentrate, and which industries were the most sensitive to the impacts of congestion charging and improved transit accessibility?

These specific research questions were prompted by noting gaps in the congestion pricing and travel demand management literature, and by my observations while doing fieldwork in London.

Previous studies about the London congestion charge and other cities where a similar policy has been implemented may note that bus services were an important complementary strategy, usually not much detail is given about the scope and quality of service changes. Traveling around London, I was struck by the prevalence of dedicated bus lanes throughout the region. This observation was corroborated during interviews, when bus priority was often noted as a key transportation policy affecting travel behavior. When I investigated the policy origin of the bus lanes, I discovered a major regional bus network which has not been documented in academic or policy journals. Much of the data presented in Chapter 4 was provided to me directly by the Head of Bus Network Development at Transport for London, including the GIS layers which allowed me to calculate the extent of the bus network. I pieced together the story of how the network was built from interviews and articles in obscure English engineering journals.

A ten-year policy evaluation of the London congestion charge fills an obvious gap in the literature: so few cities have congestion charging that empirical data is very scarce. My initial research question was simply, what happened over ten years—is congestion charging still working as planned? An additional question emerged from the literature, a disagreement in early policy evaluations as to whether the system was financially sustainable or not. Further questions emerged from my interviews, when I learned that congestion levels had returned to pre-congestion charging levels. Through my interviews with the Planning Director at Transport for London that I learned rising congestion levels were not considered a failure, but an unexpected—and welcome—result of road space reallocation within the charged area.

My third research question emerged from the literature and from reflecting upon how changes in vehicular access and transit access might affect location decisions. Whitehead proposed that congestion charging influences decisions on three orders, over time: first order travel decisions by drivers (mode, route, and time of day), second order location decisions by households and firms (to optimize new accessibility), and third order land use and infrastructure decisions by governments and developers (to build new roads, transit, housing, offices, retail, etc). (Whitehead 2002) This chapter of the dissertation addresses ‘second order’ location decisions. In my prospectus, I initially set out to investigate how the congestion charge zone, as an ‘accessibility access zone’ might have begun to affect the location decisions of both firms and households. My committee wisely advised to choose one or the other. I chose to look at firms because of their importance to regional commute travel patterns. I found a debate within the congestion charging literature on the question of how firms would locate in a region with a congestion charge zone. In the absence of empirical data, theoretical models have been developed to predict whether firms would be influenced to locate inside the charged area, or avoid it, resulting in a net dispersal or concentration of employment. I addressed this question using a unique dataset of firm microdata that allowed for an unprecedented type of study using panels of firms to track movements over time. The methodology that I developed for the relocation analysis in Chapter 6 is original, as far as I am aware, as I did not find anything similar in the firm demography literature.

1.2 Overview of the dissertation

In this chapter, I discuss the motivation and key research questions of this dissertation, and define congestion charging. It concludes with a summary of original research contributions.

Chapter 2 gives an introduction to London’s transportation system and planning context. A brief history of the politics of transportation planning is given, emphasizing the importance of recent institutional reforms, and an overview of expansions to London’s rail network is given.

Chapter 3 describes six long-term trends in London’s population, employment, travel, and land use.

Chapter 4 addresses the role of bus priority, including re-allocation of road space, and describes the efforts to transform London’s buses to compete with cars. The specific ways in which bus services were improved as a complement to congestion charging are investigated. Previously unpublished data about London’s regional network of bus lanes is presented, along with the story of how it was built in three phases from 1992 to 2003.

Chapter 5 evaluates the costs and benefits of the congestion charging policy over its first decade. Time series data on traffic, safety, and bus reliability benefits is presented and discussed, as well as financial performance data. It concludes with a discussion of unexpected impacts of the policy on culture and attitudes.

Chapter 6 explores the longer-term impacts of the combination of reduced traffic congestion and improved transit services in the congestion charge zone (CCZ), using location decisions by firms as an indicator which industry sectors benefit most from these accessibility changes. It is hypothesized that improved accessibility is being capitalized into higher rents in the CCZ, influencing the industry sectors who benefit least to locate elsewhere or move out.

The dissertation concludes in Chapter 7 with a re-cap and synthesis of the major findings and their policy implications, and a discussion of remaining questions.

1.3 Congestion charging: rationale and issues with implementation

Traffic congestion is a condition on urban road networks that occurs as use increases, where excess demand at peak times and on key routes results in traffic levels that approach or exceed road capacity, resulting in travel delay for drivers. (Meyer and Miller 1984) Traffic congestion is characterized by slower speeds, longer trip times, and increased vehicular queueing. It is a diseconomy of urban agglomeration, and most modern cities have levels of traffic congestion, where excess traveler delay and fuel consumption are considered excessive and wasteful. For instance, in 2010 car commuters in U.S. cities experienced an average of 34 hours of delay in traffic congestion per year, costing each an estimated $750. (Schrank, Lomax et al. 2011)

The idea of congestion charging emerged from economic theory. The economist Arthur Pigou developed the concept of economic externalities and proposed that negative externalities be taxed in order to increase economic efficiency. (Pigou 1920) Later, Nobel-laureate economist William Vickrey applied the idea to the case of traffic congestion, where the negative externality is the delay imposed by one driver on all other drivers using a congested road. (Vickrey 1963) Congestion costs due to a particular vehicle have two components: an internal cost consisting of the value of time delay to the occupants of that vehicle, and an external cost consisting mainly of the value of time delay to all other users of the roadway, plus environmental impacts. Vickrey proposed that the price of road use should reflect, as closely as possible, the marginal social cost of each additional road user in terms of the costs that user imposes upon others. (Vickrey 1969)

Ideally, congestion charging would optimize road use by targeting the three prongs of the ‘triple convergence’ problem of traffic congestion: delay resulting from crowding by single-occupant vehicles on major routes at peak times of day. (Downs 1992) In practice, non-optimal ‘second-best’ congestion charges that are simpler to understand and communicate are most often proposed. The level of the charge is set based on a combination of cost recovery and political feasibility. (King, Manville et al. 2008) It needs to be high enough to cover the costs of building, operating and enforcing the system, and to achieve the desired traffic reductions, but not so high that it will fail on the ballot.

Congestion charging remained in the realm of economic theory for decades, in part due to technical limitations on implementation. The first city to experiment with congestion charging, Singapore, introduced a system in 1975 using paper licenses displayed in the vehicle windscreen. This low-tech system was effective: it led to an immediate 45% reduction in traffic and a 25%

decline in vehicle crashes, even as average travel speeds increased from 11 mph to 21 mph in the charged area. (Phang and Toh 2004) The rise of information communications technologies (ICTs) has made it more feasible to implement electronic congestion charging systems, and to differentiate pricing levels by levels of traffic congestion. In 1995, Singapore became the first city to introduce an electronic road pricing system. Called ERP, the system requires every car to carry an on-board unit that communicates with sensors on an overhead gantry when the car passes underneath. (Goh 2002) A display tells drivers the current fee, based on the time of day and current traffic conditions, and then the fee is deducted from the drivers account.

Another reason that congestion charging has not been widely implemented is a lack of public support. In some cities, such as Edinburgh in 2005 and Manchester in 2008, congestion charging initiatives failed in spite of political leadership and institutional support when brought to a public vote on the ballot. (Gaunt, Rye et al. 2007, Vigar, Shaw et al. 2011) Privacy concerns and lack of perceived benefits were factors in Hong Kong failing to renew a successful pilot in the 1980's. (Hau 1990) The 'losers' from congestion pricing tend to set the debate—as noted by Deakin and Harvey, the beneficiaries of pricing are more difficult to mobilize, because the benefits of reduced traffic delay are diffuse and spread beyond drivers. (Deakin and Harvey 1996) Many argue that congestion charging revenues should be used to cross-subsidize public transit, so that time savings benefits are widely distributed across income groups, which makes the policy more fair and politically feasible. (Komanoff 1997, Levine and Garb 2002)

Despite these barriers, congestion pricing has increasingly gained the interest of policy makers in recent years because it has an immediate impact on traffic congestion while generating significant revenues to pay for new transportation infrastructure or services. (Bhatt, Higgins et al. 2008) Most congestion charging projects have three broad goals: cost recovery for transport infrastructure, pricing of externalities, and transportation demand management. (Lo, Hickman et al. 1996) In cities where congestion pricing has been adopted, investing revenues into the city's transit system was a key factor to gain support. For example, re-investment of congestion charge revenues into public transit was essential to win public support in Stockholm and London. (Eliasson and Mattsson 2006, Santos and Bhakar 2006) In Stockholm, a congestion charging system was introduced on a six-month trial basis in 2005, and proved so effective at cutting travel times (by 20-25% during peak hours) that citizens approved a ballot referendum to institutionalize it in 2006. (Borjesson, Eliasson et al. 2011)

1.4 Methods and data

I used a mixed-methods approach to explore the research questions posed in this chapter. An obvious issue with this study is the lack of a counter-factual case, that is, the lack of data from London after 2003 without bus priority and congestion charging in effect. The congestion charge was introduced as part of a policy package of measures aimed at reducing driving, and it was introduced during a time of rapid change and growth in London—both factors contributing to the complexity of evaluating the impacts of any single measure.

To deal with this complexity, I first sought to identify large-scale trends in transportation and land use. I then sought to understand the impacts of specific measures like bus priority and congestion charging within a larger context of change and regional evolution over time, and to identify confounding factors. Rather than a 'treatment/no treatment' design, this research approach sought to 'triangulate' a consistent storyline about trends before and after bus priority and congestion charging were implemented. I compared expectations from theory to empirical results in order to demonstrate that alternative outcomes were less likely.

1.4.1 Quantitative analysis

Much of the analysis in Chapters 3, 4 and 5 relies upon time series data to identify changes like a kinked trend line where the slope changes. I sought transportation and land use data time series that would allow me to not only identify background trends, but also to compare trends within the congestion charging zone (CCZ) and its boundary. I applied two criteria to select data sources: 1) availability of several years of data prior to 2003, to allow for pre-post comparisons, and 2) availability of a fine-grained geography (LSOA or ward) to allow for inside-outside comparisons of the CCZ. A list of key data sources and how I cleaned and transformed them for analysis is given in Appendix B.

Lacking a budget to purchase commercial data sets, I relied entirely upon publicly collected and published data. I used several methods to identify appropriate datasets. First, I searched online on individual government agency websites, such as Transport for London, the UK Department for Transportation, and the Office for National Statistics. I also used centralized data services such as the London Data Store, UK Data Service, Nomis, WICID and NeSS. Secondly, I asked the experts that I interviewed about data. Some interviewees directly provided data for this study, for example the director of bus planning at Transport for London shared their bus network database, and a business property investment consultant with CBRE provided some proprietary data for free. Other interviewees suggested sources of unpublished public data, for instance, a website called 'What do they know' where data not normally published in reports is made available by citizen request under the UK Freedom of Information Act.

Chapter 6 presents the major original quantitative analysis of this dissertation. After creating two panels of firms from 1997 to 2012, I use logistic regression to identify which industry sectors were most sensitive to the changes in accessibility in the CCZ brought about by improved transit access and congestion charging. Binary logistic regression was selected as a method because it can be used to model binary outcomes like relocation, where some firms move and others do not. This method allows outputs to be expressed as odds ratios, which are an easy-to-understand way to compare categorical variables. This was important, as my set of explanatory variables was fairly limited.

The dataset of firms that I used for this analysis was the secure version of the Business Structure Database, which is published by the UK Office for National Statistics. The secure version contains potentially compromising microdata, and so my research application was reviewed and approved by the Office for National Statistics, and I completed a training before research commenced. To access the data, I was required to book a terminal in the Virtual Microdata Lab (VML) at the Office for National Statistics headquarters at One Drummond Gate in Pamlico, London. All the outputs that I produced were then reviewed by VML staff to ensure that the confidentiality of survey respondents was protected.

Identifying an appropriate time series of rent data proved to be a challenge. For the firm location analysis, I required annual commercial rent data from 1997 to 2012. Through colleagues at the Centre for Advanced Spatial Analysis (CASA) at University College London, where I was hosted for the duration of my fieldwork, I found a researcher in UCL Energy Institute who had a dataset that I could use. It was a time series of commercial property valuations from the UK Valuation Office Agency (VOA), which I decided was a reasonable proxy for commercial rent. I then requested, and was granted, permission from the VOA to acquire the data from this colleague and use it for this research project. VOA property valuations are adjusted every five years, and so I imputed the intervening years to create an annual time series. Regional rent trends revealed by this data are discussed further on in this chapter.

The firm location analysis also required a time series measure of accessibility, which was the most challenging to identify. I sought a generalized measure of the accessibility of a given location, ideally an index reflecting the quality of both transportation infrastructure and transit services. Transport for London (TfL) publishes a suitable index, called Public Transit Accessibility Levels (PTALs), but it is not a time series. Further, TfL staff are continually improving the data inputs and algorithm used to calculate PTALs, and so they advise against trying to compare year-on-year outputs. Again, through colleagues at CASA, I met a researcher in the UCL Space Syntax group who offered to use Space Syntax Integration to calculate the accessibility index variables I needed. Regional accessibility trends revealed by this data are discussed further on in this chapter, and results using both of these accessibility measures are presented in Chapter 6.

1.4.2 Qualitative analysis

My statistical analysis was supplemented by several dozen interviews with local experts in London. The main purpose of these interviews was to provide further insight into the trends and patterns revealed in the data, such as the role of confounding factors, and potential alternative explanations to my hypotheses. The interviews also served an important secondary purpose, which was to explore impacts of congestion charging that are not observable in the data, for example, impacts on cultural norms and the daily lived urban experience.

I aimed to interview local government officials who played a key role in implementing bus priority and congestion charging, for their insights into why certain decisions were made, and how impacts over time have aligned with expectations. To evaluate the longer term impacts of congestion charging, sought representatives from interest groups who had gone on record both supporting and opposing it, to ask whether their hopes or fears had been realized. I sought transportation and land use experts who could provide insight into the role of bus priority and congestion charging in influencing travel and land use trends, both separately and as paired measures. For deeper insight into the anticipated impacts of congestion charging on land use and employment, I sought out experts in commercial real estate and economics.

I began to identify potential interviewees from documentation of the public consultations for congestion charging, and from impacts monitoring reports. Many interest groups submitted comments during the initial public consultation process, and so I contacted those organizations to find someone who either had participated or who could comment on their current position on the issue. In most cases, I was able to meet people who had participated directly in the debate—in some cases, they had since retired. I accrued a growing list of potential contacts by asking interviewees using the ‘snowball’ method of asking them to suggest appropriate people. Many interviewees helped me to identify and approach appropriate staff at public agencies, for instance the Greater London Authority and London boroughs. Some provided an entrée to contacts at private organizations I would not have been able to meet with otherwise, for instance, British Land, a large developer. During the course of the research, it became evident that staff capacity at most boroughs was too constrained to consent to research interviews—despite many attempts, I was only able to interview staff at the largest and most well-resourced boroughs, Westminster and the City of London.

In total, I invited 55 people to participate in this study, and conducted 34 interviews. Eleven participants were senior planners at local government agencies such as Transport for London, the Greater London Authority, the City of London, and the City of Westminster. I interviewed eight representatives of stakeholder interest groups, including London First, the London Chamber of Commerce, the British Retail Consortium, the Freight Transportation Association, and the Cyclists’ Touring Club. Seeking expertise on London transportation and land use policy, and the wider economic impact of congestion pricing, I interviewed ten professors at University College London, Westminster University, the London School of Economics and Oxford University, and a transportation consultant. I sought expertise on London real estate and property markets from planning executives at British Land, a major developer, and research consultants at IPD Property Group and Ramidus Consulting.

Appendix C gives a list of the experts I interviewed for this dissertation. The interviews were conducted using a semi-structured set of questions, some of which were asked of all interviewees, and others which were tailored to their expertise. Although a formal questionnaire was not used, examples of interview questions that I used is also provided in Appendix C.

1.5 Summary of research contributions

As one of the first studies using empirical data to evaluate the impacts of congestion charging over ten years or more, this dissertation makes several important contributions to the academic and policy literature on travel demand management and road pricing.

This is the first study to consider the role of a paired policy of bus priority in the implementation of congestion charging. Bus priority is a term that encompasses many measures that increase bus capacity, including road space reallocation for dedicated bus lanes, redesign of bus stops and intersections, and signal priority. This study is the first to document development of a regional bus priority network in London from 1994 to 2003, using grey literature and interviews. The scope of this bus priority network is discussed using previously unpublished data. It was found that approximately 15% of London's arterial road network was reallocated to create a 1,100 mile (1,800 km) regional network of dedicated bus lanes. An analysis of Census travel to work data before and after congestion charging revealed that declines in driving and increases in bus ridership were highest along bus network corridors. I argue that the implementation of regional bus priority explains why car use and VMT began to decline the London region in 1999, and then played a key role in preparing transport system capacity to absorb drivers switching to transit when congestion charging was introduced in 2003.

This research is the first evaluation of the costs and benefits of London's congestion charging policy over the period of a decade or more. Due to the rare implementation of congestion charging, it is the first longer-term evaluation of any congestion charging policy using empirical data. Investigated using grey literature and interviews, the research revealed that travel speeds in the CCZ have declined such that congestion levels today in central London are approximately the same as they were before congestion charging; this fact was cited as evidence of policy failure in a recent study. (Givoni 2012) Through interviewing city officials, this study found that rising congestion levels are not considered a failure, but an unexpected—and welcome—result of capacity reductions to the central road network made possible by congestion charging, that improve bus function and pedestrian safety. Lower traffic volumes moving at slower speeds in the CCZ are considered an environmental and safety improvement over pre-charging conditions, which could not have been achieved without implementing congestion charging.

An important finding from this research is that the geographic extent of congestion reduction and travel time savings benefits extends well beyond the CCZ. Using traffic count, flow, and speed data, this study found that these benefits extend throughout Inner London. From the grey literature and interviews, it was found that these time savings benefits have been deliberately and systematically redistributed away from drivers to buses, bicyclists and pedestrians. I argue that the extent and redistribution of these benefits is the key reason that the CCZ is considered non-controversial today. Rather, it has become part of London's urban fabric.

The study also documents the limitations on public acceptance for congestion charging illustrated by the removal of the Western Extension zone implemented in 2007, and how congestion charging has influenced the culture and attitudes of Londoners. From interviews, it was found that the main reasons the Western Extension was removed were 1) a lack of significant traffic reduction benefits, and 2) the effective campaign of a small but powerful neighborhood association to remove it. Nevertheless, interviewees were convinced that experiencing the benefits of congestion charging has changed prevailing attitudes of London residents in favor of a general acceptance of de-prioritizing vehicular travel. The willingness to de-prioritize cars in the center has enabled greater reallocation of road space for improvements to bicycle and pedestrian infrastructure, for example the removal of three lanes of traffic on the Victoria Embankment to construct a wider walkway and bicycle superhighway.

Finally, this study is the first to consider the longer-term implications of changes to vehicular and transit accessibility in the CCZ on firm location decisions. It contributes empirical findings to a debate in the literature as to whether congestion charging would tend to disperse or concentrate employment. In London, congestion charging paired with bus priority and enhanced rail capacity led to greater concentration of employment over time. It was hypothesized that improved accessibility in the congestion charging zone are being capitalized into higher land and rent costs. Evidence of rents rising faster in the CCZ than in similar competing areas was found. However, the pull of accessibility on firms moving into the CCZ was stronger than the push of rising rents on those moving out. Firms valuing accessibility were found to be the most likely to remain or to move in, in spite of rising rents.

The study found the concentration of larger firms has been increasing inside the CCZ since 2004. Industry sectors that depend upon agglomeration economies have been concentrating at there at the highest rate, especially ‘knowledge’ industries like Computers/Telecomm/Research & Development and Business Management Consulting. Evidence was found of increased churn, or rates of firm relocation into and out of the CCZ. For larger firms, the ratio of moves in to moves out increased from 1.02 in 1998-2002 to 1.14 in 2008-2012, indicating a preference for locating in the CCZ. Most firms that moved into the CCZ improved their transit accessibility by 20% to 40%. The net flow of jobs moving in to out also increased from .80 in 1998-2002 to 1.16 in 2008-2012. Retention of tourism sector firms increased in the CCZ, including Theatre & Cinema and Sports & Culture. Sectors vulnerable to rising rents and factor costs, including Retail and Restaurants, had increased odds of moving out of the CCZ. Rising rents were a statistically significant factor for firms moving out, and these firms were likely to have reduced accessibility after the move.

The limitations of these findings are discussed in Chapter 6. This study does not attempt to prove that congestion charging was a causal factor for firm location patterns. Interviewees emphasized that the CCZ is not a significant factor in firm location decisions—it is not an attractor, nor has it had a dampening effect on the attractiveness of locating in the central business district. Rather, this study views congestion charging as a paired policy enabling accessibility improvements that would not have been otherwise achievable, which in turn have an impact on location decisions. The impacts of the CCZ on firm location patterns are indirect, realized through changes to accessibility and land values. The findings from this study corroborate findings from other studies on the relationships between transit investment, accessibility, and property value uplift, as well as studies on the relationship between accessibility and firm location. (Cervero and Murakami 2009, Cervero and Kang 2011, de Bok and van Oort 2011, Chatman and Noland 2014)

These findings are of interest to policy-makers in cities struggling to address rising traffic congestion while meeting sustainability goals and reducing VMT. They are of particular interest to cities considering a congestion charging policy. The policy implications of this dissertation are enumerated in its final chapter.

Chapter 2. Understanding London as a Transit Oriented City

This chapter provides some important background context and definitions that will be used throughout this dissertation. First, some aspects of London geography which may be unfamiliar to a U.S. audience are introduced, including an overview of UK administrative and Census geography. Then an overview of London's governance structure is provided. The congestion central congestion charge zone (CCZ) and Western Extension charge zone (WEZ) are shown for in each of the context maps below for reference only. The politics and impacts of the two congestion charge zones are discussed in more detail in Chapter 5.

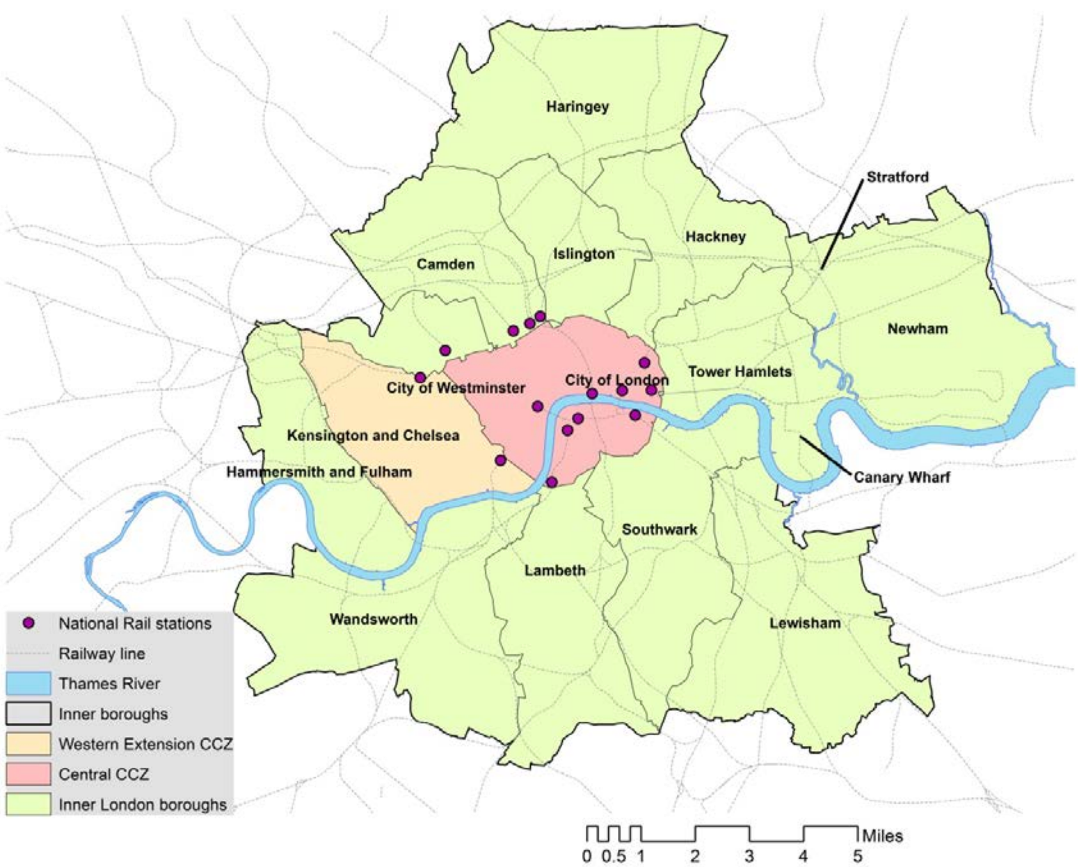
2.1 Historic context and major areas of London

The city of London was founded over 2,000 years ago in the southwest corner of England. Today it is the thriving capital city of the United Kingdom, home to 8 million people over a land area of 600 square miles. Figure 2.1 shows the thirty-two boroughs of Greater London and the City of London. It also shows Inner London, the innermost fourteen boroughs which are defined as a statistical area for planning purposes by the UK Office for National Statistics.

Figure 2.1 The Greater London region, Inner London and congestion charging zones

The City of London is often referred to as “the square mile” due to its size. Fully contained with the CCZ, the City of London is a historically independent entity that is treated as a borough for statistical purposes. It is London’s most ancient quarter, distinguished by a city wall and roads built by the Romans. The City’s heavily fortified perimeter, bounded over time by the Tower of London, St Paul’s Cathedral, and the River Thames, formed the edge of built London for its first 1,300 years. It was granted a city charter and the right to elect a Lord Mayor in 1189, a governance structure which has survived countless local reorganizations to remain intact today. From medieval times, the City was not only a major port and center of trade, but the center of England’s wealth and political leadership. In the 16th century, it became a major center for banking, international trade and commerce. The Bank of England and Royal Exchange have functioned in the City since that time, as well as a handful of major corporations such as Lloyd’s insurance. The City’s financial, insurance and legal sectors gained in strength in the 19th and 20th centuries, even as shipping and industrial uses faded away from the center of London. Today the City remains one of the most influential financial agglomerations in the world. Its employment base anchors the economic geography of London. In 2011, the City had a resident population of 7,000 but over 300,000 people commuted to jobs there.

Figure 2.2 Inner London, with congestion charging zones and major rail stations shown



Inner London, shown in Figures 2.1 and 2.2, forms a distinct economic area. The innermost boroughs have a density and mix of land uses reflecting their development from medieval times up to the railway suburbs of the late 19th century. The remaining nineteen boroughs, referred to as Outer London, were largely built out during the 20th century in an auto-oriented manner. Inner London is smaller, both in terms of land area and population, but the density of population is more than double that of Outer London. In 2011, Inner London's population numbered 3.2 million at a density of 26,000 per square mile, while 5 million lived in Outer London at a density of 10,000 per square mile. The population of Inner London peaked in 1911 at 5 million, after which the population of Outer London grew faster. However, since its low point of 2.5 million in 1981, the population of Inner London has been growing more rapidly than that of Outer London. From 1991 to 2001, Inner London's population grew by 9%, compared to 5% in the Outer boroughs; from 2001 to 2011 they grew by 13% and 11%, respectively.

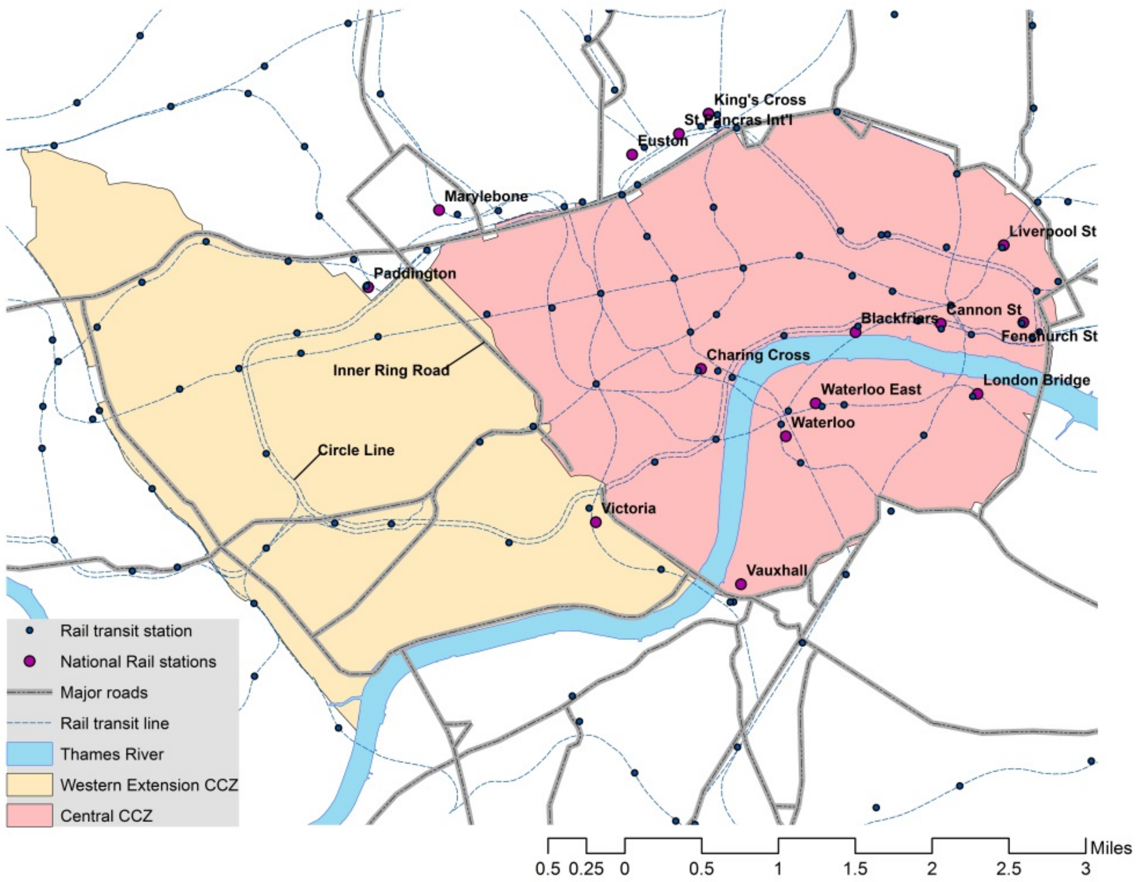
Inner London is very socio-economically diverse, containing some of the richest and poorest neighborhoods in Europe along an east to west division. Historically, London's ports, wharves, and industrial uses were mainly located to the east of the City of London, along the river. These industrial East End areas were heavily bombed during World War II and have only been redeveloped for other uses slowly since then. The East End is known as a poor and socially troubled area, and as a stronghold of liberal politics. Two major redevelopment projects have had noteworthy impacts on its economic geography, Canary Wharf and Stratford (shown in Figure 2.2).

Canary Wharf is the result of redevelopment of the defunct Docklands area of Tower Hamlets borough during the 1980s and 90s. Abandoned wharves on the Isle of Dogs peninsula in the Thames were demolished and new skyscrapers built as a secondary employment center to the City of London. Known as Canary Wharf, today this high density development contains over one million square feet of modern office and retail space, and over 100,000 people are employed there. In 1987, a transit line called Docklands Light Rail (DLR) began service, connecting the two employment centers and London City Airport, which opened the same year. The DLR traverses the boroughs of Tower Hamlets and Newham, two of the most socially deprived local authorities in the UK. In the 2000s, new housing and supportive commercial uses have filled in along the DLR corridors, bringing much-needed investment but also processes of gentrification and displacement.

Redevelopment of Stratford township in Newham was spurred by London's successful bid to host the 2012 Olympics. In addition to the Olympic housing and sports facilities, a new shopping center, new transit hub and two new rail transit lines were built in Stratford during the 2000s. With 1.8 million square feet retail, Westfield Stratford City is currently the largest shopping center in Europe. Stratford International Station is the hub of £17 billion worth of new transportation links, including a bus terminal, rail transit connections, and Eurostar high speed rail service to Europe.

In contrast to the East End, the West End of London is the historic home to the city's wealthiest residents, the nobility and political elite. Developed in the 17th, 18th and 19th centuries, the West End was originally built as a series of palaces, town house squares and fashionable high streets in close proximity to Buckingham Palace, Parliament and Westminster Abbey. The term 'West End' may have different meanings in different contexts. It often refers to the two wealthiest London boroughs, the City of Westminster and Kensington and Chelsea. The borough of Kensington and Chelsea was originally two separate villages. Westminster is the only other London borough to retain "city" in its name, due to its history as an independent village, however, its modern boundaries reflect many iterations of annexation and local reorganization. These boroughs form a distinct area of London known for luxury housing and shopping, and for their staunchly conservative and politically influential residents. The term West End can also refer to a small area of central London west of the City, the entertainment and shopping districts around Leicester Square, Piccadilly Circus, Oxford and Regent Streets.

Figure 2.3 Central London, with major rail stations, the Underground network, and the Inner Ring Road



London’s key eras of growth were entwined with development of its rail system, meaning the entire region has excellent access to the central business district (CBD) by rail. In Figure 2.3, Central London is roughly defined by a ring of fifteen Network Rail stations. These rail stations were all built between 1830 and 1870, and form a ring due to a ban on railway lines entering the city center. Since Victorian times, all inter-city and commuter rail services have terminated at these stations. The world’s first subway rail system, the London Underground, was born in 1863 of the need to connect them with the Circle Line, also shown in Figure 2.3. Although it is a seamless system today, the Underground was as separate lines by competing railway companies. It wasn’t until 1933 that several companies were amalgamated into one rail transit provider and the Circle Line was reorganized to connect all the major terminals with a single seamless service.

Also shown in Figure 2.3 is the Inner Ring Road, a 12-mile circular route formed from a number of major roads radiating from central London, which today forms the CCZ boundary. The plan to connect them into a ring originated in the 1940s in Abercrombie’s County of London Plan. While it is often referred to colloquially as the Inner Ring Road after its function, the historic road names are in use for each segment, and so it cannot be found on a map. The boundary of the western extension congestion charge zone was defined by a series of major arterials, or ‘A’ roads, bounding the borough of Kensington and Chelsea.

Figure 2.4 Motorways and Arterial ‘A’ Roads in Greater London

In comparison to London's extensive heavy rail, commuter rail, light rail, and subway infrastructure, the road network is under-developed. Figure 2.4 shows the network of high-capacity high-speed motorways and trunk roads in Greater London. Note that none of the motorways penetrate into Inner London. Many of the trunk roads have similar capacity to urban highways in the U.S., with sections of separated grade rights-of-way and junctions with on and off ramps, for example the North and South Circulars. Plans to increase the capacity of the entire trunk road network in these ways were halted by public protests in the 1960s. Thus much of road system in Inner London has relatively low capacity, compared to U.S. cities, functioning as at-grade urban arterials, controlled by traffic signals. Inner London's dense network of streets funnels traffic onto just a few high-capacity arterials, which become easily congested.

2.2 Governance

Administratively, London has a two-tiered system of local and regional governance. Each borough is an independent local authority with its own town hall and council, local services, school district, and authorities over land use and planning. London is unique in England in that it has two forms of regional governance. Historically, the boroughs have formed an association to work together, today called London Councils, in order to coordinate both service provision and lobbying at the national level. London Councils is composed of representatives from each Borough, the Police Authority and the Fire Brigade. In 2000, a new regional authority was created, called the London Assembly, composed of 25 directly elected borough representatives and an independently elected Mayor as its chief executive. The public agency headed by the Mayor and London Assembly is called the Greater London Authority (GLA).

The GLA prepares long-range transport and land use plans for the region, and works with local authorities to implement them. This allows for strong regional coordination of land use and transportation planning, and the enforcement of development controls like the London Greenbelt. The Mayor has a strong influence over regional spatial planning through development of the London Plan, a regional comprehensive plan (aka spatial development strategy). But authority over land use ultimately lies at the local level, with each borough responsible for reviewing development proposals and granting building permissions. Each borough is required to produce a Local Implementation Plan which is in alignment with the London Plan.

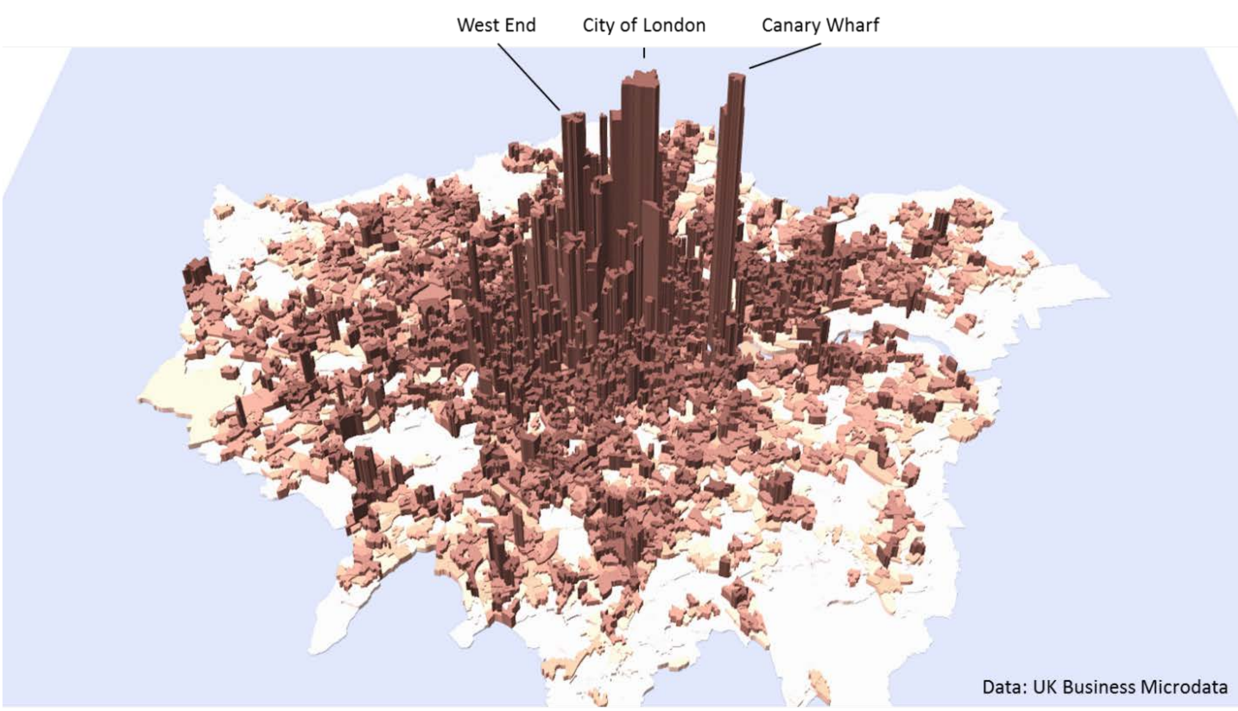
Most intercity road and rail infrastructure in the UK is owned by the national Department for Transport (DfT). Services on these lines are mostly run as franchises operated by private train operating companies, and marketed together as Network Rail. Authority over roadways is split between the DfT, responsible for national motorways, and the boroughs, responsible for local streets. Since 2000, responsibility has also been shared by a regional agency called Transport for London (TfL), which has responsibility for trunk roads and a strategic network of urban arterial roads called 'red routes.' TfL was established in 2000 alongside the GLA, and also has the Mayor as its chief executive. It is a powerful agency which controls road space, parking and traffic signals on red routes, owns and manages rail transit infrastructure and services, and manages provision of bus and taxi services through private contracting and licensing.

This governance structure empowers the Mayor, as the head of TfL, with executive authority over the public transportation system throughout the Greater London region, and an annual transportation budget of £5 billion or more. The mayor sets transportation priorities and policy goals through a document called the Mayor's Transport Strategy (MTS), a statutory document required under the Greater London Authority (GLA) Act 1999. Essentially a comprehensive transportation plan, the MTS must, "describe how the Mayor intends to develop and implement policies for the promotion and encouragement of safe, integrated, efficient and economic transport facilities and services, to, from and within Greater London." (1999) Each borough's local transportation implementation plan must support the MTS, a requirement which has played a key role in developing sub-regional transport plans that align with the region's strategic goals.

2.3 Economic structure of Greater London

In 2001, there were 4.7 million jobs in Greater London, and 5 million in 2011. London is a highly monocentric city, employment-wise, with about 30% of the region's jobs concentrated in Central London. Figure 2.4 shows Greater London's three major employment centers: the City of London, a cluster for the finance, insurance, and tech industries, Canary Wharf, a back-office cluster for those industries, and the West End, a retail and arts center.

Figure 2.5 Employment density and major job centers in Greater London (by LSOA)



Data source: (ONS 2014), visualization by author using GeoCanvas

Total employment in London declined during the 1970s and 1980s, mainly due to the declining manufacturing base. Employment has grown strongly since the 1990s, primarily due to London's leadership position in globalization processes, which have resulted in expansion of the city's financial, legal, and business services sectors. This trend that is expected to continue and to dominate over the next two decades. In 2010, less than 200,000 manufacturing jobs remained. (GLA 2010) Canary Wharf was planned as a 'secondary CBD' during redevelopment of the London Docklands during the 1980s and 1990s. Employment grew from 17,000 jobs there in 1991 to 87,000 in 2005. (GLA 2008) It is considered an adjunct to the CBD, rather than a separate rival cluster, as these two centers are only 11 minutes apart by Docklands Light Rail. The Financial sector has found this area increasingly attractive since the Jubilee Line extension of the Underground opened in 1999; financial jobs grew from 9,000 during the 1990's to 47,000 jobs by 2006. (GLA 2008)

Table 2.1 Greater London employment by industry sector, 2010

Industry Sector	Number of jobs	Inner London	Outer London
Health and social work	390,400	58%	42%
Retail excluding motor vehicles	378,200	49%	51%
Financial intermediation	331,800	86%	14%
Transport, storage and communication	307,000	42%	58%
Education	309,600	46%	54%
Hotels and restaurants	303,000	62%	38%
Other community, social and personal service activities	300,300	61%	39%
Public administration and defence; compulsory social security	223,500	58%	42%
Other business services not elsewhere in table	205,600	60%	40%
Manufacturing	178,200	46%	54%
Labour recruitment and provision of personnel	170,700	62%	38%
Wholesale	151,500	40%	60%
Construction	122,500	35%	65%
Computer and related activities	129,600	62%	38%
Industrial cleaning	110,200	48%	52%
Business and management consultancy activities	100,200	71%	29%
Real estate activities	109,700	66%	34%
Legal activities	86,000	85%	15%
Accounting and related activities	62,000	67%	33%
Architectural, engineering and related activities	69,800	67%	33%
Sale and repair of motor vehicles, and related activities	41,300	23%	77%
Advertising	37,700	81%	19%
Renting of machinery and equipment	16,700	29%	71%
Research and development	18,000	71%	29%
Agriculture, fishing, mining and utilities	14,700	57%	43%
Total	**4,168,500**	**57%**	**43%**

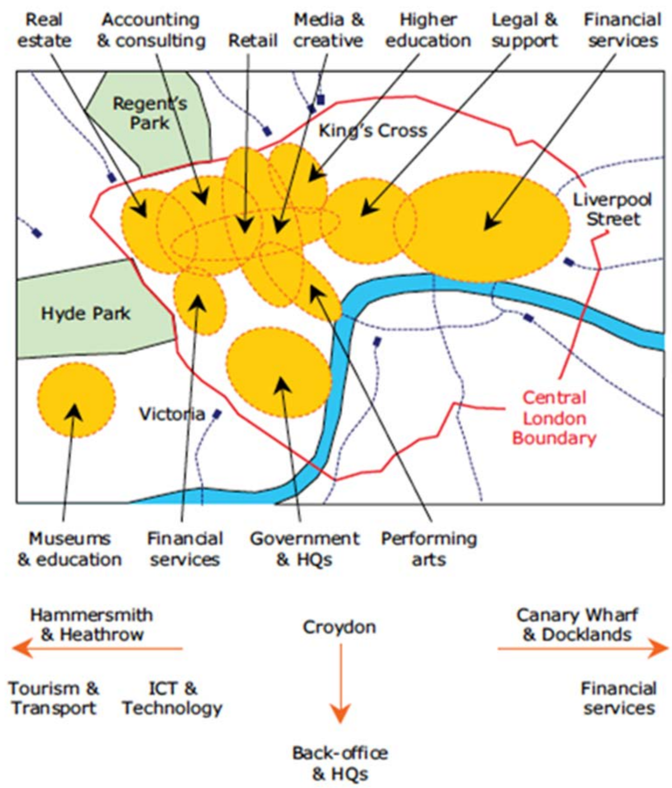
Source: GLA 2010

As shown in Table 2.1, business services is the largest employment sector in London, forming approximately 25% of the region's total employment. Approximately half of business services jobs are in high-value business service and creative industries such as law, accountancy, management consultancy, architecture, engineering and advertising. The remainder are lower wage jobs, including business support services such as cleaning, security, real estate and property management. The public sector is a major employer, with health, education and public administration accounting for over 1 million jobs. (GLA 2010) Other significant employment sectors in London are financial intermediation with 330,000 jobs, retail with 400,000 jobs, and hotels and restaurants with 300,000 jobs. (GLA 2010)

Key industry clusters in the Central Business District

The CCZ encompasses the London CBD, an area with 1.5 million jobs (one-third of London employment), 300,000 residents and many of the city's most popular touristic destinations, including theatres, museums and shopping districts. (GLA 2008) The CBD economy is distinctive from much of the rest of London in terms of the nature and prominence of the business activities located there. London's CBD is home to the headquarters or "command and control centers" of many large multinational corporations, as well as banks, legal firms and software suppliers.

Figure 2.6 Key industry clusters in London's central business district



Source: (GLA 2008)

Figure 2.6 shows key industry clusters in the CBD. Aside from the financial district in the City of London, the most prominent industry clusters are Media and Creative in Soho, Retail in the West End, Legal and Support services around Holborn/Midtown and Higher Education south of Euston/King's Cross. Employment in these CBD clusters, including Canary Wharf, "forms a complex web of collaboration and mutual dependency between various sectors that thrives on proximity…The benefits of spatial concentration of expertise and human capital (agglomeration) are borne out by London's superior productivity in finance and business services, which is estimated to be 40 per cent higher than in the rest of the UK," (GLA 2008).

Financial services and insurance are both clustered in the City of London. London is widely viewed as one of the world's most important centers for international finance and business services, unique in terms of its extensive linkages to other cities and financial centers. This status serves to attract the most capable and qualified workers, and CBD firms benefit from a proximate labor pool which reduces employee search costs and improves productivity. London's insurance industry is the third largest in the world, and is very highly concentrated within the Square Mile.

Accounting firms and other professional services serving the international business needs of these firms form an industry cluster ae clustered in the West End. Legal services, particularly international legal services, form an industry cluster between the City of London and West End, close to the Royal Courts of Justice. Management consultancy, a rapidly expanding area, is predominantly clustered around the West End and the Square Mile; there are also emerging subclusters just outside the CBD. Creative industries, including radio and TV, computer software and games, fashion, architecture, publishing, advertising, art, film, and the performing arts are clustered in the West End or immediately adjacent, in Camden, Lambeth or Southwark. More than 70% of the demand for creative products is from other businesses, therefore they tend to cluster close to clients. (GLA 2008)

One consequence of the co-location of finance, business services and other companies is that pressure on available commercial space in London's CBD are extremely high, which is reflected in high rents compared to financial centers in other cities. Office rents in the City of London are double those of New York, and up to triple in the West End. The GLA argues that high rents are offset by lower overall costs of doing business and by the advantages of agglomeration economies, accessibility and environmental benefits in the CBD. (GLA 2008) Workers in industry clusters thrive on interaction, which builds trust and collaboration; face-to-face contact is especially important for ongoing input throughout the supply chain. "Changes to the design or delivery of content are expressed most effectively face-to-face, and to be fully understood require close proximity between various players. Such processes have been found to work best when firms are concentrated in small areas." (GLA 2008)

The West End is the largest retail center in England, both in terms floorspace and turnover. The range of shops and the quality of goods offered attracts tourists from around the world. Retail spending represents 20% to 33% of expenditures by visitors from the US and the EU (GLA 2008). Shopping is often combined with other activities in the West End, such as eating and cultural entertainment—almost half of London's 100 or so theatres are located in the West End (GLA 2008). For these reasons, retail rents in Central London are among the highest in the world. New Bond Street prime retail rents rank fourth after Fifth Avenue (New York), Causeway Bay (Hong Kong) and L'avenue Champs Elysées (Paris). (GLA 2008)

Retail firms in the CBD also face other types of higher costs, compared to competitor locations, including higher staffing costs than anywhere else in London, and a number of problems with servicing and delivering that are unique to the West End. (GLA 2008) Yet the GLA argues, "the numerous benefits in terms of critical mass of customers, accessibility and reputation outweigh the higher costs to business of being located in the central area. The CBD's key advantage over other retail locations is its accessibility not just from work locations but also from many of London's tourist and leisure attractions by public transport and on foot." (GLA 2008).

In a report on the evolving economic structure of London, the GLA noted that "fringe" areas to the CBD are becoming more competitive, developing subclusters and experiencing employment gains. (GLA 2008) They argue this trend demonstrates the premiere amenity value of the CBD, and allows the region to become more economically efficient, "The emergence of significant concentrations of firms in fringe areas outside the CBD underlines the growing locational advantage of the CBD in providing a critical density of employment and businesses. With London's economic structure predicted to move further towards business services, locations around the CBD are likely to grow in importance as key employment areas." (GLA 2008)

Notable "CBD fringe" locations are Paddington, Islington & Clerkenwell, Camden and Southwark. These areas are starting to host company headquarters and professional business services. King's Cross is a redevelopment area which is becoming an alternative office location to the CBD, a trend which is expected to accelerate with the opening of Crossrail. Camden and Islington are growing as the creative sector expands, hosting significant publishing, design and arts-related clusters.

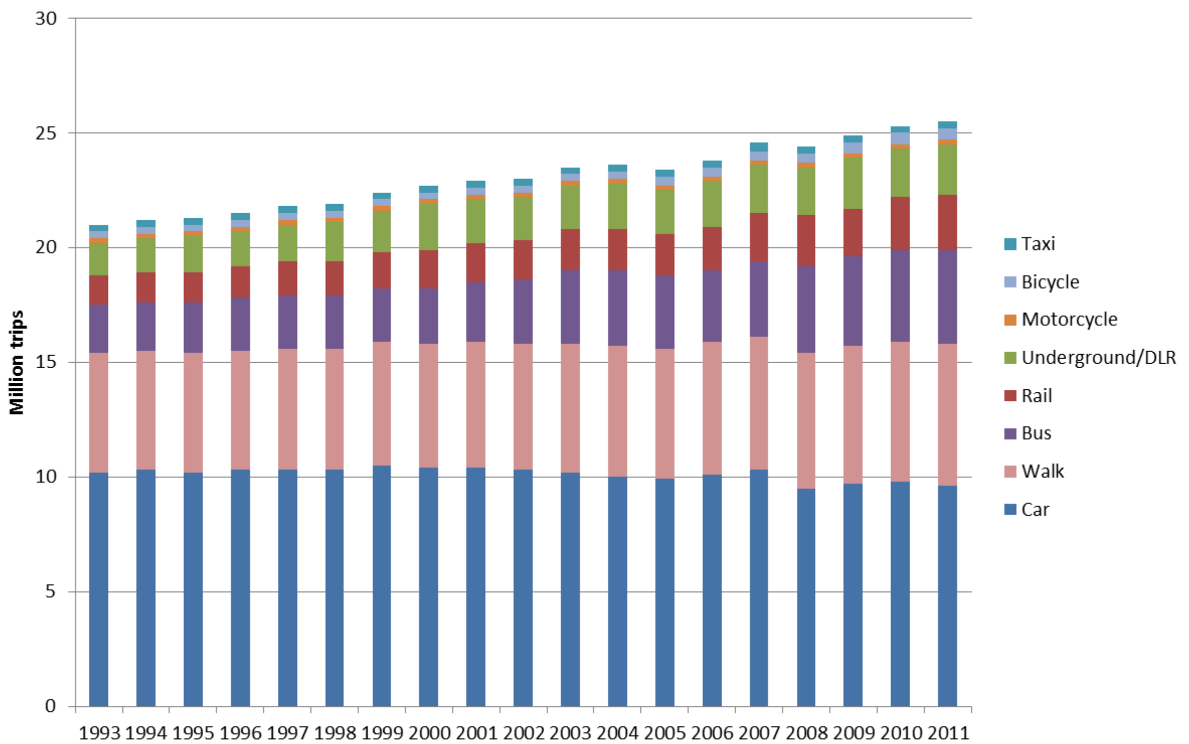
Another notable process is the dispersal of some firms as industry sectors develop routine functions that do not depend upon agglomeration economies, "Innovative and cutting edge activities which reap the greatest agglomeration benefits are always likely to be located in London's CBD, but move out to lower cost locations as they mature and become more routine," (GLA 2008). This implies that firms are expected to spin off from the CBD to spread jobs more widely throughout the region, over time.

2.4 A brief history of the politics of transportation planning in London

2.4.1 Transit use

London's transit-based urban structure and lack of urban highways means the city has never been totally dominated by car travel. Car ownership and use are far lower in dense Inner London than Outer London, but even taken on average, the mode shares for driving and transit are about equal. Figure 2.5 shows the average daily number of trips made in London annually, by mode. It can be seen that personal vehicles accounted for about half of daily trips in 1993, with the remainder split between public transit and walking. By 2011, the number of driving and walking trips are roughly the same, meaning that nearly all growth in trips has been absorbed by public transit.

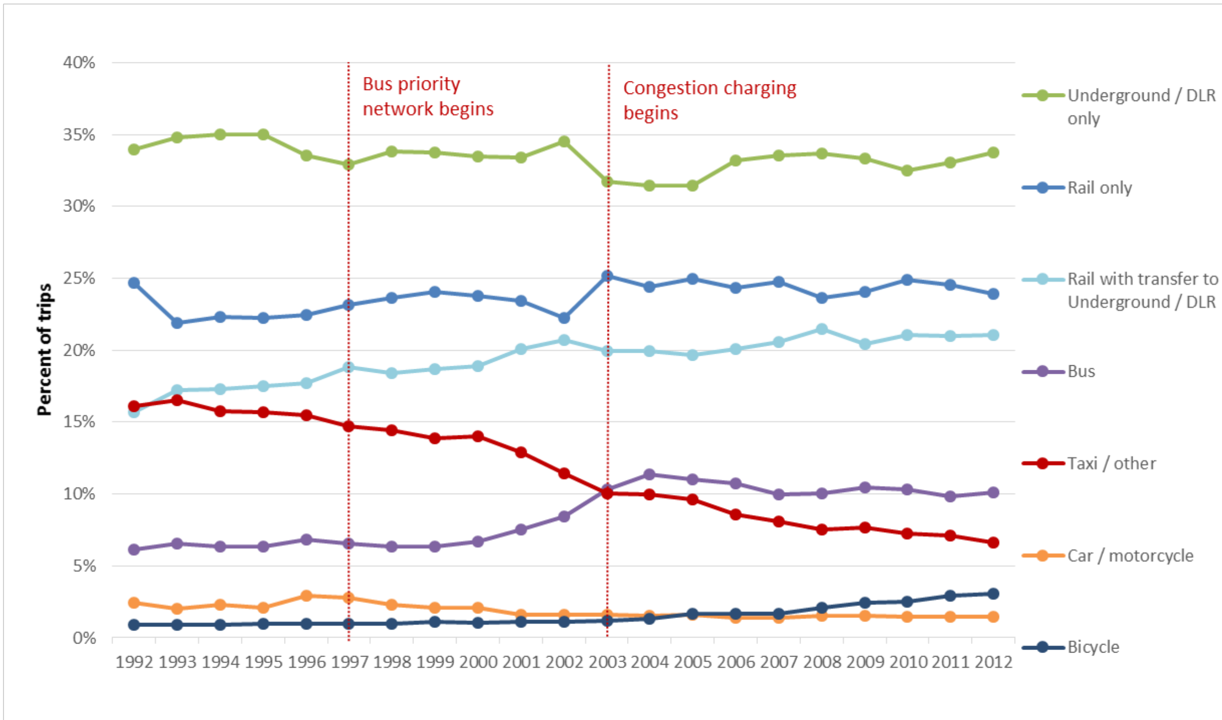
Figure 2.7 Estimated daily average number of trips, by main mode of travel, 7-day week (millions)



Data source: TfL Travel in London Report 5, 2012

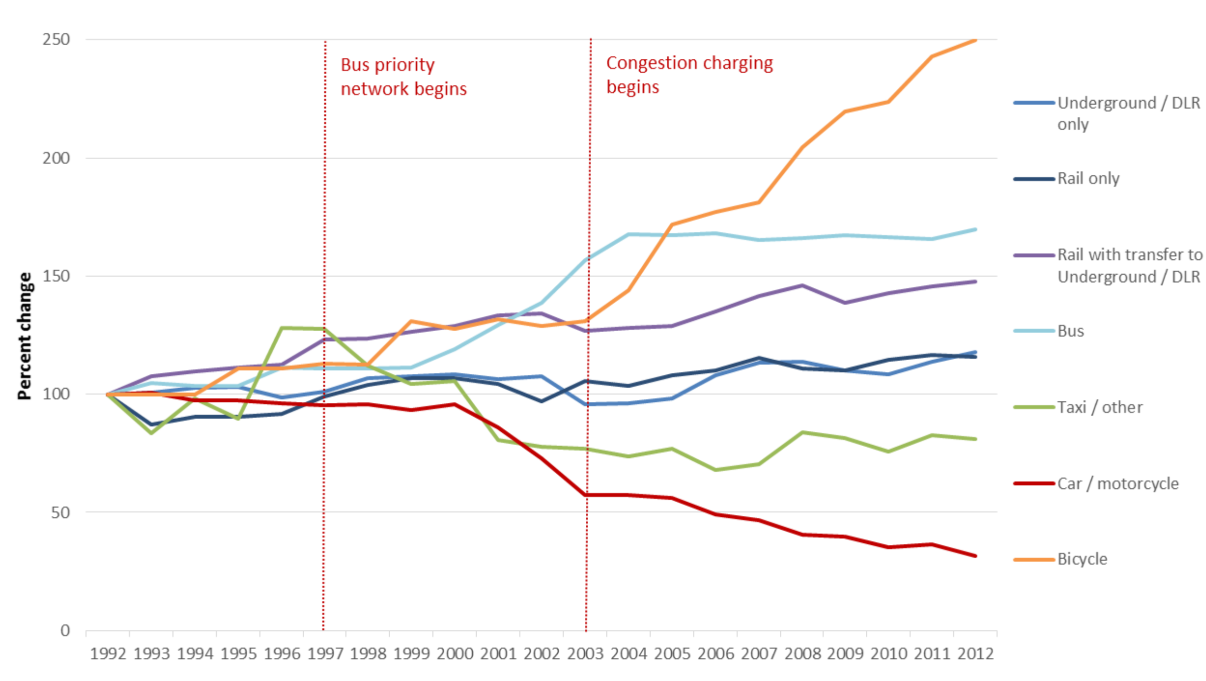
This trend is most clearly illustrated by traffic entering central London during the morning peak. Figure 2.6 shows the mode split from 1992 to 2012, and Figure 2.7 shows the mode split trend, indexed to the year 1992. Bus travel increased rapidly after 1997, and bicycling after 2003, while driving declined steadily from 2000 onwards. Rail ridership increased by smaller percentages.

Figure 2.8 People entering Central London in the weekday morning peak, by mode



Data source: TfL Central London Peak Count (CAPC) Supplementary, 2014

Figure 2.9 Trend in people entering Central London in the weekday morning peak, by mode (1992=100)



Data source: TfL Central London Peak Count (CAPC) Supplementary, 2014

2.4.2 Historic role of transit in London

London's historic urban structure and culture affect public attitudes toward transit investment. Londoners place a high cultural value on investment in transit as an essential mobility option for all. Voters support a high level of subsidy for bus services, such that those over 65, under 18, or with a disability receive a free bus pass, and students and job seekers get discounted passes. A recent study investigated the impacts the 'Freedom Pass' for senior citizens on their quality of life and found that it was highly valued not just for providing access to essential goods and services, but as a mechanism to participate in the life of the city and avoid marginalization. The authors argue that mobility, health and well-being are linked reflects the ideology behind the Freedom Pass, "Our data suggest that in contexts where good public transport is available as a right, and bus travel not stigmatised, it is experienced as a major contributor to wellbeing, rather than a transport choice of last resort." (Green, Jones et al. 2014)

London's transport system has undergone several eras of development and management, flipping back and forth between the public and private sectors. The major period of building was during the Victorian era, when the majority London's railway lines and stations were constructed by private investors. London's 150-year-old subway system, known today as the Underground or the Tube, developed during this period as competing lines. A period of state intervention in the public transportation market began in the 1930's, when London's first regional transit authority, London Transport, was formed, and national legislation regulated bus services. (Harris 2011) From the 1930s to 1980s, London's commuter rail, Underground and bus networks were each managed by separate public agencies, under the auspices of London's regional government, the Greater London Council.

2.4.3 Changing support for public transit across two recent political eras

In 1979, an era marked by an ideology of privatization, competition and deregulation began when the Conservative party came to power, led by Margaret Thatcher. The Conservative government was voted to power on promises to reduce public expenditure and increase the private sector role in public services. This era was characterized by a political philosophy that public transit should be self-sustaining, and that private operators were best equipped to achieve this. Eventually, the government decided that the best way to deal with decades of declining bus ridership and rising public subsidies was to deregulate public transportation and allow services to be subject to competition.

At this time, the Mayor of London was a hardline leftist Labour party leader known as "Red" Ken Livingstone. He fiercely resisted pressure by the national government to reform London's public transport and other services to align with the new paradigm. For years, tensions simmered, until finally the London Regional Transport Act of 1984 removed transport responsibility from the Greater London Council and created a new agency, London Regional Transport, that reported to a Thatcher appointee, the Secretary of State for Transport. (Harris 2011) London's Underground and bus services were then re-privatized. Soon after, Parliament abolished the Mayor's office and the Greater London Council altogether with the Local Government Act of 1984. (HoC 1999) This devolved all powers to the London boroughs and other entities, including London Regional Transport. Finally, the Transport Act of 1985 deregulated bus services throughout Great Britain, except for London. (HoC 1999)

Around the same time as the Thatcher administration abolished the Greater London Council, it deregulated and privatized public transportation services. From 1984 to 2000, London's transport system was managed by two subsidiary companies of London Regional Transport, London Buses Limited and London Underground Limited. (Harris 2011) Services were provided via a competitive tendering system in which routes, fares and frequencies were set by the public agency, and private companies then bid for routes. Over 20 private companies operated services, each serving a single Underground line or a set of bus routes. Bus ridership remained stable in London, however fares rose steeply throughout the 1990s as declining government support pressured private operators to cover costs from fares alone. (HoC 1999) By 2000, farebox recovery was 99% for buses and 130% for the Underground. (TfL 2001) Meanwhile, the system suffered from chronic deferred maintenance, especially the Underground, whose worn-out trainsets, stations, and signal systems could barely support its ridership.

A new era of support for public transportation began in 1997, when the Labour party was elected to leadership in Parliament for the first time in thirty years, led by Tony Blair. The new Government's "New Deal for Transport" white paper in 1998 promised a "radical change in transport policy…to create a better, more integrated transport system…[because] motorists will not readily switch to public transport unless it is significantly better and more reliable." (Blair 1998) The new policy emphasis was on an *integrated* public transportation system, with an emphasis on buses, to be achieved via greater local control. The vision statement described an integrated transport system as having several dimensions: integration within and between different types of transport; with the environment; with land use planning; and with education, health and wealth creation policies. One of the first actions to improve public transportation was to require cities to develop 5-year Local Transportation Plans.

The Labour party's electoral manifesto pledged to restore regional governance to London, and to create a new position of Mayor, each to be directly elected. During the two-year period during which a new regional governance structure for London was debated, London was given an immediate infusion of £1 billion to begin repairs on its transport system, including £365 million for urgent maintenance on the Underground. (Richards 2006) Other projects initiated with during this timeframe included intensive implementation of the London Bus Priority Network, a light rail extension to London City Airport, and pedestrianization of Trafalgar Square.

When it came to rail and bus services, the new Government did not attempt to reverse privatization. Blair represented the 'New Labour' wing of the party, which sought to modify, rather than replace, many Conservative policies. They saw a strong role for the private sector in public services, and public private partnerships (PPPs) as the solution to problems that had arisen from pure privatization. (Blair 1998) They believed the public sector should retain ownership of its capital assets, and play a strategic planning role, while services should be provided by private operators to ensure cost-effectiveness. Privatization and deregulation were seen to have failed because they fragmented public transport networks and ignored the public interest. The main tool proposed to improve customer service were Quality Partnerships, or contracts setting quality standards and performance incentives for concessionaires. Rail services were left privatized, but a new Strategic Rail Authority was created to oversee passenger services and re-negotiate franchise. Bus services outside of London were brought back under the control of public regulators, but followed the London model of private tendering, which was considered a success.

The changeover of national government also created a moment of opportunity for an idea that had long been floating around London—congestion charging. Immediately after the 1997 election, the Labour party began circulating green papers with ideas for the new government's ten-year transportation plan. (Richards 2006) This included floating an idea that had been gaining support in London's business community, using economic instruments to influence travel behavior, including congestion charging and workplace parking levies. Policy green papers and responses from public forums and consultations indicated that voters would accept such measures as long as the revenues were recycled back into the local transport system. For example, a business advocacy group called London First, representing over 250 of London's largest employers, published a green paper proposing congestion charging as part of an "action plan to improve the quality of bus services; make cycling and walking safer and more pleasant; improve management of parking, loading and streetworks; strengthen enforcement of traffic and parking controls; restrain the use of private cars; and clean up vehicle exhausts." (Yass 1995)

This 'policy window' for congestion charging emerged in part because the idea of road pricing has deep roots in England. It was first proposed by an Englishman, Arthur Pigou, in 1920, and the basic road pricing model developed by another, Alan Walters, in 1961 (after Vickrey). (Lindsey 2006) Soon after, the UK Ministry of Transport assembled a panel of experts, the Smeed Commission, to explore different versions of road taxation. The resulting Smeed report was a highly influential work that recommended road user charges accounting for the differing congestion costs of journeys at different times of day. (Smeed 1964) A plan for congestion charging in London's central area was first developed by the Greater London Council in the early 1970s, but abandoned. One of the Commissioners, Gabriel Roth, later served as an advisor to Singapore when it became the first city in the world to implement road pricing. (Richards 2006) Another Commissioner, Ken Livingstone, would bring the idea back to life nearly three decades later.

The idea of congestion charging was first revived in 1991 when the DfT commissioned the London Congestion Charging Research Programme. (DfT 1995) At that time, the DfT was beginning to shift away from road-building as the principle policy solution to congestion, and toward previously neglected solutions such as demand management. (Dudley 2013) Congestion had become one of the foremost issues of concern to the public, and there was no political will for expanding highway capacity. Jones noted a shift in public opinion polls in the mid-1990s, “urban road pricing has become much less unpopular than major new road building or motorway tolling – a very significant shift politically.” (Jones 1998) The DfT report concluded that a congestion charge would reduce congestion, pay for its setup costs, and produce wider economic benefits. The DfT study got the idea of congestion charging buzzing among civic and business leaders in the late 1990s, such that when a political opportunity arose, key interests were poised for action.

Supporters of congestion charging recognized a moment of opportunity, anticipating that the legislation restoring independent governance to London could include enabling powers for road user charging. (Yass 2013) In 1998 DfT’s London office formed a working group of technical experts to inform Mayoral candidates on how they might use their road user charging powers, called Road Charging Options for London, or ROCOL. (Richards 2006) Its members included leaders from local and regional governments and transport agencies, academics, consultants, and interest groups ranging from the Royal Automobile Club to the business lobby group London First. ROCOL’s aim was to assess key issues related to the use of road charging powers and produce an independent, objective congestion charging proposal that could be implemented quickly, recognizing that any newly elected Mayor would need to produce results within the first four-year term to realize any political benefit. (Richards 2006) The ROCOL report was intended to enable any newly elected Mayor to leap into action with a technically sound plan that had been vetted by stakeholders and experts. Many options were explored using the recently developed DfT models, including scenarios with multiple cordons, differentiated pricing, and a workplace parking levy.

As congestion charging gained momentum among London civic leaders, Labour party leaders in Parliament worked on the necessary enabling legislation. The national Treasury had long held a doctrine that revenues from any taxes and levies should be treated as part of national income, to be spent on priorities set by the national government, rather than earmarked for a specific locality or purpose. (Richards 2006) In order to make experimentation with congestion charging possible, the Blair government first had to persuade the Treasury to accept the principle of hypothecation. (Yass 2013) An agreement was reached that local road user charges could be earmarked for local uses for the first ten years, extendable by the Secretary at that time.

In 1999, Parliament created the Greater London Authority (GLA) and Transport for London (TfL) as an executive agency within it, both led by a directly elected mayor. As expected, creation of the GLA served as a moment of opportunity for congestion charging. The position of Mayor was empowered with executive authority over transportation and land use, and allowed to introduce two forms of pricing, congestion charging and levies on workplace parking spaces, “for the purpose of directly or indirectly facilitating the achievement of any policies or proposals set out in the Mayor’s Transport Strategy.” (1999) Furthermore, the revenues arising from these policies were allowed to be programmed by the Mayor, as long as for a transport purpose. At that point, the ROCOL report was projecting net annual revenues of £250 million, money the new

Mayor could immediately invest in improvements to public transportation. The next year, the Transport Act of 2000 extended these powers to the rest of England. Disagreement persisted for many years about whether local revenues raised by using them should replace or supplement revenue support from the national government.

The business community, through London First, played a prominent role in supporting congestion charging through their sponsorship of the ROCOL working group and research. (Yass 2013) These large employers recognized the economic burden of congestion and realized that without better transit access, they were limited in their ability to grow within the CBD. Those located in the Square Mile also recognized the less tangible benefits of an enhanced pedestrian environment. After an attempted terrorist bombing in 1993, the financial and insurance industries had worked with the City of London to install a security perimeter called the ‘ring of steel’, consisting in part of road closures, bollards, traffic diverters, and security cameras. (Rees 2013) An unexpected outcome of this ‘ring of steel’ security installation was to enhance walkability in the City, due to reduced traffic volumes. Congestion charging was anticipated to have similar traffic reduction and security benefits by this influential constituency.

Eleven candidates entered the Mayoral race, yet only two were willing to consider congestion charging, and only one promised to implement it. Conservative candidate Steve Norris and Labour candidate Frank Dobson both promised not to introduce congestion charging in their first term, saying that public transit improvements had to be made first, although without specifying how they would be funded. (Richards 2006) Candidate Ken Livingstone, who ran as an independent, was one of three candidates promising to introduce congestion charging. His election manifesto proposed to reduce road traffic by 15% and “consult widely about the best possible congestion charge scheme to discourage unnecessary car journeys in a small zone of central London…with all monies devoted to improving transport.” (Livingstone 2000) On May 4, 2000, Livingstone beat Conservative Norris in a run-off with 58% of the vote to become the first directly elected Mayor of London.

The ROCOL final report, published in March 2000, was highly influential during the election and ultimately served as the body of research underpinning the new Mayor’s congestion charging proposal. (DfT 1995) When Livingstone published his draft Transport Strategy in January 2011, it contained a congestion charging proposal almost exactly as recommended by the ROCOL report, including the same boundaries, enforcement using Automated Number Plate Recognition (ANPR) technology, and charge level of £5. (Leape 2006)

2.4.4 Integrating the public transit system

When the Labour party came to power in 1997, the new policy emphasis was on *integrated* public transportation, and the new government hugely increased the level of funding for planning and subsidizing transit services. (Blair 1998) During the three-year period before the GLA legislation was passed, London was given an immediate infusion of £1 billion, including £365 million to address urgent maintenance on the Underground system and funding for implementation of the London Bus Priority Network, a light rail extension to London City Airport, and pedestrianization of Trafalgar Square. (Richards 2006)

When TfL was created in 2000, it took ownership of London's Underground and light rail networks, but bus services in London are still provided through a contract tendering system with private companies. TfL acts as regulator and manager, setting fares and standards for buses and driver training, and providing customer information. An in-house subsidiary company, London Buses Limited, plans routes, specifies service levels, monitors service quality, and is responsible for bus stations and stops. Performance improvements are achieved via performance contracting which provides incentives for hitting specific reliability targets. (Barry 2014)

In 2000, London's public transportation system was fragmented and deteriorating. The state of the system reflected its history of fragmented ownership and inconsistent investment. Livingstone made system repair and integration was a top priority in his first Mayor's Transport Strategy in 2001:

> "London has an extensive and complex transport network that has grown up over many years, often in an ad hoc way. As a result, physical connections between different means of travel and services are frequently long and difficult, and many interchanges are badly laid out and unattractive. This is made worse by the tendency of transport providers to focus resources and attention on the services and facilities that they directly provide or manage. Little attention has been paid to enabling people to move easily between one method of travel and another, or how they access their bus stop, rail or Underground station. As a result, people often face wide variations in standards of ease, safety, security, network accessibility and comfort during different parts of their journey. Poor co-ordination between the many organisations that have been involved in planning and operating London's transport network compounds these problems. This failure to co-ordinate results in poor service connections, confusing and partial information, and a complex system of fares and tickets." (TfL 2001)

The framework for TfL and transport system integration was set by the Blair government, which sought to retain a reduced public role in transport service provision. Their plan was to retain a privatized system with some modifications, rather than restoring full public ownership. TfL was to take ownership of London Buses from the central government, but keep the tendering system in place. The private Underground operators were to be consolidated into three new infrastructure companies that would enter into a public private partnership (PPP) with TfL. (TfL 2001)

The Livingstone administration agreed with leaving the bus system unchanged, because private bus operators had performed well and grown their ridership throughout the 1990s. However, the Mayor disagreed with a plan to operate the Underground as a public private partnership with London Underground Limited. He saw the Underground as a critical public asset and argued for full public ownership and control. In Annex 3 of the Mayor's Transport Strategy, TfL argued that a PPP would place the burden of ownership and capital investment on public, and no accountability for operations on the private operator. Public managers, they argued, would be responsible for public safety and reliable performance while lacking practical means to control operations. (TfL 2001) They also argued that the scale of repairs necessary to upgrade the

Underground to meet increasing demand would require central coordination and timing of repairs on each line to keep the system functioning reliably. The dispute went on for several years, during which TfL was told it would not obtain a multi-year funding commitment from the Treasury except via a public private partnership.

Eventually the Government changed its position, and in 2005 TfL was given full ownership and control of the Underground, as well as a five-year funding commitment from the Treasury to finance system repairs through bond sales. TfL announced a £10 billion investment program:

> "A groundbreaking settlement with Government has provided a once-in-a-generation opportunity for London to reverse this decline. We have the certainty of being able to invest £10 billion in London's transport over the next five years. For the first time, TfL is allowed to borrow funds to get major projects moving. There is £3 billion in new borrowing on top of £4 billion scheduled to be invested through existing PPP and PFI contracts. And there is £3 billion of capital investment funded from a Government grant." (TfL 2005)

The five-year investment program allowed TfL to take a comprehensive approach to repairing and upgrading London's transport infrastructure. Even though some of the major projects would take longer than five years to be delivered, they could be planned, as the program signaled a long-term commitment from the Government to investing in London's transport system—a real turnaround after decades of neglect.

With £10 billion to invest, a range of capital projects comprising a system overhaul were undertaken as part of the five-year investment program. Basic repairs for safety, like track and signal upgrades, allowed TfL to increase Underground frequencies and deliver an extra 3 million service kilometers per year by 2010. Over 200 stations were refurbished to relieve overcrowding and improve disabled access, including new entrances, interchange tunnels, escalators and elevators, and bicycle parking, 7,000 bus stops were upgraded with lighting, and £200 million was invested in walking and cycling improvements, focused in town centers, and the London Cycle Network. Over £250 million was invested in safety improvements on TfL's strategic road network. All projects planned as part of its 'once-in-a-generation' system overhaul were complete by 2012. (TfL 2005) An important aspect of system integration was launched in 2003, a new smartcard ticketing system called the Oyster Card. Smartcard readers were installed in all Underground stations and buses, significantly reducing boarding times and easing transfers. Within the first year, 27% of weekday journeys on the Underground, and 18% on buses, were made using the Oyster card; single journey tickets were nearly entirely phased out 10 years later. (TfL 2005)

In 2008, Ken Livingston lost his second re-election bid to Conservative candidate Boris Johnson, but efforts toward many key policies and programs that he set in motion continued, such as system integration, a priority on bus services, and the congestion charging zone.

2.5 Rail transit investments, 1990 to 2012

The supply of public transit infrastructure and services was expanding throughout the timeframe of this study. As the remainder of the dissertation is focused on measures improving bus capacity, this section covers important expansions to London's rail transit network.

2.5.1 Rail capacity investments

London residents and business leaders have historically recognized the value of public transportation and supported transit investments. Even during its period of austerity in the 1980s and 1990s, London managed to expand its rail transit network. As shown in Table 2.2, from the start of Docklands Light Rail construction in 1987, until 2012 when the orbital Overground route was completed, 129 miles of track and 176 stations were added to London's rail transit capacity. About half of the stations (47%) and one-third of the track (33%) were added during the 1990s. These rail capacity expansions are illustrated in Figures 2.8 (1987 to 2000) and 2.9 (2001 to 2012).

Table 2.2 Capacity expansions to London rail transit systems since 1987

New rail transit capacity	Year opened	Stations	Miles of track
DLR first two lines	1987	15	7
DLR extension to Canary Wharf	1991	2	1
DLR extension to Beckton	1994	11	5
DLR extension to Lewisham	1999	5	3
Jubilee Line extension to Stratford	1999	11	10
Croydon Tramlink system, two lines	2000	39	17
Subtotal (% of Total)		83 (89%)	43 (83%)
DLR extension to London City Airport	2005	4	3
DLR extension to Woolwich	2009	2	2
DLR extension to Stratford	2011	4	4
Subtotal (% of Total)		10 (11%)	9 (17%)
Total		**93**	**52**

During the 1990s, two new localized rail transit services, Docklands Light Rail and Croydon Tramlink, were built via public private partnerships, using abandoned or under-utilized rail right of ways. In 1999, an extension of the Jubilee line of the Underground from Green Park to Stratford through south and east London was opened. Since TfL was created in 2000, the focus has shifted to repairing, upgrading and integrating existing rail capacity. Besides repairing the Underground, TfL's most significant project TfL during the 2000s was taking over several commuter rail lines and linking them together to form the Overground, a new orbital service. Each of these projects shall be discussed in turn.

Figure 2.10 Capacity expansions to London rail transit from 1987 to 2000

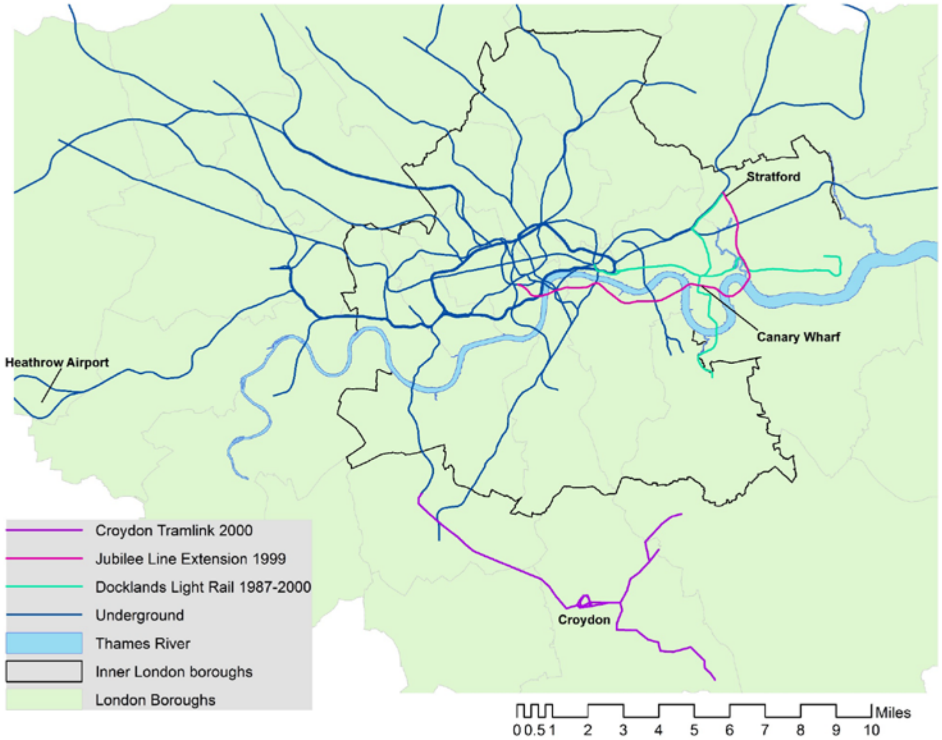
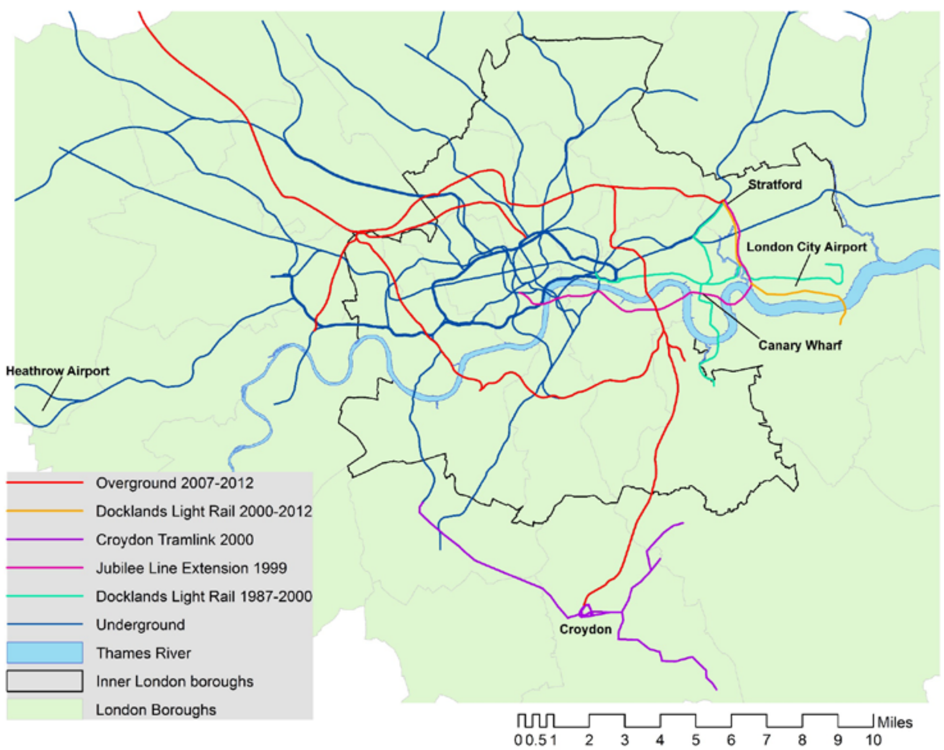


Figure 2.11 Capacity expansions to London rail transit from 2001 to 2012



The first new rail transit system to supplement the Underground was Docklands Light Rail (DLR), which began service in 1987. It was developed by the Docklands Development Corporation, a quasi-public agency set up to regenerate London's defunct industrial harbor, an eight-square-mile area adjacent to the City of London. The infrastructure was owned by Docklands Light Railway Ltd, and operated via 7-year concession contracts, this first of which was awarded to Serco Docklands Limited. (LDDC 1997) The DLR used existing rail infrastructure to connect the City to a new financial center, Canary Wharf, and a new airport to serve business travelers, London City Airport. Its lines traverse the economically deprived boroughs of Tower Hamlets, Newham, and Greenwich. An explicit aim of the system was to generate jobs and economic activity in these areas, but it has been criticized for failing to serve existing residents and spurring a process of gentrification and displacement.

The first rail transit system located entirely in Outer London opened in 2000, Croydon Tramlink. It is a light rail system centered on the town of Croydon, fifteen miles south of central London. Croydon is the largest urban center outside of central London, with nearly 100,000 people employed there. Tramlink serves the populous boroughs of Croydon and Merton, which have no Underground service. It was built via a private finance initiative contract and operated by a concessionaire, Tramtrack Croydon Limited, under a 99-year lease. (RT 2009)

When TfL was created in 2000, it became responsible for both the DLR and Croydon Tramlink. The transition of the DLR was a smooth one, with TfL re-awarding a concession contract to Serco. TfL has continued to expand the system, with the most recent line to Stratford opening in time for the Olympics in 2012. Croydon Tramlink proved to be more problematic, due its private ownership and minimum income guarantees. In 2006/07, TfL was forced to pay £4 million to TCL in compensation for changes to fare arrangements. As the amount was expected to increase throughout the life of the private finance initiative contract, in 2008 TfL agreed to buy out TCL for £98 million. (RT 2009)

2.5.2 The Overground

In 2006, TfL began to assemble a major new orbital rail network, the Overground, by acquiring and rebranding existing commuter rail lines. Figure 2.10 shows a conceptual map of the Overground as a circle around central London. Its name reflects that the Overground runs above grade, on Victorian rail viaducts built to shuttle freight, known in recent decades as the North, East and South London Lines. Similarly to the idea of congestion charging, the idea of an orbital rail route around central London had been proposed in the 1970s and 1980s, and circulated among civic leaders in the 1990s. In 1997, briefings and lobbying aimed at Mayoral and GLA candidates promote the "Outer Circle" railway concept, and a 1999 report argued the 'suburb-to-suburb railway could support economic regeneration in Inner London. (Hall, Edwards et al. 1999) After he was elected, Livingstone floated the concept to the public with a positive response, and included it in his first Mayor's Transport Plan in 2001.

Figure 2.12 Conceptual diagram of the London Overground

Source: Wikimedia contributor Sameboat, 2009

The moment of opportunity for the Overground arose as a result of two separate processes that came together serendipitously to give TfL the necessary funding and to piece it together. The process of securing funding for track repairs and extensions of the East London Line was already well underway when Livingstone took office. During the 1990s, a lobbying group called the East London Line Group was formed by boroughs and developers seeking to spur regeneration along the historic East London line, and build new extensions to the linking to the Northern and Southern lines. (Roberts 2010) They worked together with London Underground and the DfT to secure £39 million to kickstart redevelopment of the East London Line in 2001. But it wasn't until 2004 that the funding question was finally settled, by the £10 billion five-year investment program from the national government discussed previously. The package included £1 billion in grants and borrowing authority to finance the East London Line extension project, which eventually expanded to become the Overground.

Although the project was funded, TfL lacked the powers to own and operate the future Overground system. This question was settled during a major review and restructuring of the UK rail industry by the national Department for Transport (DfT). (DfT 2004) Most intercity and commuter rail infrastructure is owned by the DfT, and services on these lines are run as franchises operated by private train operating companies. During the review process, TfL put forward a proposal that it should be given regulatory powers to act as a London regional rail authority and take over the management of rail franchises within London, as part of its efforts to integrate public transportation services. TfL argued that this authority was necessary to achieve its 'whole journey' approach, fully integrating commuter rail services with Underground and bus services, providing a similar quality of service throughout, with seamless transfers. (TfL 2004)

The proposal was accepted by DfT, effectively expanding TfL's role to include management of London's regional commuter rail services as of 2006.

These new powers allowed TfL to take over and rebrand two existing franchises and combine them with the East London rail extensions to form the Overground network. In 2007, the franchise contract on the North London line came up for renewal. The Silverlink franchise, in operation since 1997, was regarded as dangerous, unreliable and congested. (Sharp 2007) TfL awarded the franchise to a new operating company, London Overground Rail Operations Ltd (LOROL), while retaining control over branding, ticketing and fares. Services terminated while repairs and upgrades to North Railway track and stations were made, to bring them to a similar standard as the Eastern line extensions still under construction. The final piece fell into place in 2012, when the franchise contract on the South London line expired and TfL awarded it to LOROL. Some new right of way extensions were needed in order to link the rail lines, pieced together from existing viaducts and new construction. The development timeline of the Overground orbital railway is summarized in Table 2.2.

Table 2.3 Development of the Overground service in three phases

New rail transit capacity	Year opened	Stations	Miles of track
First four lines, North London	2007	54	60
Former East London line	2010	23	10
Former South London line	2012	6	7
Total		**83**	**77**

When it began operation in 2008, the new Overground service debuted new air-conditioned trainsets and a new schedule with service frequencies improved from every 30 minutes to every 10 to 20 minutes. (TfL 2008) On all lines, stations were upgraded to have a similar appearance and level of service as Underground stations. They were rebranded with a new Overground logo (using the TfL roundel), and fare gates accepting TfL's Oyster Card electronic tickets were installed. Security was improved with CCTV, better lighting, and increased staffing. (TfL 2007)

When Mayor Johnson took over TfL in 2008, he inherited the Overground project enthusiastically. His new Mayor's Transport Strategy described it as 'one of unsung success stories of TfL,' and he pledged to complete it and increase service frequencies. (TfL 2008) Since 2012, the completed orbital route of the Overground crosses the spokes of London's radial transport network, connecting town centers on adjacent spokes that had previously lacked a direct public transport connection. It allows for travel across London without going into the central business district, meaning that travel times to jobs in the inner suburbs have been greatly reduced.

Chapter 3. Long-Term Trends

This chapter presents the results of my analysis of time series data to identify long-term trends in travel, car ownership, land use, rents, and employment. I sought to compare trends in two ways. First, I compared trends in geographic areas between the Inner London, Outer London, the CCZ, and edge areas to the CCZ. Secondly, I compared trends over time in defined periods pre-and post- bus priority and congestion charging. Findings are mainly presented as series of maps, with some accompanying text discussing the trends they reveal. I interspersed the maps and discussions, rather than placing all the maps in an Appendix, to reduce the amount of flipping back and forth for the reader.

In this chapter the English “VKT” (vehicle kilometers travelled) is used rather than “VMT” (vehicle miles travelled), reflecting how the data in the maps was published. Although they use different units of distance, they are both measuring the same thing—distance travelled by vehicles.

Six major trends were found:

1. Commuter infill throughout Inner London.
2. The greatest VMT reduction is in Inner London
3. Car ownership has greatly declined throughout Central and Inner London.
4. Commute mode shift from cars to transit and biking has greatly increased throughout Inner London
5. Rail transit has improved most in Inner London’s East End
6. Office and retail rents rose fastest in Inner London’s West End

These findings reveal that London has experienced reductions of traffic congestion and VMT in a much wider area than the CCZ, throughout Inner London. Car ownership has declined, and rail transit, bus, and bicycle use for commuting grown, throughout Inner London. Both of these trends are even found in suburban Outer London, to some extent. Besides behavior change, these trends reflect the impacts of the economic recession that hit London in 2008. It is likely that many non-car owning households are new arrivals to London who did not bring a car, but the number of ‘disappearing’ cars indicates that many households also gave up cars. VMT and car ownership are likely to increase in Outer London, as the economy recovers.

The ‘commuter belt’ in Inner London has spread into the East End. The influx of commuting households, and the growth of transit and bicycle commuting there may be due in part to the combination of improved rail transit accessibility in Inner east boroughs, and steeply rising rents in the West End.

3.1 Commuter infill throughout Inner London

Figure 3.1 shows the density of commuter residences per hectare in London, using data from the 2001 and 2011 Census, by LSOA. In both maps, Inner London is clearly has much higher density of commuters than Outer London. In 2001, the highest density commuter LSOAs (shown in red) were in the West End, to the west and south of Central London. There are very few high density LSOAs to the east. In 2011, a different pattern is seen, with far more red LSOAs in East London.

Figure 3.1 Commuter density by LSOA, 2001 and 2011

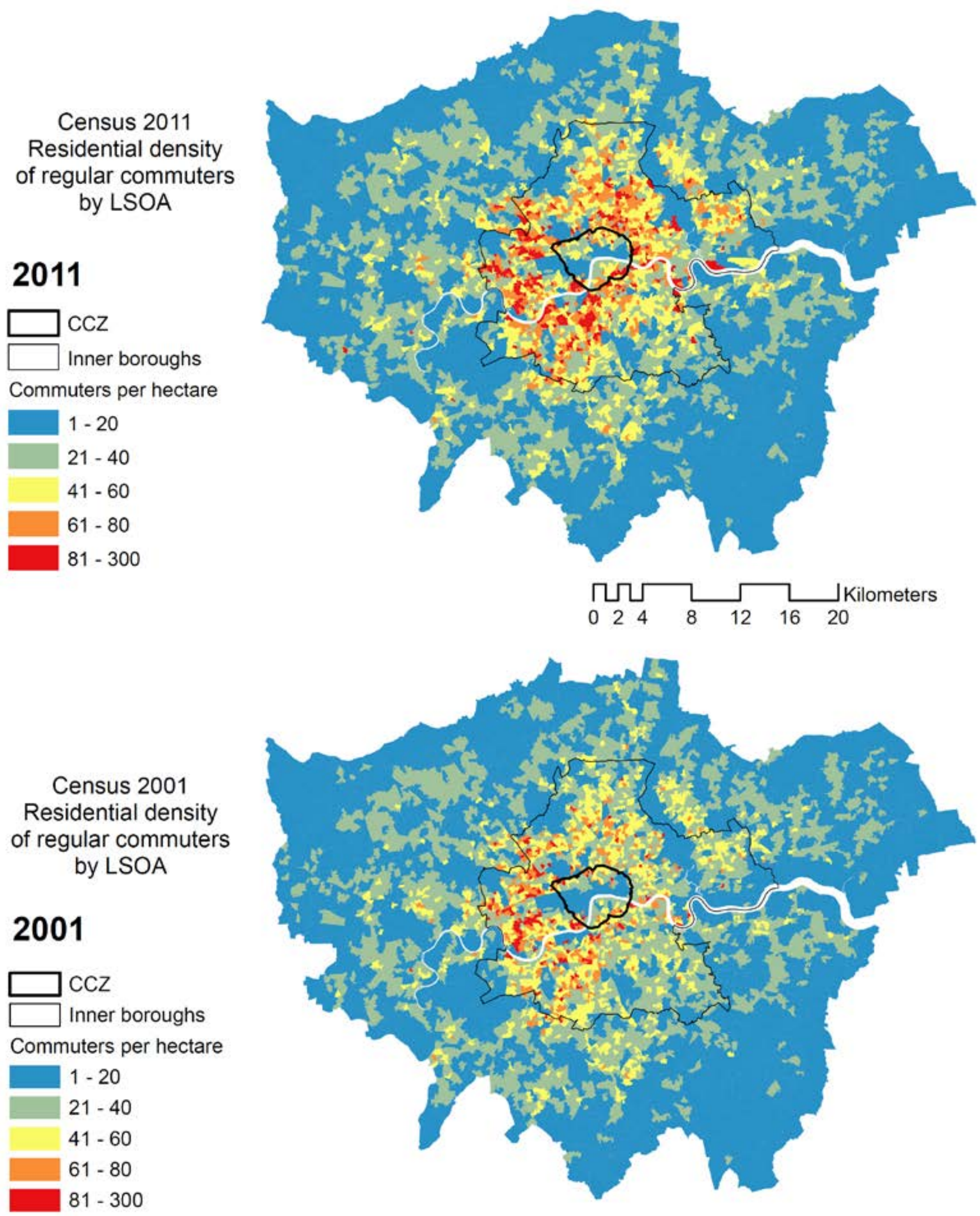
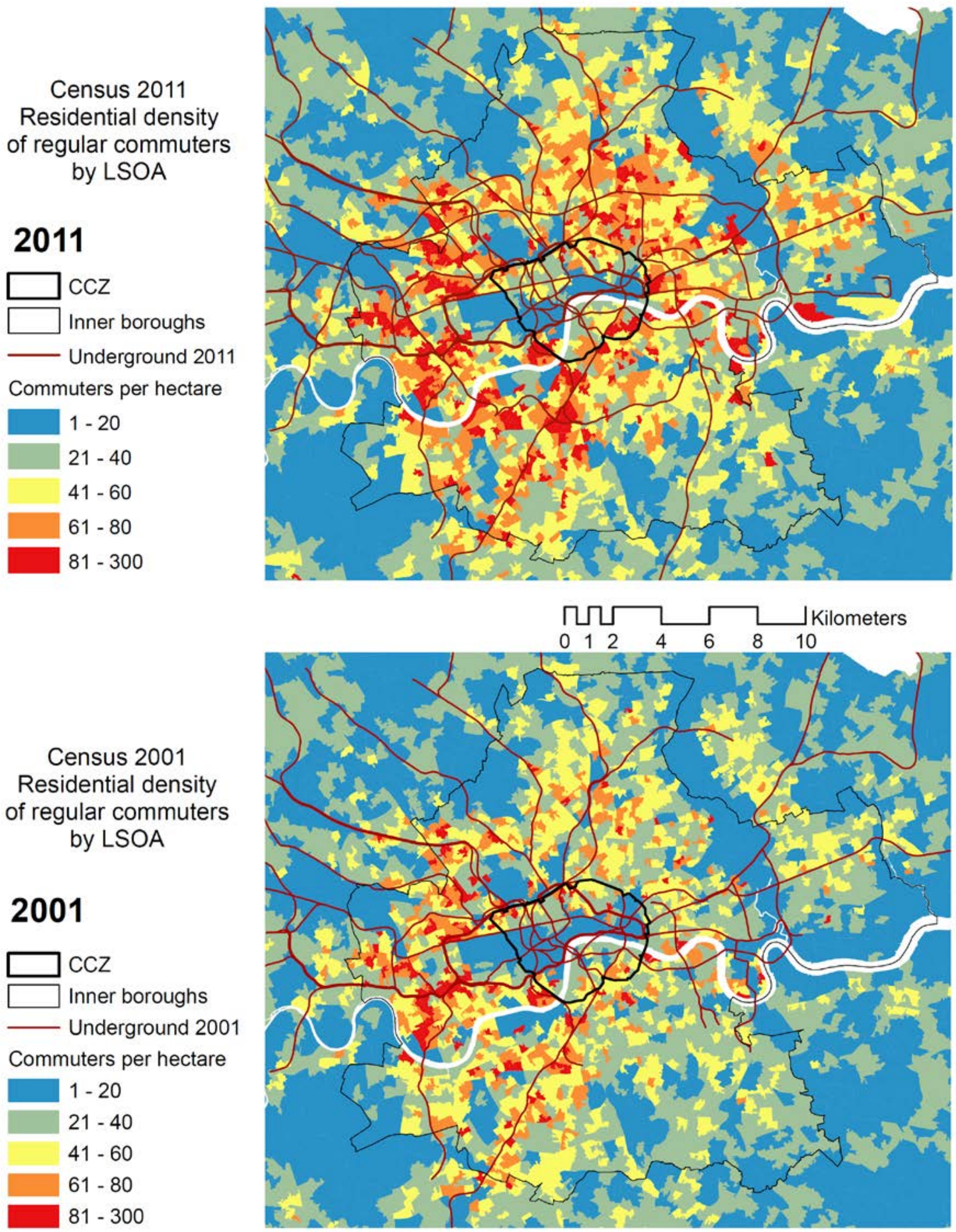


Figure 3.2 shows the same two maps, zoomed in, and with the Underground system. The pattern of increasing commuter density in the East End can be seen more clearly, as well as it is concentrated along rail transit lines.

Figure 3.2 Commuter density in Inner London by LSOA, 2001 and 2011



3.2 Declining VKT in Inner and Outer London

Figure 3.3 shows the average annual VKT for cars only, by borough. In period 1 (1993 to 1997), cars travelled a total of 25.9 billion kilometers, 17.7 billion in Outer and 8.1 billion in Inner London. That amount that increased to 26.4 billion kilometers in period 2 (1998 to 2002). But VKT began to fall in period 3 (2003 to 2007), to 25.5 billion kilometers, and by period 4 (2008 to 2012), VKT had fallen below period 1 levels. Most of this decline took place in Inner London. In 1993, private vehicles were responsible for 80% of VKT in Inner London and 84% in Outer London, but by 2013 these proportions had fallen to 76% and 81%, respectively.

Figure 3.3 Average annual VKT by borough, cars only, 1993 to 2012

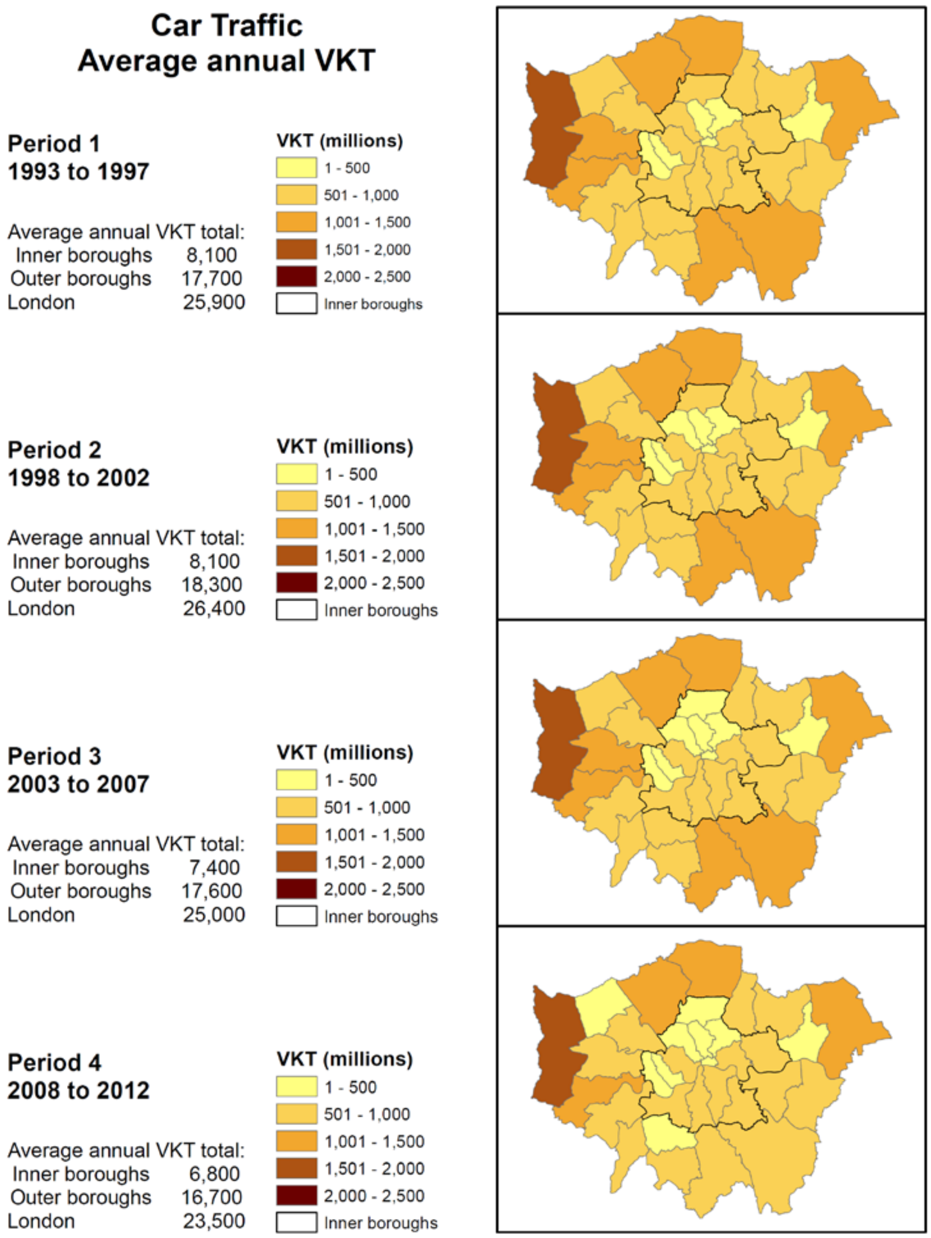
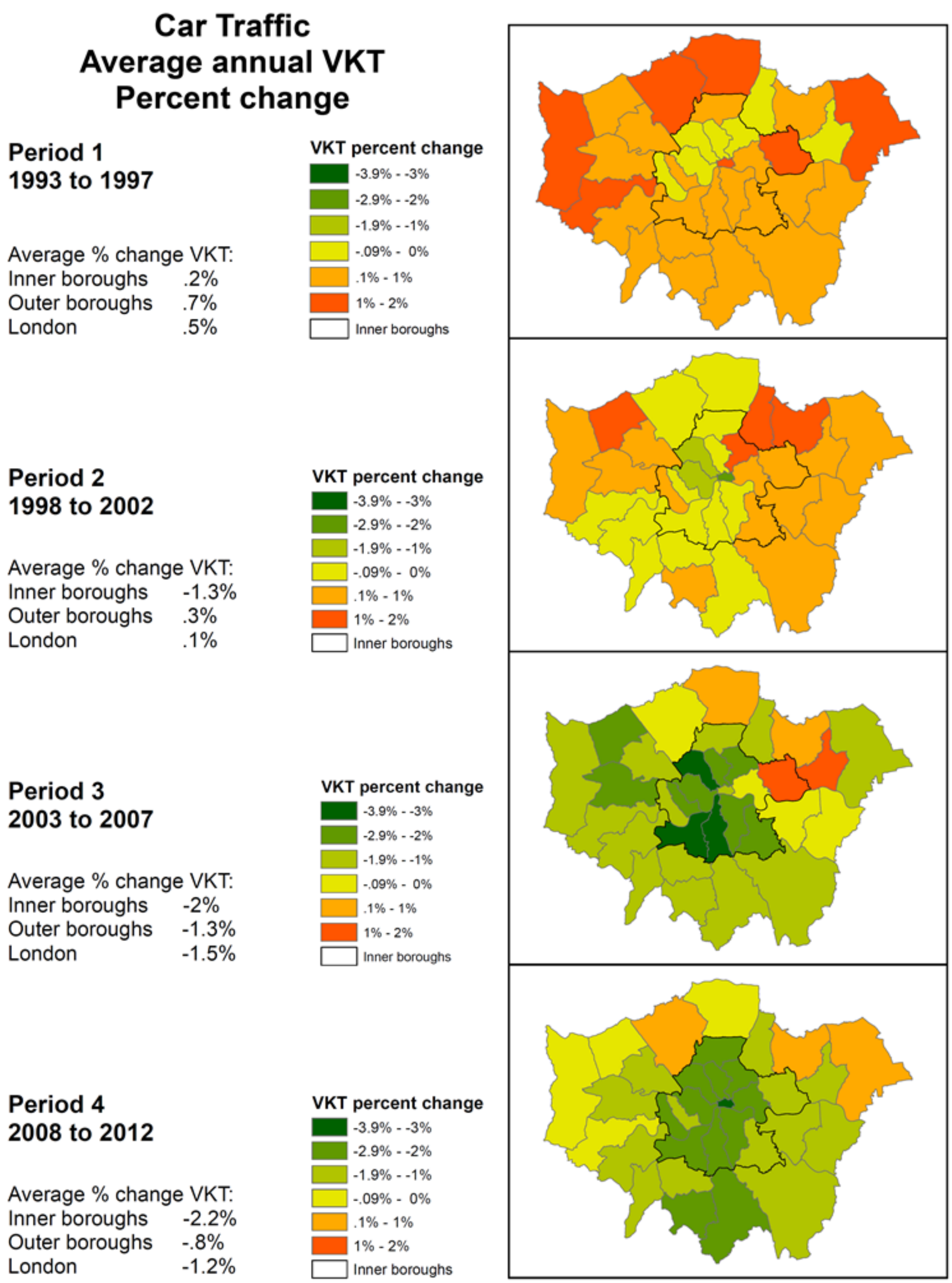


Figure 3.4 shows the percent change in annual VKT for cars, by borough. In period 1, VKT grew throughout the region in Outer (.7%) in Inner London (.2%). In period 2, VKT began to decline in Inner London (-1.3%), but continued to grow in Outer London (.3%). In period 3, VKT began to decline throughout all of London, by a total of 1.5%. This trend continued into period 4 in Inner London (-2.2%), but VKT began to creep back in Outer London (-.8%).

Figure 3.4 Percent change in average annual VKT by borough, cars only, 1993 to 2012



3.3 Declining car ownership

Figure 3.5 shows London's car population by ward. In 1991, there were 2.25 million cars in Greater London, a number that increased by 16% over the 1990s, to 2.62 million in 2001. Then during the 2000s, while the population of people increased by 8%, the population of cars increased by only 2%, to 2.66 million.

Figure 3.5 Car population by ward in 1991, 2001 and 2011

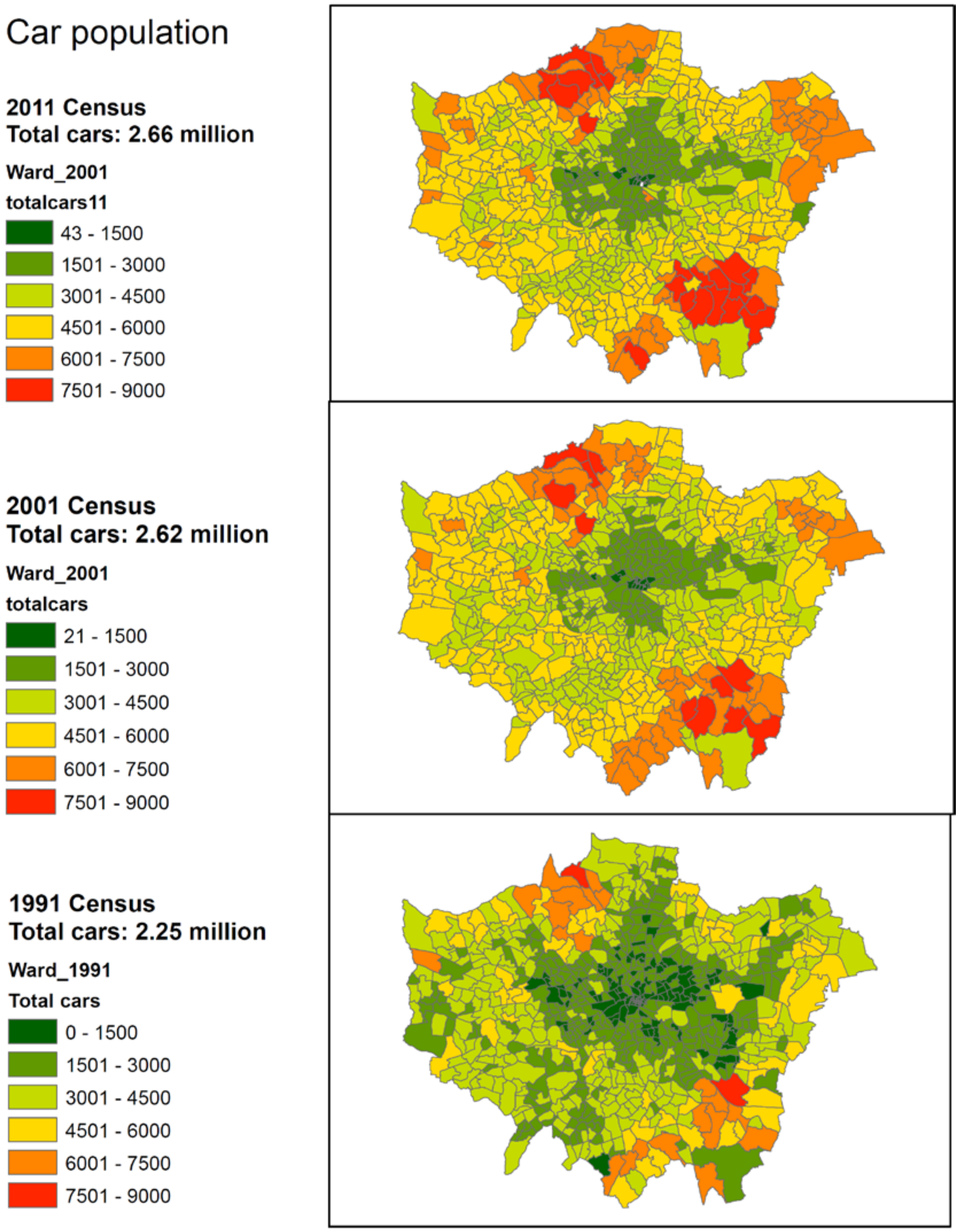
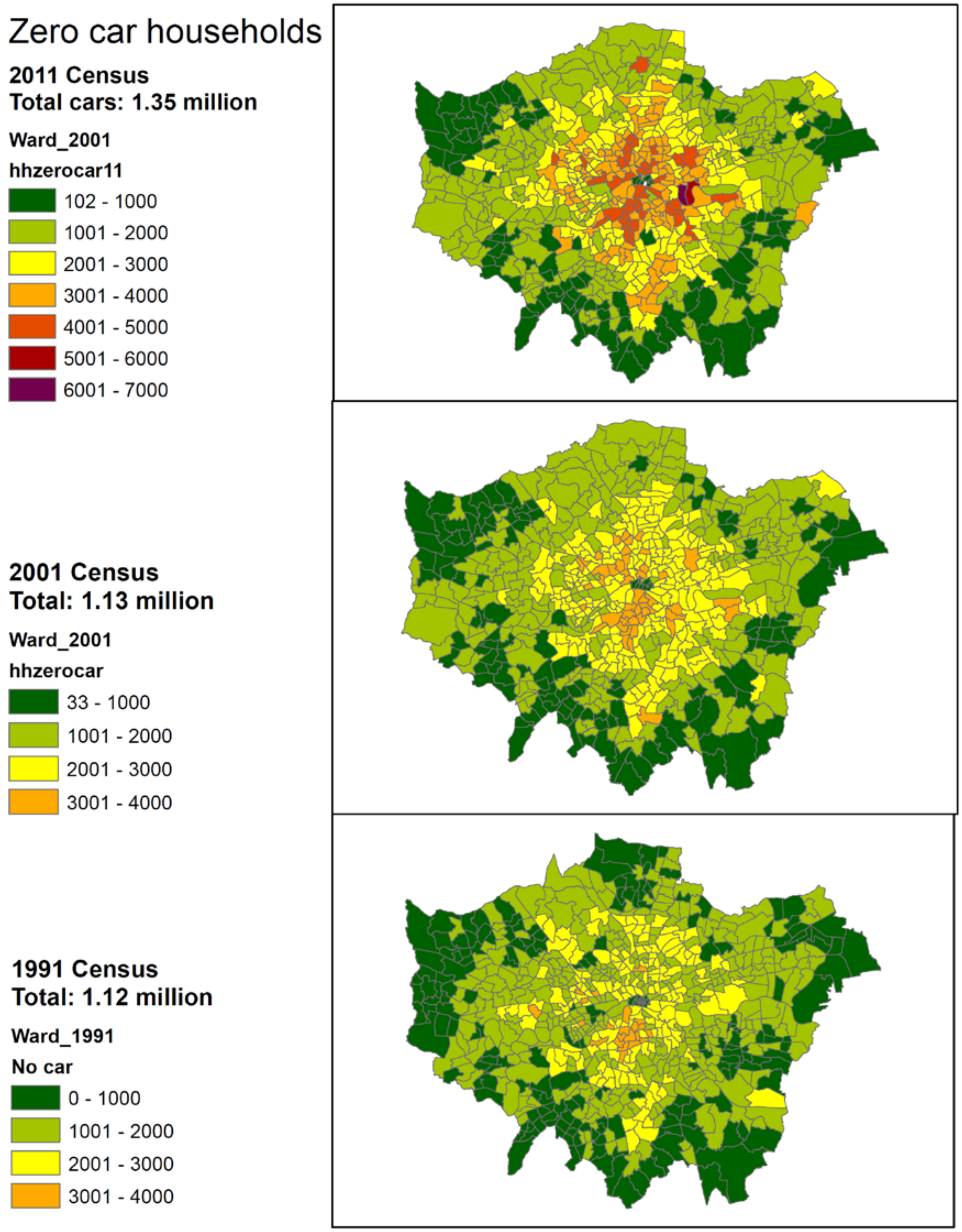


Figure 3.6 shows non-car owning households by ward. In 1991, there were 1.12 million zero car households in Greater London, a number that barely increased to 1.13 million in 2001. The number of zero car households increased by 19% during the 2000s, such that there were 1.35 million by 2011. These households were concentrated in Inner London, near transit lines.

Figure 3.6 Zero car households by ward in 1991, 2001 and 2011



3.4 Commute mode shift to transit, biking and walking

Figure 3.7 shows the mode split for driving by ward, that is, the percentage of commuters traveling to work by car. In 1991, the lowest rates of driving were in Inner London, along rail transit lines. Starting in 2001, a new pattern is visible, with driving declining in wards not directly located on rail transit. By 2011, rates of commuting by car are very low throughout all of Inner London, and into the nearest and most transit-rich areas of Outer London, like Croydon.

Figure 3.7 Commute mode share for driving, by ward, in 1991, 2001 and 2011

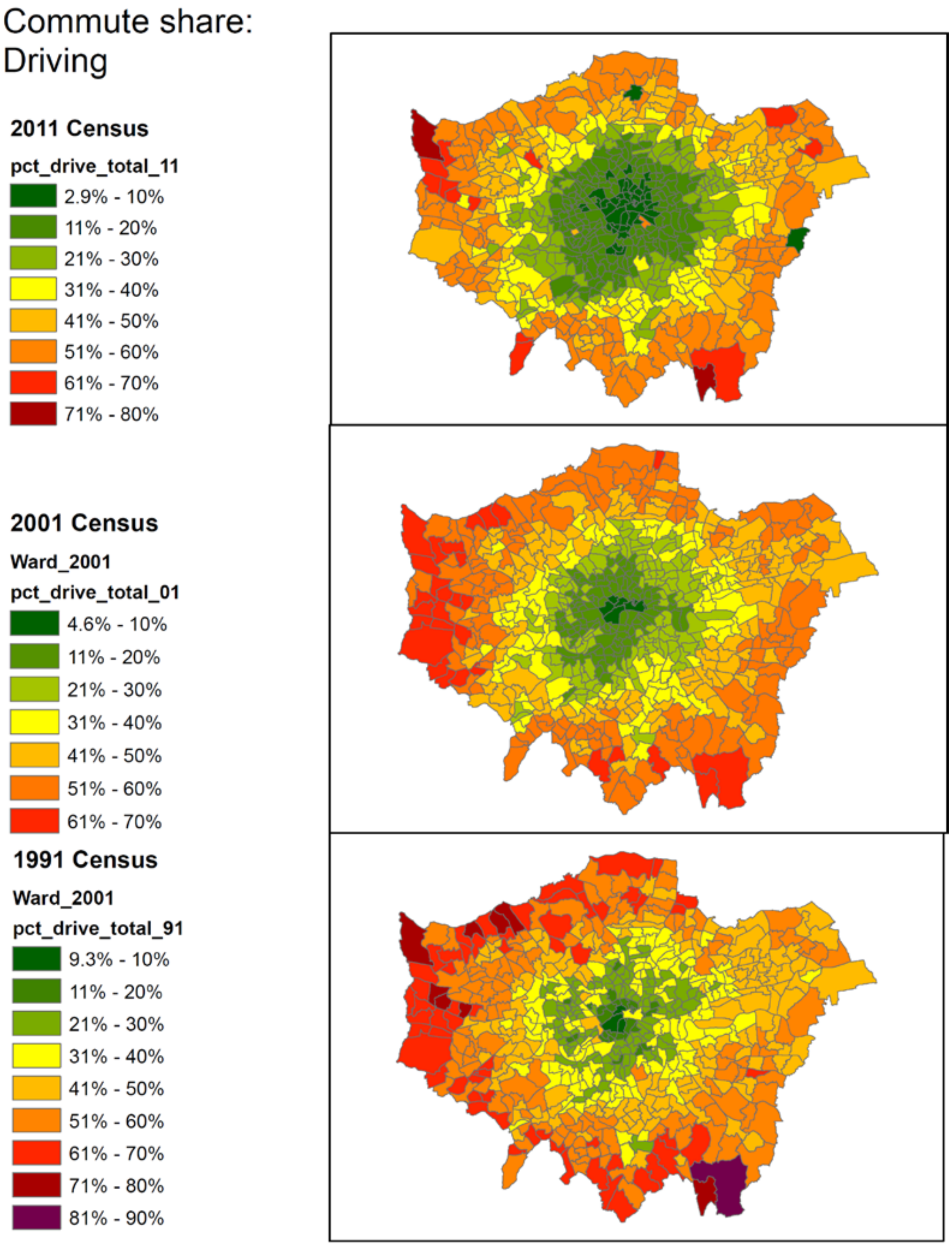


Figure 3.8 shows the mode split for rail transit by ward, including Underground, DLR, and other light rail such as Croydon Tramlink. In 1991, high rates of commuting by rail transit were concentrated along Underground lines to the west and southwest of London. By 2001, this pattern had intensified, with higher mode share for rail transit in the same wards, but new DLR service was being heavily used in the East End. In 2011, there was not only further intensification and higher rail shares in the same areas, but growth throughout Inner London and especially to the northeast.

Figure 3.8 Commute mode share for rail transit, by ward, in 1991, 2001 and 2011

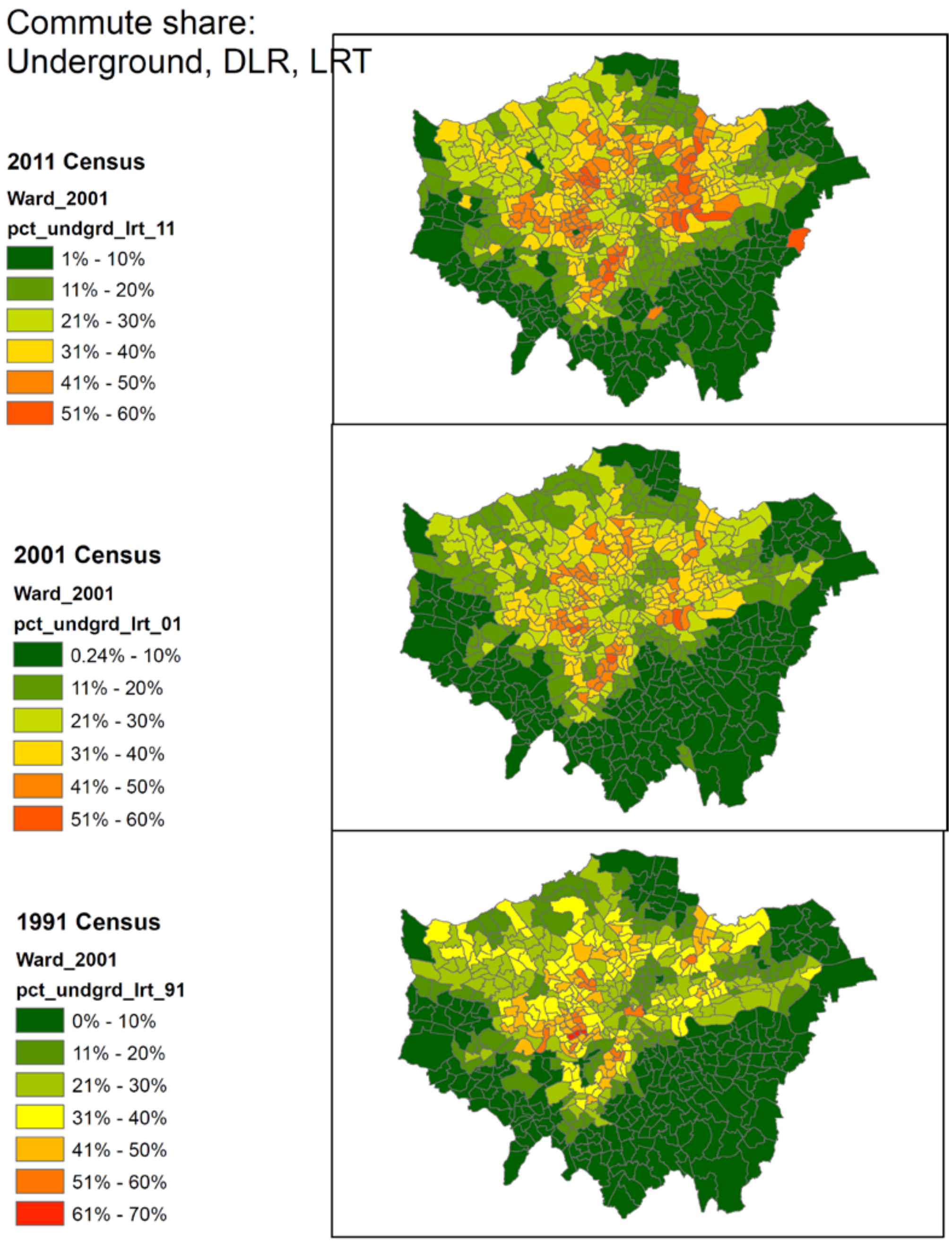


Figure 3.9 shows the mode split for bus by ward. In 1991, high rates of commuting by bus were concentrated in two areas of Inner London to the northeast and southeast of the center. This pattern had not changed much in 2001, but in 2011, many more wards in Outer London had a high mode split for buses. This increased use of buses for commuting is highest in areas with competitive service due to bus priority.

Figure 3.9 Commute mode share for bus, by ward, in 1991, 2001 and 2011

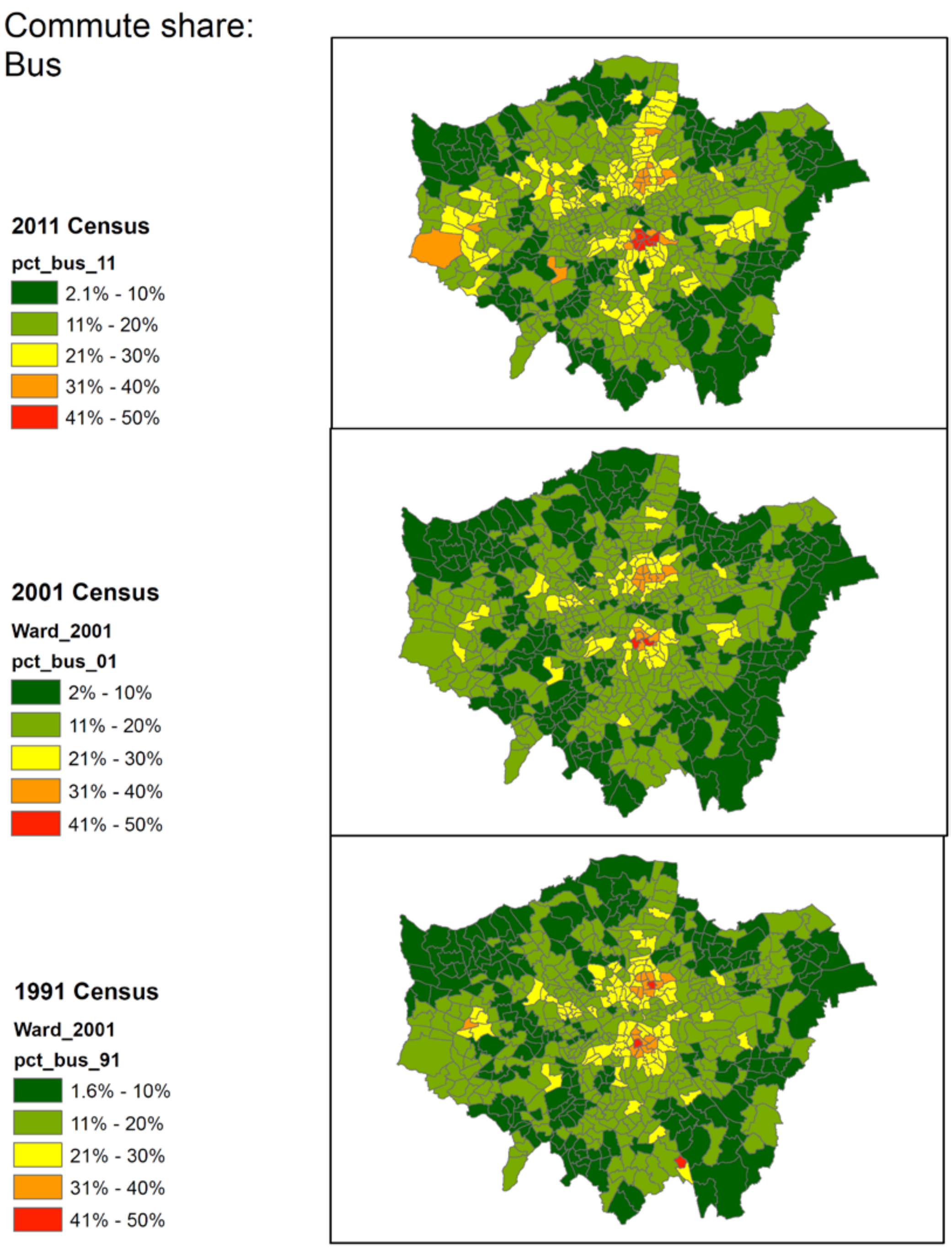
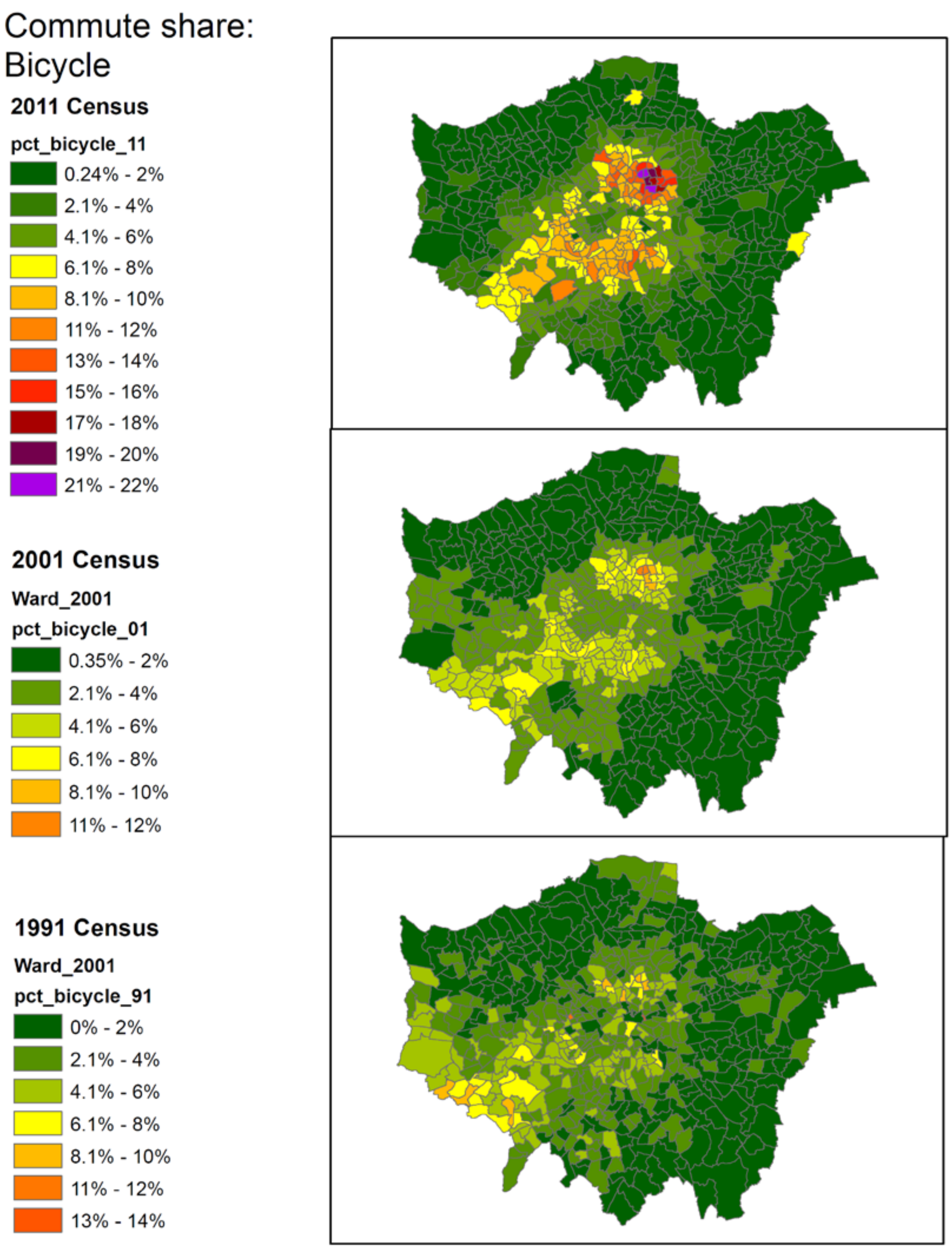


Figure 3.10 shows the mode split for bicycle by ward. In 1991, almost no wards had a noticeable share of bicycle commuting, and many of those that did were in semi-rural Sutton borough. In 2001, increasing bike commuting was visible in southwest Inner London and in northeast Inner London. By 2011, bike share had grown tremendously in the Inner northeast boroughs of Hackney and Islington, and throughout southwest Inner London.

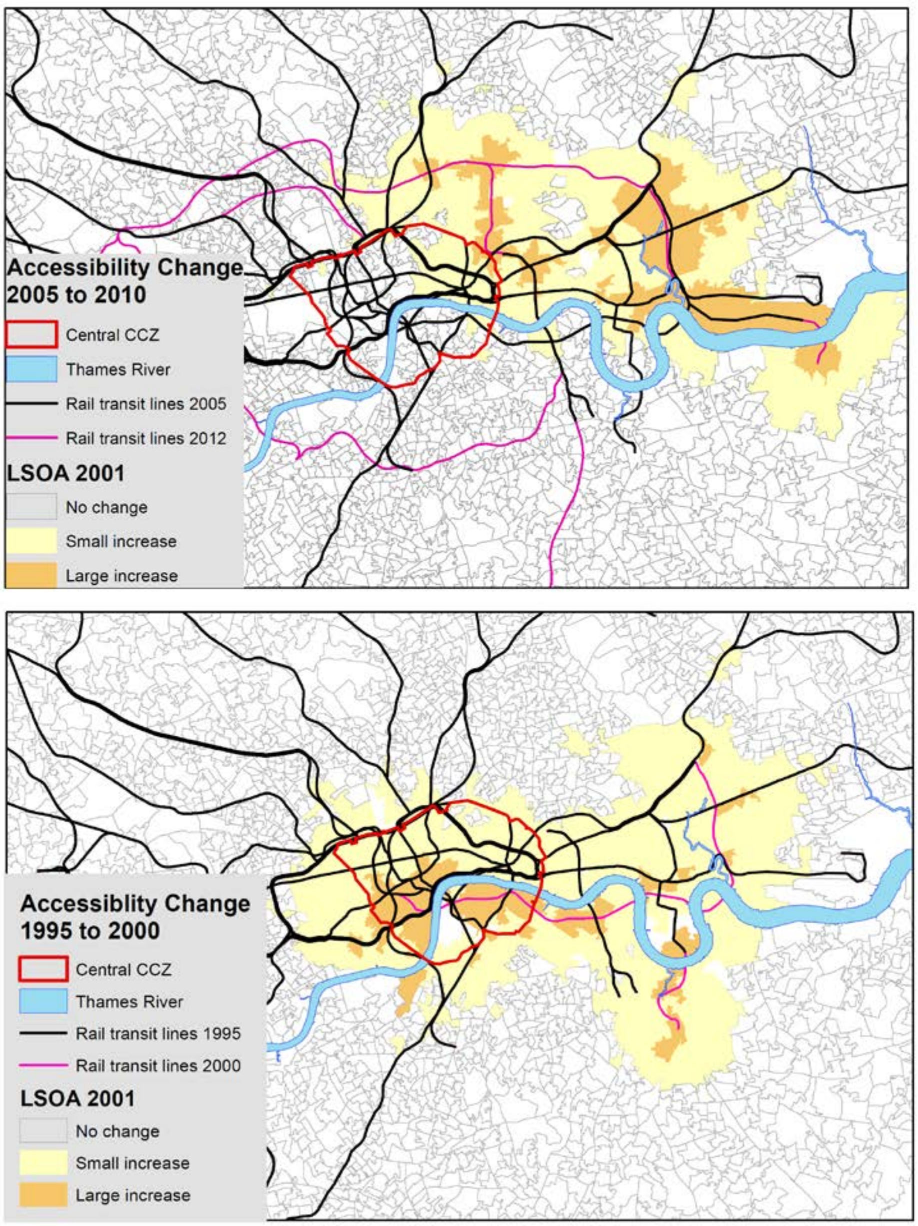
Figure 3.10 Commute mode share for bicycle, by ward, in 1991, 2001 and 2011



3.5 Improved accessibility to Central London from the East End

Figure 3.11 shows the change in accessibility using the SSI2k measure, for Inner London, by LSOA. Rather than percent change values, two categories are shown representing small and large percent changes. From 1995 to 2000, there were large percent change increases in the SSI2k accessibility measure for areas along the Jubilee extension line and DLR, in London's East End. From 2005 to 2010, there were large accessibility improvements to the east, once again, focused in areas with new DLR and Overground services.

Figure 3.11 Change in accessibility (SSI2k) in Inner London, by LSOA



3.6 Rising commercial rents Central London and the West End

Figure 3.12 shows assessed values for office space per square meter, by LSOA, which are used in this study as a proxy for commercial rent. In 1995, office rents were highest in Central London and the West End, a pattern which intensified in 2000, when the two main employment centers in Central London become visible, eg the City and the West End. Notably, rents rose very little from 2005 to 2010 in the city center, reflecting the economic downturn. In 2010, tremendous demand for office space in the West End is visible through the region's highest rents.

Figure 3.12 Office rents by LSOA

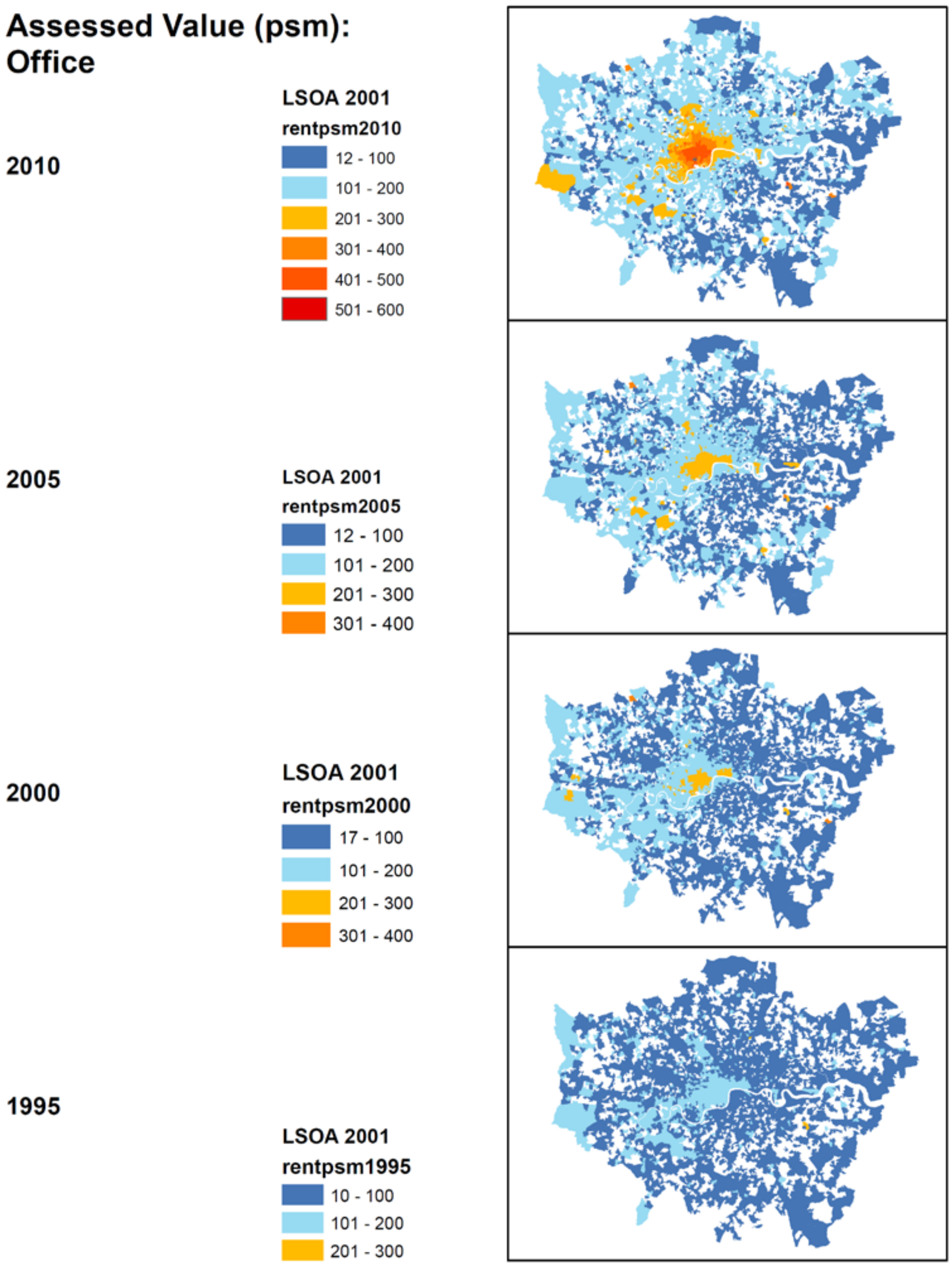


Figure 3.13 shows assessed values for retail space per square meter, by LSOA. In 1995, retail rents were highest in Central London and the West End, a pattern which intensified up to 2010. Yet rising retail rents are visible in town centers throughout the region. In 2010, the West End and Croydon commanded the region's highest rents.

Figure 3.13 Retail rents by LSOA

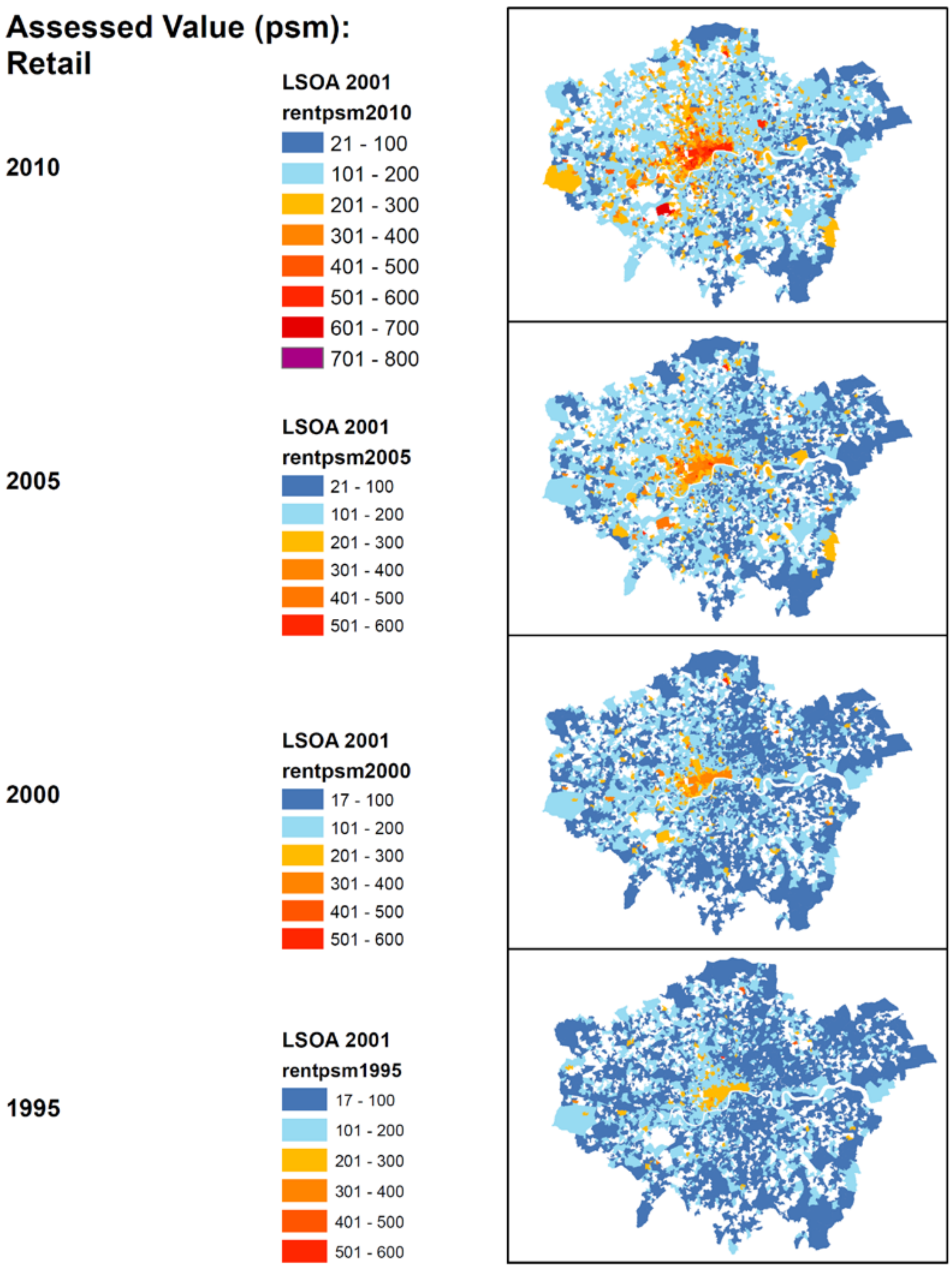


Figure 3.14 defines some areas for comparison of commercial rent trends: the CCZ, three ‘edge’ areas to the west, south, and east, the remainder of the Inner Boroughs, and the Outer boroughs. The CCZ and edge areas were defined by LSOA. Figure 3.15 shows an analysis of the office rent trend, using these defined geographic areas. Office rents in the CCZ and West Edge were the highest in 1997, and remain so. Rents were rising in all areas during the entire timeframe, but there is a kinked slope in 2005 for the CCZ and West Edge, indicating that rents in those areas were rising at a faster rate than other areas of the region.

Figure 3.14 CCZ and edge areas defined

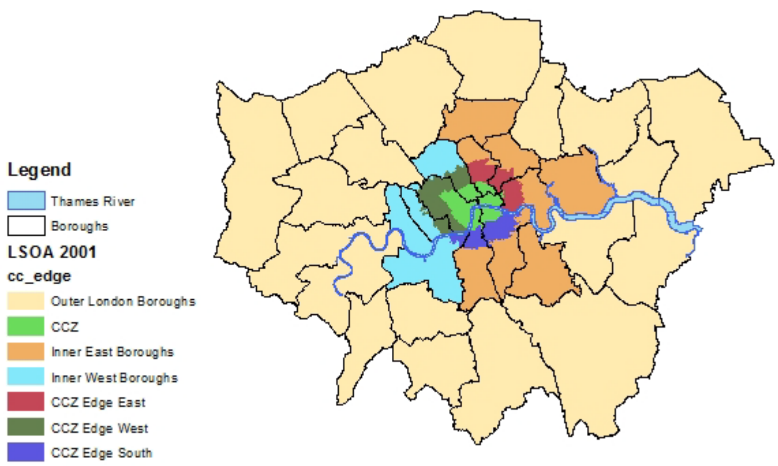
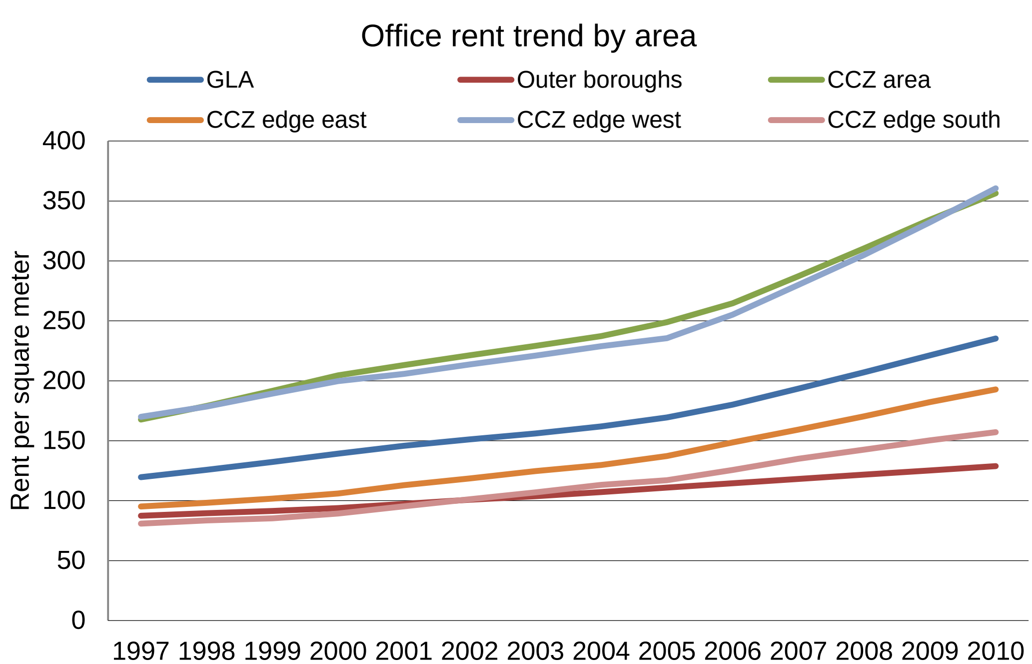


Figure 3.15 Office rent trend in CCZ and edge areas



Chapter 4. Bus Priority as a Complement to Congestion Charging

4.1 Introduction

When I interviewed transportation experts in London about measures contributing to declining VMT, nearly everyone stressed it would be a mistake to consider these trends the result of congestion charging alone. Congestion charging was part of a *package* of measures, they said, that complemented each other and worked together. Many of the measures were 'carrots' to encourage use of public transit: bus priority, expanded bus service hours, upgraded bus vehicle and stops, and an electronic payment system. Others were 'sticks' to discourage driving: congestion charging, traffic calming and diversion, parking removal, and roadspace reallocation.

Yet in the literature on the London congestion charge to date, little attention is given to complementary measures and the critical role of buses in absorbing drivers switching to transit. A critical analysis which explicitly considers the congestion charge as part of a policy package notes,

> "Research on the effects on the congestion charging scheme, naturally, focus on the reduction in congestion and when other effects are considered they are usually attributed, explicitly or not, to the congestion charge. The possible effects of other measures taken (such as the improved bus service) get much less attention, while they might be equally or more important in contributing to the effects." (Givoni 2012)

The aim of this chapter is to fill this gap. Failing to consider the synergistic effects of complementary measures is to risk overstating the impacts of the congestion charge. This chapter is the first to consider the London congestion charge as one part of a package of measures. It argues that a bold and prolonged policy of road space reallocation played a key role in preparing transport system capacity to absorb drivers switching to transit. The primary result of this effort was a regional network of dedicated bus lanes at peak hours that allowed buses to slice through congestion and provide a superior alternative to driving. Begun in the 1990s, London's extensive regional bus priority network helps to explain why car use was already in decline by the time the congestion charge was implemented in 2003. The development and scope of this bus priority network is discussed in detail using previously unpublished data made available by Transport for London.

4.2 Literature review

To date, the literature documenting London's experience with congestion charging has largely overlooked complementary measures. Congestion charging, a policy emerging from economic theory, has only been implemented in a few cities in the world. Many scholars have made use of the rare empirical data available in London to study different types of impacts. Naturally there was significant interest in evaluating the congestion charge from an economic perspective, as it tested the idea that demand for driving could be influenced by price. Surprisingly, there has been less attention to how London's transport system prepared to absorb drivers shifting out of cars. Most evaluative studies have focused narrowly on the congestion charge policy utilizing a before-after treatment structure. They mention complementary measures such as expanded bus services, but not in detail, and not as having influenced travel behavior.

In economic appraisals, expanded transit services are discussed in the context of social benefits. For instance, early economic impact evaluations calculated social costs and benefits including increased investment in transit and increased transit ridership (Santos and Shaffer 2004, Leape 2006, Peirson and Vickerman 2008). Similarly, evaluations of equity impacts identified time savings and improved journey reliability benefits realized by bus riders as a main reason the congestion charge nets positive social welfare. (Santos and Rojey 2004, Santos and Bhakar 2006) None of these studies provided a detailed discussion of changes to bus services.

Evaluations of environmental impacts discuss expanded bus services as offsetting reduced car emissions inside the charged area. For example, one study used VMT data and an emissions model to estimate NOx and PM10 reductions within the charged area. Decreases in car (-29%) and heavy goods vehicles (-11%) VMT, and thus emissions, were offset by increases in bus (+20%) and taxi (+13) VMT. (Beevers and Carslaw 2005). The emissions model could not account for the introduction of diesel particle traps on buses, making the results inconclusive. Another study compared ambient air pollutant concentrations inside and outside the charged zone, before and after it was introduced, and found low magnitude air quality improvements. (Atkinson, Barratt et al. 2009) The authors concluded these could not be wholly attributed to charging, as it was "one specific action within a general programme of measures" introduced concurrently, including bus lanes and increased bus frequencies. These studies imply the reverse is true—the environmental impacts of increasing bus services are offset by congestion charging.

The literature on public acceptance draws a direct connection between the acceptability of congestion charging and investments in public transit and other complementary measures. The trend is clear: cities with a well-developed transit system, transit-oriented urban form, and a high transit ridership tend to have higher support for congestion charging. (Kottenhoff and Brundell Freij 2009) However, some argue this is less applicable in the US where transit ridership in major cities is much lower. (King, Manville et al. 2008) Kottenhoff and Freij argue that public transit improvements are necessary, or at least helpful, for meeting traffic reduction goals with congestion charging. Transit must offer a competitive alternative, in terms of travel time, to driving. Drivers are unlikely to switch modes if transit travel times are too long, too low frequency, and vehicles too congested, while driving travel times decrease. Investments in vehicle quality guard against negative impacts on existing transit riders, like excessive crowding, and help ensure that new riders have a high-enough quality first experience to retain them.

Few empirical studies have considered congestion charging in a wider policy context, or as explicitly paired with bus services. In Stockholm, public transit was directly linked to congestion charging as a policy package, with charge revenues closely linked together in political decisions and public communications. (Kottenhoff and Brundell Freij 2009) During the trial period when congestion charging was tested, expanded public transit services were brought into effect four months before charging began, and continued five months after it ended, allowing for a comparison between congestion pricing paired with bus service expansions and bus service expansions alone. Frequencies were increased on 20 existing bus lines, and 14 new bus lines were introduced, offering direct service as an alternative to transferring to rail. Before the trial period, the authors found the new direct bus services had only a small attractive force as a stand-alone measure, with transit ridership increasing about 2%. During the trial, there was a 20% reduction in car traffic crossing the cordon during charging hours (6:30am-6:30pm), and a 6% increase in transit ridership city-wide. (Kottenhoff and Brundell Freij 2009)

When congestion charging was being debated in London, experts argued "road pricing…needs to be implemented with an appropriate package of complementary transport and land use measures, to address [barriers to public acceptability]." (Jones 1998) Alternatives to congestion charging were perceived as inadequate, on their own, to deal with traffic congestion. Public transit investments were seen as necessary but not sufficient, while parking restrictions would not address congestion from through traffic or drivers using free spaces provided for employees and customers. (Jones 1998, Banister 2003) It was important to the public that improved transit services be introduced *prior* to charging. (Banister 2003) During the public consultation process for the congestion charge in 2001, the top issue raised by stakeholders and the public among 2,300 comments was the "need to improve public transport before [the congestion charge] is introduced." (TfL 2002) For example, the London Chamber of Commerce commented, "there must be sufficient public transport available to absorb the potential 15% transfer of people from their cars." (TfL 2002) Despite this emphasis on complementary measures in the planning phase, evaluations of the London congestion charge seldom focus on them.

4.3 Research questions and methods

The aim of this chapter was to investigate the role of bus priority and other complementary measures in the success of London's congestion charge. Several research questions are posed:

- How were bus services improved, and in what ways were services extended?
- What complementary measures were implemented, and when?
- What role did improved bus services and complementary measures play in winning stakeholder support for congestion charging?
- How did bus services and complementary measures impact the effectiveness of congestion charging?

As discussed in the Introduction, a mixed-methods research approach was used to address these questions, where data analysis to identify trends was complemented by expert interviews. Primary data sources included reports, conference papers and data published by Transport for

London (TfL) and the UK Department for Transport (DfT), as well as UK Census data. Only one data source is not publicly available, the Bus Lane Database, which was provided to the author by TfL upon request. Forty semi-structured interviews were conducted in London during the 2013-14 academic year. Interviewees included representatives of various transportation and business interest groups, developers, academics, and planners at Transport for London and the Greater London Authority. Many of the findings presented in this paper emerged from the interviews, and from data made available by interviewees. Findings are presented in two main sections. The development of a bus priority network is discussed first, and then TfL's complementary measures program is discussed.

4.4 A package of measures

Congestion charging is a key measure in a package of transportation and land use measures implemented with the aims of boosting transit ridership and restraining private car traffic. Table 4.1 shows a summary of these measures. Not all of these measures will be discussed in this chapter, but they are offered as context to show the way that measures were paired, and their sequencing. Bus priority was a 'carrot' measure well underway prior to congestion charging becoming a real possibility. It became linked with congestion charging at that point, and implementation of bus priority measures was accelerated.

Table 4.1 Summary of transportation and land use measures for reducing VMT

Measure	Implemented
Bus priority lanes on red routes and central streets	1997-2008
Bus replacement - low emissions, double entry	2001-2012
Congestion charging	2003
Abolish parking minimums and relax height restrictions	2004
Smartcard fare system, Legible London wayfinding	2004-2006
Repair and upgrade Underground for faster headways	2005-2010
Expansion of Docklands Light Rail to Inner East	2005-2011
Integration of Overground rail network	2007-2012

4.5 Expanded bus services as a paired measure to congestion charging

When Livingstone took office in 2000, buses were a top priority. His 2001 Transport Strategy set out to increase bus ridership by 40% from 2001 to 2011, using fare policy, road space reallocation and a comprehensive overhaul of every dimension of bus service quality. "People's experience of travelling by bus must be transformed: the chronic problems of unreliability and slow journeys will be tackled. Buses must be reliable, quick, convenient, accessible, comfortable, clean, easy and safe to use, and affordable." (TfL 2001) With this directive, accompanied by significant funding increases, TfL planners sought to not only increase bus capacity, but to make buses competitive with cars in terms of comfort, travel time, and reliability.

Buses were seen as key to the success of congestion charging, because London's Underground and commuter rail services were already operating at full capacity, and required significant upgrades and repairs for services to be improved. In order to prepare the public transport system to absorb drivers switching from cars, TfL planners focused on bus services. Buses were seen as a mode that could be turned on and off again, quickly. As the Planning Director of TfL commented,

> "Some people said we couldn't do [congestion charging] without building more rail lines. And we said, we can, because if you look at some of the trips that are being made, they are actually quite short. So we'll push them onto the buses, and the longer ones will spill onto the Tube, and the shorter ones on the Tube will spill onto the buses—there will be a cascade effect. Also, you push some people out of cars onto bikes, and you push some people out of cars into carshare." (Dix 2013)

Major investments were made in six different areas to transform bus travel: expanded service hours and frequency, expanded network coverage, upgraded vehicles and bus stops, simplified fare structure and an electronic fare payment system, and road space reallocation for bus priority. Each shall be discussed in turn.

4.6 Measures to increase bus capacity

4.6.1 Expanded bus service kilometers

Normally bus services are planned in response to changes in demand, but leading up to congestion charging, new bus services were introduced proactively. TfL focused making bus services more consistent, frequent, and easy to use. Frequencies were boosted on 53 routes, 300 new buses were purchased, including bigger buses on 10 routes, and seven new routes were added. High-frequency service (ten minute headways) on most lines serving Central London.

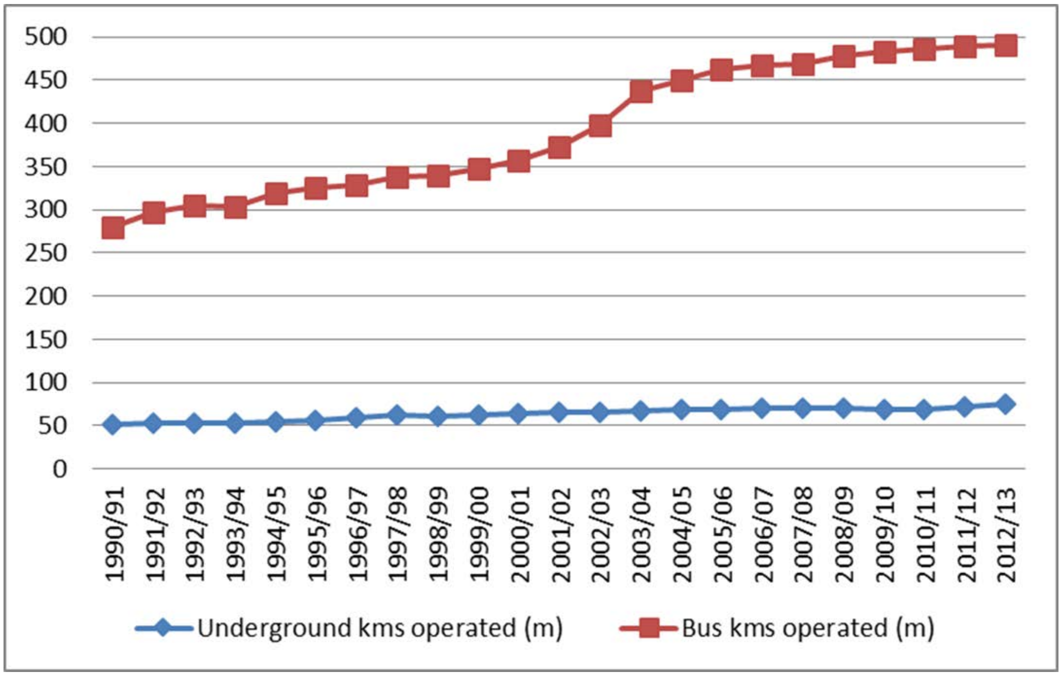
Bus services in London are provided through a contract tendering system with private companies. TfL acts as regulator and manager, setting fares and standards for buses and driver training, and providing customer information. The contracting system allows London's bus network to be dynamic and respond quickly to growth and changing needs. Every year up to 20% of total bus services are re-tendered[1]. (TfL 2008) The contracts are for five years and specify the bus route and level of service, for example, every 10 minutes for 24 hours per day using a double-decker bus and meeting a minimum performance standard of 90% on-time reliability. Similarly, TfL sets design standards for bus vehicles but does not own them.

Figure 4.1 shows the annual rail and bus service kilometers operated by TfL, illustrating the rapid growth of bus service compared to rail service. From 2005 to 2010, the growth trend for the Underground was flat, as the system was in a constant state of repair. Bus service kilometers were growing during the 1990s, but bus service kilometers increased at a much higher rate from 2000 to 2003. To prepare for congestion charging, bus operations were increased from 350,000

[1] Operators submit bids based on a per-mile cost, but they may earn more or less based on performance, due to the use of quality incentive contracts. In 2014, a typical per-mile cost was between £6 and £7. (TfL, 2014)

service kilometers per year to 450,000 by 2003 (nearly 30%), and then continued to increase as TfL invested congestion charge proceeds into bus services. (TfL 2005, TfL 2013)

Figure 4.1 Annual transit service kilometers (million)



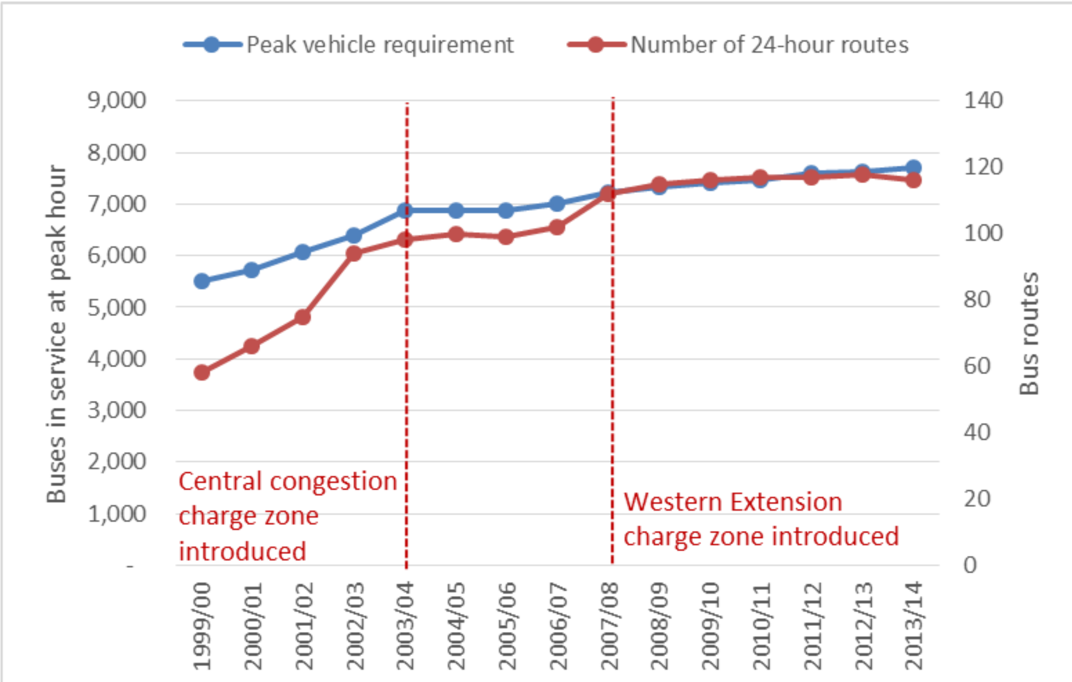
Data source: TfL Travel in London Report 6 2013

4.6.2 Bus routes and frequencies

Increased bus service kilometers took the form of longer operating hours and higher frequencies on existing routes, and extended services on new routes. Figure 4.4 shows two measures of increased bus services to illustrate - the number of 24-hour bus routes, and the bus peak vehicle requirement. As the number of London bus routes has grown, so has the proportion of routes with 24-hour or night-only service (rail replacement). In 1995, London had 560 bus routes and 53 night routes, about 10%. Driven by growth in London's nighttime economy, the number of bus routes with night service increased from 49 in 1990 to 66 in 2000, and ridership grew by over 40%. (TfL 2001, Barry 2014) In 2000, TfL changed their planning approach from having a separate night network to planning for service to remain the same throughout a 24-hour period. (Barry 2014) Hence in 2013, the 116 routes shown were a mix of 24-hour services and night-only services (rail replacement services).

Also shown in Figure 4.2 is the peak vehicle requirement is the number of buses required to provide scheduled services during peak hours of service. In 1995, peak services required about 5,000 vehicles, and this had increased to about 5,700 by 2000, but as services expanded rapidly leading up to congestion charging, the peak vehicle requirement grew to 6,800 by 2003 (20%); in 2013, the peak vehicle requirement was 7,700. (Barry 2014)

Figure 4.2 Number of bus routes running 24 hours and bus peak vehicle requirement



Data source: TfL Bus Network Team, 2014

4.6.2 Expanded bus network coverage

Another measure bus service expansion is the geographic scope, or number of stops and the percentage of Londoners living within a short walk of a bus stop. The MTS noted that bus network coverage was extensive and had grown during the 1990s, but would be expanded further with objectives of attracting new users and offering comprehensive coverage of residential and employment areas. (TfL 2001) TfL uses network accessibility as a performance measure in this regard. In 2003, it was estimated that 91% of Londoners lived within a five minute walk of a bus stop (400 meters); by 2013 that percentage increased to 94.5. (TfL 2014) This was accomplished in part by increasing the density of bus stops. In 2001, there were approximately 17,000 bus stops in Greater London, and by 2013 there were 19,000. (TfL 2001, TfL 2014) The number of bus routes has increased to serve the expanding network. In 1995 there were 560 bus routes, while there were 675 in 2013, 15% f which operated 24 hours per day. (Barry 2014)

4.6.3 Upgraded vehicles and bus stops

The 2001 Mayors Transport Strategy included access to bus stops as a critical part of bus journeys. A long-term program to upgrade bus stops was launched to ensure the provision of timetables and route information at all stops, and minute-by-minute service information (countdown until the next arrival) in high volume locations, and shelters, seating, lighting and maps at the great majority of sops. (TfL 2001) For example, 4,000 electronic countdown signs were targeted for installation by 2005 at locations serving 60% of bus passengers. (TfL 2001)

Similarly, bus vehicle design was seen as key to system accessibility in the MTS. TfL reviewed bus design standards and changed them to require features allowing for quicker boarding. The new standards, combined with expanded service hours, resulted in significant fleet turnover. By the end of 2005, all London buses were accessible to the physically disabled, updated to Euro II emissions, and fitted with CCTV; by 2009 they were equipped with iBus vehicle location devices, enabling real-time passenger information service. Expanded service hours also caused growth of the bus fleet. From 2000 to 2005, London's bus fleet grew by 1,500 vehicles (23%), and 3,000 vehicles were replaced, for a total of 4,500 new vehicles out of 8,000 in service. (Banister 2008)

Perhaps due to rising bus ridership, bus design became an issue in the 2008 Mayoral election. Livingstone encouraged the adoption of low floor articulated buses were favored as way to both speed boarding and provide a higher proportion of accessible seats. However, these "bendy buses" proved unpopular with Londoners, and candidate Boris Johnson promised to remove them from service. After his election, bus standards were revised again in 2010 to revive London's classic double-decker Routemaster bus with three doors and two staircases. Figure 4.3 shows the sleek new buses, which were designed by an architect.

Figure 4.3 The revived London Routemaster bus

Photo: Transport for London

4.6.4 Fares and electronic payment system

The MTS set bus fare policies with the explicit purpose of encouraging a shift to public transport and complementing congestion charging. A complementary pricing strategy to congestion charging was implemented in 2002—a simplified fare structure with a flat rate bus fare of £.70 throughout Greater London, which was frozen for three years. (TfL 2001)

As a measure to improve the simplicity and convenience of the public transit system, the MTS promised introduction of a new electronic smartcard system called the Oyster Card. Previously, different parts of London's public transit system required different tickets, for instance, the Underground, buses, and Docklands light rail. The smartcard allowed for integration of into one seamless fare collection system when the Oyster Card was introduced in 2003. Smartcard readers were installed in all Underground stations and buses, significantly reducing boarding times and easing transfers. Within the first year, 27% of weekday journeys on the Underground, and 18% on buses, were made using the Oyster card; single journey tickets were nearly entirely phased out 10 years later.

The MTS also promised to retain concessionary fares for senior citizens and extend concessionary fares to children. Since the 1970s, disabled Londoners and all those over 60 years old have been eligible for a free bus pass. Called the Freedom Pass today, it allows free travel on all bus and rail transit services during off-peak hours, and on limited commuter rail routes. Since 2005, children travel free in the company of an adult on buses and rail transit, but those aged 11 to 15 can also travel for free on buses independently if they get an Oyster ID card.

4.6.5 Bus priority

More than a single measure, 'bus priority' stands for a planning approach developed in London during the 1990s to improve bus travel times and reliability. In this 'whole route' approach, bus routes are reviewed from start to end to identify ways to improve bus travel speeds. Different measures are used along the route, tailored to reduce delay in a variety of ways, such as signal priority, intersection design, parking removal and bus lanes. For example, on-street parking was removed along high-capacity radial arterials managed by TfL (red routes). Road space reallocation to create dedicated bus lanes is a major bus priority strategy to improve bus speeds and reliability. TfL also reallocates of road space to change the design of intersections in favor of faster bus speeds, for instance by installing advance stop lines for buses or 'bus gates' that allow bus only access. The next section discusses the application of bus priority to the majority of bus routes in Inner London, in three phases.

4.7 Development of a regional bus priority network in three phases

When Livingstone took office in 2000, he made intensified bus services a key part of his first Transport Strategy, including accelerating the completion of an ongoing bus priority program and launching a new one. Starting in the early 1990s, London has taken a strategic management approach to urban road capacity and created a network of bus routes where buses take priority over other traffic. On each bus priority route in the network, road space has been reallocated away from cars and traffic signals retimed to favor buses.

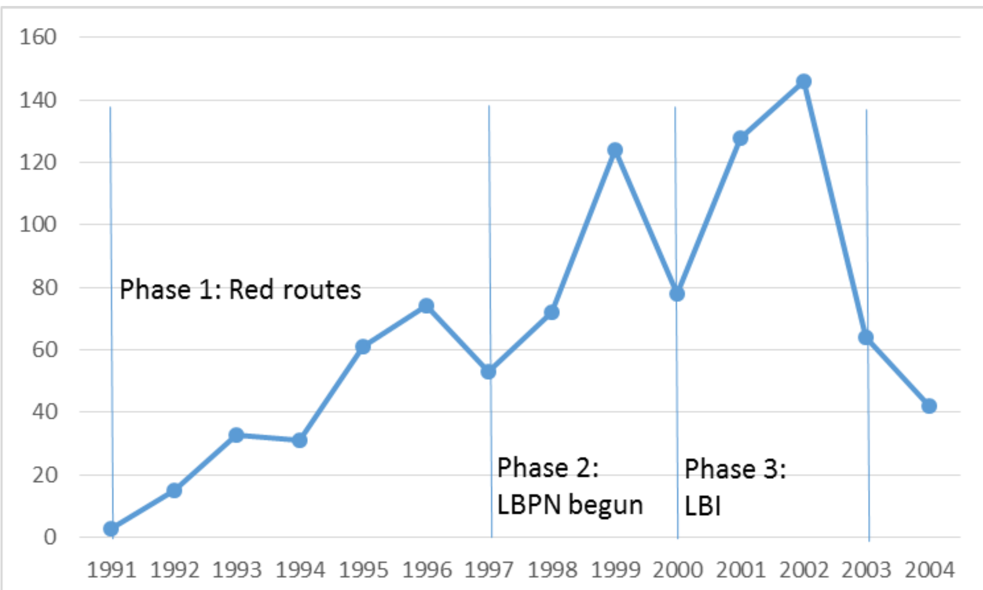
Table 4.2 summarizes the development of the bus priority network that is in place today, built in three stages. From 1991 to 1997, a regional strategic road network ('red routes') was developed with the aim of improving traffic flow, including many bus priority measures. From 1997 to 2000, the London Bus Priority Network was begun, and it was finished via the London Bus Initiative from 2001 to 2003. The number of bus lanes introduced each year during these three phases is shown in Figure 4.4.

Table 4.2 Three phases of development of London's bus priority network

Implemented	Bus Priority Program	Added to Network	Cost (million)
1992 to 1997	Transport for London Road Network (TLRN) or 'red routes' (partial bus priority)	360 miles (580 km)	£130
1996 to 2004	London Bus Priority Network (LBPN)	536 miles (865 km)	£29
2000 to 2003	London Bus Initiative (LBI)	248 miles (400 km)	£60
	Total	1,144 miles (1,845 km)	£219

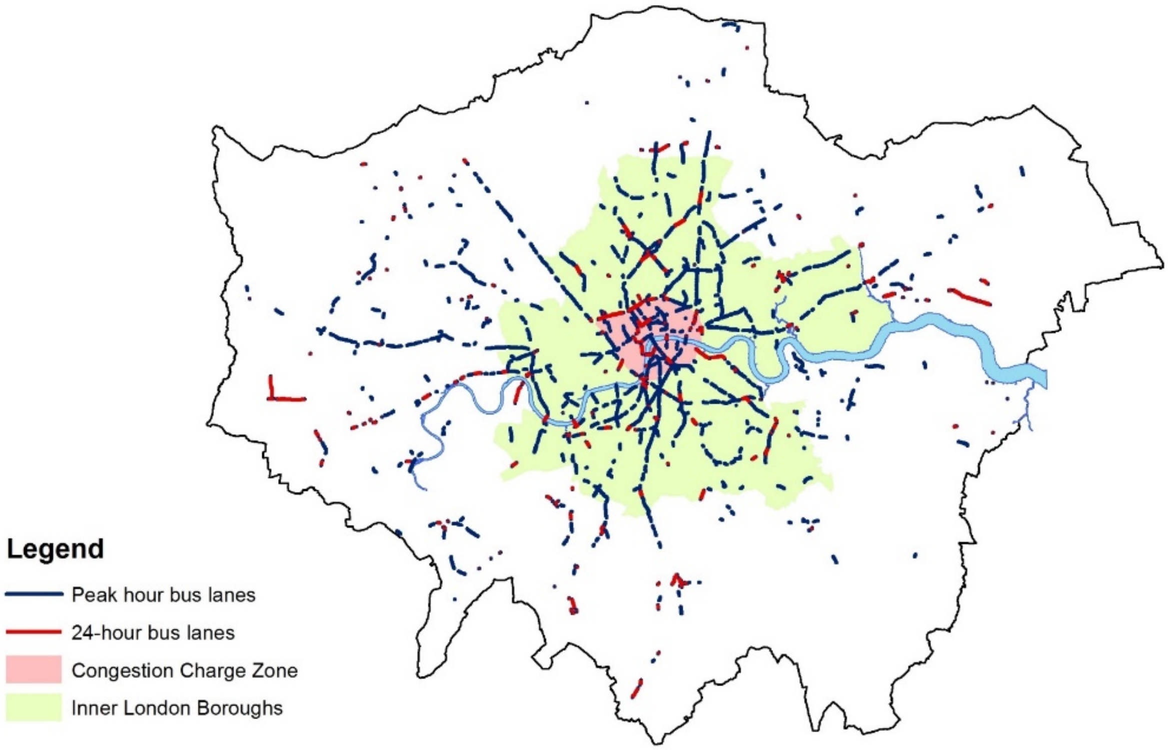
Sources: Hayward 1997, Hodges 2007, HoC 2010, Mayors Transport Strategy 2001

Figure 4.4 Number of bus lanes introduced per year



Data source: Gardner, 2006

Figure 4.5 The London Bus Priority Network

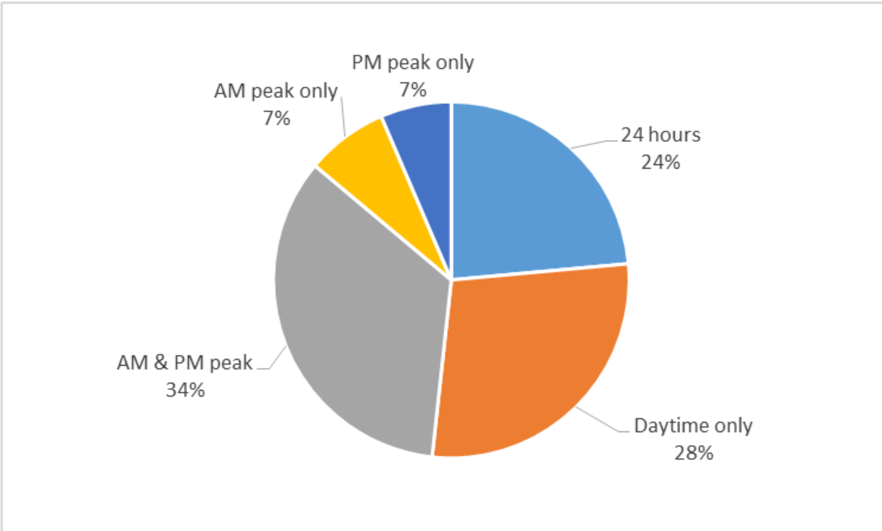


Data source: TfL Bus Lane Database 2014

The completed network, shown in Figure 4.5, totals 1,144 miles of road where buses take priority over other traffic. On much of the bus priority network, roadspace is dedicated exclusively to bus traffic. TfL does not publish the cumulative length of bus lanes on London's road network, but provided the author with their bus lane database in order to perform calculations. The analysis revealed there are approximately 1,100 bus lanes in Greater London, about 800 feet long on average, but this includes many "compact" dedicated bus spaces, such as in front of a bus station, bus boxes at traffic signals, and "gates" where buses may enter a road but other traffic is diverted. About two-thirds of these bus lanes are in Inner London, and one-third in Outer London.

As shown in Figure 4.6, about one-quarter of London's bus lanes are in operation 24 hours per day, seven days a week, about one-quarter during daytime hours only, and about one-third during morning and evening peak hours only. In total, about 15% of roadspace on London's major arterial ('A') roads has been reallocated for bus use only during some part of the day. This is a much higher percentage of the road network than cities of comparable size.

Figure 4.6. Dedicated bus lanes in Greater London (180 miles total)



Data source: TfL Bus Lane Database, 2014

London's bus priority network was built in three phases from 1992 to 2003. To get it done required sustained political will, three major infusions of funding, and a deeply committed team of bus network performance professionals. The next section tells their story.

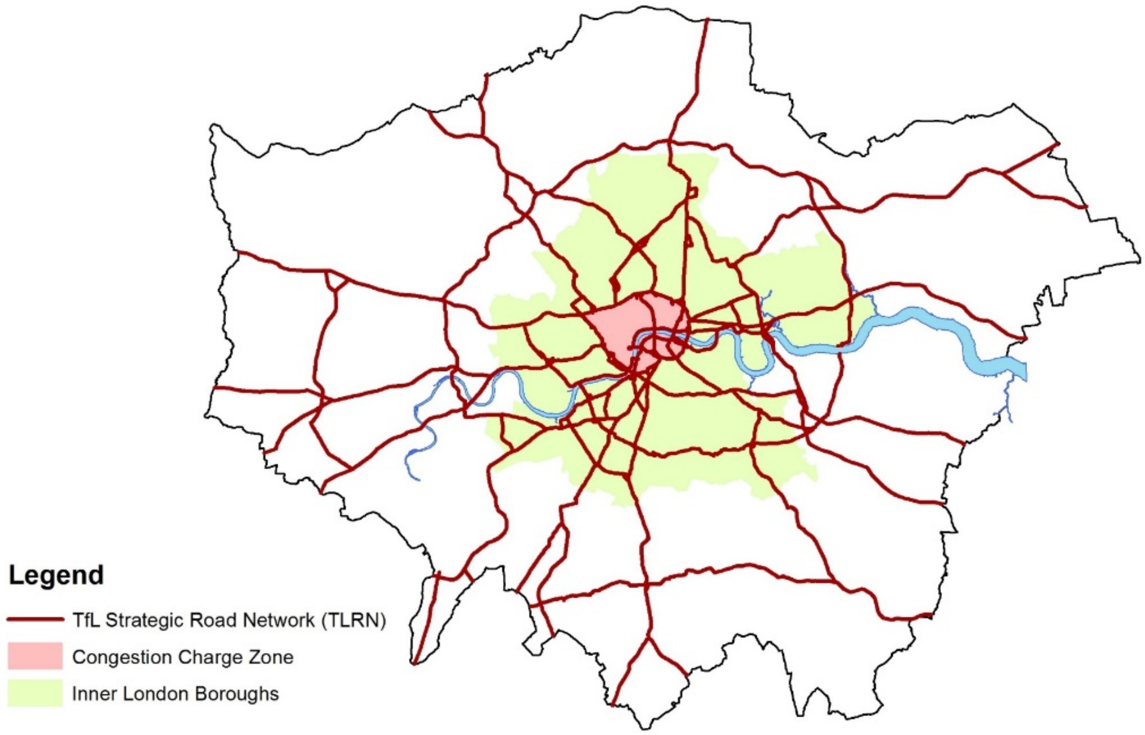
4.7.1 Phase 1, Red Routes

The idea for a regional strategic road network first emerged after a prolonged debate over the best way to deal with urban traffic congestion. The UK Department for Transport (DfT), having experienced significant opposition to road building proposals in the 1980s, began to focus on ways to increase capacity on existing roads. (Turner 1997) Commuters using major arterial roads leading to central London were experiencing significant delays due to flow disruptions from loading by taxis and trucks, as well as illegal parking at bus stops. The Boroughs, which had jurisdiction over parking and traffic controls on these roads, were unable to respond in a coordinated way. For example, on roads which formed the boundary between two Boroughs, one would say the other should remove its parking.

In 1991, the DfT proposed a way to overcome these local conflicts for the greater good of the region: the development of a 360-mile strategic network of 'red routes' where the authority to implement measures improving traffic flow, such as stopping and parking restrictions, road design and signal retiming, would be given to a new regional position, the London Traffic Director. The Boroughs were not immediately ready to cede authority over their roads, but they became supportive after two DfT pilot trials demonstrated the effectiveness of start-to-end bus priority measures along a bus route. During the trial on an eight-mile long route, journey times improved by 25%, bus reliability improved 33%, and bus ridership increased by 9%. (Wood and Smith 1993)

The legal framework for red routes was set by the Road Traffic Act of 1991, which required Boroughs to implement the network plan. (HoC 2010) Implementation commenced after the London Priority Route Order, specifying which roads would become red routes, was approved in 1992. (Butcher 2010) The most strategically important arterial routes in Greater London were selected to be part of the network, mainly ‘A’ roads, as shown in Figure 4.7.

Figure 4.7 The Transport for London Road Network (TLRN), or ‘red routes’



Data source: TfL GIS data layer, 2014

All aspects of traffic management on these routes were reviewed and upgraded to improve traffic flow and bus operations. Red routes are marked by single or double red lines at the sides of the road, indicating whether ‘clearway’ regulations prohibiting curbside parking or loading are in force from 7 am to 7 pm or 24 hours. Bus routes operate on about 250 miles (70%) of the network. (Gardner 2000) £12 million was invested in bus priority measures, including the installation of roadside and on-board cameras to enforce stopping restrictions; 300 stretches of road were reallocated for dedicated bus lanes during peak hours. (Turner 1997) Dedicated bus lanes were installed on 76 miles (21%) of the network, of which one-fourth are in operation 24 hours / 7 days, and the remainder during peak hours only. £22 million was spent improving walking conditions along red routes, £19 million improving pedestrian crossings, and £19 million on traffic calming on residential roads parallel to red routes. (Turner 1997)

The network was expected to be implemented over five years at a cost of £50 million; in the end it was operational by 1997, but at a cost of £130 million. (Butcher 2010) When TfL was created in 2000, it took over management of the red route network and left it largely unchanged. The Traffic Act of 2004 formally transferred jurisdiction over red routes from the Boroughs to TfL by defining them as a new category of road, the Strategic Road Network. The network is now officially called the Transport for London Road Network (TRLN), but it is still widely referred to as red routes. Today, TfL is entirely responsible for infrastructure and traffic operations on the network—Boroughs must seek approval from TfL before exercising road management powers that may impact red routes. Despite representing only 5% of the total road network, red routes currently carry one-third of all vehicular traffic in London and nearly half of the road based freight movement. (TfL 2013)

4.7.2 Phase 2, the London Bus Priority Network (LBPN)

The London bus priority network (LBPN) was proposed in 1993 to complement the red route network with bus priority measures on network feeder roads still controlled by the Boroughs. While red routes addressed 30% of the worst regional traffic bottlenecks for buses, the LBPN would address 65% of the remainder, including nearly all bus routes within Inner London. (Gardner and Cobain 1997) The goal was to treat bus route corridors from end to end comprehensively, rather than in an ad-hoc fashion, as had been done previously. This corridor management or 'whole journey' approach included consideration of access to bus stops and intermodal transfers. The concept was tested with demonstration projects on three high volume bus routes in South and West London with a total length of about 50 miles. (Gardner and Cobain 1997) Measures were developed in partnership between the DfT, the Boroughs, and bus operators. The demonstration routes showed travel time savings of 15% and increases in bus ridership of 10 to 15% compared to 'control' routes, including a mode shift of 3.7% away from private cars. (Gardner and Cobain 1997)

Following the success of the demonstration projects, in 1994 the Secretary of State approved funding for the development of the LBPN as a 540-mile bus priority network on Borough roads. (Gardner 2000) Work began with a review of traffic measures on nearly all major bus routes in Inner London, and all others with high frequency service (at least eight buses per peak hour). Implementation began in 1996, with £29 million in government support allocated toward the anticipated total cost of £77 million. (Gardner and Cobain 1997, Hayward 1997) As in the demonstrations, bus priority measures were designed for each specific problem area along the routes, ranging from reallocation of road space for bus lanes and Selective Vehicle Detection (SVD) at traffic signals, to on-board and roadside cameras to improve enforcement. (Gardner and Cobain 1997) Each project had to compete for funding on a cost-effectiveness basis. Meantime, DfT made complementary system improvements such new bus shelters with improved route information maps, timetables, and an automated bus information system telling customers the arrival times of the next few buses. (Hayward 1997)

4.7.3 Phase 3, the London Bus Initiative (LBI)

In 1997, the Labour party won control of the UK Parliament for the first time in 30 years, signaling a major political shift. Implementation of the LBPN carried on as planned in spite of this change in leadership, because the new government was deeply committed to investing in buses throughout the UK. As stated in their transport platform Green Paper, "The bus has a vital role to plan in urban transport. For all but the heaviest flows of passenger journeys, and particularly for shorter trips, the bus provides by far the most effective means of public transport." (Labour Party 1997, Transport: The Way Ahead)

The new Government pledged to restore independent regional governance to London, which had been stripped away by the Conservative party in the 1980s. In 2000, the Greater London Authority Act was passed, creating Transport for London as the new regional transport agency, with a directly elected Mayor as its head. Shortly afterwards, Ken Livingstone was elected London's Mayor on promises to upgrade bus vehicles and service levels, while holding fares steady, and to implement congestion charging.

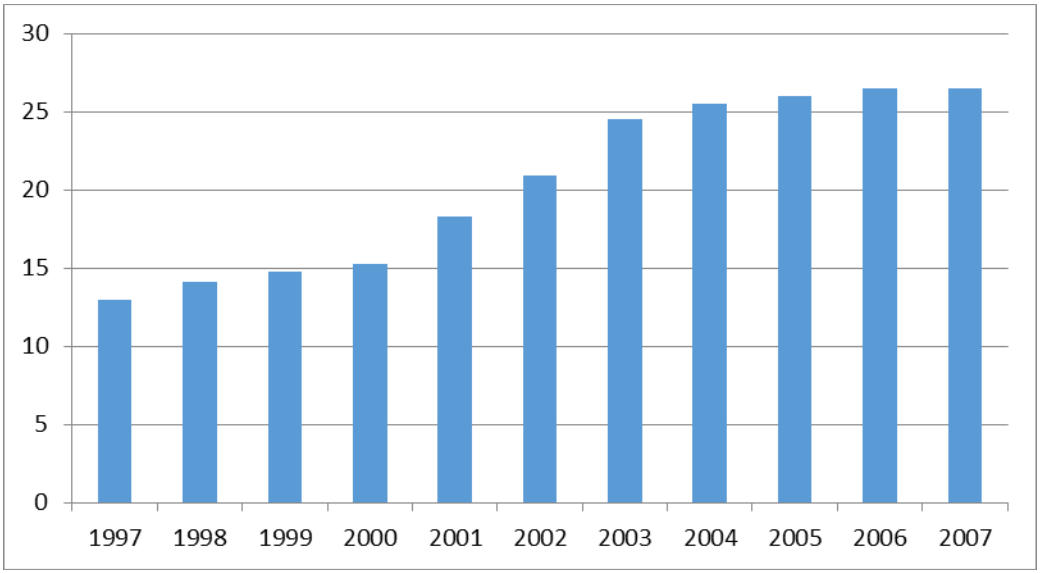
Completion of the LBPN became a top priority for the newly created Transport for London (TfL). The Mayor's Transport Strategy set the goal to complete the LBPN by 2004, and launched a new bus priority effort, the London Bus Initiative (LBI), focused on improving bus capacity serving central London in anticipation of congestion charging. (TfL 2001) The aim of the LBI was:

> "To bring about a real change in the actual and perceived quality of London's bus services by making buses a first choice mode on LBI routes by improving services and promoting a change in travel habits, and delivering this on a 'whole route' basis…to achieve: reductions in variability of passenger waiting times, reductions in the variability of bus journey times, reductions in whole route bus journey times, improved customer satisfaction by a variety of attributes, and increased patronage." (MTS 2001, p. 182)

From 2000 to 2003, the national government allocated £60 million in support of the LBI. (Hodges 2007) The LBI focused bus priority measures on 27 high-ridership routes totaling over 400 km in length. (Hodges 2007) It included 100 new bus lanes, 50 new pedestrian crossings, and 300 new SVD-equipped intersections. (Hodges 2007) An evaluation study of LBI routes showed that travel times and reliability improved on all 27 routes, and combined ridership increased by 22% over the course of the initiative. (Hodges 2007)

TfL changed the way that potential bus priority measures were evaluated, in order to favor reallocation of roadspace. Bus planners argued that more dedicated bus lanes were needed in order to spur significant mode shift away from cars. (Gardner and Cobain 1997) Scope for roadspace reallocation was limited by requirements that bus priority measures "must not have an adverse effect on traffic or any class of traffic." The procedures for evaluating costs and benefits of proposed bus lanes were revised to include travel time improvements for bus riders as an evaluation criteria. Figure 4.8 shows the intensification of roadspace reallocation for bus lanes in central London from 2001 to 2004.

Figure 4.8 Total length of bus priority lanes in central London (CCZ area)



Data source: TfL Bus Network team, 2014

TfL has continued to develop bus priority measures throughout the decade since 2003. Launched in 2005, a second London Bus Initiative (LBI2) expanded the network to include a further 42 routes, and took a more multi-modal approach, including measures to improve pedestrian and cyclist safety. In 2006, TfL adopted 'third generation' bus priority (3GBP), a fully multi-modal approach to corridor management intended as a ten-year program expanding the 'whole route' approach to all bus routes in London. (Hodges 2007)

In the end, at least £90 million was invested to create the LBPN, although a total cost estimate has not been published, and it remains in development today. As travel demand and traffic patterns shift, bus routes continue to be reviewed, and bus priority measures are added or removed as needed. In contrast to the red route network, which is static, the LBPN is continually adapting.

4.7.4 Impacts on congestion charge zone

Gardner, head of TfL's bus priority team, named four critical factors contributing to the success of the bus network: bus priority measures, enforcement of those measures, quality incentive contracts, and the congestion charge. (Gardner, Melhuish et al. 2006) He argued that bus priority was critical to the success of the congestion charge. "The London bus network has proved its adaptable and responsive nature by catering for the mass modal shift achieved by congestion charging whilst patronage on the Underground and national rail networks remained fairly static." (Gardner, Melhuish et al. 2006) Changes to the bus network improving reliability and service quality were already increasing demand for buses, such that the congestion charge boosted the existing trend along. "In the first year of charging there was an increase of 37% in passenger numbers entering the zone by bus during charging hours. Around half of this was assessed to have been as a result of the scheme, the other half due to a background trend of growth." (Gardner, Melhuish et al. 2006)

Bus riders were also the chief beneficiaries of the scheme, according to Gardner, "A less congested road space with lower volumes of traffic facilitated by the introduction of the [congestion] charge in central London provided greater opportunity for [buses]… Put simply, the moving-motor-vehicle capacity of the network had been adjusted in favour of the people-moving capacity of the network." (Gardner, Melhuish et al. 2006) Several interviewees agreed with this assessment, and pointed out that the critical difference was in prioritization of road space.

Today, every weekday over 7,000 scheduled buses carry over six million passengers throughout Greater London on 675 different routes. Ten percent of those routes run 24 hours a day, seven days a week. As stated on their website, "Buses are widely recognized as the best option for increasing public transport capacity in the short-term. Many initiatives are in place to make journeys as easy, reliable, quick, convenient, comfortable and affordable as possible." (Tfl Website 2014)

4.8 Complementary Measures Program

In order to implement congestion charging within the desired timeframe of eighteen months, it was critical to gain stakeholder support. The purpose of the complementary measures program was to mitigate anticipated negative impacts of congestion charging on boundary areas and radial access roads. As stated in the program's summary report, "A Complementary Measures workstream was conceived as an integral element of the Congestion Charging programme, with the objective of effectively managing traffic that diverted away from the charged zone on to appropriate roads." (TfL 2005) Relying upon traffic modeling outputs to identify areas that could experience changes in traffic patterns, a 'congestion charge zone of influence' was identified as within a radius of 3 km from the charging area.

Of particular concern were parking and intersection capacity along high-volume radial arterials accessing the charged area, and parking capacity near rail stations. Management of these roads was shared between TfL and the local governments of the London region, the 33 Boroughs. By funding mitigation measures, the complementary measures program thus helped TfL gain the cooperation and support of the Boroughs affected by the congestion charge zone. TfL worked closely with the Boroughs to implement measures that discouraged 'rat running', or avoidance traffic near the zone boundary, and eliminated on-street parking adjacent to the zone boundary and near rail stations. The program was very well funded and extended to a range of projects desired by the Boroughs, whether or not they had a strong link to the congestion charge zone. (Williams 2014) In this way, the complementary measures program built goodwill and helped mitigate traffic impacts from congestion charging by providing comprehensive mitigation measures. Table 4.3 shows the total number of projects and expenditures for the complementary measures program, adapted from the program's summary report.

Table 4.3 Summary of complementary measures projects implemented from 2001-2002

Measure	Number of projects	Cost (£ million)	Percent of total
Traffic management (calming, diversion, road closures)	51	7.1	12%
Home zones / 20mph zones	49	13.3	23%
Controlled parking zones (inner area)	34	6.9	12%
Controlled parking zones (outer area)	53	3.3	6%
Capital works projects on TfL roads	27	22.2	38%
Traffic signal operations	25	2.5	4%
Soft measures (targeted programs)	22	2.9	5%
Total	261	58.2	100%

Source: (TfL, 2005)

4.8.1 Traffic management and 20 mph zones

Within the congestion charge zone of influence area, 51 projects aimed at slowing and diverting traffic were completed, mainly on routes known to be used by drivers avoiding the central area. These were mainly physical changes to the road network such as road closures and traffic diverters, traffic calming (changes to street and intersection design) such as speed tables and speed humps, neckdowns, raised sidewalks and chicanes, and non-physical measures like truck traffic restrictions.

Another 49 projects were specifically aimed at creating 20 mph zones, where traffic calming measures are widely used to slow traffic. The zones are marked by signage and paint at entrance and exit points, as shown in Figure 4.9. Each is individually designed to account for the characteristics of the road and land uses, in a process involving the public. The most elaborate version of a 20 mph zone are “home zones”[2], or shared space areas designed to slow and de-prioritize car traffic while allowing for a variety of activities. These interventions have proven popular with residents, but have not been widely implemented due to cost, as they require costly high-quality materials.

Implementation of 20 mph zones was gaining popularity among London residents when the effort to implement congestion charging got underway. TfL supported them as part of the Mayor’s 2001 Safety Initiative. The complementary measures program served as a funding mechanism to increase the pace of adoption. Figure 4.10 shows the number of 20 mph zones implemented in London each year from 1991 to 2008. A major uptick in the number of zones can be seen from 2001 to 2002, as the Boroughs made use of funding from the complementary measures program. It can be seen that most of the zones implemented during this timeframe were located in Outer London. This implies that at least some of the some of the zones were built with

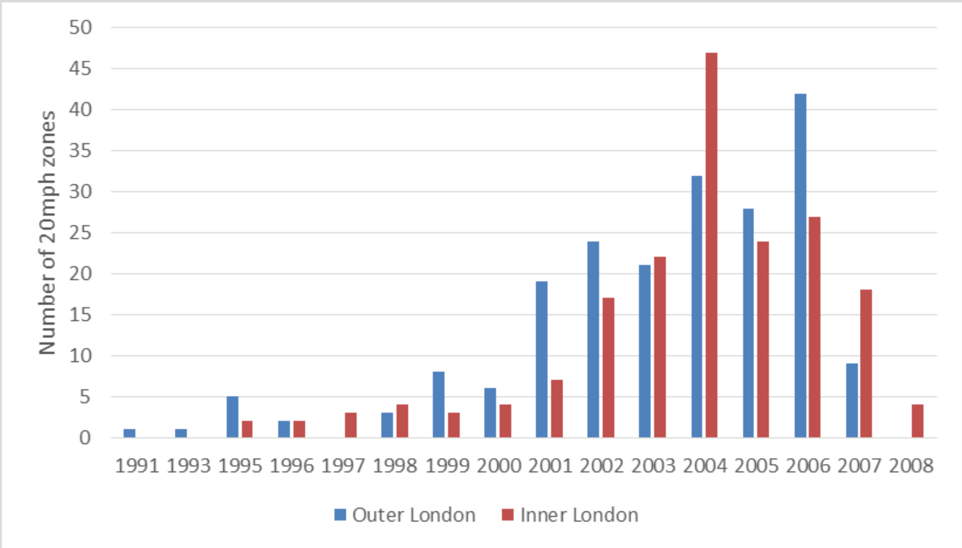
[2] Home zones were first introduced in the UK in 1999, modeled after the Dutch ‘woonerf’ concept of a street typology for residential areas with shared space between vehicles and other road users to slow vehicle speeds to well below 20 mph. The goal is not only to reduce casualties, but also to change perceptions of how streets are used. (Grundy et al., 2008)

little direct connection to the congestion charge zone, but out of goodwill. The number of zones implemented in Inner London increased dramatically in 2004, after congestion charging started, implying that neighborhoods likely responded to changing traffic patterns. A 2003 evaluation report demonstrating the effectiveness of 20 mph zones at reducing vehicle travel speeds and pedestrian fatalities also likely played a role. (TRL 2003)

Figure 4.9 Photo of a 20mph zone

Photo: Michael Kodransky

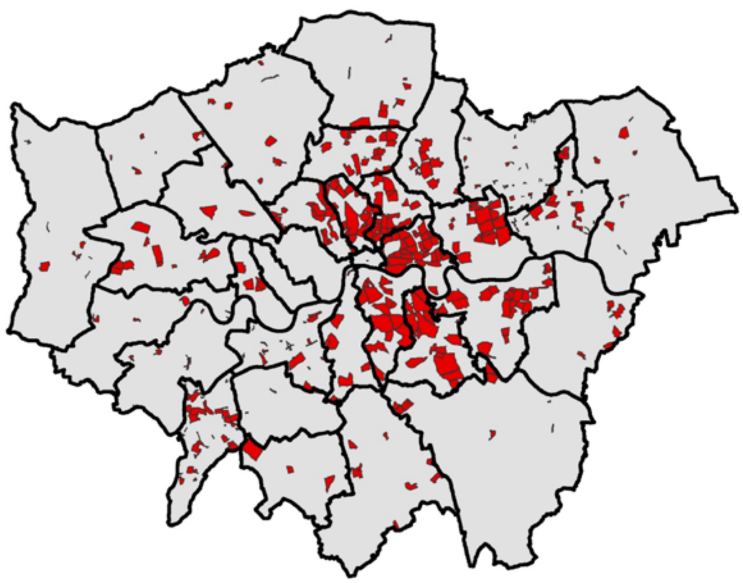
Figure 4.10 Number of 20 mph zones installed annually



Data source: Grundy, Steinbach et al., 2008

By 2008, London had 399 20 mph zones. Figure 4.11 shows the location of the zones, and it can be seen that while they are scattered throughout the region, boroughs on the Inner East side were the most enthusiastic, designating the largest areas. This pattern reflects local politics, as those Boroughs are historically Labour, and the most staunchly Conservative boroughs on the Inner West side declined to implement any 20 mph zones, including Westminster and Kensington & Chelsea. Evaluations of 20 mph zones have found they are highly effective at reducing injuries and fatalities, especially among children under 15. For example, a time series regression by a team from the London School of Hygiene and Tropical Medicine found a 42% reduction in traffic fatalities within 20 mph zones, compared with outside areas. (Grundy, Steinbach et al. 2008)

Figure 4.11 Location of 20 mph zones



Source: Grundy, Steinbach et al., 2008

4.8.2 Controlled parking zones

Regulation of on-street parking, especially around Underground and commuter rail stations, was a widely used mitigation measure. Controlled parking zones restricted on-street parking to residents only. All but one of the neighborhoods immediately adjacent to the congestion charge zone boundary already had controlled parking in place. The complementary measures program reviewed the operating hours of these existing zones, to ensure they would align with the congestion charge zone hours. The boundaries of a few zones which spanned the congestion charge boundary were reconfigured such that the congestion charge boundary became the controlled parking zone boundary. A total of 34 new controlled parking zones were created within the congestion charge zone of influence area, around nearly every rail station and “completing a comprehensive network of [controlled parking zones] in residential areas.” (TfL 2005)

Many boroughs located outside the congestion charge zone of influence sought funding for controlled parking zones due to concerns about ‘railheading’, where motorists would park their cars at local stations and continue their journey to the charged area by rail. Although TfL modeling indicated that railheading was unlikely to increase as a result of congestion charging, a total of 53 new and extended controlled parking zones were implemented in Outer London, in order to address these concerns.

4.8.3 Capital works projects, traffic signal operations, and soft measures

Part of the complementary measures program was funding for physical changes to roads at the boundary of the congestion charge zone to ensure its smooth operation. The road design at each of the 165 entrances to the charged zone was reviewed with an eye to enforcement. A total of 27 projects were carried out, including lane restriping and curb reconfiguration to better channelize traffic and ensure that vehicle registration plates would be captured by the enforcement cameras. Another concern was re-timing major capital improvement projects that were scheduled for roads forming the congestion charge boundary during the period when congestion charging would be introduced. Funding paid for these projects to be completed earlier than scheduled, as well as for general repairs and resurfacing of the boundary road and major radial roads leading to the charged area.

Similarly, a portion of complementary measures funding went toward traffic signal timing changes to ensure the efficient movement of traffic on congestion charge boundary roads and radial routes. The timing changes were carried out via London’s centralized traffic signal control system, SCOOT. Further, “the implementation of the congestion charging acted as a catalyst for the creation of a London Traffic Control Centre.” Unlike many major cities, London previously lacked a centralized traffic monitoring and control center staffed by police, bus operators and traffic and signal engineers. In this way, part of the complementary measures program funds were about upgrading and modernizing the city’s ability to manage traffic congestion and monitor the performance of key routes and junctions.

The remaining portion of complementary measures funding was invested in soft measures, that is, a variety of targeted interventions to encourage switching from cars to transit. Many programs had to do with improving the availability of information about transit services, for instance, new bus maps and personalized journey planning for National Health Service employees. Nearly £.5 million served as start-up funds for a new car sharing service in the inner western boroughs. A few capital projects were also included, for example a ‘personal security project’ improving lighting and streetscaping around Lambeth North station.

4.8.4 Impacts

The complementary measure program was considered a success in two important ways: accomplishing the goal of traffic mitigation, and establishing effective working relationships between TfL and the boroughs. As the summary report concluded, "the level and pattern of traffic displacement outside the congestion charging zone did not emerge as an issue following the introduction of the [congestion charge zone]." (TfL 2005) Traffic levels on the congestion charge boundary roads, radial routes leading to the charged zone, and in neighborhoods within the congestion charge zone of influence were extensively monitored during the first year of congestion charging. The monitoring report noted a slight increase in traffic on the boundary roads (+4%), a decrease on radial routes (-5%), and stable or decreasing traffic volumes on local roads surrounding the charged zone. (TfL 2004)

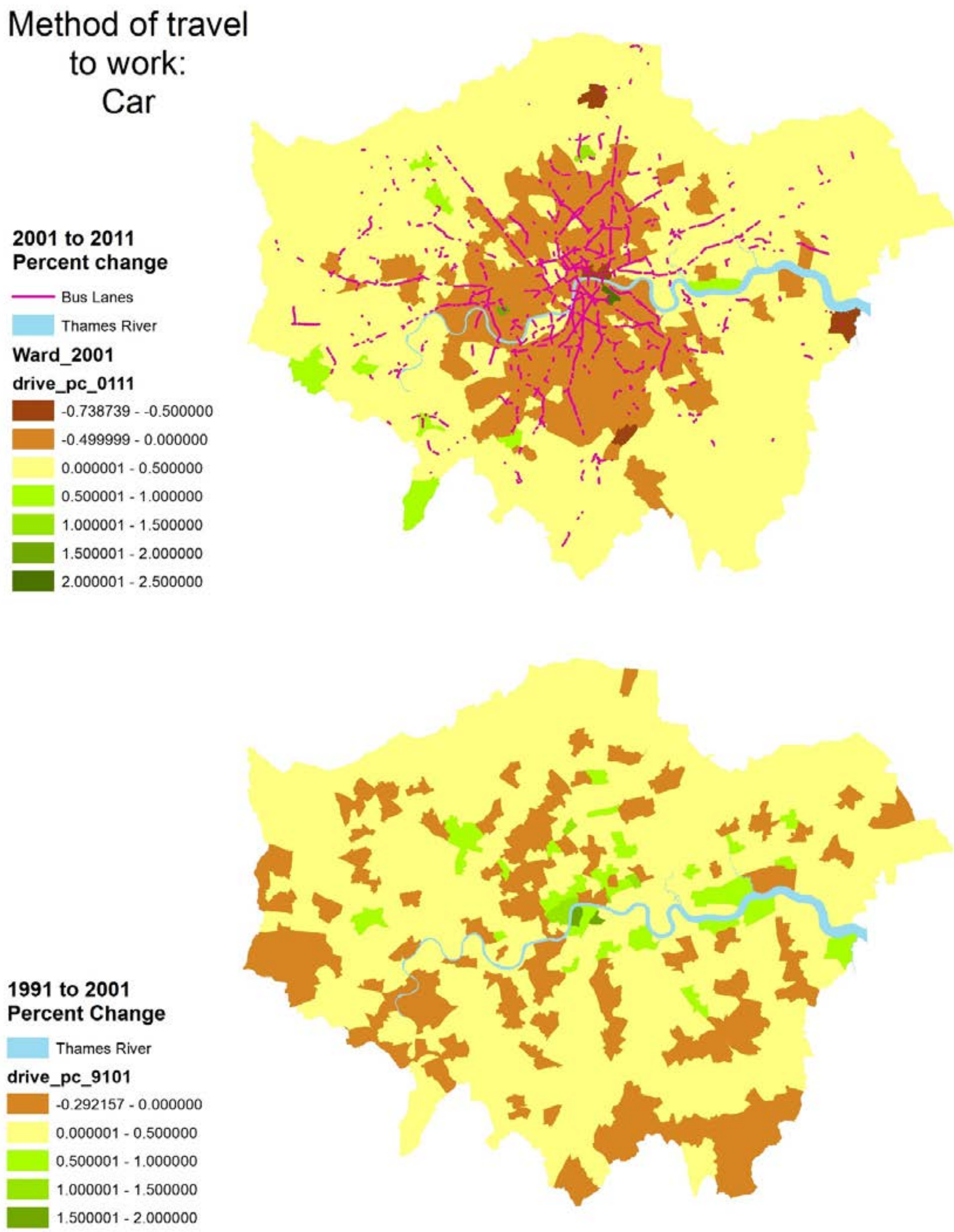
A challenge facing the new mayor and fledgling TfL in 2000 was navigating the complex inter-relationships of local, sub-regional, and regional governance bodies. The complementary measures program was instrumental in accomplishing implementation of a radical measure, congestion charging, in a short period of time. Approaching the boroughs with generous funding and a spirit of partnership, "allowed the organisations to explore and develop areas of mutual interest." (TfL 2005) Implementation of complementary measures was an iterative process, where there was scope to amend and refine them until borough stakeholders were satisfied their concerns were met. (Williams 2014)

4.9 Impacts on travel behavior

The trends, in terms of reduced driving and increased bus ridership, have been clearly shown. But in order to assess how they may be related, we need to know the geographic patterns. To do this, I used the 'method of travel to work' variable from the UK Censuses from 1991, 2001, and 2011 at the ward level to calculate the percent change in commuting by car and bus during two periods, 1991 to 2001 and 2001 to 2011. The results are shown in Figure**s** 4.12 and 4.13.

The maps in Figure 4.12 show different patterns of change in car commuting over each period. From 1991 to 2001, there were some areas of Greater London where car commuting declined, and some areas where it increased, notably in the central area boroughs of Westminster and Kensington & Chelsea, but there is no clear pattern overall. From 2001 to 2011, there is a clear pattern of change where car commuting declined throughout Inner London. I have shown the bus lane network on this map because it was growing rapidly during the first half of the decade, and fully operational by 2008. There is a spatial correlation between the areas with declining car commuting and the density of the bus lane network.

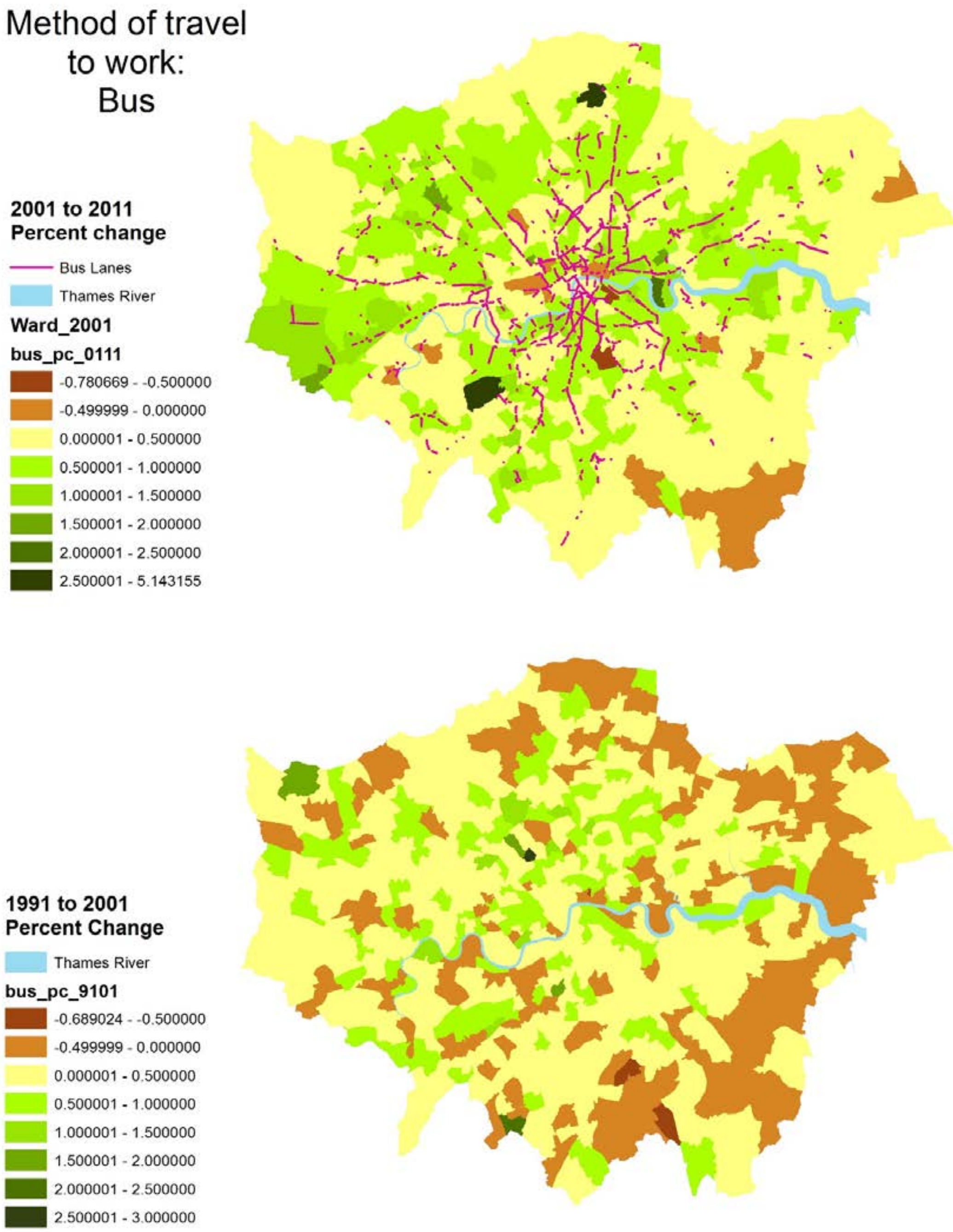
Figure 4.12 Percent change in travel to work by car, 1991-2001 and 2001 to 2011



Data source: UK Census 1991, 2001 and 2011

Similarly, the maps in Figure 4.13 show different patterns of change in bus commuting over each period. From 1991 to 2001, bus commuting grew in some areas and declined in others, mainly in Outer London. From 2001 to 2011, bus commuting grew in nearly every ward, with a radial pattern out from the center. Again, the bus lanes have been overlain and show a spatial correlation between the rate of increase in bus commuting and the density of bus lanes.

Figure 4.13 Percent change in travel to work by bus, 1991-2001 and 2001 to 2011



Data source: UK Census 1991, 2001 and 2011

4.10 Conclusions

London's experience illustrates an emerging challenge, the battle for road space in re-densifying cities. The city's success at achieving mode shift and reducing VMT must be understood as a result of its willingness—of political leadership and the public—to embrace measures which de-prioritize private vehicular travel.

In this chapter, I have argued that bus priority vastly improved bus services and played a critical role in supporting mode shift away from cars. While London's congestion charge has become widely known the world over as an effective approach to urban traffic management, it must be understood as paired with bus priority. The use of road space reallocation to create a regional bus priority network with played a key role in the success of the London congestion charge. Due to the capacity constraints of the Underground, TfL relied most heavily on buses to bear the load of drivers switching out of cars when the congestion charge was introduced. The development of a regional bus priority network vastly improved bus travel times and reliability. The bus priority network offered than just an alternative to driving, it gave buses a key competitive advantage to cars—faster travel times.

The London experience demonstrates the potential of a strategic bus priority network to influence travel behavior and grow mode share for buses. The use of road space reallocation to create a bus network on already-existing roads provides a cost-effective alternative to building a new network. For example, bus rapid transit systems typically require significant capital investment in new lanes, stations, and vehicles. In addition to saving money, London's use of existing road space made its bus network doubly effective as a transportation demand management measure. First, increased road space for buses improved operations (reduced travel times and improved reliability) increased the attractiveness of the system, pulling drivers toward buses. Secondly, reduced road space for cars worsened conditions for driving, pushing drivers toward buses.

The defining aspects of London's bus priority network that affected its effectiveness were: 1) management by a centralized authority that was able to control road space and coordinate bus operations, 2) a 'whole route' approach to improving performance, with an emphasis on reducing delay at stops and intersections, 3) liberal capital investment in upgraded bus stop and intersection design to improve performance (curb bulb-outs, advance stop lines, bus gates, signal priority, etc), 4) complementary investments measures improving customer experience (an electronic fare-collection system, iBus/NextBus vehicle location, real-time passenger information). All of these factors together contributed to London's 'bus renaissance' trend where new riders are being attracted and retained.

Chapter 5. London's Congestion Charge, Ten Years On

5.1 Introduction

To date only a few large cities have implemented congestion charging, a policy of managing traffic congestion by pricing access to congested areas during peak hours. The costs of implementing a system to enforce a congestion charge can be prohibitive, and increasing costs to drivers is generally politically unpopular. Yet London adopted a central congestion charge zone in 2003 with voter approval, and has retained it in spite of political regime change and the removal of a second zone. The congestion charge was considered an instant success when implemented, in terms of 'doing what it said on the tin': 20% fewer cars drove into central London, meaning reduced congestion and faster bus services. Over time, it has attracted criticism as congestion levels crept back to pre-charging levels, even as the charge rose from £5 to £11.50. In spite of these factors, the central congestion charge zone has proven so uncontroversial over time as to have become a part of the city's fabric.

This chapter evaluates the costs and benefits of the congestion charging policy over its first decade. The chapter provides details on how the congestion charge was implemented and modified over time. Time series data on traffic, safety, and bus reliability benefits are presented and discussed, as well as financial performance data. The chapter concludes with a discussion of unexpected impacts of the policy on attitudes toward traffic restrictions.

The chapter argues the main reason the congestion charge zone has remained widely accepted and still in force is that its benefits, rather than being realized by drivers alone, have been spread equitably among bus riders, pedestrians, and bicyclists. By law, revenues have been used to cross-subsidize bus services and improve pedestrian and bicycle infrastructure. Further benefits have been realized by planners' ad-hoc efforts to redistribute the time and space savings of reduced traffic congestion away from the transport system's most privileged users, to enhance urban quality, livability, and walkability for all users. Beyond its role as a traffic measure, the congestion charge zone has helped make central London a nicer place to visit, work, and live.

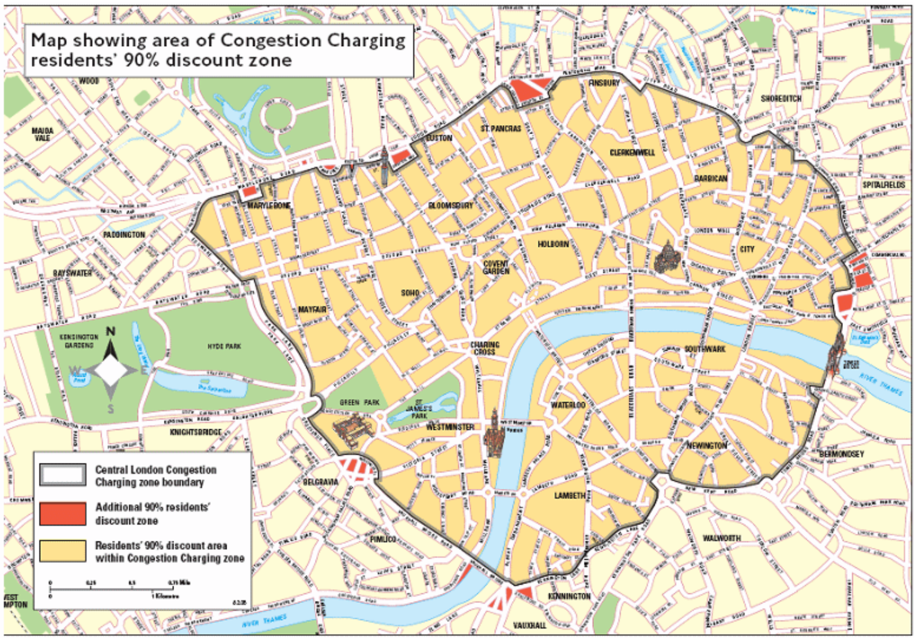
5.1.1 London's congestion charge areas

The central congestion charge zone (CCZ) went 'live' on February 3, 2003. It applies to the central business district, an eight square mile area shown in Figure 5.1. The charging cordon boundary follows the Inner Ring Road defining London's historic center, which has excellent rail and Underground access. Vehicles pay the charge upon crossing the cordon during weekday business hours (7:00 am to 6:00 pm); residents get a 90% discount. Payments are enforced by a ring of cameras that scan vehicle plates upon entry and compare them to a payment database[3]. The congestion charge system is managed by London's regional transportation agency, Transport

[3] Drivers can pay in advance or after the day of travel, but there is a steep penalty for late payment.

for London (TfL), but day-to-day operations such as customer service and enforcement are handled by a contractor. Figure 5.2 shows a photo of the congestion charging boundary marked by red stripes and signage with a “C” in a red circle. The photo was taken on part of the Inner Ring Road near Kings Cross Station and shows a dedicated bus lanes typical of the boundary.

Figure 5.1 London’s central congestion charge zone



Source: Transport for London

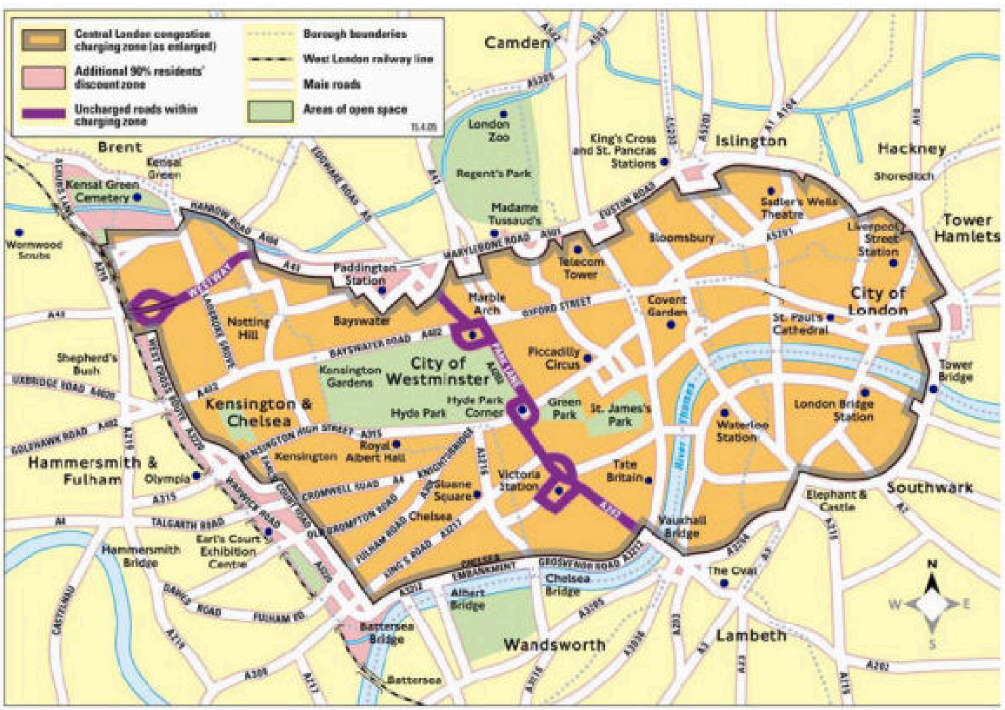
Figure 5.2 Photo of the congestion charging boundary

Photo: Andrea Broaddus

As noted in earlier chapters, the congestion charge was introduced at £5 by a populist Liberal mayor with deep political roots, Ken Livingstone, who had first proposed congestion charging while serving on London City Council in the 1980s. In his campaign, Livingstone promised to implement congestion charging and use the revenues to upgrade the city's aging and overcrowded public transportation system. He won with enthusiastic support from inner London residents and the business community. In response to public consultations, residents were given a 90% discount, and exemptions were created for taxis, low-emission vehicles, motorcycles, and disabled permit holders. To address concerns raised by the small business community, a fleet discount was offered, and certain commercial vehicles were exempted, most notably 'white van' trades vehicles operated by plumbers, electricians, and so forth.

Livingstone was re-elected in 2004 after congestion charging had proven a success, promising to expand the charging zone. He then raised the charge to £8 in 2005, and introduced a western extension zone (WEZ) in 2007 in spite of opposition by local shops and residents there. Shown in Figure 5.3, the WEZ was a primarily residential area of the city, home to Livingstone's most entrenched political opposition. They convinced the Conservative candidate in the 2008 Mayoral election, Boris Johnson, to remove the WEZ. After Johnson was elected Mayor, he fulfilled this promise and removed it in 2011, raising the congestion charge to £10 at the same time. He raised it again to its current level of £11.50 in 2014. Table 5.1 shows a timeline of changes to the congestion charge from 2003 to 2014.

Figure 5.3 The western extension congestion charge zone



Source: Transport for London

Table 5.1 Timeline of changes to the London congestion charge

Congestion Charge	Date	Notes
	May, 2000	Ken Livingston elected as Mayor, promises to implement congestion charging zone
£5	February, 2003	Central congestion charge zone goes into effect
	June, 2004	Mayor Livingston re-elected, promises to extend congestion charging zone
	December, 2004	Public consultation on raising charge to £8
	May, 2005	Public consultation on creating new Western Extension zone
£8	July, 2005	Congestion charge is raised by 60%
	February, 2007	Western Extension zone goes into effect
	May, 2008	Boris Johnson elected as Mayor, promises to remove Western Extension zone
	September, 2008	Public consultation on removing Western Extension zone
£10	January, 2011	Western Extension is removed and congestion charge is raised by 25%
£11.50	June, 2014	Congestion charge is raised by 15%

5.2 Research questions and methods

As noted earlier, when London adopted congestion charging, five specific aims for central London were set out: 1) reduced traffic volumes, 2) increased vehicle travel speeds, 3) improved transit services, 4) reduced vehicle emissions, and 5) improved safety for bicycles and pedestrians. (TfL 2001) This chapter seeks to assess whether these goals are still being met after more than a decade, and whether unexpected impacts or unintended consequences have emerged. The following research questions are addressed in the chapter:

- **Durability of traffic impacts**. Why are congestion levels in the Central charging zone approximately the same as before charging began? Was there growth in avoidance traffic on radial routes?
- **Durability of benefits to bus riders, pedestrians and cyclists.** Have improvements in bus reliability been retained? Have injuries and fatalities fallen?
- **Financial sustainability**. Why has the level of the charge more than doubled over the decade?
- **Public acceptability**. Why has the Central charging zone remained acceptable while the level of the charge has risen, and the Western Extension zone was removed?
- **Social norms**. Has the CCZ affected attitudes about driving?

A challenge over the longer term is that it becomes more difficult to know which changes are directly attributable to the congestion charge. TfL discontinued 'impacts monitoring' reports after the first five years. The congestion charge was part of a package of travel demand management policies continuously implemented by TfL since 2000, which have had a cumulative impact on travel patterns into and within central London. This chapter attempts to evaluate the impacts of congestion charging over the longer term while acknowledging that it is impossible to disentangle the role of congestion charging from other policies contributing to the low rates of car use and high rates of transit use, walking and bicycling prevalent in central London today. We lack a counterfactual case to isolate the role of congestion charging, holding all other factors constant.

A mixed methods approach is used to account for the complexity of time and confounding factors. Trends over time are analyzed to assess progress toward the initial goals of congestion charging. Time-series data on travel, land use, employment and firm locations are used to identify trends over the longest period for which data was available. Trends are then analyzed to compare pre- and post-congestion charging periods, and areas inside and outside the charged zone. The data analysis was complemented with interviews with local experts and practitioners. Interviewees included planners with TfL, the Greater London Authority and local Boroughs, experts from academia and consulting firms, land developers, and representatives of interest groups who gave comments during the public consultation on the congestion charge, such as the bus riders union, bicycle advocates, land developers, freight operators, and the Chamber of Commerce.

5.3 Literature review

TfL extensively monitored and documented the impacts of the CCZ during its first five years. In addition, baseline conditions reports were produced in the years before introduction of the central and western extension congestion charge zones, which were used to assess impacts. (TfL 2003, TfL 2006) Annual monitoring reports for the first five years tracked traffic levels, transit ridership, impacts on businesses and public opinion. (TfL 2004, TfL 2005, TfL 2006, TfL 2007, TfL 2008) After intensive monitoring of the congestion charge zone ended, traffic and travel patterns into and within central London continued to be monitored in TfL's annual Travel in London reports. (TfL 2009, TfL 2010, TfL 2010, TfL 2011, TfL 2012, TfL 2013, TfL 2014)

The TfL reports document the congestion charge successfully meeting its goals in its first year. On the day it was introduced, traffic entering the CCZ decreased by 20% (65,000 cars), meaning that congestion, measured in reduced travel delay, had decreased by 30%. (TfL 2004) With emptier streets, the average traffic speed increased from 14 to 17 kilometers per hour (kph), that is, 21% in the first year. (TfL 2004) Less traffic moving at faster speeds resulted in 2-5% fewer vehicle crashes and a 12% reduction in both NOx and PM10 emissions. (TfL 2004, TfL 2005) Enhanced safety benefits for pedestrians and bicyclists were not observed, as crash rates inside the CCZ remained similar to other areas of London. (TfL 2005) Introduction of the charge was paired with major expansion of bus service kilometers, including the introduction of 300 new buses and 7 new routes, helping to explain why the number of people entering the charged zone by bus increased by 37% (71,000 passengers). (TfL 2004) Travel speeds increased inside the charged area by 7%, including for buses, contributing to a rise in public transit ridership of 21% (Peirson and Vickerman 2008). Bus journey time reliability increased by 34%, meaning that bus riders gained a faster and more reliable trip. (TfL 2010) Traffic on the main route around the charged zone, the Inner Ring Road, increased by 4% to 5% in the first year. (TfL 2004)

People and traffic patterns adapted quickly, and it became widely accepted. Of the car trips no longer made to the CCZ, TfL estimated that the majority of drivers switched modes—55-60% to public transport and 8-15% to walking, biking, or taxis—while the remainder either diverted around the zone, made their trip outside of charging hours, or traveled elsewhere. (TfL 2004) Surveys of Londoners showed that opinions shifted favorably after introduction of the CCZ. Prior to its introduction, 38-40% of those surveyed supported and 40-43% opposed it, but afterwards 48-59% supported and 24-31% opposed it. (TfL 2010) At-risk groups were specifically investigated to see how they were impacted, and social inclusion impacts were found to be generally beneficial. (Bonsall and Kelly 2005) A business survey found that the majority of businesses located in the CCZ or close to the boundary had little impact on costs or performance, and were generally supportive, except for retail and leisure businesses. (TfL 2010)

Naturally there has been significant interest in evaluating the congestion charge from an economic perspective, as it tested the idea that demand for driving could be influenced by price. TfL used vehicle count data to estimate demand elasticities for travel to central London as revealed by congestion charging, estimating elasticity as -.55 with a £5 charge. (TfL 2008) The demand elasticity of raising the charge from £5 to £8 was estimated as -.16, suggesting that those more sensitive to the price were largely deterred by the initial introduction of congestion charging, and that remaining drivers were less sensitive to the charge.

The environmental impacts of congestion charging were expected to be mixed. The link between congestion pricing and reductions in vehicle emissions is complex, as the vehicle mix has changed to include higher proportions of goods vehicles and buses, and there may be induced travel due to faster travel speeds. Research exploring whether air quality improved after congestion charging yielded results depending on the scale of analysis. One small-scale study attributed NOx and PM10 pollution reductions to the congestion charge, by approximately 8-13%, respectively, while a larger-scale study noted that air quality worsened relatively less inside, as compared to outside, the charged zone. (Ho and Maddison 2008, Rich and Nielsen 2008). Air quality improvements in London are due in part to the 'low emissions zone' which encompasses all of Greater London, and to increasing efficiency of the vehicle fleet over time (Banister 2008).

5.4 Longer-term adjustments: mode shift and car shedding

After the CCZ was introduced, TfL's intensive monitoring allowed for estimation of how drivers had coped with the change. Table 5.2 shows their summary of driver adjustments to the charge. Most drivers shifted modes to public transit (55 to 60%), or to other modes (8 to 15%). A significant portion kept driving, but changed their route to divert around the charged area (25 to 30%). The majority of these were goods traffic. Others who kept driving changed the timing of their trip to travel outside of charging hours (5%), or reduced how frequently they made trips into the charged area (5%). There may have been some trips that were not made at all, but these were not estimated.

Over time, mode shift continued as capacity on London's rail services increased, and a bike sharing system was introduced. From 2005 to 2010, £10 billion was invested in the Underground network for long-overdue repairs and improvement to travel speeds with a new signal system. A new Underground line, the Jubilee, opened in 1999. From 2000 to 2012, London added four new extensions to its Docklands Light Rail (DLR) system. From 2007 to 2012, major upgrades were made to the city's commuter rail network, including extensions to form a new orbital rail service called the Overground. Mayor Johnson fulfilled his election promise to introduce a shared public bicycle system in 2010, providing 5,000 bikes and 315 docking stations distributed across a 17 square mile are of Inner London. (TfL 2010)

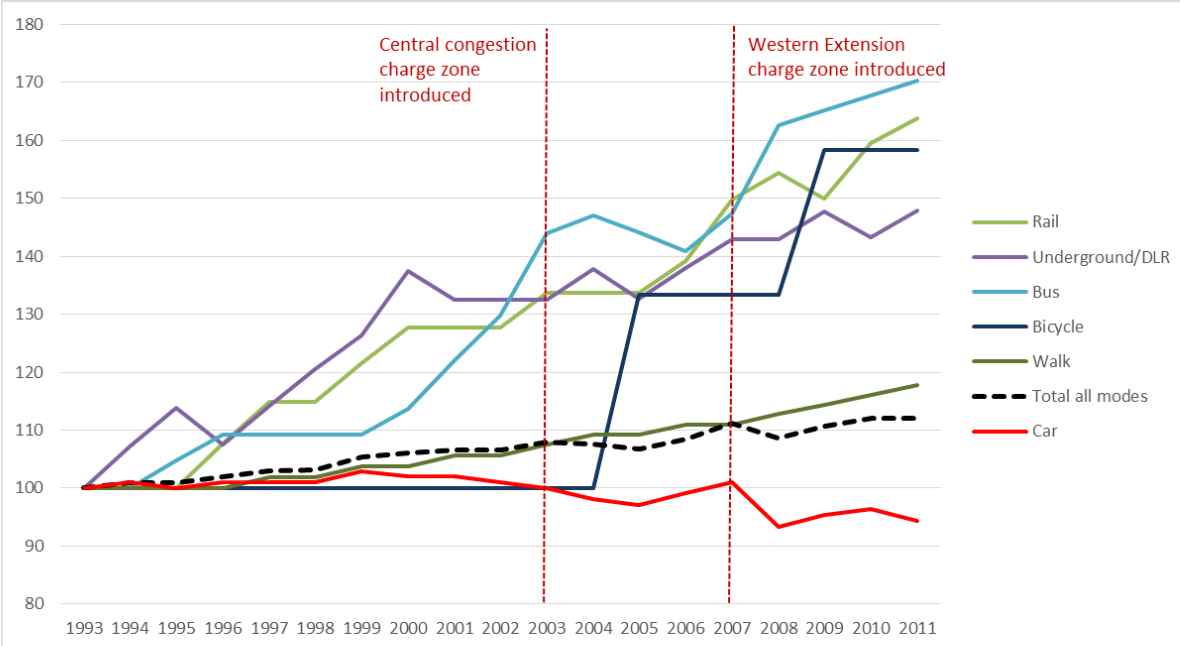
Table 5.2 Driver adjustments to the congestion charge

Type of shift	**Behavioral change**	**Estimated number of car trips reduced per charging day (65,000 to 70,000 total)**	**Estimated percentage**
Mode	Transfer to public transit (bus or rail)	35,000 to 40,000	55% to 60%
Mode	Transfer to other modes (walk, bicycle, taxi, etc)	5,000 to 10,000	8% to 15%
Route diversion	Through trips diverting around charging area	15,000 to 20,000	25% to 30%
Time of day	Trip made outside of charging hours	Under 5,000	5%
Avoidance	Travel to alternate destination, reduced frequency	Under 5,000	5%
Suppression	Trip not made at all	Not estimated	

Source: Transport for London, 2008

The net impact of measures to reduce driving and improve public transportation has been wide-scale mode shift. This trend is evident in aggregate travel patterns, as illustrated in Figure 5.4 shows the growth trend for each mode. From 1993 to 2003, there was some growth in car trips as a share of all travel, but it began to decline from a peak of 33% mode share in 1998. By 2003, car share was 31%, and by 2011 it was 28% of all trips. Bus mode share grew from 7% of trips in 2000 to 10% in 2003, for all the reasons discussed in Chapter 4. By 2011, bus mode share was 12% of all trips, a 50-year high for London. Buses currently account for around half of all public transport use by London residents.

Figure 5.4 Trend in aggregate travel in Greater London by main mode of travel (7 day week) (1993=100)



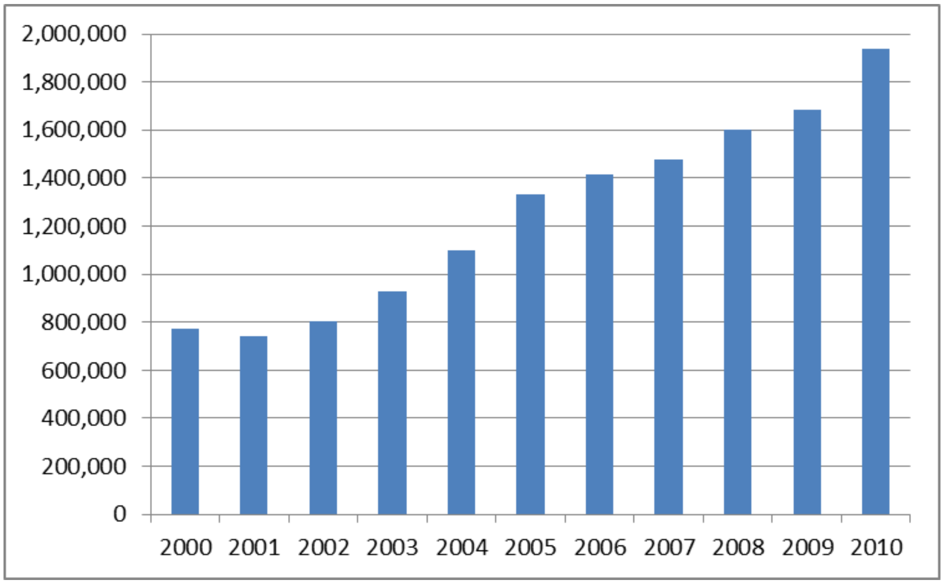
Data source: TfL Travel in London Report 5, 2012

As shown on Figure 5.4, the other mode that changed significantly after congestion charging was bicycling. Bicycle trips were a stable and very small share of all travel (.98%) until the CCZ was introduced. Afterwards, mode share for bicycle trips began growing, with almost all new trips taking place in Inner London. Figure 5.5 shows annual bicycle flows on TfL red routes, where bicyclists were allowed to ride in dedicated bus lanes. By 2011, bicycle share was 1.45% of all travel.

As Londoners increasingly used public transportation and other modes, many found that owning a car no longer made sense. Figure 5.6 compares the percentage of households with zero, one, and two cars in Inner and Outer London, using Census data from 2001 and 2011. It can be seen that car ownership declined steeply over the decade from 2001 to 2011, especially in Inner London. The percentage of one and two car households fell, while the number of households without a car grew.

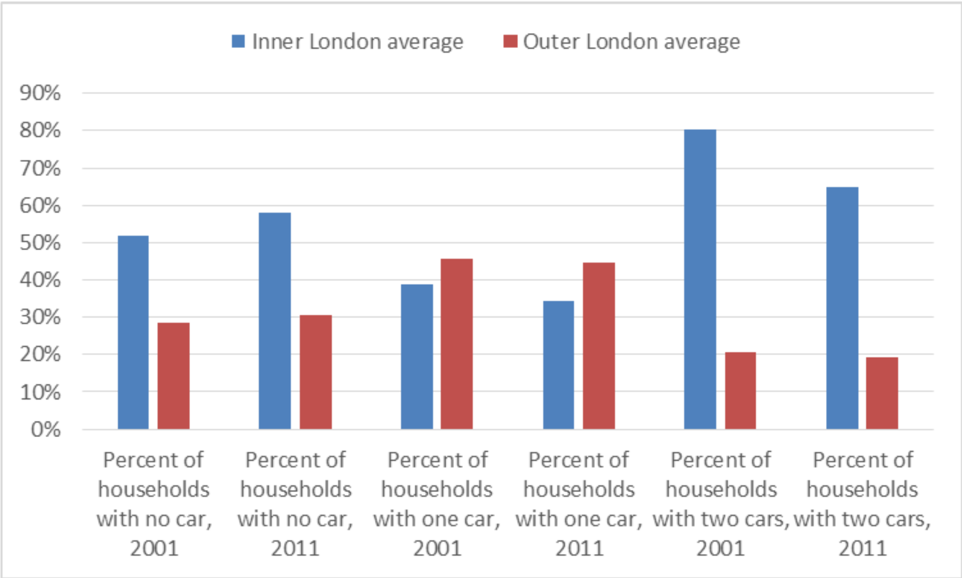
The most dramatic change was in Inner London, where one car households fell from 39% in 2001 to 34% in 2011, and no car households grew from 52% to 58%. For this reason, average car ownership among Inner London households fell from .60 in 2001 to .52 in 2011. It also declined in Outer London, from 1.02 cars per household in 2001 to 1.04 in 2011. Undoubtedly the economic recession during this period was an influential factor, but it served to boost a car-shedding trend that was well underway by 2008, as discussed in Chapter 3.

Figure 5.5 Annual bicycle flows on TfL 'red routes'



Data source: Travel in London Report 3, 2010

Figure 5.6 Comparison of car ownership in Inner and Outer London Boroughs, 2001 and 2011



Data source: UK Census 2001 and 2011

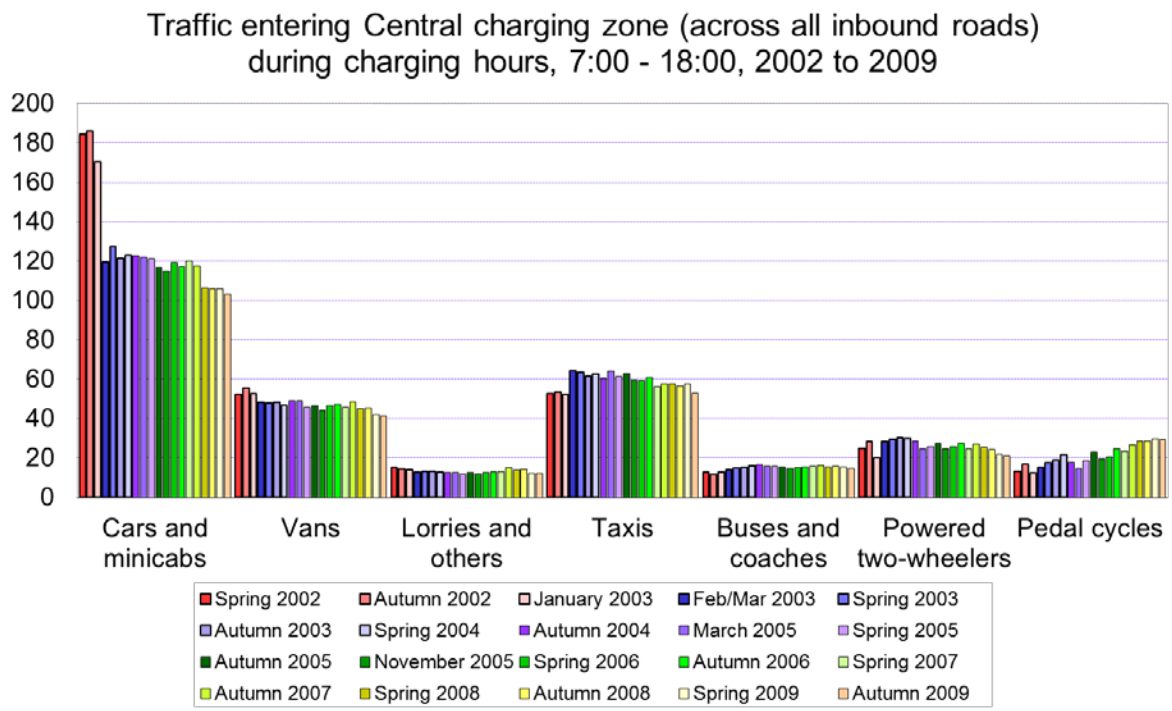
5.5 Durability of traffic impacts

When adopted, the stated aims of the congestion charge policy were: reducing traffic volumes, increasing vehicle travel speeds, improving transit service, reducing vehicle emissions, and improving safety for bicycles and pedestrians. (TfL 2011) In the early years, all of these goals were met, as discussed in the literature review. Over the longer term, performance has been mixed.

5.5.1 Traffic volumes have remained stable

Remarkably, the initial traffic reduction of 65,000 fewer cars per day entering the zone was maintained over time with no ‘creepback’ to higher traffic levels, as shown in Figure 5.7. The congestion charge was paid by only the first three types of vehicles, cars / minicabs[4], vans, and lorries. In the congestion charge’s first year, 27% fewer chargeable vehicles entered the charging zone in total; cars were the most sensitive to the charge, decreasing by 33%, and vans and lorries each decreased by 11%. (TfL 2008) Increasing the charge from £5 to £8 in July 2005 had only a mild additional impact, deterring 3% more chargeable vehicles. (TfL 2008)

Figure 5.7 Traffic entering congestion charge area by mode, 2002 to 2009



Source: Travel in London Report 2

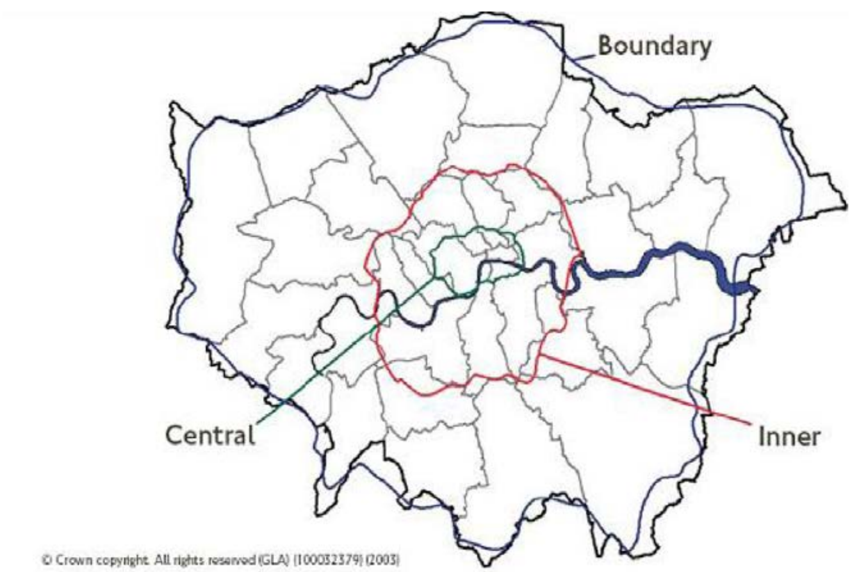
TfL concluded that most non-essential car trips were priced off the roads by the initial congestion charge. The impact of the subsequent price increase from £8 to £10 was estimated

[4] There are two types of regulated car hire services in London, black taxis and minicabs. Black taxis, or simply taxis, are regulated by medallion, may be hailed, and have drivers that have passed “the Knowledge” test. Minicabs are neighborhood-based services with casual drivers using personal vehicles; they are dispatched from a minicab stand within a defined neighborhood zone and may not be hailed. Black taxis are exempt from the congestion charge, while minicabs are not.

using TfL's central cordon count data[5], and found to have deterred only 1% more vehicles. (TfL 2013) Using the change in price and change in quantity of cars to calculate the price elasticity of demand, the long run demand for travel into central London with congestion charging was estimated[6] to be approximately -.04. Nevertheless, these incremental traffic reductions have added up over time; traffic volumes in the CCZ today are about 24% lower than pre-charging levels. (Buckingham 2013)

Over the longer term, traffic volumes in central London have reflected a background trend of declining traffic in Central and Inner London. Figure 5.8 shows the boundaries of the central, inner, and outer cordons where traffic counts are conducted on a rotating annual basis. Data collected at these cordons over the past twenty years is shown in Figure 5.9. The central cordon counts show that traffic volumes were already in decline in Central London when the congestion charge was introduced. A general trend of declining traffic began in the late 1990s, and accelerated from 2000 to 2003, when major improvements were made to bus services in Central London. Traffic continued declining after 2003, with congestion charging in place. The inner cordon counts show that traffic has also been declining throughout a much larger area than the congestion charge zone since the late 1990s. The introduction of congestion charging in 2003 further suppressed the number of cars crossing the inner cordon on the way to Central London, accelerating this trend.

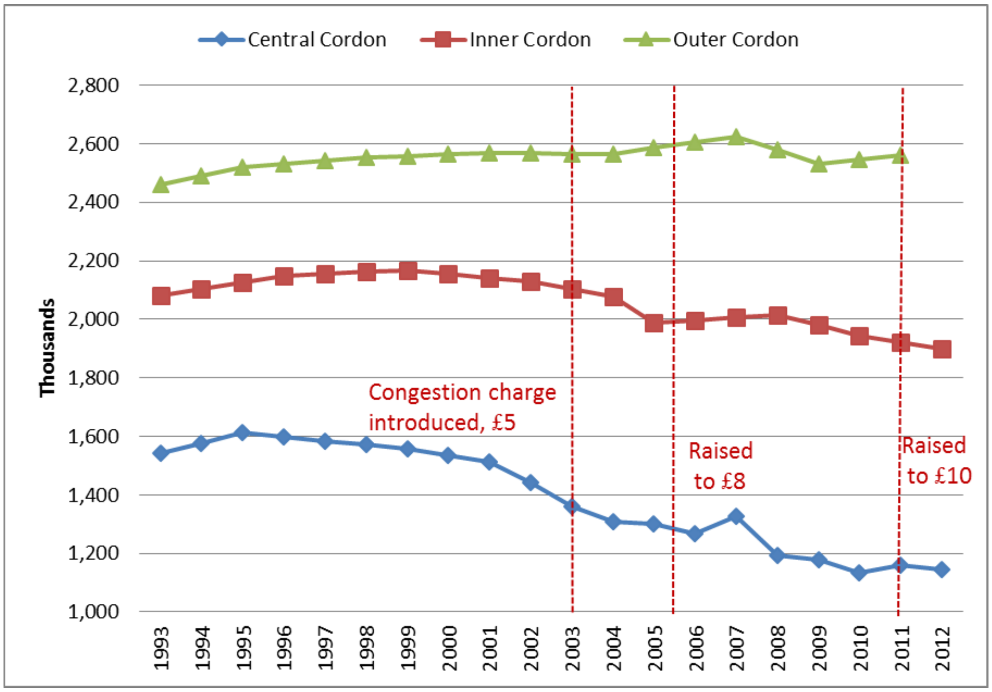
Figure 5.8 Traffic count cordons



Source: GLA 2003

[5] Counts of vehicles paying the congestion charge were not published, after 2009, and so central cordon counts are used as a proxy. The central cordon is different from the congestion charging area; it is situated outside the Inner Ring Road and encloses a slightly larger area to the west.
[6] Author's calculation, using TfL central cordon count data from 2010 and 2011 (all chargeable vehicles): (260,720-259,570)/259,570)/((10-8)/8)

Figure 5.9 24-hour Cordon Counts, All Vehicles



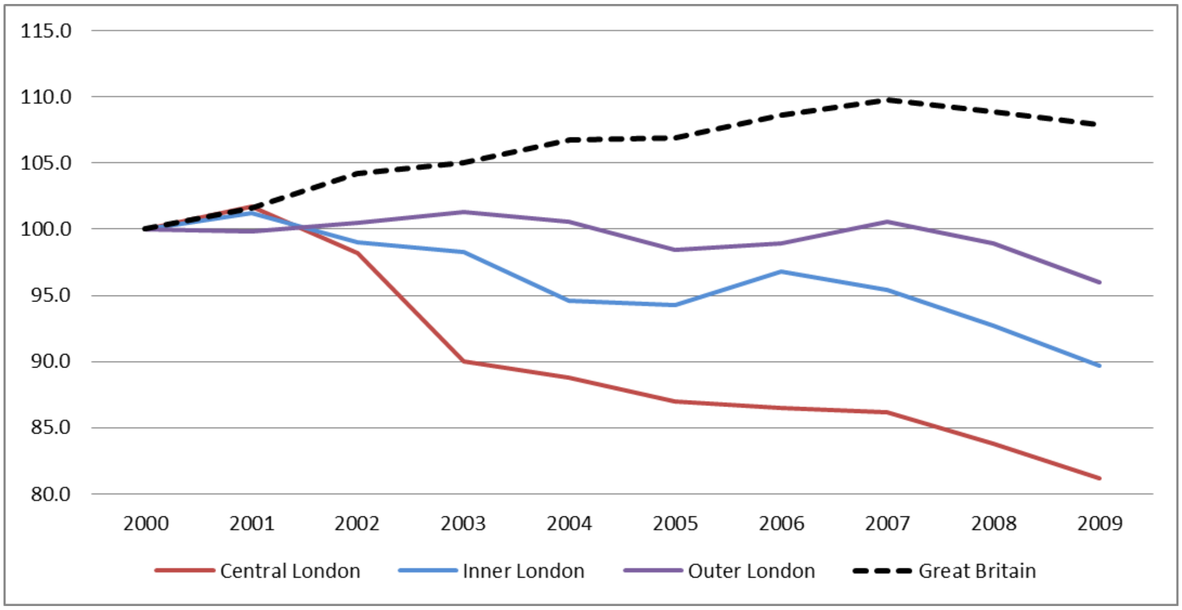
Data source: TfL Traffic Note 3, 2013

The declining traffic trend is further illustrated in Figure 5.10, which shows the trend in vehicle kilometers travelled (VKT) on all roads in the Central, Inner and Outer boroughs, compared to Great Britain. It can be seen that while VKT has increased in Britain as a whole, it has declined throughout London, including the Outer boroughs. Traffic declined at a steep rate from 2001 to 2003 in Central London, as measures discouraging driving were put in place, including road space reallocation, pedestrian safety infrastructure, and parking removal.

TfL have attributed the background trend of declining traffic throughout Inner London as a consequence of congestion charging paired with stronger parking policies. Starting with national policies intended to reduce car use and promote other modes, London's on and off street parking policies were revised to become more prohibitive, in a variety of ways. Parking is largely regulated by local Boroughs, but they must conform to a regional spatial development plan developed by the Mayor and the Greater London Authority, London's regional government, which in turn follow national guidelines. (GLA 2004) Most Boroughs revised minimum parking standards for new residential development to maximums[7] between 2000 and 2004. (Li and Guo 2014) The London Plan also encouraged the creation of residential controlled parking zones. As discussed in Chapter 4, Boroughs near the congestion charging zone were given funding to create new residential parking zones in areas expected to be impacted by spillover effects.

[7] Parking standards for commercial development already were already maximums.

Figure 5.10 Trend of motor vehicle traffic on major and minor roads, Greater London Index (Year 2000=100)



Data source: Travel in London Report 3, 2010

5.5.2 Congestion levels have risen

As shown in Figure 5.11, average traffic speeds in central London increased in the first year of congestion charging. The average speed of general traffic increased from 14 kph to 17 kph (20%), while average bus speeds stayed the same, 11 kph. Increased speeds were a direct result of reduced traffic volumes due to congestion charging, that is, congestion delay was reduced without any changes to the road network or signal timing.

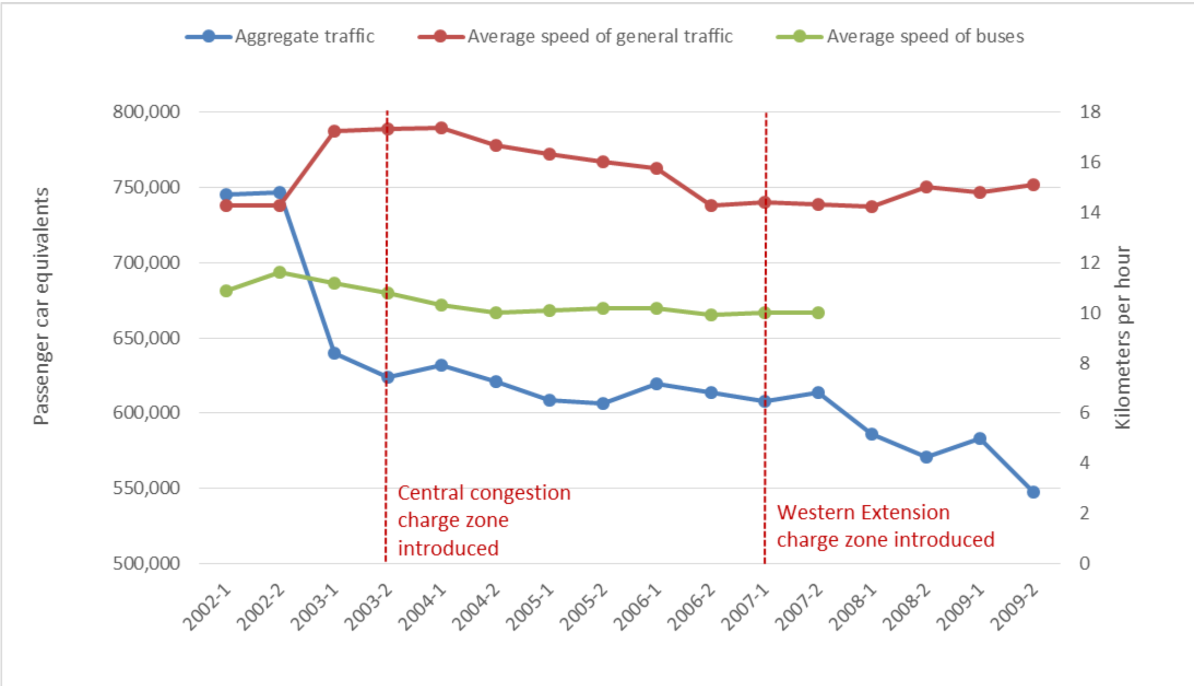
In the next few years, average travel speeds began to decline. TfL attributed this trend to higher-than-expected congestion levels caused by major roadworks for water and gas main replacements undertaken by the Boroughs, which caused significant network disruptions[8]. By 2007, average traffic speeds were consistently back to pre-charging levels. "In the central zone, congestion worsened during the day between 2005 and 2007 by .7 minutes per kilometer." (TfL 2010) The roadworks were completed by 2009, but travel delays continued, even with declining traffic flows.

This paradox prompted TfL to conduct a study to determine the cause of rising congestion levels. Their analysis concluded that since demand was steady, it must be a supply-side issue: the network capacity must have been reduced. The report concluded, "There has been a net loss of

[8] Network disruption was significant enough to prompt TfL to adopt a new 'lane rental' policy where utilities are required to schedule work in advance and pay for the amount of time and disruption they cause.

about 20% in effective network capacity for road vehicles in the period between 2004 and 2008." (Buckingham, Doherty et al. 2010)

Figure 5.11 CCZ Aggregate traffic volume and average travel speed of general traffic compared with average bus travel speeds



Note: 2002-1 = January to June, 2002-2 = July to December, etc. Average general traffic speeds are for all charging hours. Average bus speeds are for weekday morning peak only.

Data sources: Travel in London 2 Figure 11.15 and TfL Bus Network Team 2014

This finding raised the question, where had the capacity gone? After an internal review, TfL concluded that network capacity had been reduced as result of a multitude of projects to improve bus priority and pedestrian safety in Central London after congestion charging was introduced. The Boroughs control 95% of London roads, with six different Boroughs having some roads inside the charged area. Borough traffic engineers had worked together with TfL to identify the most problematic intersections and re-design them to improve bus and pedestrian safety and performance. In most cases, this meant two types of changes: signal re-timing and road space reallocation for bus lanes, bicycle lanes, and crosswalk bulb-outs. Dozens of intersections and street corridors were addressed, on an ad-hoc case-by-case basis, such that the cumulative effect on the network went unnoticed until it all added up. As explained by TfL's Planning Director,

> "Traffic engineers doing the work would look at a road junction and say, if we could tweak this junction to do so and so, it should have a neutral effect on the network—because they were just looking at that junction. [Our review found] that the cumulative effect of all these little changes was actually much more significant. A significant proportion of the space was taken away, for good reasons, but the cumulative effect is that congestion has increased." (Dix 2013)

Traffic engineers had whittled away at the road capacity released by congestion charging until it amounted to a significant ‘capacity grab’ of road space and travel time savings away from drivers and toward bus riders, pedestrians, and cyclists.

Rising congestion levels in the charged area has been noticed by Londoners, who have a general impression that congestion charging isn’t working any more. It has also drawn bitter criticism from drivers and the freight industry. For instance, the UK Automobile Association greeted the tenth anniversary of the congestion charge with a claim that it has “‘sucked’ £2.6 billion from drivers while failing to cut congestion.” (Standard 2013) TfL responded by pointing out that although levels of travel delay within the CCZ are similar to pre-charging levels, they are experienced by 20% fewer drivers. Yet this complaint illustrates how the less salient benefits of congestion charging, such as a net reduction in traffic and ten years’ worth of travel time savings to businesses and travelers throughout Inner London, may be less understood and valued by the public. However, the fact that decisions to reallocate road space are made on the local level, the most responsive to constituent concerns, makes them in a way an expression of the peoples’ will. As a transportation planner for Westminster Borough put it,

> “Ultimately Borough members make the decision whether they want to lose all their roads to other modes. For instance, with the Piccadilly two-way conversion, we probably lost about 20% of through vehicle capacity. A decision was made by this Council on the basis that we have congestion charging in the area that released capacity—because anecdotally the capacity was freer there anyway.” (Brennan 2013)

Although widespread road space reallocation and signal re-timing to slow traffic had the unintended consequence of re-congesting Central London, they reflect a desire among Londoners to re-prioritize urban space for pedestrians and other modes. TfL staff also point out that the released capacity could not have lasted very long, in a dynamic city. There was a recognition that the savings from faster traffic could be kept for a period of time, but not forever, and so efforts were made to protect against erosion. (Dix 2013) Raising the level of the charge was one such effort to suppress rebound effects as people adapted. In the end, reallocating road capacity toward walking and cycling served to lock in benefits for those modes. To regain previous levels of vehicular access, all the bus lanes, bike lanes, wider sidewalks, etc, would have to be taken out, but that’s not the public sentiment—people recognize the benefits. (Buckingham 2013)

5.6 Durability of benefits to bus riders, pedestrians, and cyclists

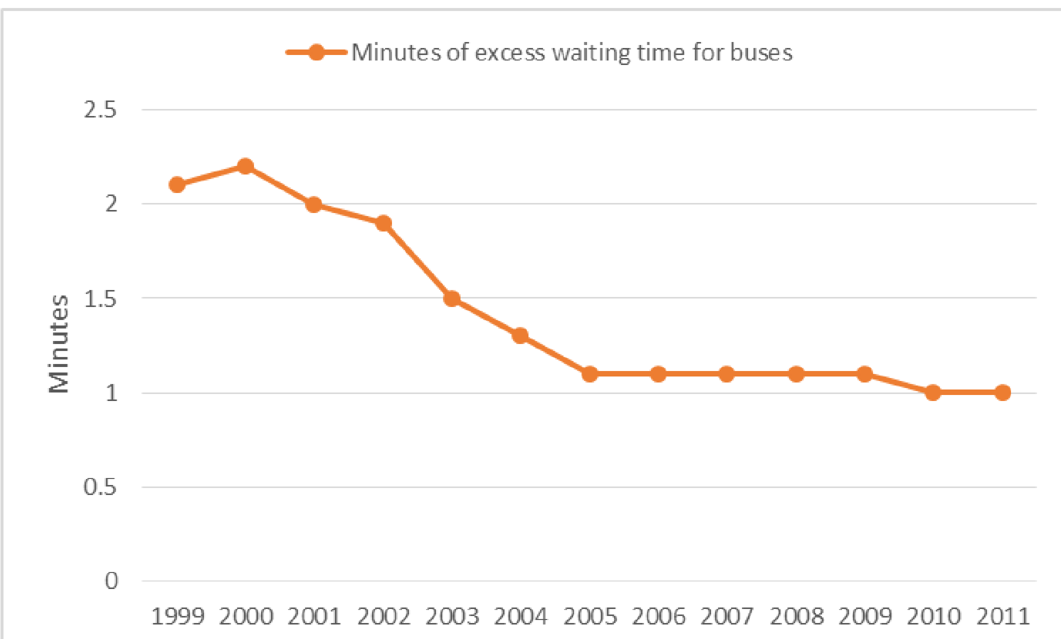
As discussed in the literature review, several evaluations of the congestion charging zone have concluded it has contributed to improved transit service and safety for bicycles and pedestrians. Over the longer term, we may ask whether improvements in bus reliability been retained, or whether changes to network capacity have affected their performance. And although pedestrian injuries and fatalities may have seemed to decline a bit in early years, we may ask what has happened as more and more people have taken to the streets as pedestrians and cyclists.

5.6.1 Improved bus reliability

Buses benefited from reduced car volumes, and bus travel speeds were further enhanced by TfL's investment in bus lanes and other bus priority measures such as parking removal, advance stop lines, and bus-only gates. As shown in Figure 5.11, as average traffic speeds for general traffic declined back to pre-charging levels, bus priority measures were effective at keeping bus travel speeds stable. Therefore the competitiveness of buses kept improving over time, in comparison to travel times offered by taxis and other private vehicles. As the average occupancy of buses is much higher than other motorized vehicles, this meant that travel time benefits were much more widely distributed.

Bus reliability was improved by bus priority measures, such that passengers' waiting time for late buses was reduced. TfL compares the actual amount of time passengers wait for buses to the bus schedule in order to calculate excess wait time due to buses running late or cancelled. Figure 5.12 shows that minutes of excess wait time were cut in half from a system-wide average of 2.2 minutes in 2000 to 1.1 minutes in 2005. An important factor improving on-time reliability in this timeframe was the introduction of performance quality contracting, where bus operators[9] were given economic incentives for meeting scheduled arrival times.

Figure 5.12 Bus reliability in Greater London



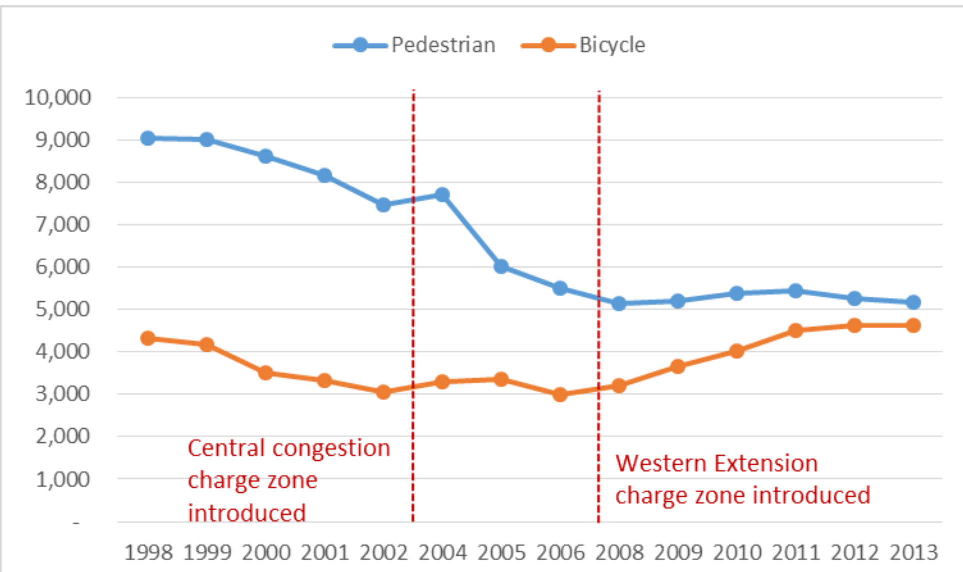
Data source: TfL Bus Network Team, 2014

[9] London's bus services are planned by TfL, but buses are operated by private sector companies on a contract basis.

5.6.2 Reduced injuries and fatalities

In addition to expanded bus services, congestion charging was paired with measures improving walkability and road safety for cycling. As with parking measures, Mayor Livingstone's 2001 Transportation Strategy reflected national policy. It set aggressive goals for improving road traffic safety based on national targets for 2010: 40% reduction in people killed or seriously injured (KSIs) in road collisions; 50% reduction in child KSIs, and 10% reduction in 'slight' injuries, expressed as the number of people slightly injured per 100 million VKT, all relative to London's 1994-1998 average. These goals motivated intensive investments in road safety, enabling London to achieve all of these safety targets by 2004. In 2006 Livingstone announced new 2010 targets, expanding them to include specific goals for improving pedestrian and cyclist safety: 50% reduction in KSIs, 50% reduction in cyclist and pedestrian KSIs, 40% reduction in motorcycle KSIs, 60% reduction in child KSIs, and 25% reduction in the 'slight' casualty rate.

Figure 5.13 Pedestrian and bicycle casualties in Greater London



Note: these data are the totals for killed, seriously injured, and slightly injured.

Data sources: TfL Accidents and Casualties 2002, Travel in London Reports 2005-14

The success of London's road safety efforts is illustrated in Figure 5.13, which shows pedestrian and bicycle casualties (KSIs and slightly injured) from 1998 to 2013. This data was compiled from TfL's annual Travel in London reports from 2005-14, and from a special road safety report produced in 2002 that included data for prior years[10]. Both pedestrian and bicycle casualties fell steeply from 1999 to 2002, and then rose in 2004. This may be related to a surge in new pedestrian and bicycle travel related to congestion charging. Pedestrian casualties plummeted sharply from 2004 until 2008, and then more or less stabilized. This trend is likely related to

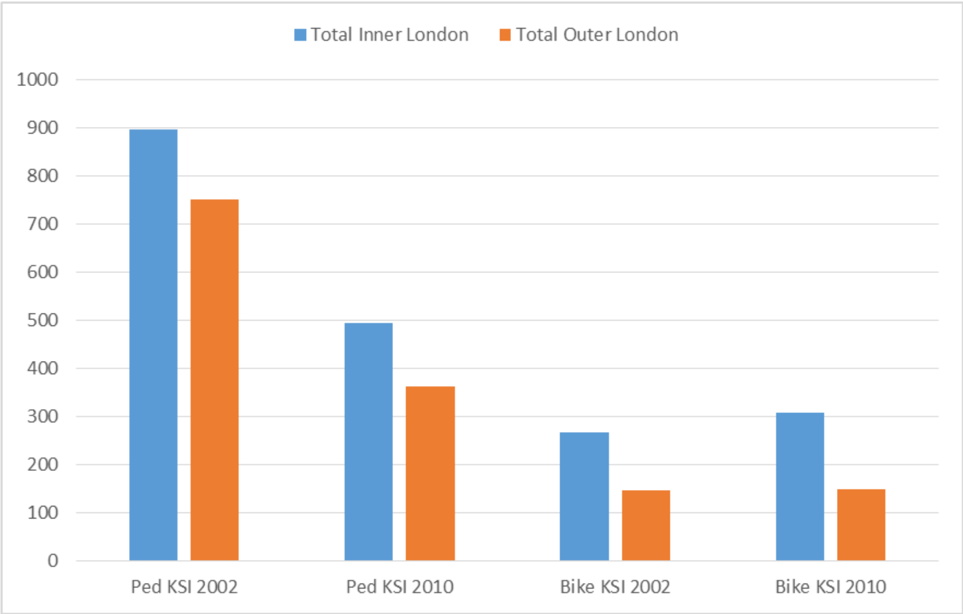
[10] The original source of data are accident statistics reported by police to the Department for Transport (DfT).

TfL's program of re-timing traffic signals to increase pedestrian crossing time. Bicycle casualties were relatively stable during the same period, but then increased rapidly after 2008. This trend is likely related to rapidly increasing rates of cycling, and the introduction of public shared bikes in 2009, as discussed previously.

Figure 5.14 Comparison of pedestrian and bicycle fatalities

Source: TfL Road accidents 2002, DfT 2010

Figure 5.15 Comparison of pedestrian and bicycle KSIs



Source: TfL Road accidents 2002, DfT 2003

Safety improvement trends were realized throughout London, but they especially reflect conditions in Inner and Central London where most walking and bicycling trips were made. Figures 5.14 and 5.15 compare pedestrian and bicycle fatalities and KSIs in Inner and Outer London in the years 2002 and 2010, the first year DfT published Borough level data. Pedestrian fatalities were higher in Outer London in both years, most likely due to higher average traffic speeds. Bicycle fatalities were higher in Inner London in both years, due to higher rates of cycling. Pedestrian fatalities were halved in Inner London in 2010, compared to 2002, but only by 40% in Outer London. However, bicyclist KSIs were increased by 15% in Inner London in 2010, compared to 2002, but only by 1% in Outer London.

These safety benefits were achieved through a combination of traffic reduction, largely due to congestion charging, paired with improvements to bicycle and pedestrian infrastructure and re-timing traffic signals. TfL controls signal timing on red routes and all local streets in Central London with a system called SCOOT which optimizes network performances. In the early 2000s, signal settings were overhauled to give more crossing time to pedestrians. Besides the safety benefit to people crossing roads, this had the general effect of slowing down traffic and reducing the severity of injuries from collisions. This measure contributed to the trend of slowing traffic in the Central area, as discussed earlier.

5.6.3 Focus on walkability

Travel fatalities and serious injuries were the lowest on record in 2011, in spite of a greater share of vulnerable travelers on the roads (TfL 2012). Most Inner London boroughs adopted policies to reduce traffic and actively encourage walking, in the early 2000s. For example, Camden adopted a Walking Plan in 2006 that stated, “The Council is pursuing a policy of roadspace reallocation towards the pedestrian. This is not just in terms of wider pavements but also about space and priority given to pedestrians on roads and road layouts that give clear sightlines between pedestrians and vehicles.”

Several high profile pedestrian infrastructure projects in the Central area were led by Westminster Borough, the borough with the most area inside the charged zone, including pedestrianization of Trafalgar Square, where a 46-foot vehicle right-of-way became the North Terrace in 2003. This movement gained momentum after the 2005 announcement that London would host the 2012 Olympics, for example conversion of Piccadilly St from one-way to two-way traffic and a new contra-flow bus lane and pedestrian crossings at Piccadilly Circus in 2008, and diagonal pedestrian crossings with an all-red ‘scramble’ signal phase at Oxford Circus in 2009. Private sector property owners were key collaborators in the general effort to reduce car traffic and improve pedestrian safety and amenities. For instance, the iconic Regent Street corridor received a £1 billion total make-over with wider sidewalks and improved bus stops and bicycle access, sponsored by its owner, the Crown Estate.

5.7 Financial sustainability

By law, during the first ten years of congestion charging, net proceeds were to be spent on expanded bus and rail services, safety improvements for cycling and walking, and public realm improvements in the streets. (TfL 2011) From its introduction to the end of the 2014 fiscal year, £1.5 billion in congestion charge revenues were available for these purposes, as shown in Table 5.3. TfL estimates that two-thirds of this amount (~£1 billion) was invested in the bus network, £100 million on roads and bridges, £70 million on road safety, £50 million on Borough transport plans, and £40 million on road safety and pedestrian and cycling facilities. (TfL 2014)

5.7.1 Unexpectedly high operational costs

In spite of its nature as a revenue generating mechanism, the congestion charge required many adjustments over ten years to keep it financially net positive. The first challenge was revenue shortfalls as a result of the charge's effective in deterring drivers—it became a victim of its own success. Traffic fell by 20% in its first year, more than expected, as that was the maximum projection from modeling studies in the planning phase. As shown in Table 5.3, first year gross revenues fell short of the expected £200 million, totaling only £187 million. (TfL 2004)

Table 5.3 Congestion charging costs and revenues

		A	**B**	**C**	**D**		**E**	
Fiscal Year (April 1-March 31)	Congestion charge	Operating costs - expenditures (million)	Internal operating costs (million)	Gross revenues (million)	Net revenues (million)	Cost Recovery Ratio (A/C)*	TfL total gross revenues (million)	Percent of total TfL revenue (C/E)*
2002 projections	£5**	£70**		£200**	£130**	0.35		
2003/4	£5	£122.9	£18.5	£186.7	£45.3	0.76	£2,320.8	8.0%
2004/5	£5	£121.4	£2.0	£218.1	£96.4	0.57	£2,554.5	8.5%
2005/6	£5/£8	£143.9	£3.9	£254.1	£106.3	0.58	£2,737.6	9.3%
2006/7	£8	£130.4	£32.9	£252.4	£89.1	0.65	£2,965.6	8.5%
2007/8	£8	£171.7	£19.5	£328.2	£137.0	0.58	£3,278.8	10.0%
2008/9	£8	£167.2	£10.0	£325.7	£148.5	0.54	£3,451.5	9.4%
2009/10	£8	£144.4	£10.1	£312.6	£158.1	0.49	£3,594.3	8.7%
2010/11	£8/£10	£102.6	£10.4	£286.5	£173.5	0.39	£3,884.2	7.4%
2011/12	£10	£81.2	£8.7	£226.7	£136.8	0.40	£4,180.9	5.4%
2012/13	£10	£82.8	£7.1	£222.0	£132.1	0.40	£4,495.5	4.9%
2013/14	£10	£81.2	£4.2	£234.6	£149.2	0.36	£4,789.6	4.9%
2014/15	£10/£11.50	£80.7	£4.2	£257.4	£172.5	0.33	£5,039.2	5.1%

Data source: Columns A, B, C, D and E are figures published in TfL Annual Reports

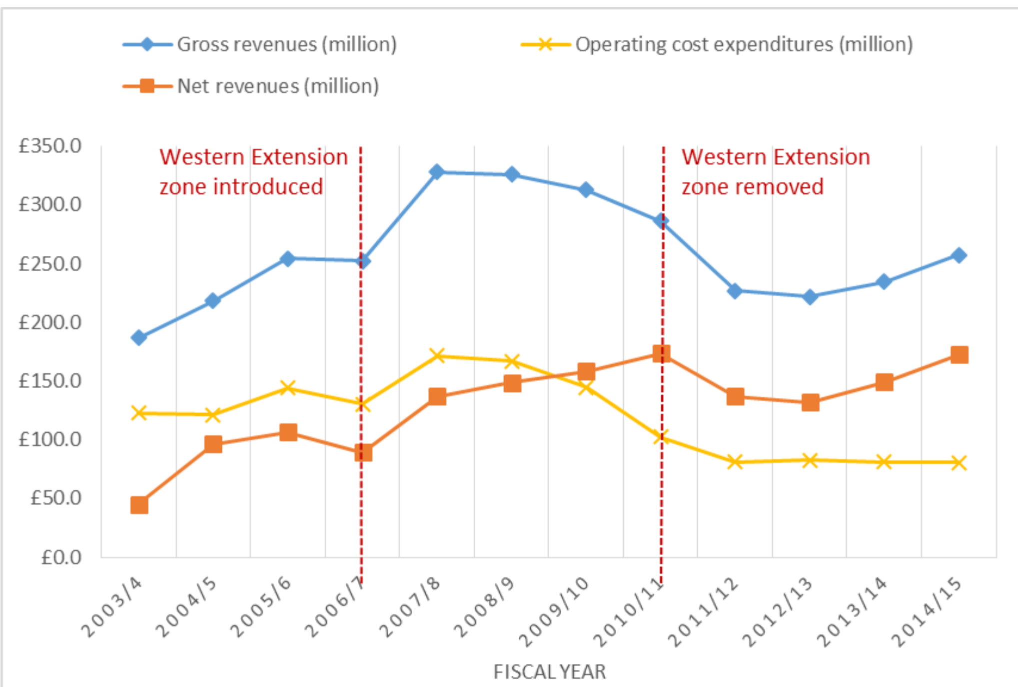
**Author's calculations*

*** Estimated costs and revenues from projections in congestion charge planning studies, as reported in Richards 2002, "Congestion Charging in London".*

The second challenge was the cost of operating the system, which was much higher than expected. Figure 5.16 illustrates the data in table 5.3, showing how the costs and revenues of operating the congestion charging system have changed over time. Over £186 million was collected from drivers in the first year of congestion charging, but the system only netted £45 million after expenses, including a payment of £123 million the system operator. (TfL 2004) The cost recovery ratio of .76 was more than twice the target ratio of .35 projected in planning studies; this target was not achieved until 2013/14. Part of the expense was due to shortfalls by the system operator in the number of penalty charges being issued to drivers who failed to pay the congestion charge; TfL worked with the operator to improve services, the number of penalties for non-payment issued more than doubled, to 7,000 per day (compared to about 110,000 payments). (TfL 2004)

In 2009, operations costs were reduced even further when the operations contract was awarded to a new operator through a competitive tender. (TfL 2007) After 2009, net revenues finally began to exceed costs.

Figure 5.16 **Costs and revenues of the congestion charging system**



Data source: TfL Annual Reports

5.7.2 Declining role in TfL's overall budget

As the cost recovery ratio improved, net congestion charge revenues grew from £45 million in the first year to £173 million in 2014/15, a 281% change. One might infer these revenues have therefore played an increasingly important role in TfL's budget, yet the opposite is true. TfL has continually grown its bus and rail network and extended service hours, such that its annual gross revenues have more than doubled (to £5 billion) and the contribution of congestion charging has declined over time. As shown in Table 5.3, congestion charging revenues formed 8% of TfL's total revenues in fiscal year 2003/4, but amounted to only 5% by 2012/13, a level which has remained stable.

Finally, the extra expenses of financing the expansion of the congestion charging system to create the Western Extension zone in 2007, and then to remove it 2011, put additional pressure on revenues. The congestion charge's first increase from £5 to £8 was made by Mayor Livingston in July 2005, on the heels of public consultations on raising the charge (December 2004) and extending the charging zone westward (May 2005). (TfL 2007) The second time the charge was raised from £8 to £10 by Mayor Johnson in May 2008, following public consultations on whether to keep or remove the Western Extension zone. (TfL 2010) The £10 charge came into effect on the same day that the charging in the Western Extension was discontinued, January 2011[11]. While charge increases were not explicitly linked with Western Extension zone costs, TfL staff cited the need to cover costs and recoup revenue losses. (Buckingham 2013, Dix 2013)

The charge has most recently been raised from £10 to £11.50, by Mayor Johnson in 2014. (TfL 2014) When asked why the charge needed to be raised, staff cited the need to ensure the congestion charge remains effective as a traffic deterrent, and to keep pace with rising public transit fares. (Dix 2013) This insensitivity to a rising charge has continued over the longer run.

5.8 Public acceptability

The level of the congestion charge has been raised several times since it was introduced, with a summary shown in Table 5.1. According to TfL staff, none of the price hikes were related to travel demand. The first increase, £8 (60%), to was made by Mayor Livingstone in July 2005, in order to generate revenue for installation of the Western Extension. (Dix 2014) The second increase, to £10 (25%), was made by Mayor Johnson in January 2011 in order to pay for the removal of the Western Extension. (Dix 2014) The most recent increase, to £11.50 (15%), was again made by Mayor Johnson, in order to keep parity with rising transit fares and keep the relative cost of the charge high enough to continue to be a deterrent. (Dix 2014)

5.8.1 Equitable distribution of benefits

The amount of reduced travel delay experienced by each driver was a quantifiable benefit estimated by TfL in a 2007 report. (TfL 2007) With a £5 charge, the total value of travel time and reliability savings to businesses and customers was estimated as £266 million, with operating costs of £101 million and other estimated financial costs and economic losses of £94 million,

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[11] The delay was due to a legal requirement that the intention to remove the zone be part of the Mayor's Transport Strategy, which was updated in the interim.

resulting in a net benefit of £71 million. (TfL 2007) Their model accounted for time savings accruing to drivers not only in the charged area, but throughout Inner and Outer London; induced traffic in these areas was estimated to reduce these time savings by one third. It accounted for different levels of times savings during peak and off peak times, and different values of time among vehicle occupants, that is, commuters, company cars, goods vehicle vehicles, taxis, and bus passengers. Time savings due to improved network reliability were limited to trips within the charged area; reliability savings were estimated as 30% of the travel time savings. Reduced vehicle kilometers travelled per charging day were estimated as 1,276 in the charged area, 14,722 in Inner and 32,708 in Outer London (including induced travel).

Table 5.4 shows the model's estimated monetized value of travel time and reliability benefits accruing to charge paying vehicles and other users for Central, Inner and Outer London. In all cases the majority of benefits were realized by road users who were not paying the congestion charge, primarily bus passengers, taxis, and goods vehicles within the charged area, and by drivers outside of it. For the original £5 charge, TfL estimated that charge-paying vehicles accrued only 43% of £117 million (in 2006 dollars) worth of time savings and reliability benefits in Central London, 8% of £80 million in Inner, and 4% of £27 million in Outer London. (TfL 2007) Higher values were calculated for the £8 charge, but the distribution remained the same.

Table 5.4 Travel time and reliability benefits with a £5 charge

	Accruing to charge-paying vehicles (£ million per year)		**Accruing to other road users (£ million per year)**		**Total (£ million per year)**	
	Time + Reliability	Percent	Time + Reliability	Percent	Time + Reliability	Percent
Central	50	43%	67	57%	117	100%
Inner	6	8%	74	93%	80	100%
Outer	1	4%	26	96%	27	100%
Total	57	25%	167	75%	224	100%

Data source: TfL Ex Post Benefits, 2007

Annual benefits accruing specifically to bus riders throughout London were estimated as well. Reduced waiting times were estimated as £20 million (in 2006 dollars), travel time savings as £9 million, and reliability benefits as £7 million. (TfL 2007) Given there were approximately 5.6 million people traveling by bus on any given day during 2006, that amounted to roughly £7 per bus passenger per year in benefits. Thus benefits from congestion charging were widely spread among other road users from the beginning, both geographically and among other modes.

Three independent cost benefit analyses, published before TfL's, had also concluded that the main beneficiaries of congestion charging were bus riders and remaining drivers, with two in agreement that the economic benefits of congestion charging outweighed the costs. (Santos and

Shaffer 2004, Mackie 2005, Prud'homme and Bocarejo 2005) Santos and Shaffer estimated a lower level of economic benefits than TfL, only £50 million, but the values of time and average trip distance they used were both lower. The most critical analysis, by Prud'homme and Bocarejo, estimated benefits to bus riders more conservatively, accounting for increased public subsidy to buses, and limited benefits to the charged zone only; it concluded that the high capital and operating costs of the scheme outweighed the benefits. Several other economic impact evaluations also concluded that the social benefits of congestion pricing outweighed social costs—due to time savings for bus riders, improved accessibility, and reduced pollution—leading to a general consensus in the literature that London's congestion charge had a net positive social welfare. (Lautso, Klaus et al. 2004, Whitehead 2005, DfT 2007)

Significant travel time savings were realized not just in the CCZ, but throughout Inner London. TfL's traffic speed survey data for Inner London showed that average travel speeds during the morning peak increased by 3% on red routes after congestion charging[12]. (TfL 2007) For Inner London, speeds were 18.3 kph in the 2003-2006 period, as compared to 17.9 kph in the 2000-2002 period. As shown in Figure 5.11, as average traffic speeds for general traffic declined back to pre-charging levels, bus priority measures were effective at keeping bus travel speeds stable. Therefore the competitiveness of buses kept improving over time, in comparison to travel times offered by taxis and other private vehicles. Further, passengers realized reliability benefits, in terms of reduced waiting times. Figure 5.12 shows minutes of excess wait time cut in half from a system-wide average of 2.2 minutes in 2000 to 1.1 minutes in 2005. As the average occupancy of buses is much higher than other motorized vehicles, this meant that travel time benefits were much more widely distributed among London travellers.

5.9 Conclusions

London's experience offers many lessons learned as to the equitable distribution of the benefits of reduced traffic congestion. The congestion charge has become indisputably part of the city's fabric—mainly due to the benefits in urban quality, bus travel, and walkability that it has produced, which have been widespread. More than a technical traffic measure in the CBD, the congestion charge policy was part of a package of measures which together aimed to delegitimize car use and improve the quality and safety of other modes. Londoners responded by changing their travel behavior. Congestion levels crept back up as a result of taking some of the benefits that congestion charging confers to drivers – faster travel speeds and improved journey reliability – and reallocating them to other transport system users.

Rising congestion levels were expected as a result of induced demand from faster travel speeds, and the declining price of the congestion charge over time, due to inflation[13]. Price hikes to the

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[12] TfL traffic speed surveys are carried out on a three year cycle, and are collected by a car moving at the prevailing speed of traffic.
[13] The purchasing power of £1.00 in 2003 was approximately £1.38 in 2013, based on the percentage increase in the UK Retail Prices Index from 2002 to 2012.

congestion charge helped to reduce rebound effects. Although unintended, reallocation of network capacity to improve bus reliability and pedestrian safety helped to ‘lock in’ the traffic reductions achieved by congestion charging. Increased congestion levels over ten years are not considered a negative outcome by system planners because outcomes for non-vehicular travel have been very positive: bus speeds and reliability have vastly improved, pedestrian fatality and serious injury rates have plummeted, bicycle use has more than doubled, and air quality has shown some small benefits. The perspective of time made clear that the congestion charge had merely played a role in a virtuous circle of declining demand by private cars freeing space for other modes, which in turn improved travel speed and quality and helped to grow demand for those modes. Another unexpected challenge was the need for constant oversight of the system operator, and continual adjustment to the level of the charge, to keep the system financially sound - it took over ten years to hit the original cost recovery target of .35.

Over time, time savings benefits began to be further distributed to benefit pedestrians and cyclists. These safety benefits were achieved through a combination of traffic reduction, largely due to congestion charging, paired with improvements to bicycle and pedestrian infrastructure and re-timing traffic signals. After congestion charging was implemented, signal settings were overhauled to give more crossing time to pedestrians. Besides the safety benefit to people crossing roads, this had the general effect of slowing down traffic and reducing the severity of injuries from collisions. This measure further contributed to the trend of slowing traffic in the Central area, discussed earlier. Reduced waiting time for pedestrians meant longer waiting times for motorized traffic, in effect a redistribution of time away from motorized traffic towards pedestrians.

There were several critical factors that made congestion charging publicly acceptable in London, and increased its effectiveness, which may not be common to all cities. London has a very high population density, at 13,500 people per square mile. It has a very dense, multi-modal and interlinked public transit system which carried 85% of all weekday trips before congestion pricing was introduced. London’s economic base is highly centralized, with the major employment centers located in the most transit-served areas. Perhaps most importantly, the share of people commuting to jobs in central London by car was very low prior to congestion charging, at only 11%.

Typical conditions in U.S. cities are considerably different, as they tend to be less dense and more poly-centric. A scenario using the results from London to calculate the potential impacts of congestion charging on a typical U.S. city found that similar ‘virtuous cycle’ results could be expected if bus ridership increased by 30%, a significantly higher amount than was achieved in London (6%). (Small 2005) In any case, London’s experience underscores the importance of pairing car restraint measures with improvements to alternative modes.

Chapter 6. An Analysis of Firm Location Choices

6.1 Introduction

This chapter considers how changing transport costs may have affected firm location patterns inside and near the London congestion charge zone (CCZ). The congestion charge increased the monetary cost of vehicular access to firms located within the zone, but also reduced vehicular travel time costs. Similarly, enhanced transit services serving the CCZ were accompanied by rising fares but also reduced travel time costs. The key outcome of congestion charging was the drop in car traffic, clearing space on the roads to make buses faster and more reliable, and walking safer and more enjoyable.

It is hypothesized that improved accessibility and amenities from reduced traffic volumes in London's congestion charge zone (CCZ) are being capitalized into higher land and rent costs. The firms that value the benefits of improved accessibility the most are more likely to remain or to move in, in spite of rising rents. This chapter presents a test of this hypothesis using two panels of firms for the period 1997 to 2012 created using microdata from the Business Structure Database (BSD) in London, one of micro firms with ten or fewer employees, the other with large firms with more than ten employees. Rent and accessibility data were added to each panel to explore the role of these factors in relocations.

The congestion charge boundary is important in that it defines the zone of greatest impact of these accessibility improvements. The CCZ is differentiated from the rest of the region in terms of density of bus and rail transit service, density of bus lanes and other bus priority measures, density of bicycle lanes and shared bike stations, density of pedestrian crossings, and lower average traffic speeds. It has become an 'access amenity zone' offering the highest accessibility level for transit and non-motorized traffic in the region. As a zone of quick and easy travel, making it a more attractive area for doing business.

The question of whether road pricing policies can influence land use and employment patterns has been explored entirely through theoretical predictions and modeling. (Wheaton 1998, Anas & Xu 1999, Eliasson & Mattsson 2001, Safirova 2002, Banister 2002). This research is the first to use empirical data. London's experience with more than ten years of congestion charging is used as a case study. Specifically, this study focuses on the firm location choice as an indicator of how the combination of congestion charging and improved transit access may be affecting regional industries and employment patterns. It is hypothesized that improved accessibility and amenities from reduced traffic volumes in the CCZ are being capitalized into higher land and rent costs. The firms that value the benefits of improved accessibility and environmental quality the most are more likely to remain or to move in, in spite of rising rents and wages.

The emphasis of this chapter is on accessibility, recognizing that there are many confounding factors in explaining changing industrial location patterns. The CCZ contains London's central business district (CBD), with several industry clusters that have their own industry-specific growth logic. The supply of office space has expanded within the CBD. The financial district (City of London) was upzoned to allow for new development, which has served to reinforce the effects of transit improvements. This expanding supply of modern new office space may explain a portion of the relocations into the charged zone, and may have helped to keep rents from rising as fast as they might with a constrained supply).

6.2 Literature Review

6.2.1 Industrial location theory

Firms face many constraints when making location decisions. Of the three factors of production, capital, land and labor, prices of the latter two can both influence location decisions. Traditional location theory considers firm location choice as a trade-off between land and transport costs. (Von Thünen 1826, Christaller 1933, Lösch 1954) Firms are highly heterogenous in size, likely to have specialized site needs, and likely to face regulatory barriers (zoning) affecting the scope of activities and the cost of doing business on many potential sites. (McDonald and McMillen 2006) Location needs also vary within a firm – for instance a headquarters office has different land and labor needs than a branch office or a plant. Access to specific labor pools is a key factor for some firms (particularly those requiring specialized knowledge or skills), while other important influences include accessibility, co-location of client firms, and corporate tax rates. (Watts 1987)

Early theories of firm location considered central urban areas as marketplaces supplying goods to peripheral populated regions (where demand resides). Central place theory predicts that as places grow in size, their central market areas become capable of supporting more diverse and more specialized firms. (Losch) Firms offering frequently used goods can locate in numerous small centers (e.g. groceries), but firms offering the most specialized and highest value goods and services (e.g. diamonds) can only locate in a few large centers. (Christaller 1933)

Marshall first theorized about industrial clustering, proposing that firms, even competitors, co-locate to benefit from four types of ‘localization economies’, or externalities of agglomeration: access to specialized production inputs or physical location characteristics, a shared pool of specialized labor, technology spillovers, and access to the greater demand generated by all the firms together. (Marshall 1920) Later industrial theory focused on the firm’s input costs as a driver of location choice. Least cost theory assumes that firms seek to minimize transport and labor costs. (Weber 1929) This theory works well to explain the preferences of materials-oriented firms with high-cost inputs, which locate to minimize transport costs (eg a stonemason), and market-oriented firms with low-cost inputs which locate near the final market (eg a brewery). Similarly, firms that require high-skill/specialized labor can only locate where workers have good access, or minimal transport costs, while firms requiring low-skill, low-cost labor can locate anywhere. (Hoover 1948)

6.2.2 External economies of agglomeration

New rationales were needed to explain firm location in the post-industrial era, as urban economies began to shift away from manufacturing toward high-value commodities, business services and information-based products, reviving interest in Marshallian external economies. For instance, traditional theory was inadequate to explain the attractiveness of the New York region in the 1950s, as its raw materials were non-existent, its harbor no longer offered a competitive advantage, its wages were high, and it had no special access to the nation's markets. (Vernon 1960) Vernon found that the firms, or parts of firms, most likely to stay in New York were those dependent upon face-to-face contact, flows of specialized information, and experts shared across firms. For instance, in the garment industry, manufacturers had moved out, but design and prototype production remained in the city. He concluded that firms "accept the handicaps of high labor costs, traffic congestion, urban rents, and urban taxes while exploiting the advantages of speed, flexibility and external economies." (Vernon 1960) He used the finance industry to illustrate these 'external-economies-oriented' firms. Financial firms have rapidly changing needs for expertise from day to day, and are able to draw upon a highly specialized labor pool as needed. Economists later found that clustering for access to special inputs or transport facilities (such as a quarry or harbor, considered as exogenous natural advantages), explained only 20% of location choices. (Ellison and Glaeser 1999)

Other theorists have looked more closely at external 'urbanization economies' arising from the spatial concentration of economic activity, such as knowledge spillovers and technological spillovers from informal interactions, and the pecuniary externalities from innovation. (McDonald and McMillen 2006) Industry clusters develop due to external economies that produce higher productivity. Such advantageous externalities of urbanization are considered endogenous due to the spatial concentration of similar firms. (McCann and Folta 2008) Firm density alone, even of dissimilar firms, has valuable externalities. Jacobs noted that urban agglomerations have 'valuable inefficiencies' where many small firms engage in multiple simultaneous experiments – there may be more duplication, and also more failure, but ultimately rapid trial and error leading to more innovations. (Jacobs 1969) She proposed innovation as the driver of economic development, rather than efficiency, arguing that new ideas, processes, or products make firms more profitable. Therefore diversification is an external economy, where the chances of generating new innovations are greater in places with a greater diversity of firms and industries. (McCann and Folta 2008)

External economies among firms in the same or inter-dependent industries can give a region a competitive advantage. Saxenian observed that complex inter-industry interactions between high-tech firms, based largely on social relationships external to firms in California's Silicon Valley helped them outcompete a similar industrial cluster outside Boston, MA. (Saxenian 1996) Silicon Valley was characterized by rapid birth and death rates of firms, and highly fluid flows of information and personnel between firms via social networks. She concluded that the secretive, vertically-integrated firms of the Boston region were out-competed by the smaller, younger, more entrepreneurial firms of Silicon Valley because they enjoyed competitive advantages enabled by social networks, namely more risk-taking capital and higher labor productivity.

6.2.3 Centripetal and centrifugal forces

Wheaton argued that tolling congestion should have a similar effect on urban form as an urban growth boundary, resulting in cities that are "orders of magnitude [denser] than market cities." (Wheaton 1998) Eliasson modeled the location effects of a proposed congestion charge cordon in Stockholm and found that pricing would have the effect of 'concentrating households and workplaces inside the city center by 7% and 9% respectively.' (Eliasson and Mattsson 2001) Safirova et al. simulated a congestion charging cordon in the Washington, DC region and found that retail firms inside the charging zone would have to pay higher wages, resulting in higher prices for customers and declining demand for retail goods. (Safirova, Houde et al. 2006, Safirova, Houde et al. 2006) They concluded that congestion pricing would drive up wages and rents in the central city, inducing some types of firms to relocate closer to workers and customers in lower-rent suburban areas. Anas and Xu created an economic model of the impacts of a cordon congestion charge in an a monocentric city and found that some residences would be induced to relocate to within the charged area to avoid the congestion charge and economize on work and shopping travel. (Anas and Xu 1999) They concluded that the centralizing effect on residences would dominate the decentralizing effect on firms, resulting in greater job and population effects in the urban center.

Since the early 1990's, 'new economic geography' researchers have sought to explain why firms locate in clusters by identifying the underlying economic forces arising from spatial proximity and interactions. For instance, Krugman's core-periphery model analyzes two regions with two industries with constant returns to scale, but the core region's labor pool is more skilled and mobile. (Krugman 1991) It predicts that the core, which has better market access, that is, is larger in terms of population and purchasing power, will tend to attract more firms. This work sets the micro-economic foundations for explaining centripetal and centrifugal forces that lead to both clustering and dispersion that may function at a range of scales. (Fujita and Thisse 2002)

Fujita, Krugman et al. name the main centripetal forces holding clusters together as economies of scale, especially in production, and beneficial external economies such as localization economies, urbanization economies and knowledge spillovers. (Fujita, Krugman et al. 1999) They name the main centrifugal forces dispersing firms as traffic congestion, urban poverty and crime, high rents and cost of goods in large urban areas, which mean employers must pay higher wages; these are also referred to as diseconomies of scale, or disbenefits of agglomeration. (Fujita, Krugman et al. 1999)

Porter considered clusters in a global context, noting that there are dimensions of both cooperation and competition between firms seeking competitive advantage both as individual firms and collectively against other clusters around the world. (Porter 1998) With the rise of communication technologies and container shipping, firms have become able to divide up functions (i.e. headquarters, sales, production, research and development) and optimize the location of each part of the firm globally, for instance, by access to specific labor markets (i.e. low-wage, highly educated, etc). (Dicken 2007) He notes a location paradox, where local specialized knowledge has become more valuable, even as inputs, information and technologies are increasingly standardized and rapidly available around the world. He claims that location is fundamental in a global economy, saying that proximity (geographic, cultural and institutional) allows for the formation of special relationships, better information, powerful incentives, and other competitive advantages in productivity growth that are difficult to tap from a distance. (Porter 2000)

Sassen describes a global hierarchy of cities that influence which firms, or which parts of multi-national firms, locate in which cities. (Sassen 2001) She says that even as globalization has decentralized and spatially dispersed production around the world, it has also resulted in the increased spatial concentration of certain services which are critical to support global companies: most notably, financial services. "…The development of multi-site manufacturing, service, and banking have created an expanded demand for a wide range of specialized service activities to manage and control global networks of factories, service outlets, and branch offices." (Sassen 2001) Advanced services for firms, or 'producer services' need to locate in close geographic proximity, she says, because they benefit from and need to locate close to other specialized firms who produce key inputs or whose proximity makes possible joint production of services. Major transactions typically require the coordinated participation of several specialized produce services firms. The employees of these firms have expectations of high amenity lifestyles that only large urban centers can offer, and they are less likely to live in the suburbs. Therefore the 'command centers' of the global economy are specialized agglomerations in just a few places, which she dubbed global cities – London, New York, and Tokyo.

The role of transportation in firm location decisions has been considered mainly through the lens of accessibility, that is, access to transport infrastructure required either for the firm's operations (eg manufacturing, shipping), or for the firm's labor inputs and customers. (DfT 2004) Recent research has begun to link externalities of accessibility to those industry sectors which rely the most on the externalities of agglomeration. De Bok and van Oort found that firms relying most heavily on Marshallian localization externalities and Jacobs' urbanization externalities, those in producer services and consumer services sectors, are characterized by a preference for locations with good accessibility to labor markets and locations with significant numbers of firm from their own industries. (de Bok and van Oort 2011) Accessibility to labor markets and employment growth is enabled by good public transportation, as found by Chatman and Noland. "Public transit improvements could cause more clustered and higher-density employment and enable urban growth, giving rise to agglomeration economies by improving labor market accessibility, increasing information exchange and facilitating industrial specialization." (Chatman and Noland 2014)

6.3 Hypothesis and analytic approach

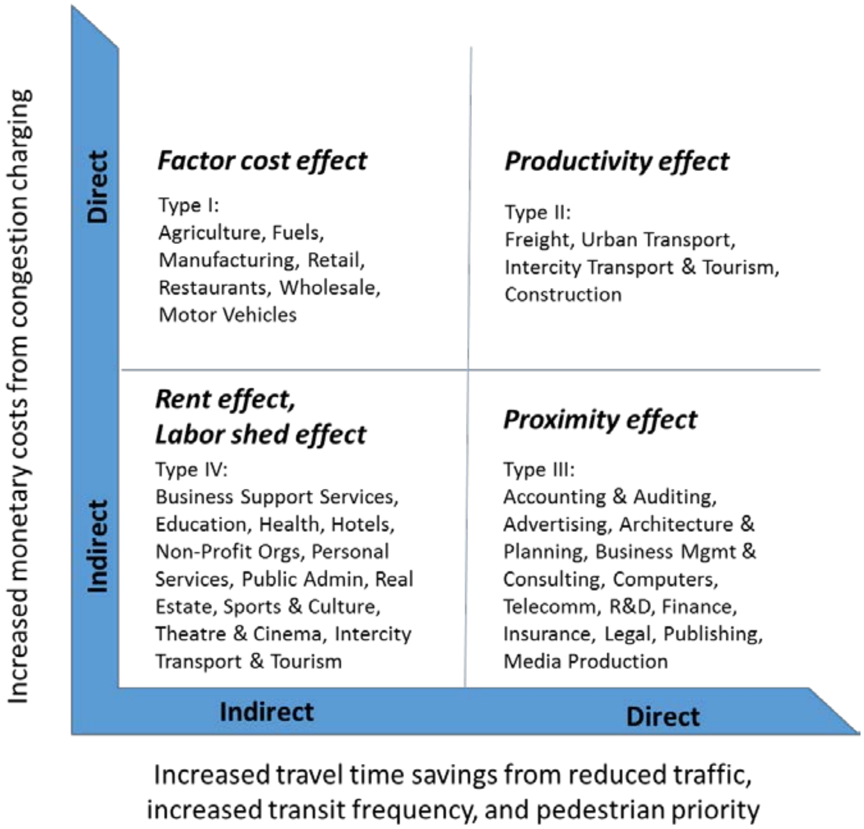
Transportation costs are a factor in the general firm production function. Firms located inside the CCZ have seen changes to both components of generalized transport cost, monetary and travel time. Increased monetary costs due to congestion charging and rising fares may have affected transportation costs for firms in two ways: directly, due to congestion charging fees paid by the firm as a cost of business (including higher delivery fees), and indirectly, due to congestion charging fees and higher transit fares paid by employees and passed along to the firm. For many industrial sectors, reduced travel time costs from enhanced transit services have an indirect impact through the labor factor of the firm production function. Reduced travel time costs may also have had direct or indirect impacts, depending on whether employees realized travel time savings while on the job or not.

Two major factors make the CCZ more attractive to firms (improved accessibility by public transit) and less attractive (rising rents). This study hypothesizes that Type III, Type IV firms in growing industries, and large firms benefit the most from accessibility benefits and environmental amenities in the CCZ, and will therefore be the most likely to remain or expand there, or to move in. Type I firms, Type IV firms in shrinking industries, and micro-enterprises are expected to be the most sensitive to increased costs in the CCZ, both due to rising transport factor costs and rising rents associated with these changes, will be more likely to move out. This sorting process will be observable over time.

The population of firms is highly heterogeneous, with the importance of transportation factor costs varying by industrial sector. Predicting how an individual firm may respond to a change in transportation costs requires consideration of the role of transportation costs in the production function for its industrial sector, that is, whether monetary or travel time costs are most significant, and whether they impact the firm directly or indirectly. In this study, industrial sectors were divided into four types based upon the type and incidence of transport costs: Type I have direct monetary costs and indirect travel time costs; Type II have direct monetary and travel time costs; Type III have direct travel time costs and indirect monetary costs, and Type IV have indirect monetary and travel time costs. These are illustrated in Figure 6.1.

Type I industrial sectors depend on flows of material inputs and outputs, for example, manufacturing firms ship raw materials in and finished goods out. Other examples include wholesale firms which ship goods intensively, and restaurants and retail firms that rely upon frequent deliveries to keep goods in stock. This means they have direct monetary transport costs from trucking and deliveries. If they own their own fleet of trucks, then these sectors may also receive travel time savings directly, when employees are driving in areas impacted by the congestion charge. Congestion charging produces a *factor cost effect* for these firms. Firms located inside the CCZ are likely to have higher shipping and delivery costs, and less salient benefits from more reliable timing of pick-ups and deliveries. Some Type I sectors require large amounts of industrial space to store goods, another increased cost factor for them in the CCZ as land values increase.

Figure 6.1 Type of incidence of transportation cost, by industrial sector



Sectors which have significant direct monetary and travel time transport costs (Type II) are those with a high percentage of employees driving motor vehicles in traffic: freight, construction, and urban transport (buses, taxis, minicabs). These firms, for example parcel delivery, typically own a fleet of trucks that are in service all day and so are especially sensitive to changes in traffic congestion and travel time. These firms have higher monetary costs due to congestion charging, but also higher travel time savings from reduced traffic. Employees are able cover more territory in the same amount of time—a *productivity effect*. Congestion charging improves productivity for these firms.

Type III sectors depend upon external and agglomeration economies, particularly flows of information between employees, clients and competitors. The more these employees are interacting, the more likely they are to benefit from knowledge spillovers. They have direct travel time costs from employees traveling around during the day to conduct business. These are high wage 'knowledge' industries where the monetary cost of employees' travel (taxi fare, etc) is not significant compared to their value of time. Type III sectors may be identified by their high location quotients (clustering) within the CCZ, and include finance, insurance, legal, business consulting, computers and telecommunications. These firms benefit not only from reduced vehicular travel time, but from improvements to walkability and environmental amenities which make it faster to walk or bike to meetings. The combination of congestion charging and improved transit and non-motorized access has produced a *proximity effect* for these firms. Reduced travel times within the CCZ means more destinations may be reached in the same travel time, so that firms are closer together and have improved productivity as a result.

Finally, Type IV encompasses all remaining firms that do not have significant direct monetary or travel time costs of transport. All firms in the CCZ experience an indirect benefit of improved transit accessibility, a larger labor shed. This *labor shed effect* means that more workers have access to jobs in the CCZ, increasing firms' ability to find specialized skills. If workers are able to pass along commuting costs to employers, congestion charging and rising transit fares will increase transport costs for firms. If they are not, then firms may be able to lower wages due to increased competition. Larger firms may benefit the most from the labor shed effect. Another indirect impact for firms located in the CCZ is the *rent effect*. Improved transit accessibility tends to get capitalized into land values and rents, and so increased rent costs are an expected outcome of these changes. Firms in industries that are weak or shrinking, such as publishing or manufacturing, may be the most affected.

Another important heterogeneity factor affecting firm behavior is size. Very small firms, or 'micro-enterprises,' have different location, growth, and relocation characteristics than larger firms. The European Union defines a micro-enterprises as firm with fewer than 10 employees, a turnover below €2 million[14]. About 80% of the firm population in London and other major European cities is micro-enterprises. Most of these firms are owned by people primarily concerned with earning a living to support their families, only growing when something changes that requires the family to earn a higher income. They are mainly local-serving firms contributing to the economy on a neighborhood scale, rather than regional or national scale. The location choice for micro-firms is driven by the owner's preferences, and is most often located close to where the owner lives. The firm is not likely to relocate unless the owner relocates. In contrast, the location choice of firms that grow to larger sizes is driven by growth and by the need for proximity to other firms—either supplier firms or firms in the same industry—to benefit from agglomeration economies. As these 'growth' firms grow to larger sizes, they often need to relocate to a larger and/or more prestigious space; conversely, if their turnover declines and they need to shrink, they need to relocate to a smaller and cheaper space.

6.4 Methodology

This hypothesis was investigated using two panels of firms representing small businesses and large employers. A binary logistic regression model was estimated for each panel to identify the

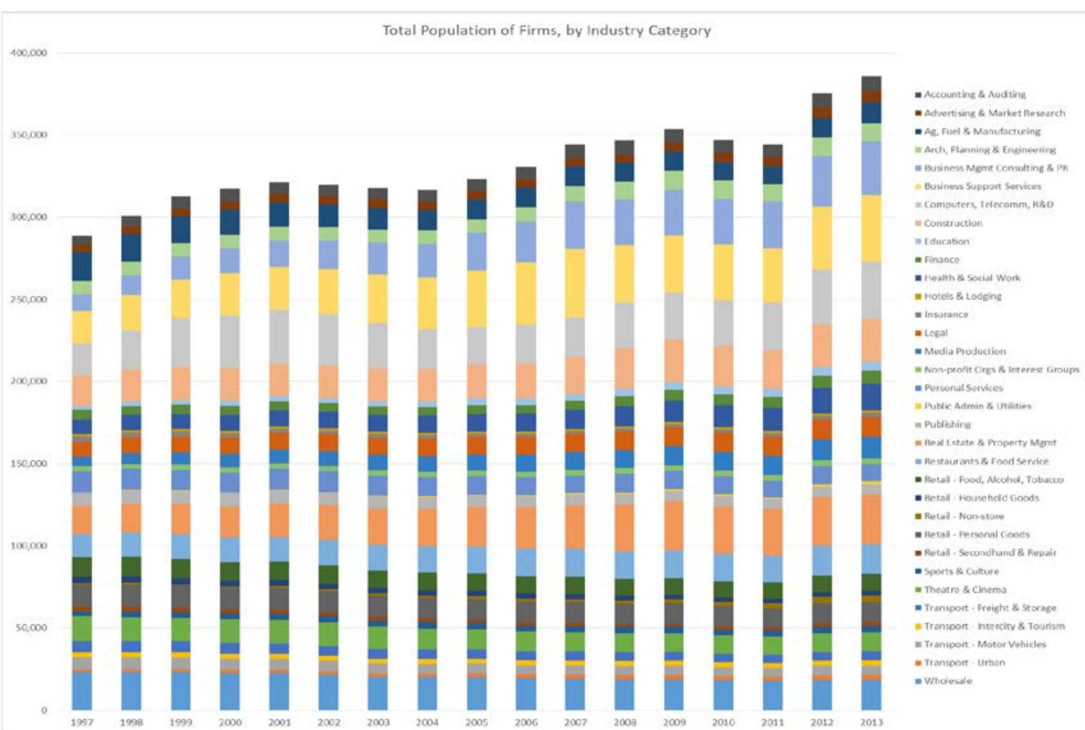
[14] Official Journal of the EU, Recommendation by the European Commission 2003/361/EC dating from 060503, Annex Article 2. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:EN:PDF

key characteristics of firms that moved 1) into and 1) out of the CCZ. Key characteristics tested included employment size, industry, and year-on-year change in employment and turnover. Industry sensitivity to the CCZ was measured using odds ratio outputs on a categorical variable representing 33 industries. To control for other factors that would influence a firm to move, variables were introduced to represent job growth and shrinkage, rapidly increasing rent, availability of new commercial space, and increased accessibility.

6.4.1 Description of the dataset

This analysis uses firm from the Business Structure Database (BSD), which is based upon the UK Business Registry, for Greater London from the years 1997 to 2012. Key variables for each firm in each year included the number of employees, turnover, postcode, and six-digit Standard Industrial Code (SIC). UK postcodes are very small (from a single building to a few blocks), and are changed frequently. For easier analysis, postcodes were matched to the smallest Census areas (LSOAs). Firms were dropped if the postcode could not be matched to at least 5 out of 6 digits (~1%), or was marked as a PO Box (~.1%), because the actual physical location was unknown. The 1992 SIC coding system was updated twice during the study timeframe, in 2003 and 2007. The BSD was published with SIC 2003 codes for subsequent years, therefore SIC 1992 codes for firms in the early part of the timeframe were converted to SIC 2003 codes for consistency. Figure 6.2 shows the total population of firms by industry category. It can be seen that the population grew from 288,810 firms in 1997 to 385,818 in 2013, overall growth of 27%.

Figure 6.2 Total population of firms by industry category



Data source: Business Structure Database Microdata

Unless noted otherwise, the source of all data presented in this chapter is BSD microdata. A variable was created to aggregate firms into major industrial categories by either the first two digits or the first four digits of their SIC 2003 code. Appendix A contains a full description of this variable, called 'indcat.' This variable was used to track the growth and shrinkage of industrial sectors, both in terms of the number of firms and total employment. Two more categorical variables were created to aggregate firms by employment size and turnover.

Figure 6.3 Total population of firms by employment category

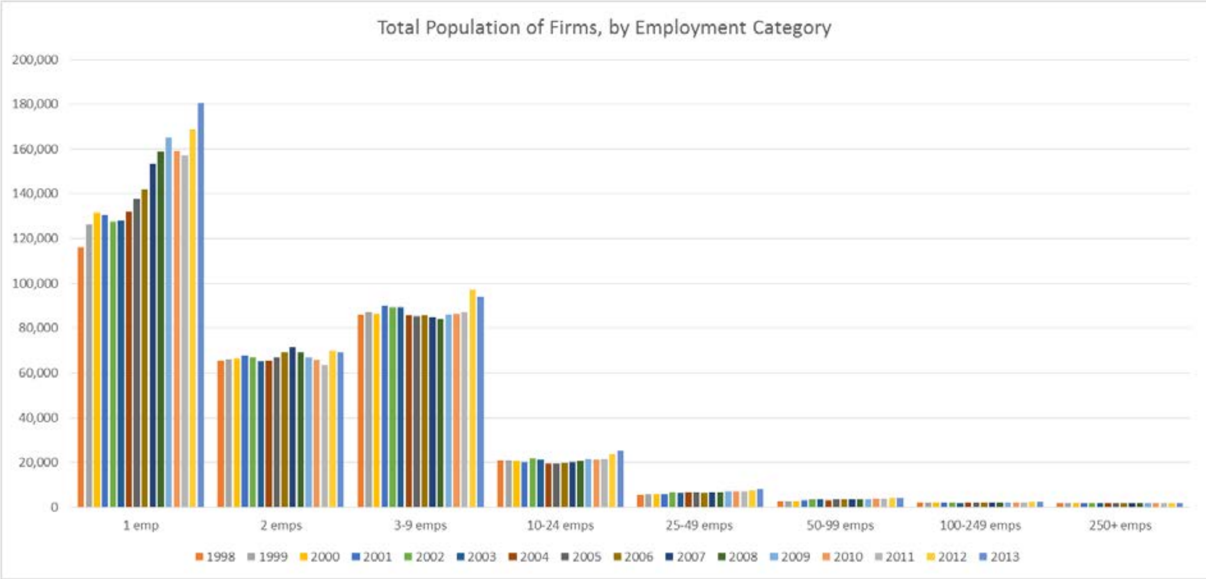


Figure 6.4 Total population of firms by turnover category

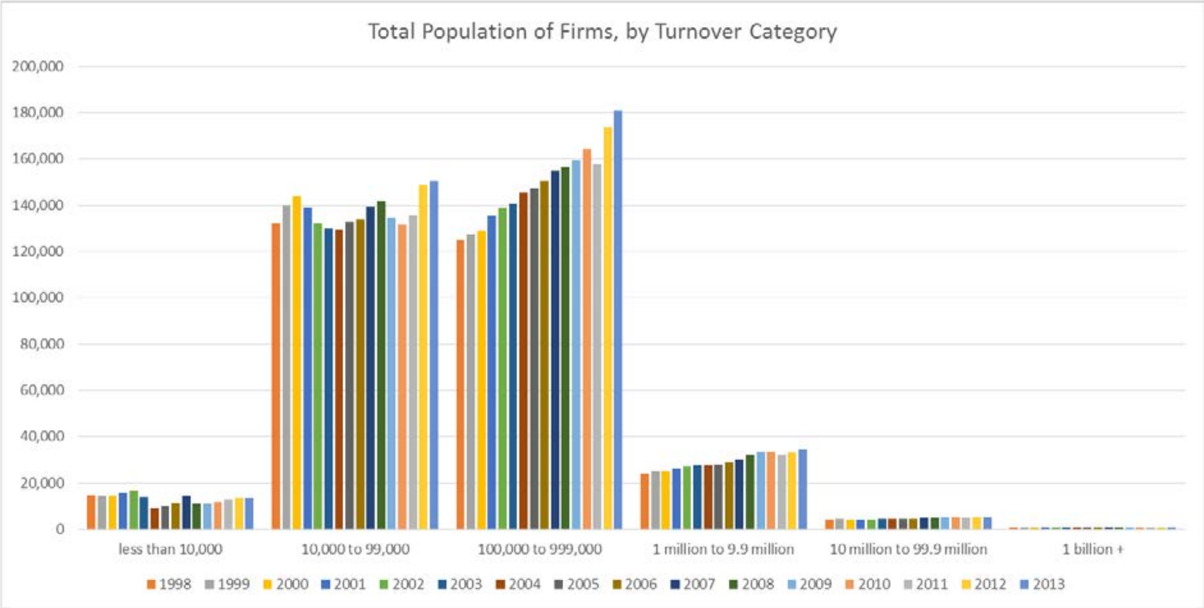


Figure 6.3 shows the time series for each employment category. It can be seen that the majority of population growth was in small firms, particularly one-person enterprises. Figure 6.4 shows the time series for each category of turnover. This revealed that the majority of firms in the population generate £10,000 to £999,000 in revenues annually, and the majority of growth was among firms earning £100,000 to £999,000. Finally, the average size of firms in 1997 and 2012 was calculated to identify which industries tend to have large average size firms. The results are shown in Table 6.1. This also allowed for a comparison of how average firm size changed over the study period. In general, firm size declined from an average of 17 employees in 1997 to 14 employees in 2012. Change was dramatic in a few industries which historically had a few large employers, such as public administration and utilities, and education. New 'firms' in these industries could have been newly privatized services, or fragmentation and localization of services resulting in the creation of new local units.

Table 6.1. Average Firm Size by Industry

Industry Sector	Firms 1997	Jobs 1997	Avg firm size 1997	Firms 2012	Jobs 2012	Avg firm size 2012	Difference	Type
Public Admin & Utilities	517	300,087	580	1,716	285,493	166	-414	IV
Education	2,509	348,509	139	5,249	430,811	82	-57	IV
Insurance	3,022	158,976	53	2,221	139,298	63	10	III
Hotels & Lodging	1,315	70,184	53	1,586	74,270	47	-7	IV
Transport - Intercity & Tourism	3,191	108,509	34	3,185	140,896	44	10	II
Finance	6,103	631,697	104	7,293	296,430	41	-63	III
Health & Social Work	8,870	304,140	34	15,804	535,515	34	0	IV
Retail - Food, Alcohol, Tobacco	11,873	236,323	20	10,334	279,968	27	7	I
Transport - Urban	1,512	49,481	33	2,689	70,719	26	-6	II
Retail - Household Goods	4,065	67,324	17	2,847	71,541	25	9	I
Sports & Culture	3,071	57,751	19	4,041	99,297	25	6	IV
Retail - Personal Goods	13,711	281,520	21	12,171	286,175	24	3	I
Non-profit Orgs & Interest Groups	3,023	48,085	16	3,517	62,202	18	2	IV
Restaurants & Food Service	13,871	236,324	17	17,955	312,365	17	0	I
Ag, Fuel & Manufacturing	17,336	427,204	25	11,519	166,036	14	-10	I
Transport - Freight & Storage	6,865	105,898	15	5,195	64,268	12	-3	II
Publishing	7,639	97,498	13	5,942	72,043	12	-1	IV
Advertising & Market Research	4,613	53,718	12	6,525	69,051	11	-1	III
Business Support Services	19,686	313,842	16	38,520	407,378	11	-5	IV
Accounting & Auditing	5,690	55,726	10	8,740	81,002	9	-1	III
Real Estate & Property Mgmt	17,400	193,143	11	29,839	266,594	9	-2	IV
Legal	9,224	79,476	9	12,051	104,044	9	0	III
Wholesale	23,385	201,052	9	18,319	153,471	8	0	I
Media Production	5,734	71,604	12	12,414	97,169	8	-5	III
Arch, Planning & Engineering	8,184	74,938	9	11,243	81,741	7	-2	III
Transport - Motor Vehicles	7,148	53,350	7	5,982	38,353	6	-1	I
Retail - Secondhand & Repair	2,638	11,789	4	2,042	11,662	6	1	IV
Construction	18,811	125,423	7	26,056	146,085	6	-1	II
Computers, Telecomm, R&D	19,094	107,340	6	33,137	174,753	5	0	III
Personal Services	12,937	58,233	5	11,129	54,035	5	0	IV
Retail - Non-store	690	11,988	17	3,796	17,755	5	-13	IV
Business Mgmt Consulting & PR	10,152	56,059	6	30,810	134,332	4	-1	III
Theatre & Cinema	14,931	44,443	3	11,471	45,123	4	1	IV
Total	**288,810**	**5,041,634**	**17**	**375,338**	**5,269,875**	**14**	**-3**	

Note—Table is sorted by average firm size in 2012

6.5 Analysis of growing and shrinking industries

Although the total population of firms grew, growth and shrinkage was highly variable among industry categories. The cumulative amount of change by industry category was calculated against an index (1997=100). The results are shown in Table 6.2. Although growth was dramatic in a few sectors, such as non-store retail, these were small numbers of firms compared to larger sectors like business management and consulting. Notably, many of the major growth sectors are high-skill, high-wage industries: business management/consulting services (118%), computers/telecommunications/scientific research and development (65%), health and social work (59%) and legal services (27%). Just two sectors, business management/consulting and business support services, accounted for nearly 40,000 new firms, or almost half the total (46%).

Table 6.2 Percent change in firm population, by industry category

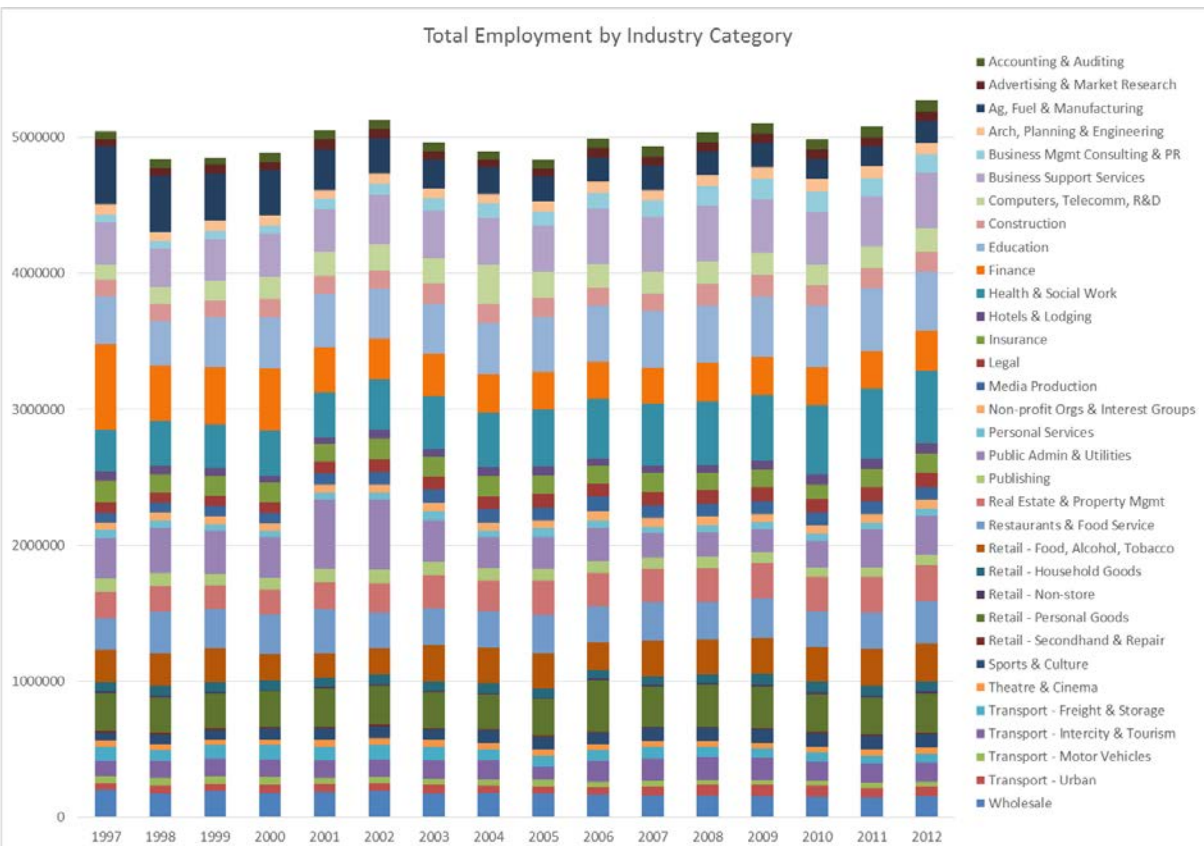
Industry Sector	1997	2012	Percent Change	Growth Rank	Shrinkage Rank	Type
Retail - Non-store	690	3,796	210%	1		IV
Public Admin & Utilities	517	1,716	138%	2		IV
Business Mgmt Consulting & PR	10,152	30,810	118%	3		III
Media Production	5,734	12,414	80%	4		III
Education	2,509	5,249	76%	5		IV
Business Support Services	19,686	38,520	73%	6		IV
Computers, Telecomm, R&D	19,094	33,137	65%	7		III
Transport - Urban	1,512	2,689	63%	8		II
Health & Social Work	8,870	15,804	59%	9		IV
Real Estate & Property Mgmt	17,400	29,839	55%	10		IV
Accounting & Auditing	5,690	8,740	48%	11		III
Advertising & Market Research	4,613	6,525	36%	12		III
Construction	18,811	26,056	34%	13		II
Arch, Planning & Engineering	8,184	11,243	34%	14		III
Sports & Culture	3,071	4,041	29%	15		IV
Legal	9,224	12,051	27%	16		III
Restaurants & Food Service	13,871	17,955	27%	17		I
Finance	6,103	7,293	20%	18		III
Hotels & Lodging	1,315	1,586	20%	19		IV
Non-profit Orgs & Interest Groups	3,023	3,517	16%	20		IV
Transport - Intercity & Tourism	3,191	3,185	0%			II
Retail - Personal Goods	13,711	12,171	-12%		12	I
Retail - Food, Alcohol, Tobacco	11,873	10,334	-13%		11	I
Personal Services	12,937	11,129	-14%		10	IV
Transport - Motor Vehicles	7,148	5,982	-17%		9	I
Retail - Secondhand & Repair	2,638	2,042	-24%		8	IV
Wholesale	23,385	18,319	-24%		7	I
Publishing	7,639	5,942	-25%		6	IV
Theatre & Cinema	14,931	11,471	-26%		5	IV
Insurance	3,022	2,221	-26%		4	III
Transport - Freight & Storage	6,865	5,195	-27%		3	II
Retail - Household Goods	4,065	2,847	-35%		2	I
Ag, Fuel & Manufacturing	17,336	11,519	-39%		1	I
Total Firms	**288,810**	**375,338**	27%			

Note--employment data by industry was only available up to 2012, so firm data up to 2012 is presented for comparison.

Among sectors that shrank, two reflect the historic shift away from a manufacturing-based to a services-based economy: agriculture, fuels and manufacturing (-39%), and wholesale (-24%). Oddly, some retail and personal services sectors shrank even though Greater London has experienced strong population growth of people. This may indicate consolidation among firms, and also the growing importance of online retail.

It is also important to look at employment trends within industry sectors, because some have a much higher average employment size than others. For example, modest growth in a sector that tends to have a large average firm size could mask major job growth. Figure 6.5 shows the total number of jobs each year by industry category. Employment is sensitive to the economic cycle, and so cyclical growth and shrinkage can be seen overall, and within industry sectors. In 1997, there were 5,041,634 jobs in Greater London, and in 2012 there were 5,269,875 jobs, a cumulative growth of 5%.

Figure 6.5 Total employment by industry category



Employment growth and shrinkage varied widely across industry categories. Once again, the cumulative amount of change by industry category was calculated against an index (1997=100). The results are shown in Table 6.3. Now there is a clear picture of where jobs are being added and lost in the London economy.

Table 6.3. Percent change in employment, by industry category

Industry Sector	1997	2012	Percent Change	Growth Rank	Shrinkage Rank	Type
Business Mgmt Consulting & PR	56,059	134,332	96%	1		III
Computers, Telecomm, R&D	107,340	174,753	73%	2		III
Sports & Culture	57,751	99,297	62%	3		IV
Retail - Non-store	11,988	17,755	61%	4		IV
Health & Social Work	304,140	535,515	58%	5		IV
Transport - Intercity & Tourism	108,509	140,896	47%	6		II
Public Admin & Utilities	300,087	285,493	44%	7		IV
Accounting & Auditing	55,726	81,002	43%	8		III
Transport - Urban	49,481	70,719	42%	9		II
Restaurants & Food Service	236,324	312,365	36%	10		I
Real Estate & Property Mgmt	193,143	266,594	36%	11		IV
Retail - Food, Alcohol, Tobacco	236,323	279,968	33%	12		I
Non-profit Orgs & Interest Groups	48,085	62,202	33%	13		IV
Media Production	71,604	97,169	33%	14		III
Advertising & Market Research	53,718	69,051	31%	15		III
Business Support Services	313,842	407,378	31%	16		IV
Legal	79,476	104,044	28%	17		III
Education	348,509	430,811	23%	18		IV
Hotels & Lodging	70,184	74,270	21%	19		IV
Personal Services	58,233	54,035	20%	20		IV
Construction	125,423	146,085	19%	21		II
Arch, Planning & Engineering	74,938	81,741	16%	22		III
Retail - Secondhand & Repair	11,789	11,662	15%	23		IV
Retail - Personal Goods	281,520	286,175	13%	24		I
Retail - Household Goods	67,324	71,541	11%	25		I
Theatre & Cinema	44,443	45,123	5%	26		IV
Insurance	158,976	139,298	-5%		7	III
Transport - Motor Vehicles	53,350	38,353	-23%		6	I
Wholesale	201,052	153,471	-25%		5	I
Publishing	97,498	72,043	-28%		4	IV
Transport - Freight & Storage	105,898	64,268	-43%		3	II
Finance	631,697	296,430	-61%		2	III
Ag, Fuel & Manufacturing	427,204	166,036	-86%		1	I
Total Jobs	**5,041,634**	**5,269,875**	**5%**			

Several of the same high-skill high-wage major sectors which had strong firm population growth also had strong job growth: business management/consulting (96%), computers/telecommunications/R&D (73%), health (58%), and legal services (28%). The most dramatic growth in terms of numbers of jobs was in the health and social work sector, which added over 230,000 jobs from 1997 to 2012. Several of the sectors which were shrinking in terms of number of firms are actually growing in terms on employment: retail, personal services, and theatre and cinema. This means the average size of these firms is growing faster than new firms are entering. Finance, which showed modest growth in terms of firms, actually had major job losses (-61%). The new firms added were most likely micro-enterprises or sole-proprietorships.

Industry sectors which shrank in terms of both firms and jobs are considered the weakest sectors. These included two major sectors (wholesale and agriculture/fuels/manufacturing), a high wage sector (insurance), two transport sectors (motor vehicles and freight), and publishing. Two sectors lost tremendous numbers of jobs from 1997 to 2012, agriculture/fuels/manufacturing (over 260,000) and finance (over 335,000).

Finally, looking at growth in terms of revenues gives an indication of which firms are becoming more profitable over time. Table 6.4 shows the percent change in turnover from 1998 to 2012 by industry, for the non-micro panel. This data was not available for the entire dataset, but only the non-micro panel. The year 1998 was used because the data from 1997 had a higher rate of error in the panel.

Table 6.4 Percent change in turnover, by industry category (non-micro panel)

Industry Sector	1998	2012	Total Change	Growth Rank	Shrinkage Rank	Type
Sports & Culture	6,473	38,276	491%	1		IV
Wholesale	17,294	66,412	284%	2		I
Ag, Fuel & Manufacturing	11,899	43,398	265%	3		I
Transport - Urban	8,311	24,751	198%	4		II
Legal	1,898	5,339	181%	5		III
Construction	4,203	9,247	120%	6		II
Accounting & Auditing	3,997	8,689	117%	7		III
Public Admin & Utilities	33,155	71,155	115%	8		IV
Theatre & Cinema	1,858	3,891	109%	9		IV
Health & Social Work	2,425	4,802	98%	10		IV
Publishing	4,722	8,866	88%	11		IV
Computers, Telecomm, R&D	5,517	10,202	85%	12		III
Insurance	99,404	180,012	81%	13		III
Transport - Freight & Storage	6,859	12,273	79%	14		II
Non-profit Orgs & Interest Groups	2,564	4,369	70%	15		IV
Arch, Planning & Engineering	3,184	5,220	64%	16		III
Retail - Household Goods	13,219	21,637	64%	17		I
Personal Services	809	1,318	63%	18		IV
Transport - Intercity & Tourism	29,918	46,983	57%	19		II
Advertising & Market Research	9,279	14,559	57%	20		III
Retail - Personal Goods	9,705	14,921	54%	21		I
Hotels & Lodging	3,899	5,854	50%	22		IV
Business Support Services	4,046	5,935	47%	23		IV
Real Estate & Property Mgmt	3,158	4,621	46%	24		IV
Retail - Food, Alcohol, Tobacco	20,499	29,854	46%	25		I
Media Production	10,832	15,396	42%	26		III
Education	3,806	4,790	26%	27		IV
Restaurants & Food Service	1,989	2,436	22%	28		I
Retail - Secondhand & Repair	2,932	3,083	5%	29		IV
Retail - Non-store	11,538	8,843	-23%		4	IV
Transport - Motor Vehicles	14,262	7,945	-44%		3	I
Business Mgmt Consulting & PR	15,129	8,029	-47%		2	III
Finance	1,004,734	282,757	-72%		1	III
Total	**2,232,645,365**	**1,515,158,489**	**-32%**			
Average (without Finance)	**11,524**	**21,660**	**88%**			

The majority of industry sectors had growth in revenues over the study timeframe. Several had stunning growth, for example, small sectors like Sports/Culture (491%) and large sectors like Wholesale (284%). Even sectors that were shrinking in terms of firms or jobs were able to maintain revenue growth. Sectors with declining revenues included Finance, Motor Vehicles, Business Management Consulting/Public Relations and Non-store Retail. Those results were surprising for the latter two sectors, given their rapid growth.

6.6 Description of the panels

Firms were selected by ID number to create two panels by employment size. The 'micro panel' was comprised solely of micro-enterprises whose employment never exceeded 10 employees throughout the study period. For the 'non-micro panel', firms were selected based upon one criteria: they had 10 or more employees in one of the years during the study period. This method retained many small firms during their growth phase, but also some which were primarily micro-enterprises, never exceeding more than 10 employees.

After selecting firms by ID number, a time series of employment, turnover and location data for each firm was created by appending those variables from each annual BSD file. A small percentage of firms (~1%) were missing data in some years. For example, Firm X may have had data for its first two years, then a gap, and then data for four more years. These gaps were the result of geocoding errors, or errors in the BSD source files for reasons unknown to the researcher. For a time-series gap of up to four years, 'lost' years were imputed using straight-line imputation and the most recent location (LSOA). Firms that were missing five or more consecutive years of data were excluded from the panels.

6.6.1 The non-micro panel

The non-micro panel used for analysis consisted of 121,424 firms, with 55,000 to 64,000 live firms in any given year. The long form N was 961,906 (number of firms x number of years of data for each firm). As mentioned earlier, the categorical variable 'indcat' was created to define firms by board industrial category. Figure 6.6 shows the distribution of firms by industry in the non-micro panel.

Figure 6.7 shows a histogram for a variable called 'pdata' which was created to represent the number of years of panel data for each firm. A plurality (20%) were had data for the entire 16-year period. About 10% had data for just one year, and the remainder were evenly distributed with about 5% each having 2 to 15 years of data. The reference category for pdata is 16 years, so that odds ratios can be interpreted in comparison.

The BSD contains a variable called 'birth' representing the year it entered the business registry. This was used to calculate the age of each firm. A histogram for this variable called 'age' is shown in Figure 6.8. In the source data, many more firms were 'born' in 1973 compared to other years, for reasons unknown to the researcher, and so these firms show as a spike. The average age of a firm in the panel was 12.9 years, with a standard deviation of 9.6.

Figure 6.6 Non-micro panel firms, histogram for variable ‘indcat’

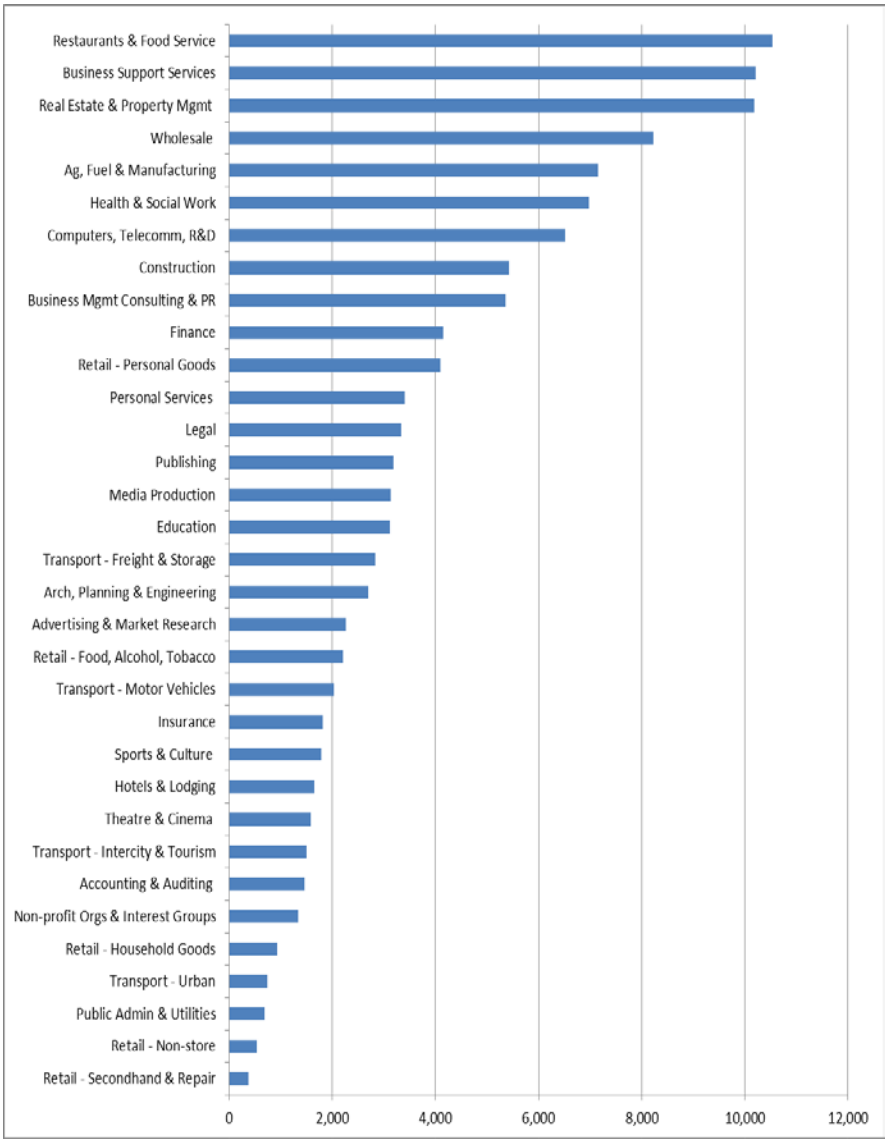


Figure 6.7 Histogram for variable ‘pdata’

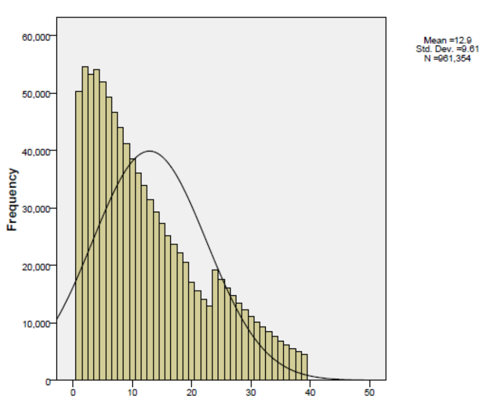


Figure 6.8 Histogram for variable ‘age’

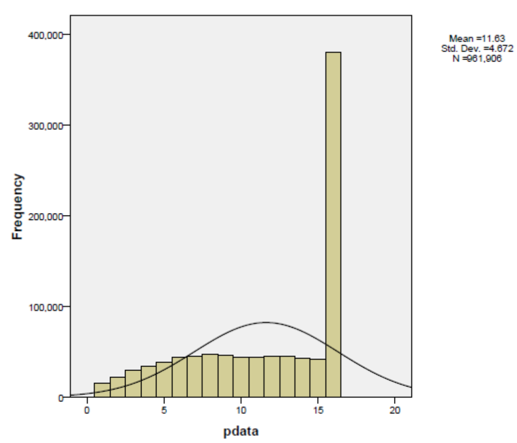
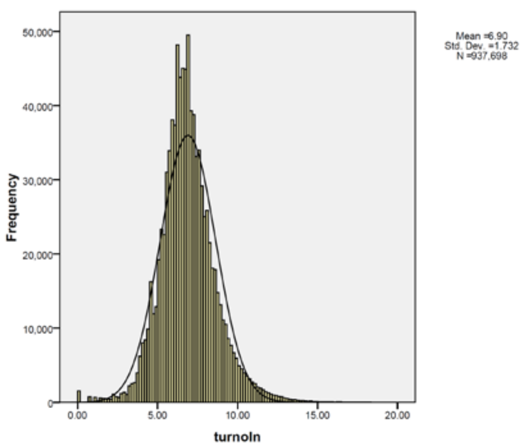
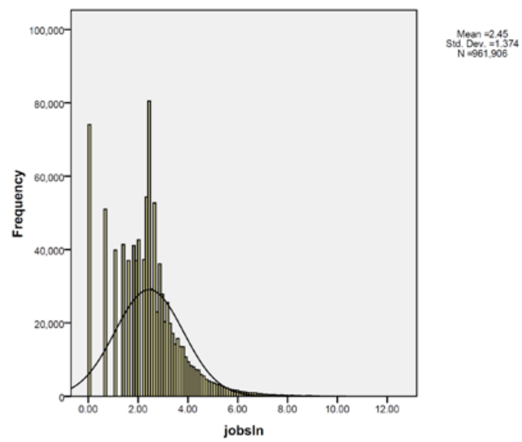


Figure 6.9 Histogram for variable ‘jobsln’ **Figure 6.10 Histogram for variable ‘turnoln’**





Each year that a firm was in the dataset, it had data for employment (number of jobs that year), turnover (revenues that year), and postcode (location that year). The jobs and turnover variables both had an extremely skewed distribution, with values clustered at the low end of the scale and then exponential decay to a long tail of extreme high values. The average number of jobs for a firm in any given year was 71.8, but this is likely skewed upwards by a few extremely large employers (over 1,000), as the standard deviation was 1,132. Similarly, the average turnover for a firm in any given year was 28,387, likely skewed up by firms with extremely high turnover (over 1,000,000), as the standard deviation was 914,070. Therefore they were transformed using the natural log (ln) and then the variables jobsln and turnoln were used for analysis; distributions are shown in Figures 6.9 and 6.10.

A categorical variable was created to track changes in firm location over time. Called ‘movecat’, the definition is illustrated in Table 6.5.

Table 6.5 Definition of variable ‘movecat’

LSOA Year 1	LSOA Year 2	Movecat value	Dummy variable name	Meaning
123xyz	123xyz	1	stayed	Firm stayed in place
123xyz	345abc	2	moved	Firm moved
.	123xyz	3	entered	Firm entered panel in year 2
123xyz	.	4	exited	Firm exited panel in year 1

A movecat value was assigned by comparing the firm’s LSOA in year 1 to year 2. If they were the same, movecat was given a value of 1, meaning the firm stayed in place. If different, it was given a value of 2, meaning the firm had moved. If the LSOA data was missing in year 1, but present in year 2, movecat was given a value of 3, meaning the firm entered the panel in that year. If the LSOA data was missing in year 2, movecat was given a value of 4, meaning that the firm exited the panel in year 1. Entering or exiting the panel could represent a birth or death, or relocation into or out of the Greater London region. Dummy variables were then created for each value of movecat.

The variables for panel data, age, jobs, and turnover were all positively and significantly correlated with each other, as expected, shown in Table 6.6. Because these variables are not normally distributed and have non-linear relationships, but they do have monotonic relationships, Spearman's correlation was used. Age and pdata had the strongest correlation (.6153) because they are similar measures, and they overlap completely for firms with fewer than 16 years of data. The correlation between age and jobs (.2379) indicates that, in general, firms grew in size over time. Similarly, correlation between age and turnover (.2310) indicates that they generally generate more revenues as they survive and age. Correlation between jobs and turnover (.6148) indicates a strong relationship between increasing revenues and jobs, or firms adding staff as revenues increase.

Each of these variables was negatively and significantly correlated with firm relocation, as indicated by the output for the dummy variable, 'moved'. As age, jobs, and turnover increase, firms are less likely to move. The strongest correlation with moved was age (-.1069), which makes sense, as firms are more the most likely to move during their early growth phase. The weak correlation with jobs (-.0222) also makes sense, as larger firms face greater location constraints and higher costs to relocate. Many of the largest employers in this panel are in the health care and education sectors, which are more stable than average as they require specialized buildings (eg hospitals and universities).

Finally, a variable was created as a simplistic measure of productivity, revenues per employee. Called 'prod', it was calculated by dividing turnover by jobs for each year. As shown in Table 6.6, productivity was positively correlated with age (.0517), indicating that in general, firms increase productivity over time. It was positively correlated with turnover and negatively with jobs, which makes sense due to how the variable was calculated. Productivity was the only variable positively correlated with moved, meaning that high productivity firms—most likely 'knowledge' firms with high-skill high-wage employees—are more likely to move.

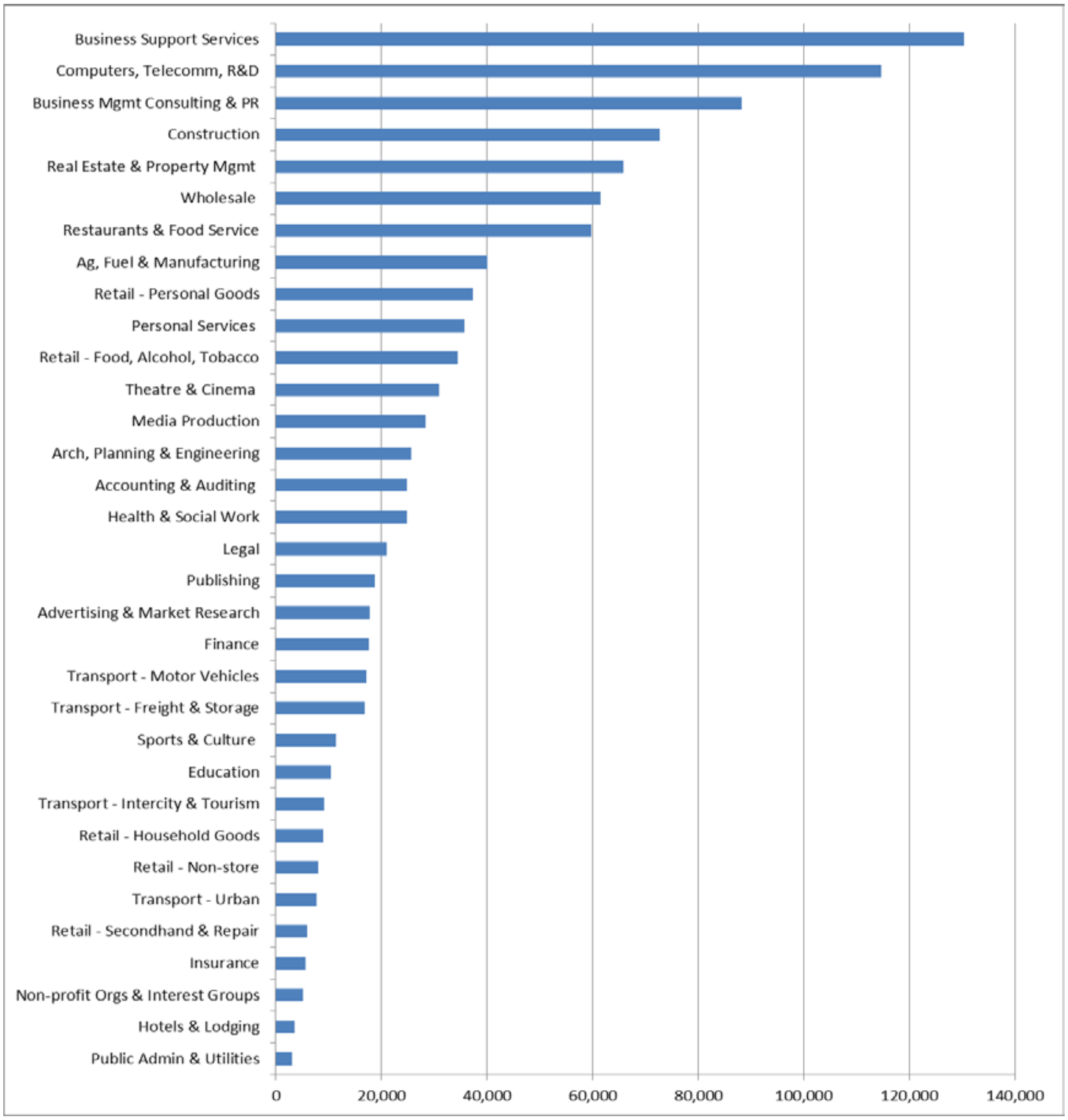
Table 6.6 Correlations between age, jobs, turnover, and pdata variables (spearman)

	pdata	age	jobs	turno	prod	moved
pdata	1.0					
age	0.6153*	1.0				
jobs	0.0642*	0.2379*	1.0			
turno	0.0783*	0.2310*	0.6148*	1.0		
prod	0.0174*	0.0517*	-0.1785*	0.5953*	1.0	
moved	-0.0889*	-0.1069*	-0.0222*	-0.0096*	0.0125*	1.0

6.6.2 The micro panel

The micro panel consisted of 1,057,981 firms, with 315,000 to 400,000 alive per year. Figure 6.11 shows the distribution of firms by industry in the micro panel. Detailed descriptive statistics were not produced for the micro panel, as it was not used for modeling. It was only used to compare relocation patterns by firm size.

Figure 6.11 Micro panel firms, histogram for variable 'indcat'

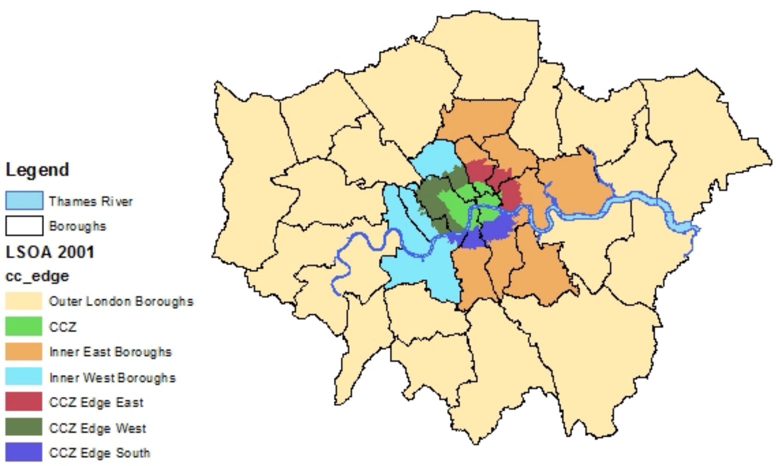


6.7 Firm location analysis

6.7.1 Spatial distribution analysis

The overall spatial distribution of firms in Greater London was explored by aggregating firms by location. Geographic areas were defined to allow comparison of firm population trends within the CCZ to comparable areas immediately adjacent to it (Edge areas), as well as the remainder of Inner and Outer London. Figure 6.12 shows a map of the defined geographic comparison areas. The Edge areas were defined using small area Census geography (LSOA) as the geographic unit. The Inner East and Inner West areas represent the remainder of the Inner boroughs, aside from the Edge areas (they do not overlap).

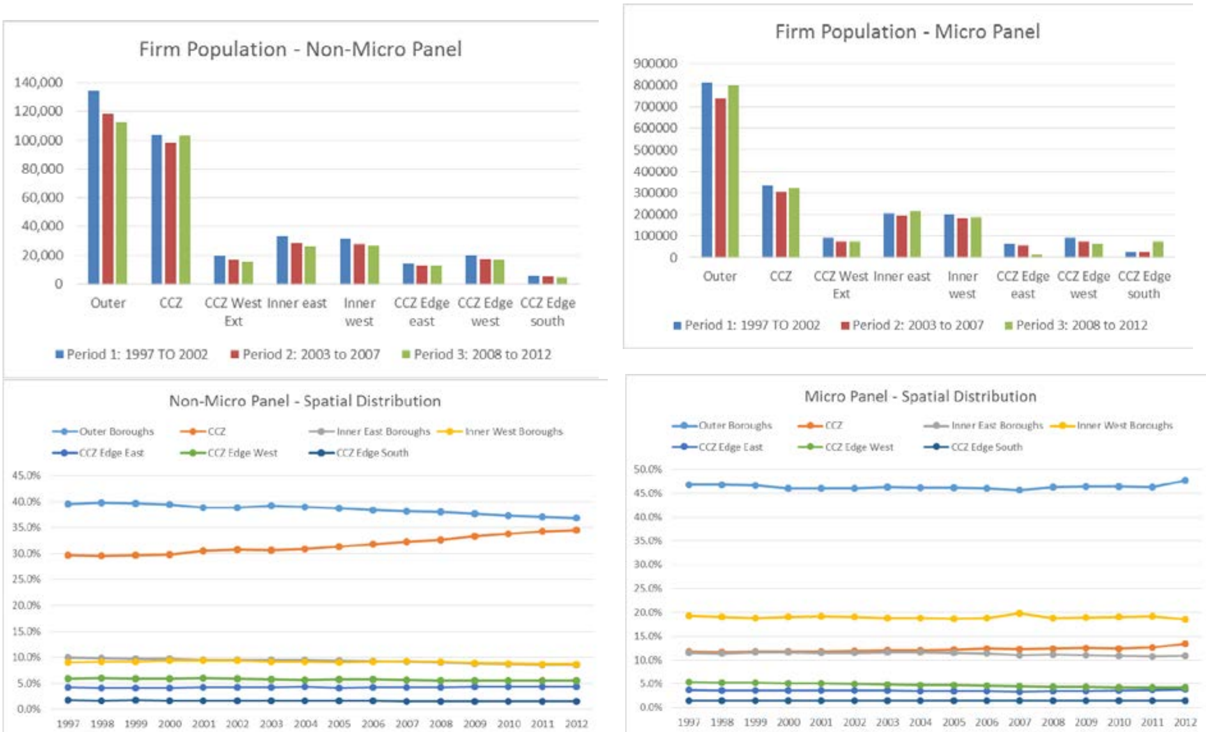
Figure 6.12 CCZ and edge areas defined



As discussed in other chapters in this dissertation, the congestion relief and travel time savings from congestion charging affected a wider area than the CCZ. For this analysis, it is assumed that the three Edge areas have all received similar travel time benefits for vehicular travel, including enhanced bus services. Pedestrian and bicycle infrastructure has been somewhat improved in the Edge areas, not as intensively as within the charged area. For example, the bicycle sharing network that was installed in 2008 extends throughout these areas. Two of the three Edge areas saw significant improvement to rail transit when the Jubilee line extension to Stratford opened in 1999, the South and East. The East saw further rail transit improvements when a Docklands Light Rail extension to the new City Airport opened in 2005, and another to Woolwich in 2009.

The results of this analysis for the non-micro and micro panels are shown in Figure 6.13, in two ways. In the first two charts, the number of firms located in each area was averaged over three time periods: 1997 to 2002, 2003 to 2007, and 2008 to 2012. In the other two charts, the percentage of all firms located in each geographic area is shown annually. Note that the first two charts include the CCZ Western Extension as a defined area, while the second two do not. The CCZ Western Extension area overlaps with the Edge West area, but is not the same.

Figure 6.13 Spatial distribution of firms on each panel

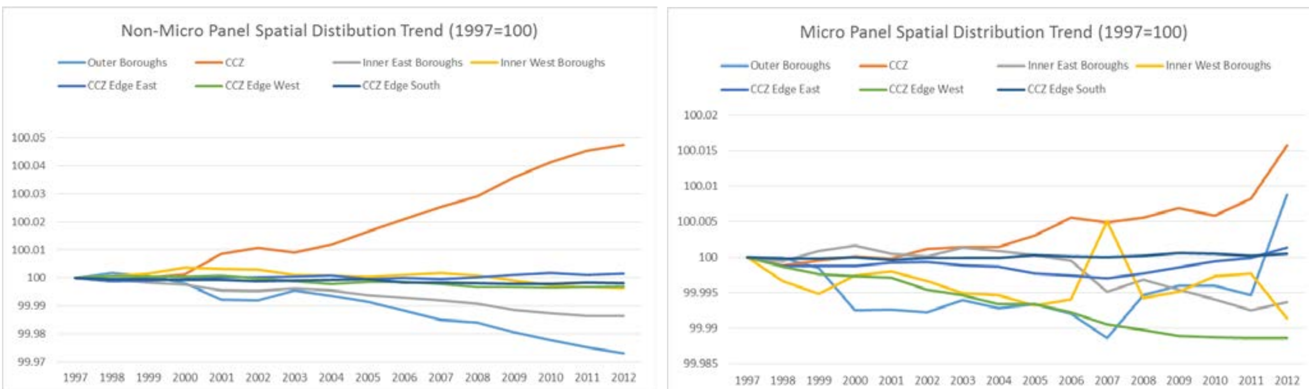


In the first two charts, the concentration of firms in the CCZ is evident, as is the higher concentration in the West edge area compared to the East and South edge areas. Comparing the charts for the non-micro and micro panels, it can be seen that the population of firms in the CCZ grew over time in both. In the non-micro panel chart, the firm population declined over time in the Outer and Inner boroughs, and even in the CCZ Western Extension area. There were slight declines in the Edge areas, but mainly from Period 1 to Period 2.In the micro panel chart, the firm population grew in the Outer and Inner East boroughs over time, but not the Inner West. Interestingly, the population declined in the East and West Edge areas, but increased in the South. This may be related to new office and retail space becoming available around Jubilee line station areas. However, this would also be expected the East, so further analysis would be needed to explain the reason.

The second set of charts showing the percentages of the total population of firms in each geographic area corroborate the first set. The non-micro panel chart shows a dramatic trend of spatial concentration of firms within the CCZ, and declining concentration in the Outer Boroughs. Similarly, the micro panel shows increasing concentration within the CCZ over time, but with declining concentration in the Inner East boroughs and Edge West area.

To take a closer look at these trends, the percent change was indexed to the first year of the time series and plotted, as shown in Figure 6.14. Now it is evident that not only have these changes increased over time, but the rate of change has also increased. The patterns are the most clear in the non-micro panel chart. There was not much change at all in the spatial distribution of firms until 2000, when the CCZ began to show increasing concentration and the Outer and Inner East boroughs deconcentration. The trend was stable until 2003, when the slope changes to become steeper for both trends, magnifying them over time. The micro panel shows a completely different pattern, with much more volatility. The most consistent trends that are evident are increased concentration in the CCZ and deconcentration in the Outer boroughs, Inner West, and Edge West areas from the earliest years throughout the timeframe. The slope on the CCZ trend gets steeper from 2004 to 2006, and again at the very end.

Figure 6.14 Trend in spatial distribution of firms on each panel



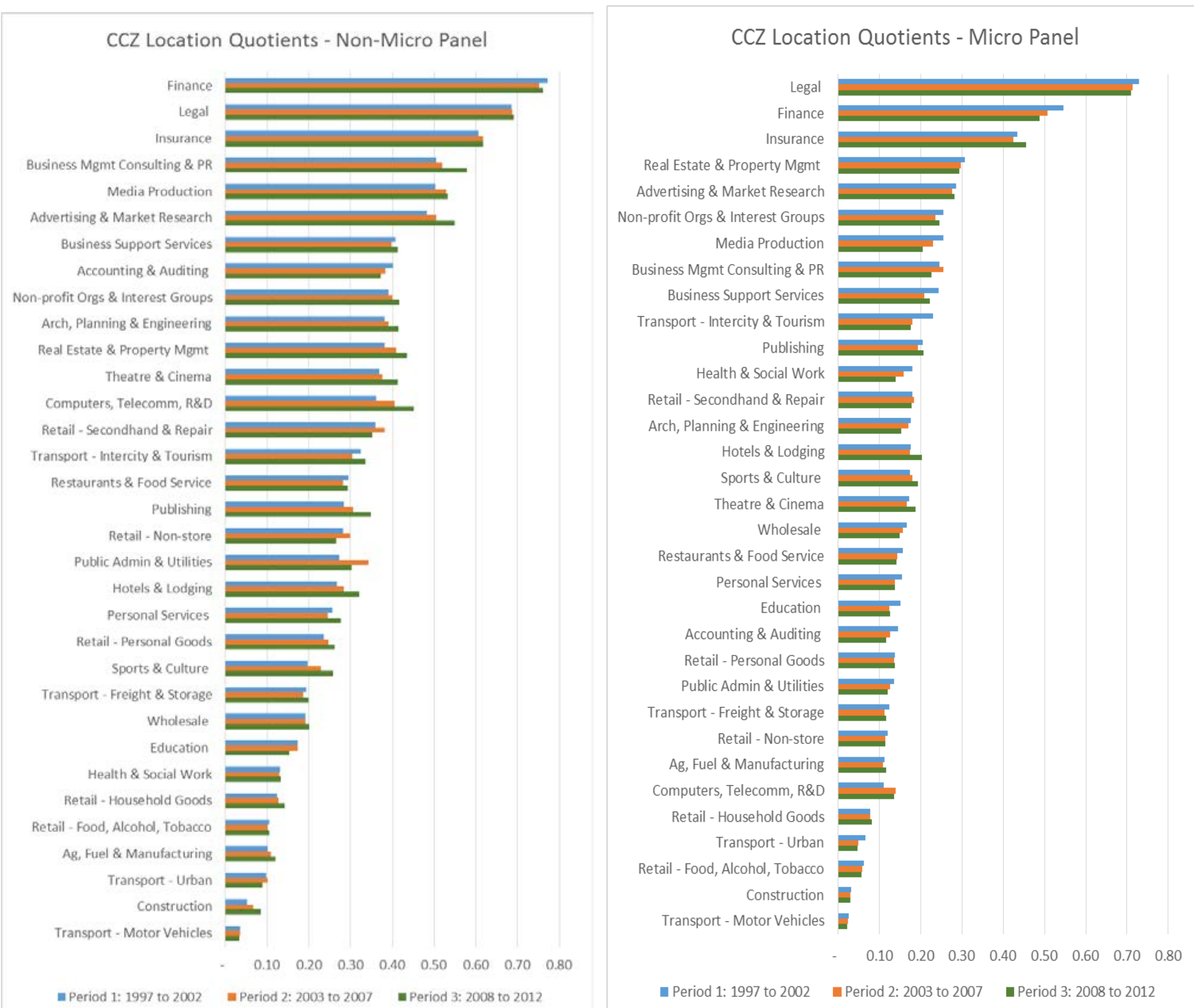
The results of the spatial distribution analysis demonstrate that the spatial concentration of firms within the CCZ has increased for both micro and non-micro firms over time. Increased concentration is the cumulative result of initial location decisions, relocation decisions, and firm survival over time. This is the expected result for any successful city. However, the increased rate of concentration for non-micro firms shown in Figure 6.14 reveals that the center has become more attractive to these firms, relative to the rest of the region, since 2000 and especially since 2003. This may also have been the case for micro firms, but the results are smaller in magnitude and more subtly differentiated from other trends.

Differentiated results between the two panels was a result predicted by the hypothesis. Larger firms were expected to benefit more from locating inside the transit-rich CCZ than smaller firms. This analysis has confirmed this part of the hypothesis. An unexpected result is the relative primacy of the CCZ to its Edge areas. Even though significant improvements to rail transit and non-motorized transportation have been made in these areas, and new office and retail space has been developed, they do not show the attractive power of the CCZ. Of the three Edge areas, the East had the largest gains in firm concentration for both panels.

6.7.2 Spatial agglomeration analysis

The hypothesis predicted that firms in industry sectors which benefit from agglomeration economies would benefit from locating within the CCZ. Increased concentration of these sectors is expected over time. To measure industry sector concentration within the CCZ, location quotients were calculated for each sector in each year of the study timeframe. Location quotients (LQs) were then averaged over three time periods: 1997 to 2002, 2003 to 2007 and 2008 to 2012. Results are shown in Figure 6.15.

Figure 6.15 Location quotients for industry sectors in the CCZ



As expected, Type III firms top the list of industry sectors for both panels. It was also expected that larger firms would tend to cluster more than small firms and sole proprietors. Most industry sectors show a higher LQ on the non-micro panel than the micro panel. The exceptions are sectors with small firms or consultants offering highly specialized services like Legal, Finance, and Insurance. The abundance of small firms supported by London's agglomeration in these industries is unique in the world, helping to define its status as a global city. Table 6.7 summarizes LQ changes over time for each industry sector. Most Type III sectors showed increasing concentration in the CCZ, as expected. Both Finance and Accounting/Auditing were exceptions, showing a deconcentration trend for both micro and non-micro firms. This is most likely due to the global financial crisis which bankrupted several large firms in these sectors.

Table 6.7 Change in location quotient over time, by industry

Industry Sector	Non-micro panel change (1997 to 2012)	Micro panel change (1997 to 2012)	Type
Computers, Telecomm, R&D	0.09	-0.03	III
Business Mgmt Consulting & PR	0.07	0.00	III
Advertising & Market Research	0.07	0.00	III
Publishing	0.06	-0.02	IV
Sports & Culture	0.06	-0.02	IV
Hotels & Lodging	0.05	-0.02	IV
Real Estate & Property Mgmt	0.05	0.02	IV
Theatre & Cinema	0.04	0.00	IV
Construction	0.03	-0.03	II
Arch, Planning & Engineering	0.03	-0.06	III
Public Admin & Utilities	0.03	-0.04	IV
Media Production	0.03	0.03	III
Non-profit Orgs & Interest Groups	0.03	0.02	IV
Retail - Personal Goods	0.02	-0.02	I
Personal Services	0.02	-0.05	IV
Ag, Fuel & Manufacturing	0.02	-0.01	I
Retail - Household Goods	0.02	-0.02	I
Insurance	0.01	-0.02	III
Transport - Intercity & Tourism	0.01	0.00	II
Wholesale	0.01	-0.01	I
Transport - Freight & Storage	0.01	-0.01	II
Legal	0.01	-0.01	III
Business Support Services	0.01	0.00	IV
Health & Social Work	0.00	-0.01	IV
Retail - Food, Alcohol, Tobacco	0.00	0.00	I
Restaurants & Food Service	0.00	0.00	I
Transport - Motor Vehicles	0.00	0.02	I
Retail - Secondhand & Repair	-0.01	0.01	II
Transport - Urban	-0.01	-0.01	II
Finance	-0.01	-0.05	III
Retail - Non-store	-0.02	0.00	IV
Education	-0.02	-0.02	IV
Accounting & Auditing	-0.03	-0.02	III

Note—table is sorted by non-micro panel change in location quotient

Several growing Type IV sectors also showed increased concentration within the CCZ as expected, notably Sports/Culture, Hotels/Lodging, Real Estate/Property Management, and Theatre/Cinema. These are all sectors that benefited from increased tourism within the CCZ.

Central London experienced a long-term boom in tourism over the study timeframe, which included hosting the Olympics in 2012. The CCZ contains most of the region's major historical and cultural sites, as well as the theatre and entertainment district. The Real Estate/Property Management industry has also boomed with a historic flow of foreign capital into London's real estate market.

All of the findings discussed so far confirm the hypothesis, however there were some interesting exceptions. Type I and II sectors were not expected to concentrate in the CCZ, as they had higher transport and spatial factor costs. Despite expectations, Construction showed strongly increased concentration. These are most likely the headquarters or management units of large firms, or could reflect some error due to SIC misclassification.

To a lesser extent, Retail Personal and Household Goods and Agriculture/Fuels/Manufacturing also showed increased concentration in the CCZ. For the latter, these are likely the headquarters or management units of large firms. Increased concentration of Retail firms within the CCZ indicates that increased factor costs are outweighed by the benefits of high quality walkability and transit services. Pedestrian volumes have greatly increased in the CCZ, especially in the major retail districts of Oxford and Bond Streets, and Covent Garden. More analysis into the patterns as to changes in footfall over time would be needed to link this directly to the introduction of congestion charging.

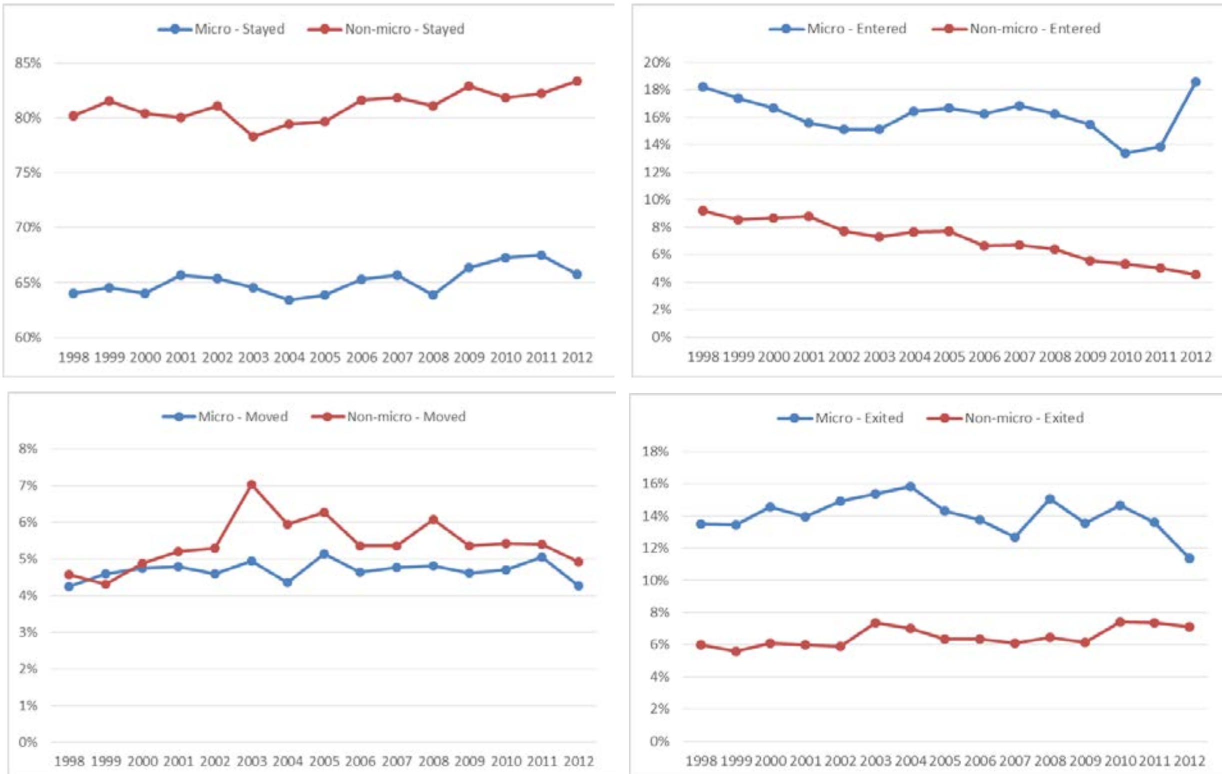
The results of this analysis generally confirmed the hypothesis that Type III and growing Type IV industries would increase their concentration inside the CCZ.

6.7.3 Relocation analysis

It was hypothesized that rising rents in the CCZ would spur a sorting process where the firms that valued accessibility the most, including larger firms, would locate there or move out, and those which could not afford it would locate elsewhere or move out. To compare location trends between the two panels, the dummy variables for each 'movecat' value were tabulated. Results are shown in four charts in Figure 6.16.

The two panels showed a similar trend in a steady slow growth of firms that stayed in place annually, but the percentages of the population that stayed were quite different. In the micro panel, about 65% of firms stayed in place annually, and in the non-micro panel about 80%. The main reason for this difference was not relocation rates. Both panels had relocation rates of 4% to 6% per year. The reason that non-micro firms were more stable was that micro firms entered and exited at much higher rates. The entry rate for micro firms ranged from 14 to 18% annually, while for non-micro firms it was 5% to 10%. Similarly, micro firms exited at a rate of 12 to 16% annually, and non-micro firms at a 6% to 8% rate.

Figure 6.16 Comparison of variable 'movecat' in micro and non-micro panels



There was a cumulative decline in the entering trend for both micro and non-micro firms from 1997 to 2012. The entry rate for micro firms went up and down over time, most likely following the economic cycle, but the entry rate for non-micro firms went steadily down over the entire timeframe. This suggests that fewer firms were making it over the 10-employee threshold to become a non-micro firm over time. Incumbent large firms may have accounted for most employment growth.

The cumulative exiting trend was different between micro and non-micro firms. Similar to entry, the exit trend for micro-firms went up and down over time, but had a cumulative downward trend, meaning more of these firms were surviving over time. The non-micro panel showed the opposite trend, with an increasing number of firms exiting each year, over time. This also appears related to the economic cycle. The recession brought losses of firms and jobs in several sectors with a large average firm size: finance, insurance, and ag/fuel/manufacturing.

Finally, the comparison of the move trend showed the expected result: micro firms relocate less frequently than non-micro firms. It appears that move rates were similar in the early years of the panels, but this is likely due to geocoding errors among the less numerous non-micro firms. Only about 3,000 non-micro firms were moving in any given year, and the earliest years of the panel had the lowest postcode match rates. Similarly, there appears to be a sudden spike in the non-micro move rate in 2003, but this is also likely due to geocoding errors. In spite of these errors, it is evident that the relocation rate for non-micro firms increased for a period from 2002 to 2008, then appeared to level out in the latter part of the study period. This could be attributable to the changes in transportation accessibility, as larger firms benefit from locating in the most transit-served places. It could also be related to changes in the availability of suitable office space for large firms.

In order to understand more about the types of moves that firms in the non-micro panel were making, dummy variables were created to tabulate certain moves of interest: moves into the CCZ area (ccmin), moves out of the CCZ area (ccmout), moves into the CCZ Western Extension area (ccwextmin), and moves out of the CCZ Western Extension area (ccwextmout). Results are shown in Figures 6.17 and 6.18.

Figure 6.17 Tabulations of moves into and out of the CCZ and Western Extension (non-micro panel)

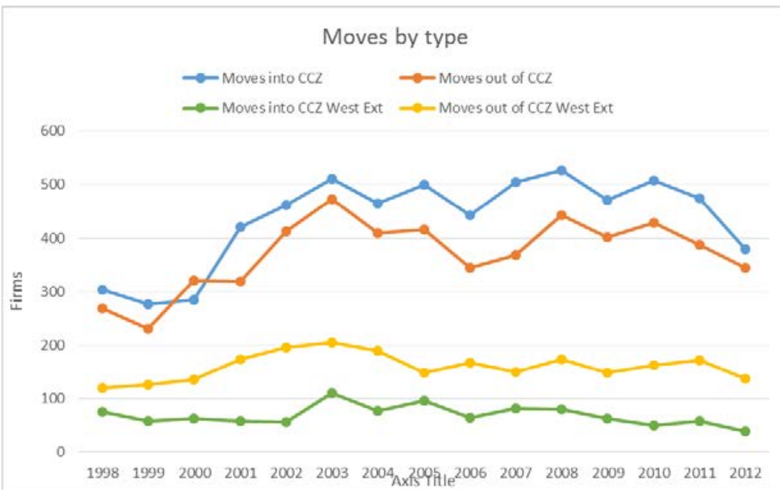
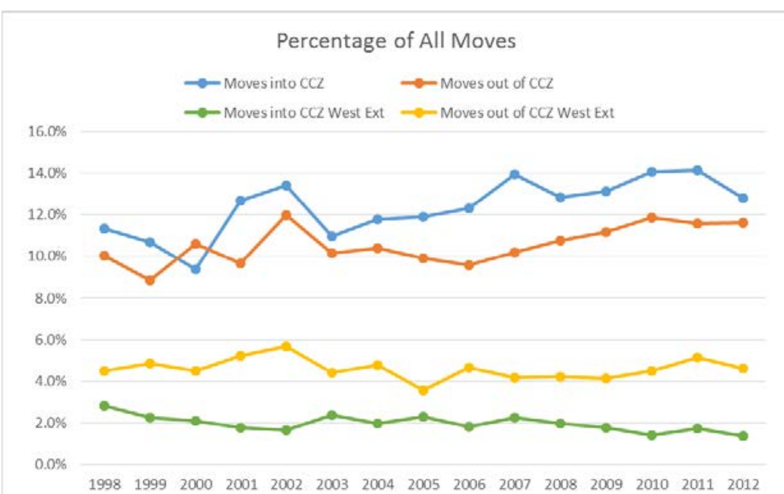


Figure 6.18 Moves into and out of the CCZ and Western Extension as a percentage of all moves (non-micro panel)



This analysis revealed that moves into and out of the CCZ were more prevalent than moves out, with an increasing rate of moving over time. Figure 6.17 shows that from 1998 to 2000, approximately 300 non-micro firms moved into the CCZ annually, but then increased to about 500 per year by 2003. Similarly, from 1998 to 2000, approximately 250 non-micro firms moved out the CCZ annually, a number which increased to about 400 per year by 2003. From 1998 to 2012, the average ratio of moves into the CCZ to moves out was 1.17. This is further confirmation of the hypothesis that larger firms benefit more from a high-accessibility location, and are more likely to relocate there as they grow.

Moves into and out of the CCZ Western Extension area showed a different pattern. Figure 6.17 shows fewer than 100 non-micro firms moving into this area annually, but 100 to 200 moving out. The average ratio of moves in to moves out from 1998 to 2012 was .44. In this area, which has excellent transit service and walkability, but less availability of office space, moves out were more prevalent than moves in. This area also has the highest rents in the region. Both of these factors form barriers to entry, making it unsurprising that that larger firms are more likely to move out than in.

Figure 6.18 shows these four types of moves as a percentage of all moves made by firms on the panel, each year. The proportions remained relatively stable over time, however both moves into and out of the CCZ both increased as a proportion of all moves, from 2003 to 2010. The most common type of move was within the CCZ, forming over half of all moves (56%). Moves into the CCZ were 12-14% of all moves, and moves out were 9-12%. Moves into the CCZ Western Extension were 1-3% of all moves, and moves out were 4-5%.

Finally, Figure 6.19 and Table 6.8 show moves into and out of the CCZ tabulated into the same three time periods as before, and the ratio of moves in to moves out. Now it is clear that the number of firms moving annually was increasing over time on both the micro and non-micro panels. For the non-micro panel, period 1 had a roughly equal ratio of moves in and out of CCZ (1.02), but this changed in periods 2 (1.16) and 3 (1.14) such that more firms were moving in than leaving. For the micro panel, the move ratio in period 1 showed that more firms moved out than in (.93), but this increased in period 2 (.99) and period 3 (.96). These findings corroborate previous findings.

Table 6.8 Ratio of firms moving into CCZ to moving out, by time period

	Period 1: 1998 to 2002	**Period 2: 2003 to 2007**	**Period 3: 2008 to 2012**	**Total (1998 to 2012)**
Micro Panel	.93	.99	.96	.96
Non-micro Panel	1.02	1.16	1.14	1.11

Figure 6.19 Tabulations of moves into and out of the CCZ

6.7.4 Job flow analysis

Since non-micro firms were moving into the CCZ at a higher rate, it is implied that jobs are also flowing into the CCZ, increasing total employment there. This analysis sought evidence of this by tabulating the flow of jobs into and out of the CCZ, with results shown in Figure 6.20 and Table 6.9. The non-micro panel did not show the expected results. In period 1, even though it was before the intensive accessibility improvements discussed earlier, the CCZ still had the best transit access in the region. It would have been expected to attract and retain large firms. Even though the ratio of non-micro firms was moving in to leaving was 1.02, there was an outward flow of jobs. The firms on the non-micro panel are very heterogeneous, ranging from micro-enterprises to several thousand employees. In period 1, the ratio of jobs flowing in to out was .80, meaning that several large employers had moved out. In period 2, this trend reversed, and there was strong job flow into the CCZ, for a ratio of 1.45. Yet it reversed again in period 3, with a ratio of .71.

To investigate this pattern, the average jobs flowing per year was calculated. Then it became evident that there were two years with that a single large employer, or perhaps a few, had moved and greatly skewed the average for those years. In most years, firms on the non-micro panel that were moving into and out of the CCZ had about 60 employees, on average. In 2003, the average was 128 jobs per firm for firms moving into the CCZ, and in 2011, the average was 186 for firms moving out. This indicates that there was likely one or a few very large employers which skewed the numbers for those years. When those two data points were taken out of the ratio calculation, it appeared more normalized. The amended ratio is reported in the table with an asterisk. In period 2, the ratio became .87, and in period 3 1.16. This would indicate a long-term shift toward large employers being attracted to the CCZ, which would fit with the hypothesis. It was expected that the initial ratio in period 1 would have been above 1, and then increased over time. However, it appears that prior to period 3, more jobs were flowing out of the CCZ than into it.

Figure 6.20 Flows of jobs into and out of the CCZ

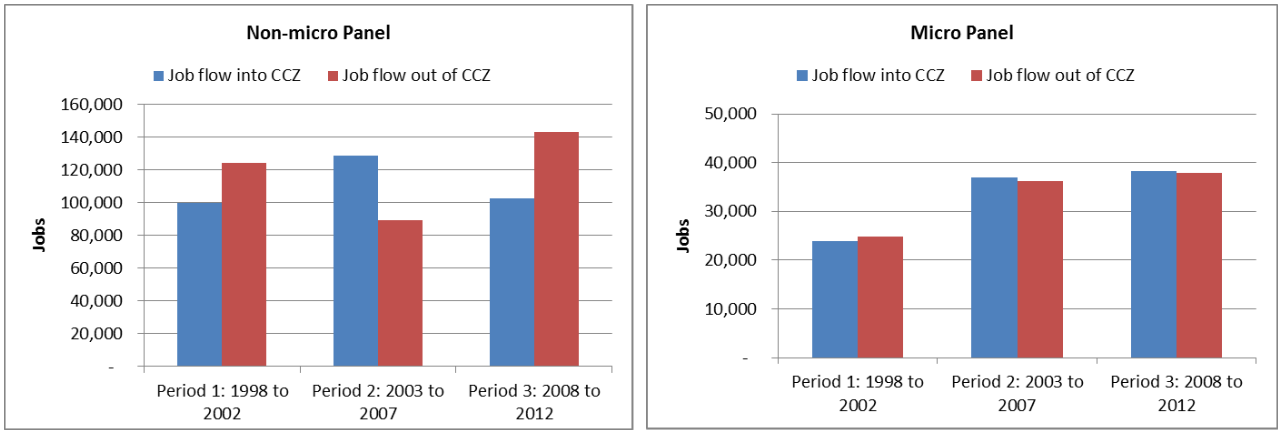


Table 6.9 Ratio of job flows into and out of CCZ

	Period 1: 1998 to 2002	Period 2: 2003 to 2007	Period 3: 2008 to 2012	Total (1998 to 2012)
Micro Panel	.96	1.02	1.01	1.00
Non-micro Panel	.80	1.45	.71	.93
Non-micro Panel*	.80	.87	1.16	.93

** Averages amended to correct for skews given by a few very large firms*

Results were as expected for the micro panel. Job flows were roughly equal, as the flows of firms were, unsurprising since they are all sole-proprietorships and micro-enterprises. In period 1, about 25,000 micro-enterprise jobs flowed into and out of the CCZ, with a ratio of .96 indicating that slightly more jobs left. In period 2, flows in and out increased to about 35,000 per year, and the ratio became 1.02, indicating that slightly more jobs were retained. This pattern continued into period 3.

6.7.5 CCZ move ratio analysis by industry

This analysis investigates the hypothesized sorting process, where industry sectors valuing accessibility improvements would enter or relocate inside the CCZ, and those that did not, and could not afford increasing rents would move out. In order to understand relocation trends by industry, over time, the dummy variables for 'moved', 'ccmin' and 'ccmout' from both panels were tabulated together, by industry for three time periods. Results are shown in Table 6.10 (sorted by move rate for period 1).

The average move rate among all sectors was 5% per year throughout the entire study period. As expected, the move rate varied greatly among industry sectors. Some sectors are 'footloose', with above-average move rates: Computers/Telecomm/R&D (7%), Media Production (7%), Advertising/Market Research (7%), Theater/Cinema (6%), Business Support Services (6%), and Business Management Consulting/Public Relations (6%), Sports/Culture (6%), and Accounting/Auditing (6%). Relocation patterns, especially a tendency toward agglomeration, was expected to be most readily observable among footloose industries.

Others sectors were quite stable, with move rates well below average: Retail (all sectors except Secondhand/Repair) (2-4%), Restaurants (3%) Hotels/Lodging (3%), Transport (all sectors except Intercity/Tourism) (3-4%), Health/Social Work (3-4%), Non-profit Organizations (3-4%), Insurance (3-4%), Legal (3-4%), and Agriculture/Fuels/Manufacturing (3-4%).

Table 6.10 Move rate and rates of moving in and out of CCZ by industry

	Period 1: 1997 to 2002				Period 2: 2003 to 2007				Period 3: 2008 to 2012				
Industry Sector	Move rate	% moves into CCZ	% moves out of CCZ	Ratio moves in:out	Move rate	% moves into CCZ	% moves out of CCZ	Ratio moves in:out	Move rate	% moves into CCZ	% moves out of CCZ	Ratio moves in:out	**Type**
Computers, Telecomm, R&D	7%	8.0%	5.8%	1.36	7%	10.0%	8.1%	1.23	7%	9.6%	8.4%	1.14	III
Media Production	7%	10.8%	10.2%	1.07	7%	9.3%	10.7%	0.87	7%	8.8%	10.9%	0.81	III
Theatre & Cinema	7%	8.1%	8.8%	0.92	7%	7.5%	8.9%	0.84	5%	8.6%	7.5%	1.14	IV
Advertising/Market Research	6%	9.6%	9.2%	1.04	7%	9.4%	9.3%	1.01	7%	12.7%	10.6%	1.20	III
Business Support Services	6%	8.9%	9.3%	0.96	6%	9.3%	8.3%	1.12	6%	10.2%	9.7%	1.04	IV
Business Mgmt Consult & PR	6%	8.1%	8.6%	0.94	6%	10.4%	7.8%	1.33	6%	9.8%	9.6%	1.02	III
Accounting & Auditing	5%	5.3%	8.5%	0.63	6%	5.3%	4.2%	1.28	5%	5.5%	6.2%	0.88	III
Publishing	5%	8.2%	10.0%	0.82	6%	9.6%	8.6%	1.11	6%	9.2%	8.1%	1.13	IV
Retail - Non-store	5%	-	-	-	6%	-	-	-	5%	4.4%	3.0%	1.44	IV
Sports & Culture	5%	6.2%	6.5%	0.95	6%	8.8%	6.7%	1.31	6%	9.7%	6.1%	1.59	IV
Personal Services	5%	5.9%	6.7%	0.89	5%	6.1%	6.2%	0.98	4%	8.3%	7.9%	1.04	IV
Transport - Urban	4%	-	-	-	4%	-	-	-	4%	-	-	-	II
Real Estate & Property Mgmt	4%	7.5%	8.7%	0.87	5%	7.6%	9.0%	0.84	5%	8.9%	8.8%	1.01	IV
Finance	4%	6.8%	11.9%	0.57	6%	7.5%	8.9%	0.84	6%	7.4%	9.3%	0.80	III
Construction	4%	3.4%	1.7%	1.98	5%	2.7%	1.7%	1.61	5%	3.1%	1.8%	1.72	II
Arch, Planning & Eng.	4%	7.3%	6.5%	1.13	5%	8.1%	7.4%	1.10	5%	7.4%	8.3%	0.89	III
Wholesale	4%	6.3%	7.6%	0.84	5%	6.2%	7.1%	0.88	5%	7.5%	8.3%	0.91	I
Transport – Intercity/Tourism	4%	2.4%	8.2%	0.29	5%	2.7%	6.4%	0.42	5%	5.4%	6.4%	0.84	II
Transport - Freight & Storage	4%	2.6%	4.0%	0.65	5%	3.8%	5.1%	0.74	5%	4.2%	3.6%	1.17	II
Education	4%	-	-	-	5%	6.0%	2.7%	2.21	5%	4.5%	6.1%	0.74	IV
Public Admin & Utilities	4%	-	-	-	6%	-	-	-	5%	-	-	-	IV
Ag, Fuel & Manufacturing	4%	5.9%	5.1%	1.16	4%	3.8%	4.7%	0.81	4%	4.5%	5.2%	0.87	I
Retail - Secondhand & Repair	4%	-	-	-	4%	-	-	-	4%	-	-	-	IV
Legal	4%	4.3%	8.8%	0.48	4%	4.0%	8.7%	0.46	4%	4.8%	9.5%	0.51	III
Non-profit Orgs	3%	2.5%	7.7%	0.32	4%	-	-	-	4%	2.3%	3.0%	0.75	IV
Insurance	3%	2.2%	2.4%	0.92	4%	-	-	-	4%	7.1%	6.1%	1.16	III
Health & Social Work	3%	2.8%	7.4%	0.37	4%	7.1%	6.8%	1.04	4%	6.2%	5.6%	1.11	IV
Retail - Household Goods	3%	-	-	-	4%	1.5%	2.8%	0.52	3%	-	-	-	I
Retail - Personal Goods	3%	5.8%	7.3%	0.80	4%	5.5%	7.8%	0.70	4%	6.9%	7.5%	0.92	I
Transport - Motor Vehicles	3%	-	-	-	3%	-	-	-	3%	-	-	-	I
Hotels & Lodging	3%	-	-	-	4%	-	-	-	4%	-	-	-	IV
Restaurants & Food Service	2%	7.8%	8.9%	0.88	3%	8.1%	9.4%	0.86	3%	8.5%	10.5%	0.81	I
Retail - Food/Alcohol/Tobacco	2%	1.8%	3.7%	0.49	2%	1.0%	1.8%	0.59	2%	0.8%	4.0%	0.20	I
Total	5%	7.4%	7.8%	0.95	5%	7.8%	7.6%	1.02	5%	8.2%	8.3%	0.99	

Note—table is sorted by move rate in Period 1

In Table 6.10, the columns '% moves into/out of CCZ' represent the percentage of all moves by firms in the industry sector that were either into out of the CCZ. This revealed that some industry sectors are much more likely to making these types of moves than others. For example, comparing two footloose industries, around 20% of all moves made by Media Production firms were in/out of the CCZ, while they only accounted for about 10% of all Accounting/Auditing firms' moves. Differences between rates of moving in and out were also revealed. For example, about 9% of moves by Computers/Telecomm/R&D firms each year were into the CCZ, but only about 7% of moves were out of it.

The column 'ratio moves in:out' in Table 6.10 gives the ratio of moves into the CCZ to moves out, by industry. For example, since the annual move in rate for the Computers/Telecomm/R&D sector was higher than the move out rate, this industry sector had a ratio greater than 1 in all three periods, indicating a net retention of firms over time due to relocation. On the other hand, both Legal and Finance had ratios less than 1 in all three periods, indicating a net loss of firms over time due to relocation. It must be noted that the move ratio does not include the initial location of new firms in the CCZ, and so the location quotient is a better measure of aggregate loss/retention patterns over time. In total, the CCZ had more firms move out than in during period 1 (ratio .95), but this changed during period s 2 and 3, hovering around 1. This implies that the CCZ changed from experiencing a net loss of firms due to relocation, to a net gain. In other words, accessibility improvements helped the CCZ improve its retention of firms.

Changes in the move ratio over time are summarized in Table 6.11 by industry (only sectors which had a ratio in all three periods). Some results were as expected, during all three time periods: Type III sectors had a net gain of firms inside the CCZ (Computers/Telecomm/R&D, and Advertising/Market Research), while Type I sectors had a net loss (Restaurants/Food Service, Wholesale, Retail/Personal Goods/Food). Improved retention of other Type III and growing Type IV industry sectors was also expected, and found. Several of these sectors which had a net loss of firms in period 1 changed to a net gain in period 2: Business Support Services, Sports/Culture, Business Mgmt Consulting/PR, Insurance, Health & Social Work, Theatre & Cinema, Personal Services, Real Estate & Property Mgmt, and Accounting/Auditing.

Table 6.11 also revealed several unexpected results. There was a net gain of firms in a Type II sector, Construction, over all three periods. The number of Construction firms grew by 34% from 1998 to 2012, so this could be due to dynamism in the industry. Growing firms may have relocated to the CCZ, or local units managing construction projects within the CCZ.

Another unexpected result was the net loss of firms in two Type III sectors, Legal and Finance, in all three periods. The challenges faced by the Finance sector have already been discussed, and here is yet more evidence of the shrinkage of this sector within the CCZ. There are two Finance agglomerations in London, the CCZ and Canary Wharf, so these results could reflect firms moving between them. The reason for the net loss in Legal firms is unclear, but it could be related to small average firm size. Legal firms were 9 employees on average, compared to 124 for Finance. This sector grew in employment and number of firms from 1998 to 2012, and had greatly increased revenues. The major Legal agglomeration is near the High Court of Justice and the Old Bailey, both inside the CCZ. However, over this timeframe, the prestige of the West End outside the CCZ was increasing, and it could be that some firms moved to more exclusive and high rent locales in the West Edge of the CCZ where they could commute by car and avoid the congestion charge. More analysis would be required to confirm this.

Table 6.11 Change in ratio of moves into and out of CCZ, by industry

Industry Sector	Period 1 Ratio of moves in:out	Period 2 Ratio of moves in:out	Period 3 Ratio of moves in:out	Type
Net gain in CCZ, all periods				
Construction	1.98	1.61	1.72	II
Computers, Telecomm, R&D	1.36	1.23	1.14	III
Advertising & Market Research	1.04	1.01	1.20	III
Net loss, changed to net gain				
Business Support Services	0.96	1.12	1.04	IV
Sports & Culture	0.95	1.31	1.59	IV
Business Mgmt Consulting & PR	0.94	1.33	1.02	III
Insurance	0.92	-	1.16	III
Publishing	0.82	1.11	1.13	IV
Health & Social Work	0.37	1.04	1.11	IV
Theatre & Cinema	0.92	0.84	1.14	IV
Personal Services	0.89	0.98	1.04	IV
Real Estate & Property Mgmt	0.87	0.84	1.01	IV
Transport - Freight & Storage	0.65	0.74	1.17	II
Accounting & Auditing	0.63	1.28	0.88	III
Net gain, changed to net loss				
Ag, Fuel & Manufacturing	1.16	0.81	0.87	I
Media Production	1.07	0.87	0.81	III
Arch, Planning & Engineering	1.13	1.10	0.89	III
Net loss in CCZ, all periods				
Restaurants & Food Service	0.88	0.86	0.81	I
Wholesale	0.84	0.88	0.91	I
Retail - Personal Goods	0.80	0.70	0.92	I
Retail - Food, Alcohol, Tobacco	0.49	0.59	0.20	I
Transport - Intercity & Tourism	0.29	0.42	0.84	II
Finance	0.57	0.84	0.80	III
Legal	0.48	0.46	0.51by	III

6.8 Industry sensitivity analysis

Another way of testing for which industries were the most sensitive to the accessibility changes brought by congestion charging and transit improvements was to calculate the odds of firms moving into or out of the CCZ, before and after it was implemented. This industry sensitivity analysis estimated time series logistic regression models for the non-micro panel using the dummy variables representing moves into and out of the CCZ as the dependent variables[15]. Models were estimated for two time periods: 1998 to 2003 and 2004 to 2012. Results are reported by industry category, as odds ratios. The odds ratios were calculated in relation to the first category of 'indcat', which was Ag/Fuels/Manufacturing. A summary of statistically significant results for moves into the CCZ is shown in Table 6.12, and for moves out of the CCZ in Table 6.13. Full results are shown in Appendix D.

Table 6.12 Industry sectors with statistically significant odds of moving into the CCZ (non-micro panel)

Industry Category	1998 to 2003 Odds ratio	2004 to 2012 Odds ratio	Difference	Type
Odds increased over time				
Computers, Telecomm, R&D*	2.74	3.42	0.68	III
Restaurants & Food Service*	1.60	2.21	0.61	I
Advertising & Market Research	2.38	2.87	0.49	III
Arch, Planning & Engineering*	1.84	2.29	0.45	III
Business Mgmt Consulting & PR**	1.87	2.31	0.44	III
Personal Services	1.57	1.95	0.38	IV
Real Estate & Property Mgmt	1.47	1.84	0.36	IV
Publishing**	2.16	2.48	0.32	IV
Business Support Services	2.14	2.34	0.20	IV
Sports & Culture	2.21	2.27	0.06	IV
Theatre & Cinema	2.36	2.42	0.06	IV
Non-profit Orgs & Interest Groups**	1.73	1.79	0.06	IV
Retail - Personal Goods*	1.68	1.73	0.05	I
Finance**	1.72	1.75	0.03	III
Odds decreased over time				
Media Production***	2.90	2.43	-0.47	III
Insurance	2.46	2.25	-0.22	III
Transport - Intercity & Tourism****	1.78	1.70	-0.07	II

*Note—asterisks indicate industry sectors that also appear in **Table** 13. * means the sector appears in the 'odds increased' section of both tables. ** means the sector appears in the 'odds increased' section of **Table** 12 and the 'odds decreased' of **Table** 13. *** means the sector appears in the 'odds decreased' section of **Table** 12 and 'odds increased' section of **Table** 13. **** means the sector appears in the 'odds decreased section of both tables.*

[15] In Stata, the command for a time series logistic regression is 'xtlogit'. For example, to produce these results estimating a model for moves into the CCZ, the command was 'xtlogit ccmin i.indcat, or'.

Table 6.13 Industry sectors with statistically significant odds of moving out of the CCZ (non-micro panel)

Industry Category	1998 to 2003 Odds ratio	2004 to 2012 Odds ratio	Difference	Type
Odds increased over time				
Media Production***	2.05	2.90	0.84	III
Computers, Telecomm, R&D*	2.14	2.57	0.42	III
Restaurants & Food Service*	1.96	2.33	0.37	I
Arch, Planning & Engineering*	1.75	2.01	0.27	III
Retail - Personal Goods*	1.71	1.96	0.24	I
Construction	0.37	0.57	0.19	II
Odds decreased over time				
Finance**	2.39	1.86	-0.54	III
Transport - Intercity & Tourism****	2.24	1.79	-0.45	II
Accounting & Auditing	2.16	1.82	-0.34	III
Publishing**	2.00	1.90	-0.11	IV
Non-profit Orgs & Interest Groups**	1.83	1.76	-0.07	IV
Business Mgmt Consulting & PR**	1.49	1.48	-0.02	III

*Note—asterisks indicate industry sectors that also appear in **Table** 12. * means the sector appears in the 'odds increased' section of both tables. ** means the sector appears in the 'odds increased' section of **Table** 12 and the 'odds decreased' of **Table** 13. *** means the sector appears in the 'odds decreased' section of **Table** 12 and 'odds increased' section of **Table** 13. **** means the sector appears in the 'odds decreased section of both tables.*

In Tables 6.12 and 6.13, similar results to the move ratio analysis can be seen. However, the move ratios were calculated using tabulations of moves by all firms, while these odds ratios were only calculated for the non-micro panel, and so some differences are expected. These results should be strongest for industry sectors that have a large average firm size, as they have better representation on the non-micro panel. They should be interpreted as the moving odds for the largest firms in each sector (not the average).

The odds ratios represent how much more likely firms in each industry sector is to move into or out of the CCZ than firms in the Ag/Fuels/Manufacturing sector. The odds for this sector were very low. In any given year, only a handful of its firms in the non-micro panel moved into or out of the CCZ (fewer than 10). Therefore these odds ratios may be interpreted as compared to nearly null.

Several industry sectors had statistically significant results for both moves into and out of the CCZ. On Tables 12 and 13, asterisks were used to indicate industry sectors that appear on both tables, and how they appear: * means the sector appears in the 'odds increased' section of both tables; ** means the sector appears in the 'odds increased' section of Table 6.12 and the 'odds decreased' of Table 6.13; *** means the sector appears in the 'odds decreased' section of Table 6.12 and 'odds increased' section of Table 6.13; **** means the sector appears in the 'odds decreased section of both tables.

6.8.1 Benefiting sectors

Several results were as expected, and corroborated with the move ratio analysis results. The odds of moving into the CCZ increased over time for nine of the industries that had a net gain in firms relocating into the CCZ after 2004: Computers/Telecomm/R&D, Advertising/Market Research, Business Support Services, Sports/Culture, Business Mgmt Consulting/PR, Publishing, Theatre/Cinema, Personal Services, Real Estate/Property Mgmt. These industries are considered the ones that benefit most from accessibility improvements and travel time savings due to congestion charging, and those that value these location factors the most. As expected, these are all Type III and IV industry sectors.

Interestingly, none of these sectors has a particularly large firm size. Sports/Culture had the largest (10 to 25 employees), and Publishing, Advertising/Market Research, Business Support Services and Real Estate/Property Mgmt all hover around 10 to 15 employees. The rest of these sectors had average employment of 3 to 6 employees. Some of these sectors were in the top twelve for employment growth (Computers/Telecomm/R&D, Business Mgmt Consulting/PR, and Sports/Culture). Several were in the top twelve for new firms (Computers/Telecomm/R&D, Business Mgmt Consulting/PR, Advertising/Market Research, Business Support Services, Real Estate/Property Mgmt). And a few were in the top twelve for growth in turnover (Computers/Telecomm/R&D, Sports/Culture, Publishing, and Theatre/Cinema.

The main thing the ‘benefiting’ sectors had in common is a strong clustering tendency in the CCZ from 1998 to 2012. Most of these sectors appear at the top of the list in Table 6.7, for the biggest changes in location quotient in the CCZ. The only exceptions are Business Support Services and Personal Services, both lower skill lower wage industries that grow as a function of the population of people and firms. It clear Business Support Services firms are increasingly located in the CCZ, as the population of firms grows there, however it is less clear why Personal Services firms are increasingly locating in the CCZ. The market for personal services is likely growing with the increasing flows of high wage employees. These firms might be expected to locate in the neighborhoods where these employees live, however, so it is interesting that so many are locating close to where they work.

There were two Type III industry sectors on Table 6.11 that had a net gain in firms moving into the CCZ over time, that did not show up on Table 6.12 as having increasing move-in odds – Insurance and Accounting/Auditing. These were both likely to have a low *n* for this calculation, Insurance because it has a low move rate, and Accounting/Auditing because it has a low average firm size. There were likely not enough moves to produce statistically significant results in this calculation using the non-micro panel. Based on the results from the move ratio analysis, which included micro firms, these should be considered benefiting sectors as well.

6.8.2 Vulnerable sectors

In Table 6.13, industry sectors whose odds of moving out increased after the implementation of congestion charging are shown. The list includes three expected Type I and Type II sectors: Restaurants/Food Service, Retail - Personal Goods, and Construction. It also included two unexpected Type III sectors, Media Production, and Arch/Planning/ Engineering. Except for Construction, these results corroborate well with result from the move ratio analysis shown in Table 6.11. They were all sectors with a net loss of firms in the CCZ from firms moving out at a faster rate than moving in. These industry sectors are considered both the most vulnerable to the combined impacts of increased factor costs from congestion charging and rising rents from improved accessibility, and the ones who value these changes the least.

Two ‘vulnerable’ Type III sectors was an unexpected result. Media Production and Arch/Planning/ Engineering both have a small average firm size (7 to 12 employees). Both experienced stronger growth in firms than jobs from 1998 to 2012, meaning the average firm size shrunk. Both had growth in revenues. A possible explanation is that creative industries prefer to cluster in ‘edgy’ post-industrial areas with a more artsy aesthetic than the CBD and where loft space is available. In London, there is anecdotal evidence that creative firms cluster East and South CCZ Edge areas in neighborhoods such as Shoreditch, Whitechapel, and Bermondsey. Perhaps these creative clusters place a greater value on aesthetics than centrality. If that is the case, then these sectors were not so much vulnerable to changes in the CCZ as opting out of it.

Another unexpected result in Table 6.13 was the appearance of Computers/Telecomm/R&D, a Type III sector that also appears in Table 6.12 as having increased odds of moving into the CCZ. These seemingly conflicting results simply mean that the flows of this sector’s firms into and out of the CCZ were both statistically significant and increasing from 1998 to 2012. Other characteristics besides industry sector explain whether a particular firm has high odds of moving out or high odds of moving in. Since the non-micro panel contains some smaller firms, employment could be a factor, with larger firms more likely to move in and smaller firms more likely to move out. This is the likely explanation for the appearance of Construction on both lists, as well. Larger construction firms in the non-micro panel showed the expected results of having increased odds of moving out of the CCZ over time, while the move ratio showed a net gain in Construction firms in the CCZ over time, due to the proliferation of small firms there. Many of the small firms could be sole proprietorships – engineers performing inspection and consulting services.

A summary of the results of the industry sensitivity analysis is shown in Table 6.14.

Table 6.14 Summary of benefiting and vulnerable industry sectors

Industry Category	Beneficiary	Vulnerable/ Non-beneficiary	Type
Computers, Telecomm, R&D	X		III
Advertising & Market Research	X		III
Business Mgmt Consulting & PR	X		III
Business Support Services	X		IV
Sports & Culture	X		IV
Theatre & Cinema	X		IV
Personal Services	X		IV
Real Estate & Property Mgmt	X		IV
Publishing	X		IV
Restaurants & Food Service		X	I
Retail - Personal Goods		X	I
Construction		X	II
Arch, Planning & Engineering		X	III
Media Production		X	III

6.9 The role of changing accessibility and rents

As discussed earlier, there are many reasons a firm might relocate, including growth or shrinkage of employees, growth and decline of revenues, to cluster with other firms in a prestigious location, or to escape high rent. This study hypothesized that firms are increasingly attracted to the CCZ due to increased accessibility benefits there, in spite of rising rents. In order to truly test this hypothesis, more information is needed about the accessibility and rent costs experienced by each firm, before and after it moves. For this reason, rent and accessibility variables were added to the non-micro panel dataset.

6.9.1 Rent data

External data representing commercial rent and public transit accessibility was added to the non-micro panel and joined to each firm based on its postcode. As a proxy for commercial rent, this study uses commercial tax valuation data from the UK Valuation Office Agency (VOA), because the tax valuation is made based upon market rent values. These valuation data are referred to as 'rent'. Appendix B gives further detail about how the VOA data was prepared.

To add the rent data to firms in the panels, the firms had to be coded according to what type of commercial space they likely used, office, retail, or warehouse. This was done using the indcat variable. In most cases the match between industry sector to type of commercial space was obvious, for instance finance and office space. It was less so for some industry categories, introducing error from mismatched rents. For example, the agriculture/fuels/manufacturing sector was assigned office, even though many of these firms may have used warehouse space.

The data was joined by postcode, such that a firm had a rent value for each year it was in the panel. Given that the variable represents the average assessed value of a type of commercial space over the postcode the firm was located in, rather than what the firm's actual cost was, there are several sources of error that could affect outcomes. However, the variable is at least consistent from year to year for each firm, so that trends with rising/declining rents can be seen, and how rent changed before and after a move.

6.9.2 Accessibility data

Three different accessibility variables were added to the panels. The first is an index of public transportation quality called Public Transit Accessibility Level (PTAL), produced by Transport for London (TfL). PTAL is calculated for each postcode based on the type, frequency, and travel time of bus and rail public transit available there. A higher score means better quality transit access. TfL is constantly refining the index and changing how it is calculated, such that staff advise against comparing it from year to year. Therefore I used only the PTAL for 2006 for this study. This means that accessibility improvements over time are not captured by this variable. Unlike the rent variable, where the firm can remain in place while rent values change from year to year, PTAL score is each year, unless the firm moved. It is useful for comparing changes in accessibility before and after a move.

The second two accessibility measures are similar, as they were both calculated using the space syntax integration (SSI) method pioneered by the research group of the same name at University College London[16]. The SSI is basically a measure of closeness. It calculates the angular distance to reach all destinations on the road network up to a given radius, including 2.5 times further on the rail network. Unlike the PTAL, it does not reflect the quality of bus service. For this study, SSI scores were calculated by postcode for all destinations within a 2 kilometer radius (SSI_2) and 10 kilometer radius (SSI_10) of Charing Cross station in Central London. A 2 km radius captures walkability, while the 10 km represents access by transit and driving. Higher SSI scores mean higher accessibility, or greater closeness to more destinations. A firm that stayed in place may have had a rising SSI_2 or SSI_10 score over time, due to changes in the road or rail networks. For example, when mapped, the SSI_10 scores reflected accessibility improvements due to new Tube capacity to the east and southeast of the congestion charge area (the Jubilee line, opened in 1999).

Average accessibility and each year for firms on the non-micro panel are shown in Table 6.15. The averages reflect all firms in the panel, including those that stayed in place and those that moved. The average PTAL score increased from 35 in 1997 to 38 in 2012, an increase of 9%. Since the PTAL did not change from year to year, the fact that it increased on average means that firms were optimizing for transit accessibility over time. The average could have increased due

[16] Methodological details are available on the Space Syntax group website, https://www.bartlett.ucl.ac.uk/graduate/research/space/space-syntax. The values used for this study were calculated by postcode by a PhD student member of the group, Stephen Law.

to new firms choosing high PTAL locations when they entered the region, and due to firms relocating to higher-PTAL locations. The average SSI_2 score increased from 509 in 1997 to 549 in 2012 (8%), and the average SSI_10 score increased from 8562 in 1997 to 9091 in 2012. These increases reflect a combination of network improvements and firms optimizing their locations on the network when entering and relocating.

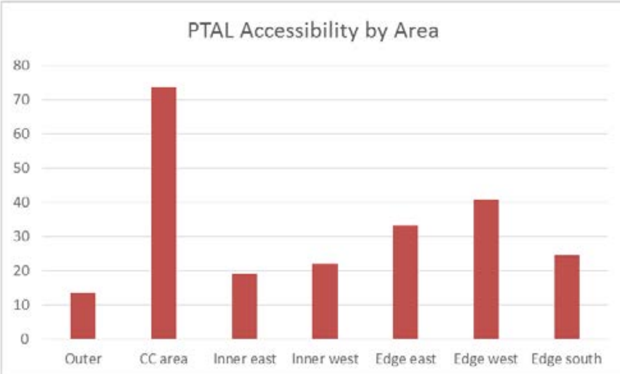
Table 6.15 also shows the average rents paid by firms for office and retail space. In general, office space is cheaper than retail space. In 1997, office rent was £118 per square meter on average, and retail was £157 per square meter. However, office rents rose in price more rapidly than retail during this timeframe. By 2010, office space was £239 per square meter on average, an increase of 103%, and retail space averaged £275 per square meter, an increase of 76%.

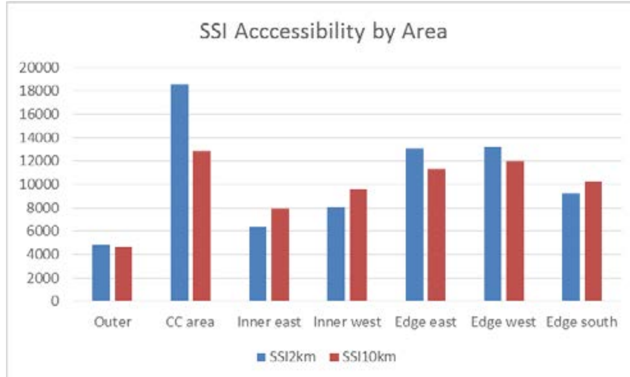
The average PTAL, SSI_2 and SSI_10 scores among firms in the previously defined geographic areas is shown in Figure 6.21. As expected, firms in the CCZ have the highest scores on all three measures. The areas with the second-highest scores are the Edge areas to the east and west of the CCZ. Interestingly, the southern Edge has much lower accessibility by all three measures, even though it is geographically just as central. This result reflects historically less intensive development of rail transit south of the Thames.

Table 6.15 Average accessibility and rent among firms in the non-micro panel

Year	Average PTAL_06	Average SSI_2	Average SSI_10	Average Office rent (psm)	Average Retail rent (psm)
1997	35	509	8562	118	157
1998	35	511	8591	124	162
1999	35	514	8631	132	169
2000	35	516	8684	139	176
2001	36	524	8754	145	183
2002	36	524	8752	150	191
2003	36	521	8720	154	199
2004	36	524	8751	159	207
2004	36	528	8785	166	217
2006	37	533	8848	178	226
2007	37	537	8910	193	238
2008	37	539	8954	208	249
2009	38	541	8994	224	262
2010	38	545	9052	239	275
2011	38	547	9073		
2012	38	549	9091		
Percent change	9%	8%	6%	103%	76%

Figure 6.21 Average accessibility scores among firms by geographic area





In order to understand which industries value accessibility the most, firms were sorted into five PTAL quantiles and then the percentage of firms in each industry in the top and bottom quintiles was compared. To measure the 'accessibility orientation' of each industry sector, the ratio between the percentage of firms in the highest accessibility quintile to the percentage of firms in the lowest accessibility quintile was calculated. Results are shown in Table 6.16. Sectors lacking a preference for accessibility would be evenly spread among quintiles, with about 20% in each. Sectors preferring high accessibility have percentages of firms in the top quintile (above 20%), and sectors that are motor vehicle-oriented or prefer to disperse have more than 20% of firms in the lowest quintile. Since a measure based on transit quality was used for this analysis, the PTAL, these results may also be interpreted as the 'transit orientation' of each sector[17].

The results shown in Table 6.16 corroborate well with the location quotient analysis shown in Table 6.7. However, while the location quotient revealed which sectors prefer to cluster with firms in the same sector, the accessibility orientation ratio reveals which sectors prefer to cluster in locations with high transit accessibility. The same Type III sectors that had the highest location quotients top the list: Finance, Legal, and Insurance. Other 'knowledge' sectors also showed a high value of accessibility: Media Production, Advertising/Market Research, Business Mgmt/Consulting/PR. A couple of sectors that might be expected to have a high transit orientation have a lower ratio, likely due to large average firm size: Education and Health/Social Work. As expected, sectors with high flows of material goods, or spatial needs for goods storage, are at the bottom of the list: Motor Vehicles, Construction, Agriculture, Wholesale, Freight. Other population serving sectors, which tend to disperse, also had low ratios: Retail and Restaurants.

[17] This is not to say that these industry sectors deliberately seek out transit oriented locations, but that their location preferences overlap with factors that make transit function well; that is, large firm clustering correlates with density.

Table 6.16 Ratio of 'accessibility orientation' (percentage of firms in top PTAL quintile to bottom PTAL quintile)

Industry sector	Percent in bottom PTAL quintile	Percent in top PTAL quintile	Ratio	Type
Finance	3%	55%	19.0	III
Legal	3%	35%	13.7	III
Insurance	6%	45%	7.0	III
Media Production	10%	37%	3.7	III
Advertising & Market Research	8%	30%	3.7	III
Business Mgmt Consulting & PR	9%	34%	3.6	III
Theatre & Cinema	11%	26%	2.4	IV
Accounting & Auditing	11%	23%	2.1	III
Business Support Services	13%	28%	2.1	IV
Retail - Secondhand & Repair	12%	23%	1.9	IV
Real Estate & Property Mgmt	14%	27%	1.9	IV
Computers, Telecomm, R&D	14%	25%	1.8	III
Non-profit Orgs & Interest Groups	13%	22%	1.7	IV
Transport - Intercity & Tourism	14%	24%	1.6	II
Hotels & Lodging	11%	18%	1.6	IV
Restaurants & Food Service	13%	21%	1.6	I
Arch, Planning & Engineering	13%	21%	1.5	III
Retail - Personal Goods	16%	18%	1.1	I
Retail - Non-store	18%	18%	1.0	IV
Personal Services	19%	18%	0.9	IV
Publishing	21%	15%	0.7	IV
Sports & Culture	29%	14%	0.5	IV
Public Admin & Utilities	31%	15%	0.5	IV
Retail - Household Goods	22%	9%	0.4	I
Retail - Food, Alcohol, Tobacco	19%	8%	0.4	I
Education	26%	10%	0.4	IV
Wholesale	33%	12%	0.3	I
Transport - Freight & Storage	42%	11%	0.3	II
Health & Social Work	25%	6%	0.3	IV
Ag, Fuel & Manufacturing	40%	6%	0.2	I
Transport - Urban	34%	4%	0.1	II
Construction	43%	4%	0.1	II
Transport - Motor Vehicles	41%	2%	0.0	I

6.9.3 Changes in rent and accessibility among firms that moved in/out of the CCZ

It was hypothesized that firms moving into the CCZ were willing to pay higher rents in order to gain accessibility benefits, especially firms in high accessibility oriented sectors named above, while firms in other sectors moving out were willing to have a less accessible location with a lower rent. This proposition was investigated by comparing firms' rent and accessibility before and after moving into or out of the CCZ. To compare changes over time, averages for three periods are shown in Table 6.17.

The results were all as expected. Firms that moved into the CCZ increased their accessibility and rents, and those that moved out decreased them. Interestingly, the percent change in accessibility has been going down over time, for all three measures, for both moves in and out of the CCZ. This implies that the relative difference in accessibility is being reduced over time, that is, competing locations outside the CCZ have been able to offer better accessibility, or more similar to the CCZ. This is also evident in the rising average accessibility scores for firms moving out of the CCZ, over time. For example, the average PTAL score for firms moving out of the CCZ in period 1 was 31 after the move, but in period 3 it was 33; average SSI_2 scores rose from 901 to 916, and average SSI_10 scores changed rose from 12541 to 12789.

Table 6.17 Comparison of accessibility and rent among firms that moved in/out of CCZ

	Moves into CCZ			**Moves out of CCZ**		
	Period 1: 1997 to 2002	**Period 2: 2003 to 2007**	**Period 3: 2008 to 2012**	**Period 1: 1997 to 2002**	**Period 2: 2003 to 2007**	**Period 3: 2008 to 2012**
Average PTAL_06						
Before move	30	33	30	67	68	71
After move	70	70	69	31	31	33
Percent change	135%	114%	129%	-54%	-54%	-54%
Average SSI2km						
Before move	490	511	492	901	895	916
After move	918	914	900	492	508	529
Percent change	87%	79%	83%	-45%	-43%	-42%
Average SSI10km						
Before move	9377	9533	9513	12541	12460	12789
After move	12662	12622	12699	9440	9554	9886
Percent change	35%	32%	33%	-25%	-23%	-23%
Average Retail Rent						
Before move	172	220	260	246	322	399
After move	245	312	357	156	200	238
Percent change	42%	42%	37%	-37%	-38%	-40%
Average Office Rent						
Before move	137	165	215	176	224	310
After move	184	223	302	135	169	217
Percent change	34%	35%	40%	-23%	-25%	-30%

The same trend held true for retail rents – the gap between the CCZ and competing locations lessened over this timeframe. For example, in period 1, firms had to pay 42% higher rent when they moved into the CCZ, on average, but by period 3 the rent was only 37% higher. The trend for office rents was the opposite. The gap between office rents in the CCZ and competing locations widened. Firms moving into the CCZ had to pay 34% higher rents in period 1, but 40% higher rents in period 3. These rent trends may reflect increasing demand for office space by Type III sector firms, and reduced demand from the Retail sector, which values accessibility less.

6.10 Modeling firm relocations

The final part of this study seeks to identify the relative importance of factors influencing firm relocations such as increased accessibility, rising rents, and employment growth, using statistical modeling techniques. As a relocation is a binary choice (to move or not to move), binary logistic regression was the method chosen. Models were estimated for three dependent variables. First, using the entire non-micro panel, a model on the variable 'moved' estimated parameters influencing a firm to move. Next, using only the firms that moved, two separate models were estimated on the variables 'ccmin', representing whether a firm moved into the CCZ or not, and and 'ccmout', representing whether a firm moved out of it or not. For all models, results were reported as odds ratios, rather than coefficients, for ease of interpretation.

6.10.1 Factors influencing a firm to move

Results for the regression on 'moved' are shown in Table 6.18. All the variables representing characteristics of the firm had the expected magnitudes and signs, and were significant: age, jobs, turnover, accessibility, and rent. The odds ratios for age (.971) and jobs (.911) confirmed that the odds of moving generally decline with firm age and size. The odds ratios for turnover (1.017), accessibility (1.003) and rent (1.001) were all very close to 1, indicating that these factors do not have a meaningful influence on firm relocation.

Several variables were calculated to represent change in rent, employment, and accessibility. The continuous variable 'rentpchg' was a simple calculation of the percent change in rent from year 1 (the year prior to moving), to year 2 (the year of the move). The high odds ratio for rentpchg (4.769) demonstrated that odds of moving greatly increased as the percent change in rent increased.

Because changes in employment and turnover were more volatile than rent changes, in this dataset, dummy variables were used to represent simple increases and decreases in these factors, rather than percent change. If the firm's number of jobs increased from year 1 to year 2 , then 'jobinc' had a value of 1, and it the number of jobs decreased, then 'jobdec' had a value of 1. Similar dummy variables represented changes in turnover, 'turninc' was 1 if the firm's turnover increased from year 1 to year 2, and 'turndec' was 1 if the firm's turnover decreased. The magnitudes for jobinc and jobdec were higher than for turninc and turndec, as expected. The variable turndec was not significant and was found to be too collinear with jobdec, and so it was removed. The others were all significant, with jobinc (1.797) increasing the odds of moving the most, jobdec (1.669) somewhat less, and turninc (.956) reducing the odds of moving.

Table 6.18 Results of logistic regression on 'moved' variable

moved	Variable definition	OR	P>|z|	Significant
age	Number of years firm has been in business	0.971	0.000	x
jobsln	Firm's employment, natural log	0.911	0.000	x
turnoln	Firm's turnover, natural log	1.017	0.000	x
ptal06	Firm's PTAL index score	1.003	0.000	x
rentpsm	Average rent per square meter in the firm's class (office, retail, warehouse) and postcode	1.001	0.000	x
rentpchg	Percent change in rent in the year of the move	4.769	0.000	x
jobdec	Employment decline in the year of the move (dummy)	1.669	0.000	x
jobinc	Employment increase in the year of the move (dummy)	1.797	0.000	x
turninc	Turnover increase in the year of the move (dummy)	0.956	0.000	x
i.ptalquant	PTAL quintile (categorical)			
2	2 - second quintile	1.008	0.626	
3	3 - third quintile	1.043	0.011	x
4	4 - fourth quintile	1.241	0.000	x
5	5 - fifth quintile	1.332	0.000	x
i.ptalpccat	Percent change in PTAL (categorical)			
2	2 - 50% to 100%	4.079	0.000	x
3	3 - greater than 100%	7.345	0.000	x
4	4 - 0 to -25%	0.894	0.000	x
5	5 - -25% to -50%	3.121	0.000	x
6	6 - less than -50%	6.487	0.000	x
i.rentquant	Rent quintile (categorical)			
2	2 - second quintile	1.249	0.000	x
3	3 - third quintile	1.461	0.000	x
4	4 - fourth quintile	1.455	0.000	x
5	5 - fifth quintile	1.496	0.000	x
i.rentpccat	Percent change in rent (categorical)			
2	2 - 30% to 60%	0.993	0.785	
3	3 - 60% to 90%	1.331	0.000	x
4	4 - greater than 90%	17.747	0.000	x
5	5 - less than 0	28.228	0.000	x

The odds ratio outputs of binary logistic regression offer a convenient way to compare categories, and so several categorical variables were constructed to compare the influence of different categories of rent and accessibility changes. The variable representing accessibility quintiles, 'ptalquant', showed that the highest quintile had the highest odds of moving (1.332). this results corroborates the results of the move rate calculation in Table 6.10 and accessibility orientation ratio in Table 6.16. Many of sectors which valued accessibility the most, and would be expected to have a PTAL score in the top quintile, were also the most footloose. The odds of moving were also high for the second-highest quintile (1.231), indicating that these effects are felt in both categories. The odds for quintiles 2 and 3 were both close to 1, and results were only significant for quintile 3. This implies that for these categories, the odds of moving were not much different from the base quintile, which we also know from the previous analyses had low odds.

The categorical variable representing percent change in PTAL from year 1 to year 2, ‘ptalpccat’, was a bit more complicated to interpret because it has categories representing both increasing and decreasing accessibility. Results for all categories were significant. The base category represented a small increase in accessibility of up to 50%. The odds of moving greatly increased for category 2 (4.079), a percent change of 50% to 100% in accessibility, and category 3 (7.345), over 100% improvement in accessibility. Odds of moving were lower for firms which did not have accessibility improvements. The odds for category 4 (.894), a slight decrease in accessibility of zero to 25%, were lower than for the base condition of a slight increase, but the category was only half as large. Similarly, the odds for category 5 (3.121), a 25% to 50% reduction in accessibility, and category 6 (6.487), more than 50% reduction, were smaller than the increase categories, but getting to similar magnitude. Rather than an influence on moving, these results shows that firms which moved were more likely to do so as the gap in accessibility increased. That is, they were more likely to make a major change in accessibility than a minor one. However, due to how the categories were calculated, it is unclear which was stronger, the odds of increased or decreased accessibility.

Rent quintiles were represented by ‘rentquant,’ which had significant results for all categories. The odds ratios were all higher than the base category, showing that in general, the odds of moving increase as rent increases. The odds ratio for the second quintile (1.249) were the lowest, and odds for the third (1.461), fourth (1.455) and fifth (1.496) quintiles were all quite similar in magnitude. This reinforces the result of the continuous rentpsm variable which showed that high rent is not itself associated with firm relocation, the change in rent is much more important.

The variable ‘rentpccat’ measured percent change in rent, similarly to ptalpccat. The base category was a small increase in rent, up to 30%. The odds for category 2 (.993) showed unexpectedly that odds declined as rents increased by 30% to 60%, but this was not a statistically significant result. Odds ratios for categories 3 (1.331), a 60% to 90% increase in rent, and 4 (17.747), an increase of greater than 90%, showed the expected result - the odds of moving increased as the percent change in rent increased. Yet the results for category 5 (28.228), which was a percent change less than zero, or rent decrease, showed the highest odds of moving. Again, these results are not influencing factors on the move, but characteristics shared by firms that actually moved. These results indicate that odds were much higher that firms which moved had lower rents afterwards than higher.

Taken all together, these results imply that the pull of lower rent is stronger than the pull of higher accessibility, for the general population of firms. The next two sections investigate the characteristics of firms making two special types of move: into and out of the CCZ.

6.10.2 Factors influencing a firm to move into the CCZ

To better understand the influence of accessibility and rent factors on firms moving into the CCZ, models were estimated using variables representing these factors for firms, before and after they moved. Time-series binary logistic regression models were estimated for the dummy variables 'ccmin,' which had a value of 1 in the year the firm moved into the CCZ, and 'preccmin,' which had a value of 1 in the year before the move. Models were estimated for each of these dependent variables for two time periods, before and after the CCZ was implemented. Results are shown in Table 6.19.

For period 1, results for the variable representing quintiles of rent (rentquant) demonstrated that rents generally went up for firms that moved into the CCZ. Before moving, odds for the second (2.048), third (2.356), and fourth (2.066) quintile were roughly the same, meaning that firms that moved into the CCZ had roughly equal odds of being in any of the rent quintiles (over the bottom one). Odds were lower for firms in the highest rent quintile, but these results were not statistically significant. Firms that had moved had very high odds of being in the fourth (16.565) or fifth (22.105) quintiles. These patterns intensified somewhat in period 2. Before moving, firms in the third rent quintile had the highest odds of moving in the CCZ (2.267), and the odds decreased somewhat for the other quintiles. The odds of firms that moved being in the third rent quintile increased (to 8.745), while the odds of being in the second quintile decreased (to1.597).

Results for the variable representing percent change in rent (rentpccat) were only significant for firms after they moved. This indicates that changing rents were not a factor influencing firms to move into the CCZ. After they had moved, firms had the highest odds of being in rent percent change category 4 representing a greater than 90% change in rent (2.959). This pattern also intensified in period 2, when the odds for this category increased (to 3.422).

Results for the variable representing accessibility quintile (ptalquant) showed a similar pattern to the results for rentquant, which was expected, as these variables are correlated. Before moving, firms in the third accessibility quantile had the highest odds of moving into the CCZ (2.306). Firms that had moved had very high odds of being in the fourth (38.543) or fifth (65.810) quintiles. This pattern was not as strong in period 2. Among firms that moved, the odds decreased of being in the fourth (24.676) or fifth (36.393) quintiles, and increased slightly for being in the third quintile.

Results for the variable representing change in accessibility (ptalpccat) demonstrated that firms that moved into the CCZ improved their accessibility score. In period 1, the odds ratio increased as the percent change in accessibility increased, from category 2 (2.194) representing a 50% to 100% increase, to category 3 (9.389) representing an increase of over 100%. The odds ratio decreased as the percent change in accessibility decreased, from category 4 (.598) representing a reduction of zero to -25%, to category 5 (.254) representing a reduction of -25% to -50%, to category 5 (.097) representing a reduction of more than -50%. The results showed a similar pattern in period 2, with slightly lower magnitudes. These results indicate that very few firms that moved into the CCZ experienced a reduction in their PTAL score.

Table 6.19 Results of logistic regression on 'ccmin' variable for accessibility and rent factors

		Period 1:1998 to 2004				Period 2: 2005 to 2012			
		Before move into CCZ (preccmin)		After move into CCZ (ccmin)		Before move into CCZ (preccmin)		After move into CCZ (ccmin)	
Variable	Variable definition	OR	P>|z|	OR	P>|z|	OR	P>|z|	OR	P>|z|
i.rentquant	Rent quintile								
2	2 - second quintile	2.048	0.006	2.356	0.000	1.597	0.035	1.718	0.000
3	3 - third quintile	2.563	0.000	7.869	0.000	2.267	0.000	8.745	0.000
4	4 - fourth quintile	2.066	0.005	16.565	0.000	1.601	0.029	16.250	0.000
5	5 - fifth quintile	1.634	0.064	22.105	0.000	0.894	0.637	19.223	0.000
i.rentpccat	Percent change in rent								
2	2 - 30% to 60%	1.292	0.474	1.476	0.001	0.813	0.538	1.417	0.007
3	3 - 60% to 90%	1.842	0.104	1.291	0.064	0.435	0.063	1.265	0.096
4	4 - greater than 90%	1.065	0.834	2.959	0.000	0.606	0.053	3.422	0.000
5	5 - less than 0	1.669	0.081	0.687	0.000	1.253	0.367	0.683	0.001
i.ptalquant	PTAL quintile								
2	2 - second quintile	1.411	0.004	2.630	0.000	1.622	0.000	2.299	0.000
3	3 - third quintile	2.306	0.000	6.152	0.000	2.126	0.000	6.860	0.000
4	4 - fourth quintile	1.720	0.002	38.543	0.000	1.427	0.000	24.676	0.000
5	5 - fifth quintile	0.479	0.000	65.810	0.000	0.478	0.000	36.393	0.000
i.ptalpccat	Percent change in PTAL								
2	2 - 50% to 100%			2.194	0.000			2.117	0.000
3	3 - greater than 100%			9.389	0.000			8.676	0.000
4	4 - 0 to -25%			0.598	0.000			0.537	0.000
5	5 - -25% to -50%			0.254	0.000			0.342	0.000
6	6 - less than -50%			0.097	0.000			0.092	0.000

Taken all together, these results indicate that firms that moved into the CCZ were optimizing for accessibility. They generally came from the third quintile for rent and accessibility, and landed in the top two quintiles. As the PTAL is a measure of transit accessibility, this implies that firms improved their transit accessibility by 20% to 40%. In contrast to the results for all types of moves shown in Table 6.18, these results demonstrate that the odds of increased accessibility were much higher than for decreased accessibility, for firms that moved into the CCZ. Higher magnitudes on the accessibility change variables than the rent change variables indicates that accessibility exerted the strongest pull for these firms. The pull was strongest in period 1, perhaps because the gap between accessibility and rents between the CCZ and competitor locations was the widest in period 1. These factors have equalized somewhat in period 2.

6.10.3 Factors influencing a firm to move out of the CCZ

A similar analysis was conducted to better understand the influence of accessibility and rent factors on firms moving out of the CCZ. Time-series binary logistic regression models were estimated for the dummy variables 'ccmout,' which had a value of 1 in the year the firm moved out of the CCZ, and 'preccmout,' which had a value of 1 in the year before the move. This allowed for a comparison of the firm's rent and accessibility characteristics before and after the move. Models were estimated for each of these dependent variables for two time periods, before and after the CCZ was implemented. Results are shown in Table 6.20.

Table 6.20 Results of logistic regression on 'ccmout' variable for accessibility and rent factors

		Period 1:1998 to 2004				Period 2: 2005 to 2012			
		Before move out of CCZ (preccmout)		After move out of CCZ (ccmout)		Before move out of CCZ (preccmout)		After move out of CCZ (ccmout)	
ccmout	**Variable definition**	**OR**	**P>|z|**	**OR**	**P>|z|**	**OR**	**P>|z|**	**OR**	**P>|z|**
i.rentquant	Rent quintile								
2	2 - second quintile	1.118	0.770	1.998	0.000	x		2.245	0.000
3	3 - third quintile	2.818	0.001	2.388	0.000	x		3.061	0.000
4	4 - fourth quintile	5.762	0.000	1.772	0.000	x		1.890	0.000
5	5 - fifth quintile	5.984	0.000	1.339	0.001	x		1.375	0.000
i.rentpccat	Percent change in rent								
2	2 - 30% to 60%	0.977	0.954	1.213	0.114	1.139	0.756	1.135	0.339
3	3 - 60% to 90%	1.241	0.616	1.076	0.609	1.127	0.791	1.335	0.037
4	4 - greater than 90%	2.234	0.008	0.584	0.000	1.978	0.038	0.560	0.000
5	5 - less than 0	1.150	0.654	2.599	0.000	0.872	0.689	2.758	0.000
i.ptalquant	PTAL quintile								
2	2 - second quintile	0.996	0.000	1.569	0.000	1.464	0.000	1.445	0.000
3	3 - third quintile	2.065	0.000	2.301	0.000	5.344	0.000	1.847	0.000
4	4 - fourth quintile	10.666	0.000	2.054	0.000	20.069	0.000	1.520	0.000
5	5 - fifth quintile	13.158	0.000	0.556	0.000	26.468	0.000	0.405	0.000
i.ptalpccat	Percent change in PTAL								
2	2 - 50% to 100%			0.570	0.000			0.596	0.004
3	3 - greater than 100%			0.155	0.000			0.170	0.000
4	4 - 0 to -25%			1.841	0.000			1.412	0.000
5	5 - -25% to -50%			3.374	0.000			3.131	0.000
6	6 - less than -50%			14.329	0.000			12.385	0.000

The results for the variable representing quintiles of rent (rentquant) showed that the odds of moving out of the CCZ were higher for firms in the top two rent quintiles. In period 1, odds of moving out of the CCZ were higher for the fourth (5.762) and fifth (5.984) quintiles than for the third (2.818), and the results for the second quintile were not statistically significant. These firms had the highest odds of being in the third rent quintile, after the move (2.388). The odds of landing in the other rent quintiles were not much lower; the lowest odds were for the top rent quintile (1.339). These results indicate that firms in the top rent quintiles were the most likely to move out of the CCZ, but economizing on rent after the move was not a strong priority. In period 2, odds ratios were unable to be estimated for firms prior to moving. Results for firms after moving showed that the odds of ending up in the third rent quintile after the move increased the most, meaning seeking lower rents had become more of a priority.

Results for the variable representing percent change in rent (rentpccat) further illuminated rent savings trends. The variable representing percent change in rent before the move had significant results for moves out of the CCZ, indicating that rising rents were a statistically significant factor. In period 1, prior to moving, firms in category 4, representing a greater than 90% rent increase, had higher odds (2.234) of moving out of the CCZ. After moving, firms had the highest odds of being in category 5 (2.599) representing a rent percent change less than zero, or rent reduction. In period 2, the same pattern persisted. Prior to moving, firms with a greater than 90% rent increase had higher odds (1.978) of moving out of the CCZ. After moving, firms again had the highest odds, even a bit higher odds, of having reduced rent (2.758).

Results for the variable representing accessibility quintile (ptalquant) showed that firms moved to less accessible locations when they moved out of the CCZ. In period 1, before moving, odds of moving were highest for firms in the top two accessibility quintiles, the fourth (10.666) and fifth (13.158). This makes sense, as most locations inside the CCZ have a very high PTAL score. After they moved, firms had the highest odd of being in the third accessibility quintile (2.301). In period 2, the odds of firms in the top two accessibility quintiles moving out of the CCZ both doubled in magnitude, and more than doubled for those in the third quintile, meaning that firms in prime locations were increasingly pressured to move. These firms seemed to distribute more evenly among accessibility quantiles after moving in period 2. The odds of ending up in any quintile were between .4 and 1.8 for all quintiles.

Finally, results for the variable representing change in accessibility (ptalpccat) also demonstrated that firms that moved out of the CCZ tended to have a reduced accessibility score. The odds ratio increased as the percent change in accessibility decreased in period 1, from category 4 (1.841) representing a reduction of zero to -25%, to category 5 (3.374) representing a reduction of -25% to -50%, to category 6 (14.329) representing a reduction of more than -50%. The odds of improved accessibility after moving out of the CCZ were low, as demonstrated by the results for category 2 (..570) representing a 50% to 100% increase, and category 3 (.155) representing an increase of over 100%. %. The results showed a similar pattern in period 2. These results indicate that nearly all firms that moved out of the CCZ experienced a reduction in their PTAL score

Taken all together, these results show that rising rents were a significant factor for firms moving out of the CCZ. The results for all types of moves shown in Table 6.18 demonstrated that rising rents greatly increase a firm’s odds of moving, but this was found to be much more important for firms moving out of the CCZ than for firms moving in. . In contrast to the results in Table 6.18, where firms had roughly equivalent odds of increased or reduced accessibility after moving, firms that moved out of the CCZ were most likely to have reduced accessibility. The odds of greatly reduced accessibility (12.385) were twice as high for this type of move as for all moves (6.487).

6.11 Conclusion

The introduction discussed two major factors make the CCZ more attractive to firms (improved accessibility by public transit) and less attractive (rising rents). Industrial sectors were divided into four types based upon the type and incidence of transport costs: Type I with direct monetary costs and indirect travel time costs; Type II with direct monetary and travel time costs; Type III with direct travel time costs and indirect monetary costs, and Type IV with indirect monetary and travel time costs. This study hypothesized that Type III, Type IV firms in growing industries, and large firms benefit the most from accessibility benefits and environmental amenities in the CCZ, and will therefore be the most likely to remain or expand there, or to move in. Type I firms, Type IV firms in shrinking industries, and micro-enterprises are expected to be the most sensitive to increased costs in the CCZ, both due to rising transport factor costs and rising rents associated with these changes, will be more likely to move out. Several analyses presented in this study produced evidence that sorting processes are underway in London. Type III and larger firms are tending to concentrate in the CCZ at higher rates since its implementation, and Type I and II firms are tending to locate or relocate elsewhere.

The spatial distribution of analysis of the non-micro panel revealed a dramatic trend of increasing spatial concentration of larger firms within the CCZ, and declining concentration in the Outer Boroughs. The micro panel also showed increasing concentration within the CCZ over time, and declining concentration in the Inner East boroughs and Edge West area. When the trend was indexed, it became clear that concentration of firms in the CCZ began in 2000, and the rate of concentration has been increasing since 2004. The rate of larger firm deconcentration in the Outer Boroughs has increased in parallel. This analysis confirmed the hypothesis that larger firms were expected to benefit more from locating inside the transit-rich CCZ than smaller firms.

The spatial agglomeration analysis tested the prediction that firms in Type III industry sectors, which benefit from agglomeration economies, would benefit the most from locating within the CCZ. Most Type III sectors showed increasing concentration in the CCZ from 1997 to 2012, with some notable exceptions. Both Finance and Accounting/Auditing showed a deconcentrating trend in this timefame for both micro and non-micro firms. Several growing Type IV sectors also showed increased concentration within the CCZ as expected, notably Sports/Culture, Hotels/Lodging, Real Estate/Property Management, and Theatre/Cinema. These are all sectors that benefited from increased tourism within the CCZ. The Real Estate/Property Management industry has also boomed with a historic flow of foreign capital into London's real estate market. Despite expectations, Construction showed strongly increased concentration. These are most likely the headquarters or management units of large firms, or could reflect some error due to SIC misclassification.

It was hypothesized that rising rents in the CCZ would spur a sorting process where larger firms would locate there more than smaller firms, because they value accessibility more. This analysis revealed that the rate of moves into and out of the CCZ had increased over time, but that more large firms were being retained than lost. From 1998 to 2000, approximately 300 non-micro firms moved into the CCZ annually, and 250 moved out but these flows increased to 500 in and 400 from 2003 to 2012. The ratio of moves into the CCZ to moves out increased from 1.02 in 1998-2002 to 1.14 in 2008-2012. For the micro panel, the ratio was .93 in 1998-2012, but this to .96 in 2008-2012. This is further confirmation of the hypothesis that larger firms benefit more from a high-accessibility location, and are more likely to relocate there as they grow. With higher retention of large firms, employment has also increased inside the CCZ. The net flow of jobs into the CCZ to out increased from .80 in 1998-2002 to 1.16 in 2008-2012. This would indicate a long-term shift toward large employers being attracted to the CCZ.

An industry sensitivity analysis sought to identify which sectors were the most sensitive to the accessibility changes brought by congestion charging and transit improvements by calculating odds ratios for firms moving into or out of the CCZ, before and after it was implemented. The odds of moving into the CCZ increased over time for nine of the industries that had a net gain in firms relocating into the CCZ after 2004: Computers/Telecomm/R&D, Advertising/Market Research, Business Support Services, Sports/Culture, Business Mgmt Consulting/PR, Publishing, Theatre/Cinema, Personal Services, Real Estate/Property Mgmt. These industries are considered the ones that benefit most from accessibility improvements and travel time savings due to congestion charging, and those that value these location factors the most. As expected, these were all Type III and IV industry sectors.

Industry sectors whose odds of moving out increased after the implementation of congestion charging were three expected Type I and Type II sectors: Restaurants/Food Service, Retail - Personal Goods, and Construction, and two unexpected Type III sectors, Media Production, and Arch/Planning/ Engineering. In London, there is anecdotal evidence that creative firms cluster East and South CCZ Edge areas in neighborhoods such as Shoreditch, Whitechapel, and Bermondsey. Perhaps these creative clusters place a greater value on aesthetics than centrality. If that is the case, then these sectors were not so much vulnerable to changes in the CCZ as opting out of it.

The role of accessibility and rents was tested by estimating binary logit models with the non-micro panel using dependent variables representing moves, and predictor variables representing rent and accessibility categories, for periods before and after the CCZ was implemented. The model for 'moved' predicting whether any firm in the population would move revealed that rising rents were the strongest predictor of a move, more than changes in employment, turnover, or accessibility. For the general population, the pull of lower rent was stronger than the pull of higher accessibility.

For firms moving out of the CCZ, rising rents were a statistically significant factor. Firms that moved out of the CCZ were most likely to have reduced accessibility. The odds of greatly reduced accessibility (12.385) were twice as high for this type of move as for all moves (6.487). Results were the opposite for firms moving into the CCZ, indicating that these optimized for accessibility. They generally came from the third quintile for rent and accessibility, and landed in the top two quintiles. As the PTAL is a measure of transit accessibility, this implies that firms improved their transit accessibility by 20% to 40%. For these firms, the odds of increased accessibility were much higher than for decreased accessibility, after they moved. Higher magnitudes on the accessibility change variables than the rent change variables indicated that accessibility exerted the strongest pull for these firms.

Concluding that the CCZ helped to make central London retain Type III and larger firms, then, is to conclude that it helped to improve the productivity and global competitiveness of London in the knowledge services and tourism economies.

Limitations

It must be emphasized that it was not the congestion charging policy itself that influenced firm location, but the significant improvements to transit service, walkability and bikeability that have differentiated the CCZ from the rest of the region as an ‘access amenity zone’ in terms of density of bus and rail transit service, density of bus lanes and other bus priority measures, density of bicycle lanes and shared bike stations, density of pedestrian crossings, and lower average traffic speeds. The CCZ is a zone of quick and easy travel, making it a more attractive area for doing business, in spite of rising rents. The pull of improved accessibility appears to have exerted a stronger pull on firms moving into the CCZ than the push of rising rents.

These findings are limited in that they cannot be attributed to any particular policy. They do not demonstrate that congestion charging and transit investment, and the benefits that they conferred, were the causal factor for firm relocations. There were many factors influencing the location choices of firms from 1998 to 2012. This evidence in this study is insufficient to conclude that optimizing accessibility was the primary one responsible for the sorting processes described in this study. However, it can be safely concluded that congestion charging did not have any type of dampening effect on the London economy. Paired with transit investment, it may have helped to hasten centralizing trends underway for other reasons.

Chapter 7. Conclusion

7.1 Policy implications

The findings of this research have many implications for transportation policy for cities in the U.S. and developing cities around the world that aiming to address traffic congestion and increased the attractiveness of urban centers.

Significant VMT reduction requires paired ‘carrot’ and ‘stick’ measures

London’s success reducing VMT via mode shift resulted from of its willingness to experiment with measures that actively discouraged driving, like congestion charging. Most cities, especially American cities, have focused exclusively on ‘carrot’ measures to reduce VMT, such as express transit services and park-and-rides, with limited success. For congestion charging to be the most effective, these measures and others that expand alternatives to driving must come first, or else crowding and evasion are likely to result.

Arguably, the public debate arising from just proposing congestion charging has a value unto itself. Policy proposals to explicitly de-prioritize private vehicular travel in congested urban centers force stakeholders to debate normative claims about desired urban quality and fair trade-offs between driving and other modes. At least two U.S. cities which have invited this debate by proposing congestion pricing, New York and San Francisco, have benefited from it. While neither city ended up implementing congestion charging, the debates resulted in increased political and public willingness to experiment with de-prioritizing cars in other ways, such as road space reallocation for buses and non-motorized modes. Introducing the idea of congestion pricing for public debate in developing cities with rapid motorization underway could play an additional role of shaping expectations as to the benefits and costs of car ownership. In the contexts where car ownership is still a luxury, it is important to normalize the idea of cars paying the fair share of the costs they impose on others, early on.

Institutional reform to create an integrated transit system optimizes its attractiveness

It is difficult to imaging London achieving is historic gains in transit ridership without the institutional reforms of the Greater London Act of 1999. This legislation transformed London’s fragmented and semi-privatized public transportation system into a fully integrated one under a single authority with a democratically elected chief, Transport for London. This allowed for seamless transfers between bus and rail with a single smartcard ticket, under a simplified fare system.

U.S. cities face two types of path dependency problems: extensive existing car-oriented transportation infrastructure and land use development patterns, and fragmented public transportation institutions. In most U.S. metropolitan regions, transit service is fragmented between locally-owned and operated systems in different parts of the region. The San Francisco Bay Area, for example, has fifteen local transit agencies with separate scheduling and ticketing. The service quality of each local service varies depending upon local political constituencies and other local factors. Some U.S. regions have a regional transportation authority which is able coordinate services, ticketing and fares, but examples of consolidated systems operated by a single agency are rare. Institutional reform is an important way forward for regions to achieve anywhere close to the effectiveness and mode shift realized in London.

High quality bus service can substitute for driving

London's experience with bus priority demonstrates that upgraded bus service quality substitute for driving. With high quality vehicles, customer service and competitive travel times, buses have absorbed drivers switching from cars, and provided a level of service suppressing car ownership among entering households. The humble bus, so often overlooked in U.S. cities, deserves more attention to realize this potential. In motorizing cities, investments in high quality bus service could serve to suppress motorization trends, and increase economic efficiency, as we are seeing with bus rapid transit investments. London's experience with developing

Road space reallocation is a key measure to improve bus services

The key measure that gave buses the competitive edge to driving was the reallocation of road space away from cars and toward buses. Not only is this a highly cost-effective approach, it has the double effect of improving bus operations and worsening driving conditions. In U.S. cities, highway HOV lanes are a step in the right direction, but they should be integrated into a regional network where buses have priority. In order to maintain a competitive advantage over driving, buses need to be able to cut through congestion on urban arterials. Not all bus lanes need to be in effect 24 hours per day, but during peak hours. More attention needs to be paid to the spatial allocation of road space, and de-prioritizing private motorized modes.

Road capacity released by congestion charging should be reallocated to other modes

In London, an unexpected outcome of congestion charging was the reallocation of released road capacity for buses, bicycles, and pedestrians. Inside the CCZ, road network was reconfigured slowly and incrementally to redistribute road space and travel time savings away from private vehicles, with the net result of 'locking in' lower network capacity. This was not a deliberate strategy, but the net outcome of many project-level designs and decisions. Yet it was appreciated by city officials as a good outcome, in hindsight, because of the widespread travel time and safety benefits these changes achieved.

This lesson learned could be applied by other cities in a more deliberate fashion. Releasing road capacity in order to re-balance and re-prioritize among modes could be an explicit goal of congestion charging. Many U.S. cities are currently struggling to recapture space from private vehicular traffic, and so congestion pricing or other forms of road pricing should be seen as a potential measure.

Congestion charging and accessibility benefits are likely to be capitalized into higher rents

The analysis of commercial rent trends revealed that office space, and to a lesser degree retail space, has been getting more expensive inside the CCZ than in comparable areas. Rising land values after transit investment is an expected outcome, as demonstrated by fast-rising rents along the new Jubilee Line extension in the part of the CCZ south of the Thames. Another factor is increased demand for central office space, which has driven up rents in Midtown. As with any policies that drive up land values, planners must be aware of how more sensitive sectors will respond. Measures may be taken to protect sectors that are both vulnerable and desirable, like independent retail.

The retail and restaurants sectors are among the likely to be vulnerable to rising costs associated with congestion charging

The firm location analysis of sensitive industry sectors revealed that retail and restaurants, two sectors which are key to a healthy and vibrant central business district, were sensitive to rising costs associated with congestion charging. This outcome was predicted based on rising factor costs for firms inside the CCZ. However, rising pedestrian travel in the CCZ implies that these firms might also be benefiting from increased footfall. Further research is needed to see how these costs and benefits are playing out for individual firms. There are larger forces afoot in the retail sector which may be impacting their competitiveness as well, like the development of large regional shopping malls in Inner London.

Accessibility improvements are valued most by ‘knowledge industry’ sectors

The analysis of firm location patterns in London revealed that the combination of travel time savings from reduced traffic congestion, increased transit frequency and pedestrian priority in the CCZ was attractive to ‘knowledge industry’ sectors and larger firms, which increased in concentration there in spite of rising rents. This demonstrates that transportation policies which reduce the disbenefits of traffic congestion can strengthen urban centers. By reducing the cost of employee travel and interaction, productivity benefits accrue to industry sectors that depend upon flows of information to succeed. The success of these industry sectors, which typically have large numbers of high-skill high-wage jobs can buoy the overall urban economy. Investing in accessibility was a key part of London’s post-industrial adaptation to a services economy.

7.2 Remaining questions and directions for future research

Location decisions of households

This dissertation set out to investigate ‘second order’ impacts of congestion charging on location decisions, but only thoroughly explored the location decisions of firms. A next step is to focus on households. How are households optimizing around the new accessibility offered by bus priority and rail transit investments, paired with congestion charging? I intend to conduct a sensitivity analysis, similar to the one in this study, to identify which households benefit most and which are most vulnerable to rising rents. My preliminary investigation of changes in household locations using Census data indicated that as higher income and skilled households have grown in the rapidly changing Inner East boroughs, the more vulnerable ones with lower income and older residents, are in decline.

Distribution of travel time savings by socio-economic class

Another key question on the distribution of benefits, which should be dug into with more depth, is how travel time savings from faster bus and rail transit travel are being distributed among Londoners, by socio-economic class. This study made it clear that bus travelers throughout Inner London are enjoying travel time benefits, but who is on the buses? Traditionally, and especially since concession fares have been expanded, buses have carried the young, senior, and non-working populations. However, as the buses attract a growing number of 'middle class' riders, the value of travel time savings is increasing. Another dimension of this question is about the spatial mismatch problem. I suspect that the new Overground service is saving lower-wage workers tremendous amounts of time commuting around the center to jobs just outside Inner London.

Land use development patterns and sub-centering in London

This study included an investigation into the potential land use impacts of congestion charging, but the analysis was not included here, as the findings were inconclusive as of yet. There are so many confounding factors at play in London. Development is both highly regulated and highly sought after. Several large redevelopment projects are underway on the edge of the CCZ at Network Rail stations, which have nothing to do with it, but with a long-planned effort to finance station upgrades and refurbishments through value capture.

A recent doctoral thesis exploring whether London is tending to develop sub-centers and more poly-centric urban structure also raises interesting questions about the role of transportation and accessibility. (Smith 2011) Some evidence of new cluster formation in areas of Inner London outside the CCZ was found, using data up to 2005. Whether this emerging pattern has strengthened or weakened since then deserves further exploration, as well as further examination of how these locations serve the needs of specific industry sectors. Also, the opening of Crossrail is a historic change to central London accessibility, the single greatest change since the development of the Underground. This new service will expand London's access to labor markets to a much larger area, presenting a great opportunity to gain further insight into the relationships between accessibility, firm location, and commuting behavior.

Institutional reforms

This study identified institutional reform as a key measure allowing London to adapt its transportation system to meet 21st century needs. As mentioned in this discussion, fragmentation of transportation and land use planning, and the delivery of public transportation systems, is a major barrier to achieving mode shift and reduced VMT. More attention to this issue is required in order to make thoughtful recommendations as to specific reforms at the local, regional and other levels. I intend to further study the roots of the Greater London Authority Act of 1999, and the politics surrounding its adoption, with the aim of finding transferable lessons learned.

Paired traffic restraint and transit investment measures offer value capture opportunities

Although there are many reasons for property value uplift in central London, improved accessibility is certainly one of them. As proposed in this study, the CCZ may be thought of an ‘accessibility amenity zone’ where the value of public investments is being captured by private land owners. Partly these investments have been financed by congestion charging, which as discussed has raised over £1 billion for buses so far. There may be ways to further leverage the value created by the CCZ to finance investments in the public realm and walkability. Further research is needed to identify potential mechanisms.

Comparative studies with New York and San Francisco

Finally, as a single case study, the findings of this research are more limited than a comparison of two or three cases. I aim to conduct comparative analyses of firm location patterns in New York and San Francisco to determine whether the patterns found in this study are unique to London, due to the CCZ and its other special circumstances, or whether there is a re-centering trend common to many cities, due to common factors in the global economy. I have conducted a preliminary analysis of firm location patterns in the San Francisco Bay Area which indicates that there is some movement back to the region’s core employment center, but the competing forces dispersing firms out to subcenters and the periphery are much stronger than in London. What is the role of accessibility, in the U.S.? If we invested on the scale that London has, would we see similar benefits?

Ultimately, the aim of my future research continuing along the lines of this dissertation is to determine how U.S. cities can best begin to reduce VMT, at scale. The example of London is inspiring. Identifying strategies for growing cities in the U.S. and around the world to move in the same direction, in spite of differences in terms of urban structure, transit infrastructure, and car ownership, is my goal.

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Appendix A. UK Administrative and Census geography

This dissertation draws upon several datasets which are published at various levels of UK administrative and Census geography.

Administrative units

Greater London is one of nine defined regions of England. It is composed of 32 boroughs and the City of London, which is treated like a borough for statistical purposes. UK Office for National Statistics maintains a website[18] dedicated to explaining the types of geographic units used for statistics, and how their boundaries have changed over time.

Figure A.1 Greater London boroughs

[18] "A Beginner's Guide to UK Geography," http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/index.html

Table A.1 List of Inner and Outer London boroughs

Inner London boroughs	Outer London boroughs
Camden	Barking and Dagenham
City of London	Barnet
Greenwich	Bexley
Hackney	Brent
Hammersmith and Fulham	Bromley
Haringey	Croydon
Islington	Ealing
Kensington and Chelsea	Enfield
Lambeth	Harrow
Lewisham	Havering
Newham	Hillingdon
Southwark	Hounslow
Tower Hamlets	Kingston upon Thames
Wandsworth	Merton
City of Westminster	Redbridge
	Richmond upon Thames
	Sutton

Each London boroughs is divided into an average of 20 electoral wards to elect councilors to the Borough Councils. Ward boundaries are revised every so often, making it necessary to convert between previous ward boundaries in order to study change over time. Table A.2 shows how the number of electoral wards has changed since 1990. When ward geography was used for this study, the boundaries from 2001 were used because they were stable for most of the study timeframe. I used lookup tables published by the Office for National Statistics (ONS) to convert between geographic units. The 2001 ward boundaries are shown in Figure A.2. The City of London has its own electoral wards, but for statistical purposes these are aggregated into three wards based on population, as shown in the figure.

Table A.2 Total number of wards in Greater London

	1990	1994	1998	2002	2014
Total number of wards	757	759	759	624	629

Source: ONS 2015

Figure A.2 Electoral ward boundaries in 2001

Census units

This dissertation most often uses small area geographic units defined by the UK Census. Data from the 1991 Census was published using administrative geographic units (boroughs and wards). In 2001, Census data was published using three new geographic units that were created based upon the data collected.

The lowest level, output areas (OAs), were drawn to represent approximately 300 residents, or 125 households. OAs were built from clusters of adjacent postcodes to fit within the boundaries of electoral wards, and using obvious boundaries such as major roads. They were also designed to be as socially homogenous as possible based on tenure of household and dwelling type, and to be entirely urban or entirely rural.

OAs were then grouped together to form larger geographic units for statistical reporting, known as super output areas (SOAs). Lower layer super output areas (LSOAs) are composed of 1,000 to 3,000 residents, and middle layer super output areas (MSOAs) contain 5,000 to 15,000 residents. The boundaries of all the output areas nest within each other, such that none are split. Since they are defined by population counts, the number and shape of OAs give an excellent representation of population density and neighborhood boundaries.

Due to population changes between the 2001 and 2011 Censuses, OA boundaries were revised in places with rapid population growth or decline. The average population size of each OA increased, and the total number of OAs increased. These changes are summarized in Table A.3. OAs that exceeded an upper population threshold (625 people) in 2011 were split into two or more OAs, and those that had shrunk below a lower population threshold (100 people) were merged with an adjacent OA. LSOAs and MSOAs were then modified accordingly.

Many areas of the UK are quite stable over time and were unaffected, but London had a high rate of population growth from 2001 to 2011, roughly twice that of rest of England. Therefore direct comparison cannot be made between, for instance, 2001 LSOAs and 2011 LSOAs, without using conversion tables published for this purpose.

Most of the analysis for this dissertation was done using 2001 LSOA geographic units, shown in Figure A.3 The UK Census has published data from 1991 and 2011 in 2001 LSOA units, to ease comparisons over time. When it was not available, I converted the units using ONS lookup tables.

Table A.3 Number and size of Census geographic units in London

Census geographic unit	**2001**	**2011**	**Percent change**
Output areas (OAs)	24,140	25,053	3.8%
Average population/OA	584	642	10%
Lower super output areas (LSOAs)	4,765	4,835	1.5%
Average population/LSOA	3,005	3,345	11.3%
Middle super output areas (MSOAs)	983	983	0%
Average population/MSOA	14,458	16,524	13.6%

Source: ONS, Changes to Output Areas 2012

Figure A.3 UK Census 2001 Lower Lever Super Output Areas (LSOAs)

Appendix B. List of Data Sources

Three types of data sources were used in this dissertation, 1) datasets published by public agencies, 2) unpublished data that is publicly available and 3) datasets that are not publicly available.

1. **Datasets published by public agencies**

Transport for London: Travel in London Reports, 2005-2014

Transport for London, 2014: Travel in London Reports. Downloaded from https://tfl.gov.uk/corporate/publications-and-reports/travel-in-london-reports.

The annual Travel in London reports summarize trends and progress toward goals for transport and travel set by the Mayor of London. Many types of relating to supply, demand, and travel behavior are reported, including trip-making and mode split patterns, performance of public transit systems, safety, and customer satisfaction. Most reports are published with a supplementary Excel spreadsheet containing the figures and data used in the report. They also include updates to long-term data series like the Central London Peak Count.

UK Census: 1991, 2001 and 2011

Office for National Statistics, 2011 Census: Aggregate data (England and Wales), Travel to Work. UK Data Service Census Support. Downloaded from: http://infuse.ukdataservice.ac.uk. This information is licensed under the terms of the Open Government Licence.

Office for National Statistics, 2001 Census: Aggregate data (England and Wales), Travel to Work UK Data Service Census Support. Downloaded from: http://casweb.ukdataservice.ac.uk / http://infuse.ukdataservice.ac.uk. This information is licensed under the terms of the Open Government Licence.

Office of Population Censuses and Surveys, 1991 Census: Aggregate data (England and Wales), Travel to Work. UK Data Service Census Support. Downloaded from: http://casweb.ukdataservice.ac.uk. This information is licensed under the terms of the Open Government Licence.

The UK Census uses standardized variable definitions and classifications to enable comparisons across time. I reviewed documentation of the variables that I used to ensure that they were counting the same things, and made adjustments where needed. I used population and car ownership data from the aggregate dat tables, and commute mode and distance data from the Travel to Work tables. The geographic units used for each Census were slightly different, which required me to convert between units. This issue is discussed in Appendix A in more detail.

UK Department for Transport: Road Traffic Survey

Department for Transport, 2014: National Road Traffic Survey, Traffic Congestion and Reliability Statitstics, Road Length Statistics. Downloaded from http://www.dft.gov.uk/traffic-counts/area.php?region=London. This information is licensed under the terms of the Open Government Licence.

Two types of traffic data are published by the UK Department for Transport (DfT): total annual volume of traffic by link (stretch of road), and annual average daily traffic flow of traffic by link. The borough is the smallest geographic unit for which these data are available. The data include counts by major 'A' roads and minor roads, and by vehicle type. Data are collected continuously on a network of automated counters on motorways and major roads (A roads). Once a year, these data are supplemented by manual counts (from 7:00 to 19:00) to identify vehicle type. VKT estimates are calculated for each link of the network by first multiplying average daily traffic flow by the length of the road link, and then by 365 days per year.

UK Ordnance Survey

Ordnance Survey, 2013: Strategi and Code Point Open. Downloaded from: https://www.ordnancesurvey.co.uk/business-and-government/products/finder.html. Contains OS data © Crown copyright [and database right] 2013.

Spatial datasets containing administrative boundary data, rivers and other natural features, transport networks, and station locations are made available by the UK Ordnance Survey.

2. Unpublished datasets that are publicly available

For data that were not published in standard surveys, I made use of a website called 'What do they know', https://www.whatdotheyknow.com/. Run by volunteers, this website publishes requests made by UK citizens under the Freedom of Information Act. Through this searchable service, I was able to find useful datasets from Transport for London such as the estimated parking spots on the TRLN network, and Public Transit Accessibility Level (PTAL) estimates by LSOA geographic units.

The PTAL is an accessibility index calculated based on the type, frequency, and travel time of bus and rail public transit available in each postcode. A higher score means better quality transit access. TfL is constantly refining the index and changing how it is calculated, such that staff advise against comparing it from year to year. Therefore I used only the PTAL for 2006 for this study. This means that accessibility improvements over time are not captured by this variable.

3. Datasets that are not publicly available

Business Structure Database (BSD): 1997-2013, Secure Version

Office for National Statistics. (2015). Business Structure Database, 1997-2014: Secure Access. 5th Edition. UK Data Service.

The research in Chapter 6 utilized data originally collected by the UK Office of National Statistics (ONS) in London, England. The data were provided to me under a confidentiality agreement. The ONS reviewed my research proposal and granted permission to use the secure access version of the Business Structure Database: 1997-2013. As an Approved Researcher, I accessed the data using the Virtual Microdata Lab at the ONS office at 1 Drummond Gate in Pimlico, London. The ONS bears no responsibility for the analysis and interpretation of results in this study, which are my own.

The BSD is derived from the Inter-Departmental Business Registry (IDBR), which is the live business registry of firms kept via Value Added Tax (VAT) and Pay As You Earn (PAYE) tax collection records. The IDBR accounts for 99% of economic activity in the UK. Only very small businesses not liable for VAT, or self-employed, are not in it. The BSD is an annual snapshot of the IDBR taken in April, and published for research purposes in September. To create it, the IDBR data are complemented with data from ONS business surveys to allow for tracking changes in ownership and restructuring of businesses. The reporting period is the financial year.

The BSD is published at two levels: 'enterprises', which represent the overall organization, and 'local units' which represent plants, or parts of the firm such as shops, branches, and factories. For each enterprise and local unit, a small number of variables is available, including employment, turnover, Standard Industrial Classification (SIC) codes for 1992, 2003 or 2007, postcode, and year of start-up, 'birth', and termination, 'death'. Enterprises which began trading prior to 1973, when the VAT was introduced, had their birth date set to 1973.

Bus Lane Database and other bus statistics

The research in Chapter 4 utilizes data provided to me by a person interviewed for this study, John Barry, Head of Bus Network Development for Transport for London. He provided the bus lane database, a GIS layer of bus lane locations, and specific data about the scope and extent of the bus network in response to my inquiries.

Space Syntax Integration Accessibility variables

I worked with a member of the Space Syntax research group at University College London, Steven Law, to create an accessibility index at the postcode level. He calculated two accessibility measures, one for walkability and another for long-distance travel by train or car. The SSI is basically a measure of closeness. It calculates the angular distance to reach all destinations on the road network up to a given radius, including 2.5 times further on the rail network. Unlike the PTAL, it does not reflect the quality of bus service.

For this study, SSI scores were calculated by postcode for all destinations within a 2 kilometer radius (SSI_2) and 10 kilometer radius (SSI_10) of Charing Cross station in Central London. A 2 km radius captures walkability, while the 10 km represents access by transit and driving. SSI_2 and SSI_10 scores were calculated for the years 1995, 2000, 2005, and 2010, and scores for intervening years were imputed using straight-line imputation.Higher SSI scores mean higher accessibility, or greater closeness to more destinations. Further methodological details about the Space Syntax Integration calculation are available on the Space Syntax group website, https://www.bartlett.ucl.ac.uk/graduate/research/space/space-syntax.

Commercial Property Valuation Data, 1995-2010

The UK Valuation Office Agency (VOA) provides property valuations and other property advice to support taxation activities. It maintains two property tax lists for all local councils in England and Wales: the ‘rateable value’ for commercial properties subject to Business Rates, and ‘tax band’ designations for domestic properties subject to Council Tax.

VOA data was used as a proxy for commercial rent in this study. It was suitable for this purpose because the tax valuation is made based upon market rent values. Properties are re-assessed every five years, and this study uses valuations from 1995, 2000, 2005 and 2010. The VOA data is published in three categories: office, retail and industrial.

For each commercial category, annual ‘rent’ values were imputed for each property for years in between valuations. For example, values were imputed for an office property assessed in 1995 and 2000 for the years 1996, 1997, 1998 and 1999, using straight-line imputation. For properties that had three sequential assessments, but lacked an assessed value in either the first or last year (1995 or 2010), an imputation algorithm was used to estimate the missing values. Values were imputed using the ‘impute’ command in Stata, which predicts future or past values using linear regression on existing data. No other missing data was imputed, including rent values for 2011 and 2012. For example, if a property had been assessed in only 2000 and 2005, values were filled in for intervening years, but not for years prior to 2000 or after 2005.

After the imputation of a fifteen year time series was complete, average rent values were calculated by postcode for each of the three commercial categories (office, retail, and warehouse). Some postcodes had many commercial properties from which to calculate averages, while others were sparse, especially in outlying areas and in the warehouse category.

Appendix C. List of people interviewed and examples of questions

Local government officials		
Michele Dix	Planning Director	Transport for London (TfL)
Charles Buckingham	Strategic Monitoring Manager	Transport for London (TfL)
Victoria Hills	Transport Investment Manager	Greater London Authority (GLA)
Margarethe Theseira	Senior Research Fellow	Center for London
Nick Lester	Transport Policy Manager	London Councils
Peter Rees	Chief of Planning	City of London
Hugh Brennan	Director of Transport Policy	City of Westminster
Michael Bach	Head of Town Center Retail Policy (retired)	UK Department of Community and Local Government (DCLG)
Brian Deegan	Bicycle Program Manager	Transport for London (TfL)
John Barry	Head of Bus Network Development	Transport for London (TfL)
Alex Williams	Director of Borough Planning	Transport for London (TfL)
Interest groups		
Vincent Stops	Senior Policy Officer	London Travel Watch
Irving Yass	Director of Transport and Planning (retired)	London First
Roger Geffen	Policy Director	Cyclists' Touring Club (CTC)
Andrew Bolitho	Policy Advisor	British Retail Consortium
Natalie Chapman	Head of Policy for London	Freight Transport Association
Pier Barrett	National Public Affairs Manager	London Chamber of Commerce
Richard Currie	Director of Public Affairs	UPS Europe
Martin Schulz	City Logistics and Public Affairs Manager	TNT Express
Transport and land use policy experts		
Martin Richards	Principal (retired)	MVA Transportation Consultants
Peter Hall	Professor	University College London
Michael Batty	Professor	University College London
Peter Jones	Professor	University College London
Robin Hickman	Professor	University College London
David Banister	Professor	Oxford University
Tim Schwanen	Professor	Oxford University
Rachel Aldred	Professor	Westminster University
Economic impacts experts		
Paul Cheshire	Professor	London School of Economics
Michael Hebbert	Professor	University College London
Michael Browne	Professor	Westminster University
Commercial property experts		
Greg Mansell	Head of Applied Research	IPD Property Group
Adrian Penfold	Head of Planning	British Land
Miles Price	Planning Executive	British Land
Rob Harris	Principal	Ramidus Consulting Ltd

Examples of interview questions

Questions for public officials:

- Why was the charge increased from 5 to 8 pounds, and then to 10 pounds?
- What was the role of bus priority, in reducing private car travel? How did the public react to road space reallocation?
- What other complementary measures were introduced?
- Were there any unexpected impacts of congestion charging?
- What were the anticipated drawbacks of congestion charging, and did they transpire?
- Why was the Western Extension zone removed? On paper, it seemed to benefit residents, so why were so many opposing it?
- Why has congestion returned to pre-charging levels, in the CCZ?
- Why is the congestion charging zone non-controversial today, in spite of the charge having doubled, and rising congestion levels?
- Do you anticipate the CCZ being extended again, at some point in the future? Or removed altogether?
- Have any trends in business location patterns been noticed or documented?

Questions for officials with a particular area (ie –borough or neighborhood):

- What sorts of complaints have you had from local constituents about congestion charging? (For instance, higher cost of parking, buses too full or slow, rents increasing)
- Did any businesses threaten to leave, if congestion charging was implemented? Have they left?
- Have any changes in business location patterns in or near the CCZ been noticed?

Questions for transportation and land use experts:

- What transport and land use measures have been implemented as a package aimed at reducing VMT, over the last 10 to 15 years? Which have made the biggest impact?
- What are the key 'carrot' and 'stick' transportation policies influencing the travel patterns we see today?
- Could London have achieved the mode shift and VMT reductions that it has, without implementing congestion charging? Would the other measures have been sufficient?
- How would London travel patterns be different today, without congestion charging?
- Who has benefited the most from congestion charging, and who has been disbenefited?
- Is there something special about London, that made bus priority and congestion charging feasible? Are these transferable policies?

Questions for interest groups:

- I saw the points of support or objection in the comments your group submitted when congestion charging was proposed. Have any of them come to pass?

- What comments would your group submit in a public consultation on congestion charging, today?
- Would your group support an extension of the CCZ? Or its removal?

Questions for economic impacts experts:

- What wider economic forces are currently shaping London's economic geography?
- Has the CCZ strengthened London's center, as a place for doing business? If so, in what ways?
- Has the CCZ had any longer-term or wider economic impacts?
- Has the CCZ influenced the amount and types of jobs inside and just outside the zone?
- Which industry sectors are most sensitive to congestion charging? To locating inside the CCZ?

Questions for commercial property experts:

- What are the major influences on Central London commercial property values?
- Do firms or property investors distinguish between locations inside and outside the CCZ, is it a criteria in the location decision?
- Has the CCZ influenced changes in land use or land values in CCZ, and on its edges?
- Has the CCZ influenced the amount or type of new development inside or on the edge of the zone?

Appendix D. Definition of variable 'indcat'

indcat value	Dummy variable	SIC03 2-digit and 4-digit	Industry activities
drop		95,96,97,99	Other - private household staff, organizations located outside the UK
1	afm	1,2,5,10,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,29,30,31,32,33,34,35,36; 7482 Packaging recoded as 23	Natural resources - agriculture, fishing, mining, quarrying, gas extraction; Natural products - food, textiles, apparel, wood, leather, paper; Manufactured products - chemicals, plastic, metal, machinery, furniture, electronic, medical, pharmaceutical,
2	pubutil	37,40,41, 75,90; 6411 National Post	Utilities – electricity, water, and gas supply, recycling, sanitation; Public administration, defense, social security
3	tspfr	60,61,62, 63,71	Land, water, air transport, cargo storage, support activities, other support, Renting of machinery, office equipment, home goods
4	tspurb	6021, 6022,6412	Urban bus and rail services, taxis courier services
5	tsptour	6010,6023,6210,6321,6330,7110	Intercity air, rail, coach transport, car rental, tours; Travel agents, tour operators
6	fin	65,67; 6511, 6512	Deposit-holding banks, central bank; Finance and credit, underwriting; Financial markets, security brokers, fund mgmt; Financial other - advisors, mortgage brokers, bureaux de change
7	comtelrd	72,73; 6420	Hardware consulting; Software consulting, development, supply, web pages; Data processing – data entry, scanning, web hosting; Database activities – web search, online data publishing; Other computer related activities; Scientific research & development
22	pub	22	Printing, reproduction of recorded media
45	const	45	Construction, civil engineering
50	mv	50	Wholesale and retail of vehicles, fuel, repair
51	ws	51	Wholesale trade except motor vehicles
53	retpers	5212,5231,5232,5233,5242,5247,5248	Non-food non-specialized retail, specialized retail, Chemists, Cosmetics, Clothing, Footwear & leather, Books, newspapers, magazines, office supply
54	rethh	5241,5244,5245,5246	Textiles, Furniture &lighting, Electrical and appliances, Hardware, building supply, paint, lawn mower, garden
55	hotel	5510, 5521, 5522,5523	Hotels, hostels, camping, other lodging
56	resto	5530, 5540, 5551, 5552	Restaurants, pubs, catering
57	retsec	5250, 5271, 5272, 5273, 5274	Second hand clothing, books, antiques; Repair of goods – shoes, electronics, watches, jewellery, bikes, etc
58	retns	5261, 5262, 5263	Mail order, vending, internet, door to door; movable stalls
59	retfood	5211,5221,5222,5223,5224,5225,5226,5227	Non-specialized stores with food, Fruit & veg, Meat, Fish, Bread, Alcohol, Tobacco, other retail of food
66	ins	66; 6720	Life and non-life insurance, pension funding, insurance agents
70	rest	70; 7470 industrial cleaning	Real estate, property mgmt & industrial cleaning
74	legal	7410,7411	Legal

76	acct	7412	Accounting, tax consulting
77	adv	7413, 7440	Market research, advertising
78	arch	7420, 7430	Architectural, urban planning, civil engineering, technical testing and certification
79	bizsup	7450,7460,7483,7484,7485,7486, 7487,7250	Labor recruitment, security, secretatial, translation, maintenance of office/accouting/computing machines
80	edu	80	Education
81	mgmt	81; 7414, 7415	Mgmt consulting, public relations, mgmt activities of holding companies
85	hsw	85	Health and social work
91	orgs	91	Non-profit business and professional member orgs, unions, political orgs, religious orgs, issue advocacy
93	pers	93	Dry cleaning, hair and nail salon, funeral home, gym, spa
96	media	7481,9211, 9212, 9220, 9240	Film/video, radio, TV & photography production and distribution, Journalism, new agencies
97	thecin	9213, 9231, 9232	Film projection, theatre and arts performance
98	cult	9233,9234,9251, 9252, 9253, 9261, 9262, 9271,9272	Libraries, museums, botanical & zoological gardens, sports facilities, gambling, fairs, arcades, dancehalls

Appendix E. Outputs from logit models testing industry sensitivity

Moves into the CCZ	**1998 to 2003**			
Industry Sector	**OR**	**z**	**p-value**	**Significant**
Accounting & Auditing	1.232471	0.71	0.477	
Advertising & Market Research	2.38	4.5	0	x
Ag, Fuel & Manufacturing				
Arch, Planning & Engineering	1.84	3.06	0.002	x
Business Mgmt Consulting & PR	1.87	3.51	0	x
Business Support Services	2.14	4.83	0	x
Computers, Telecomm, R&D	2.74	6.48	0	x
Construction	0.82	-0.96	0.337	
Education	1.20	0.71	0.479	
Finance	1.72	2.66	0.008	x
Health & Social Work	0.99	-0.07	0.941	
Hotels & Lodging	1.79	1.86	0.063	
Insurance	2.46	3.81	0	x
Legal	1.10	0.4	0.686	
Media Production	2.90	5.8	0	x
Non-profit Orgs & Interest Groups	1.73	2.06	0.04	x
Personal Services	1.57	2.28	0.023	x
Public Admin & Utilities	0.96	-0.09	0.93	
Publishing	2.16	4.09	0	x
Real Estate & Property Mgmt	1.47	2.29	0.022	x
Restaurants & Food Service	1.60	2.57	0.01	x
Retail - Food, Alcohol, Tobacco	1.24	0.65	0.514	
Retail - Household Goods	1.28	0.69	0.49	
Retail - Non-store	1.86	1.79	0.073	
Retail - Personal Goods	1.68	2.61	0.009	x
Retail - Secondhand & Repair	0.72	-0.45	0.653	
Sports & Culture	2.21	3.39	0.001	x
Theatre & Cinema	2.36	4.4	0	x
Transport - Freight & Storage	0.98	-0.1	0.918	
Transport - Intercity & Tourism	1.78	2.35	0.019	x
Transport - Motor Vehicles	0.57	-1.45	0.148	
Transport - Urban	0.97	-0.09	0.928	
Wholesale	1.15	0.79	0.428	

Moves into the CCZ	**2004 to 2012**			
Industry Sector	**OR**	**z**	**p-value**	**Significant**
Accounting & Auditing	1.430065	1.48	0.138	
Advertising & Market Research	2.87	6.68	0	x
Ag, Fuel & Manufacturing				
Arch, Planning & Engineering	2.29	5	0	x
Business Mgmt Consulting & PR	2.31	5.81	0	x
Business Support Services	2.34	6.18	0	x
Computers, Telecomm, R&D	3.42	8.93	0	x
Construction	1.26	1.37	0.17	
Education	1.43	1.94	0.053	
Finance	1.75	3.42	0.001	x
Health & Social Work	1.27	1.53	0.125	
Hotels & Lodging	1.32	1.16	0.245	
Insurance	2.25	3.74	0	x
Legal	0.83	-0.86	0.389	
Media Production	2.43	5.67	0	x
Non-profit Orgs & Interest Groups	1.79	2.64	0.008	x
Personal Services	1.95	3.97	0	x
Public Admin & Utilities	1.39	1.13	0.258	
Publishing	2.48	5.43	0	x
Real Estate & Property Mgmt	1.84	4.31	0	x
Restaurants & Food Service	2.21	5.42	0	x
Retail - Food, Alcohol, Tobacco	1.02	0.09	0.927	
Retail - Household Goods	2.08	2.82	0.005	x
Retail - Non-store	1.35	0.91	0.362	
Retail - Personal Goods	1.73	3.29	0.001	x
Retail - Secondhand & Repair	1.42	0.85	0.397	
Sports & Culture	2.27	4.3	0	x
Theatre & Cinema	2.42	4.95	0	x
Transport - Freight & Storage	1.39	1.73	0.084	
Transport - Intercity & Tourism	1.70	2.58	0.01	x
Transport - Motor Vehicles	0.80	-0.75	0.451	
Transport - Urban	0.94	-0.19	0.847	
Wholesale	1.66	3.39	0.001	x

Moves out of the CCZ	**1998 to 2003**			
Industry Sector	**OR**	**z**	**p-value**	**Significant**
Accounting & Auditing	2.16	3.23	0.001	**x**
Advertising & Market Research	1.31	1.29	0.197	
Ag, Fuel & Manufacturing				
Arch, Planning & Engineering	1.75	2.88	0.004	x
Business Mgmt Consulting & PR	1.49	2.27	0.023	x
Business Support Services	1.55	2.83	0.005	x
Computers, Telecomm, R&D	2.14	5	0	x
Construction	0.37	-4.05	0	**x**
Education	1.14	0.54	0.59	
Finance	2.39	4.77	0	x
Health & Social Work	1.26	1.3	0.193	
Hotels & Lodging	1.50	1.28	0.201	
Insurance	1.46	1.42	0.155	
Legal	1.11	0.46	0.643	
Media Production	2.05	3.84	0	x
Non-profit Orgs & Interest Groups	1.83	2.39	0.017	x
Personal Services	1.26	1.16	0.248	
Public Admin & Utilities	0.87	-0.28	0.778	
Publishing	2.00	3.78	0	x
Real Estate & Property Mgmt	1.32	1.67	0.094	
Restaurants & Food Service	1.96	3.94	0	x
Retail - Food, Alcohol, Tobacco	1.33	0.94	0.349	
Retail - Household Goods	1.95	2.25	0.024	**x**
Retail - Non-store	1.87	1.88	0.06	
Retail - Personal Goods	1.71	2.84	0.004	x
Retail - Secondhand & Repair	0.32	-1.11	0.265	
Sports & Culture	1.14	0.47	0.638	
Theatre & Cinema	1.76	2.82	0.005	x
Transport - Freight & Storage	1.18	0.76	0.448	
Transport - Intercity & Tourism	2.24	3.62	0	x
Transport - Motor Vehicles	0.46	-1.94	0.052	
Transport - Urban	1.12	0.31	0.756	
Wholesale	1.36	1.86	0.063	

Moves out of the CCZ	**2004 to 2012**			
Industry Sector	**OR**	**z**	**p-value**	**Significant**
Accounting & Auditing	1.82	2.62	0.009	x
Advertising & Market Research	2.15	4.57	0	x
Ag, Fuel & Manufacturing				
Arch, Planning & Engineering	2.01	4.06	0	x
Business Mgmt Consulting & PR	1.48	2.55	0.011	x
Business Support Services	1.89	4.44	0	x
Computers, Telecomm, R&D	2.57	6.61	0	x
Construction	0.57	-2.77	0.006	**x**
Education	1.42	1.86	0.062	
Finance	1.86	3.75	0	x
Health & Social Work	1.18	1.02	0.307	
Hotels & Lodging	1.56	1.92	0.055	
Insurance	2.96	5.23	0	x
Legal	1.50	2.13	0.033	x
Media Production	2.90	6.79	0	x
Non-profit Orgs & Interest Groups	1.76	2.50	0.012	x
Personal Services	1.55	2.43	0.015	x
Public Admin & Utilities	1.36	1.03	0.301	
Publishing	1.90	3.57	0	x
Real Estate & Property Mgmt	1.60	3.24	0.001	x
Restaurants & Food Service	2.33	5.66	0	x
Retail - Food, Alcohol, Tobacco	1.20	0.70	0.487	
Retail - Household Goods	1.64	1.74	0.081	
Retail - Non-store	2.07	2.54	0.011	x
Retail - Personal Goods	1.96	4.04	0	x
Retail - Secondhand & Repair	1.73	1.39	0.165	
Sports & Culture	1.97	3.37	0.001	x
Theatre & Cinema	1.31	1.29	0.197	
Transport - Freight & Storage	1.34	1.51	0.132	
Transport - Intercity & Tourism	1.79	2.80	0.005	x
Transport - Motor Vehicles	0.73	-1.03	0.303	
Transport - Urban	0.88	-0.35	0.726	
Wholesale	1.73	3.62	0	x