The Impact of Transport Infrastructure on Property Prices A Case Study of Crossrail

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THE IMPACT OF TRANSPORT INFRASTRUCTURE ON PROPERTY PRICES: A CASE STUDY OF CROSSRAIL

MSC International Real Estate and Planning

James Anderson

Being a dissertation submitted to the faculty of The Built Environment as part of the requirements for the award of the MSc International Real Estate and Planning at University College London: I declare that this dissertation is entirely my own work and that ideas, data and images, as well as direct quotations, drawn from elsewhere are identified and referenced.

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Abstract

A commonplace observation is that the presence of transport infrastructure generates nonpareil accessibility and amenity benefits, which incite both wider authority regeneration and local property value appreciation. Nonetheless, the literature apropos the impact of transport infrastructure on property values is mixed for both magnitude and direction. Indeed, studies range from negative, insignificant or positive impacts. This paper will, therefore, update literature by investigating this relationship within the context of Europe's largest infrastructure project, Crossrail, a 118km longitudinal railway that stretches across London. Although several Crossrail assessments exist, this study will employ an extended 16-year timeline, from before the planning inception and beyond the European Referendum vote. The results of the paper support broader theory, suggesting that properties near Crossrail stations have outperformed surrounding areas by 7.8%, while properties within 250m of stations have outperformed by an average of 10.4% over the last 16 years.

Key words: Accessibility, Amenity, Crossrail, Transport Infrastructure

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1. Introduction

Within the contemporary neoliberal climate, infrastructure development is becoming increasingly recognised as a means to sustain economic ecosystems, incite economic growth and augment national competitiveness, but further as a vehicle for authorities to express preponderant ideologies (Swyngedouw *et al.,* 2002). Through private-sector involvement and marketisation, infrastructure has been delivered via a plethora of practices, helping stimulate greater efficiency of private production factors (Rietveld and Bruinsma, 2012), but also enabling most forms of human activity (Babarinde, 1998).

A significant proportion of infrastructure investment is devoted to the transportation sector, which helps facilitate economic activity by connecting individuals to the workplace, retail and recreational activities (Diaz, 1999). Infrastructure is therefore an entity which is heavily relied on. For example, within a UK context, a 2015/2016 study reported that 1.35 billion people used the London underground within a year (TfL, 2019a), the highest in the services 154-year history (Knight Frank, 2017).

With the population of London estimated to grow to approximately 10 million by 2030 (figure 1.1), combined with the growing employment numbers within the centre of the city, the congestion on a largely outdated transport system will soon become unsustainable.

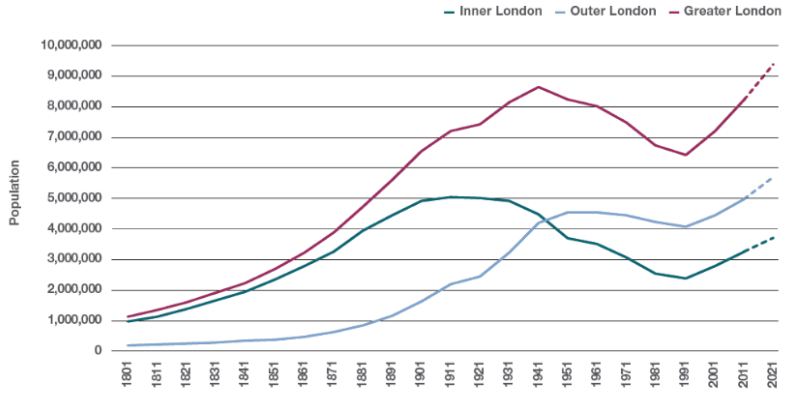

Figure 1.1: London Population Growth (Source: Savills, 2014)

Transport for London has previously attempted to address this problem with additional transport infrastructure developments, including the Jubilee Line Extension (JLE) and the expansion of the

Docklands Light Railway (DLR); however, both are only line extensions completed nearly a decade ago.

The newest addition to London's transport network will be Crossrail, informally known as the Elizabeth line. Crossrail is a new 73-mile, multi-billion-pound railway line that will serve London and the greater southeast region of the UK. The route, which runs from Reading and Heathrow eastwards to Abbey Wood and Shenfield (figure 1.2), gained permission in the Crossrail Act 2008 (CA, 2008, Section 10) and began construction in 2009. The service was initially scheduled to open in December 2018, however, due to numerous delays has been rescheduled for early 2021.

Figure 1.2: Map of Elizabeth Line (Source: Crossrail, 2019)

Crossrail serves to achieve a myriad of government objectives. Pre-eminently the service will reduce congestion and cut journey times into central London by an average of 15-minutes, and in some areas by up to 40-minutes (CBRE, 2016). As a by-product of this increased connectivity, a number of other economic aims have been achieved. Crossrail has played a significant role in attracting investment for the regeneration of areas, facilitating 'place-making' (GVA, 2012) alongside supporting the delivery of 3.25m sqm of commercial real estate and over 180,000 new homes by 2026 (City of London Corporation, 2015).

However, many scholars (including Gellert and Lynch, 2003 and Stehlin, 2015) report that infrastructure development can have potentially adverse impacts on the wider market, particularly environmental degradation (Nellemann *et al.,* 2003), gentrification, displacement (Gellert and Lynch, 2003), and property appreciation.

Therefore, this paper will attempt to answer the broader question; to what extent does the implementation of transport infrastructure impact the value of real estate? This broader question will be situated within a focused study of Crossrail, aiming to establish and compare the changes in residential prices across the route.

The motivation for this study is threefold. Surprisingly, relatively little academic work assessing the relationship between transport infrastructure and property prices has been conducted, with most focusing on assessing the impacts for macroeconomic variables, such as GDP. Furthermore, most literature studies employ a hedonic pricing model as their primary methodology, which draws a number of flaws when evaluating changes across extensive infrastructure developments. This work accordingly adopts a different methodology to attain results. Finally, most studies regarding Crossrail were conducted before the results of the European Union referendum, which are accounted for in this paper.

Therefore, to answer the research question and aim, the following objectives have been formulated;

- To establish both a 'Zone of Influence' which Crossrail will impact and a control sample, which accounts for changing macroeconomic conditions to isolate the impacts of Crossrail
- Assess the change in residential postcode property prices over two different comparison years
- Evaluate the spatial impact of Crossrail on residential property values
- Update the literature regarding the impact of Crossrail and transport infrastructure more generally

To achieve these objectives, an unbalanced panel dataset with information on the aforementioned objectives has been constructed, including data from 38 Crossrail stations (excluding Heathrow) over two different comparison years, creating 1742 idiosyncratic observations. The analysis will adopt an alternative method to the popular hedonic pricing model, by instead using benchmark control samples to isolate the impact of Crossrail for property values.

This paper continues as follows. The next section delves into the theoretical background of infrastructure and property price determinants, before examining the existing literature surrounding the topic. Thereafter, the description of the data and empirical technique will be outlined in the methodology. Next, the results established from the methodology are presented, followed by a discussion regarding their significance. Finally, the paper will conclude, synthesising and assessing any future opportunities.

2. Literature Review

2.1 Infrastructure Development and Impacts

The term infrastructure has become increasingly ubiquitous, commonly used by both experts and laymen, yet the concept is riddled with a degree of ambiguity. In orthodox economic theory and planning, infrastructure refers to the underlying structure of services required to enable productive activity (Melia, 2018; Gregory *et al.,* 2011). Indeed, it follows that "improving infrastructure leads to higher productivity of private production factors" (Rietveld and Bruinsma, 2012, p.1). Additionally, Biehl (1991) contests that infrastructure is capital that provides public services. Nevertheless, it is recognised that infrastructure is "a crucial input to economic activity and growth" (Grimsey and Lewis, 2002, p.108). Infrastructure is principally capital intensive and tends to be immobile, but it is also open of access, indivisible and creates economy-wide impacts. Biehl *et al.,* (1986) delineates an elaborate list of infrastructure sub-sections, which includes; transport, sport, tourism, communication, energy, water, environmental, education, health, social and cultural. Such lists will differ in detail, with Hirschman (1958) suggesting that the concept is confined to only transportation and power.

For years following the post-war period, infrastructure had been delivered principally by the public sector. However, the fundamental financial requirements of infrastructure and the ability for the entity to generate long-term stable returns has led to significant interest from the private sector, not solely with regards to ownership or equity considerations but as the basis for a range of disintermediated financial instruments. In recent years, infrastructure has been delivered within the structural context of public-private partnerships. Here, private companies help fund vast economic outlays, yet projects still align with public policy considerations.

A substantial body of literature concerning the impacts of infrastructure can be identified. Inherently, most scholars exclusively study the positive impacts of infrastructure, which are frequently economically orientated. Indeed, infrastructure's ability to improve the production and consumption of goods is a crucial determinant of growth. Therefore, the research includes analysis of the impact that infrastructure investment can yield on Foreign Direct Investment (Rehman *et al.,* 2011), economic development (Rietveld, 1989) and economic growth (Palei, 2015; Munnell, 1992). However, most researchers largely under-report the impact of crowding out, the financing mechanism or the general macroeconomic conditions.

Contrariwise, some consider the negative impacts that infrastructure produces, which are predominantly social and environmental. The environmental concerns are explored by Rietveld and Bruinsma (2012) and Laurance *et al.* (2015), but another adverse impact is gentrification and displacement of individuals.

For example, Jackson and Sleigh (2000) assess the displacement caused by the Three Gorges Dam in China, while Watt (2013) evaluates the gentrification caused by the 2012 Olympics infrastructure.

2.2 The Impact of Transport Infrastructure

Arguably the largest subsection of infrastructure is transportation, which is often considered the backbone of the modern economy. Transport infrastructure is an eminent ingredient for the cohesion of populations, social well-being, and economic development at every level of income (ITF, 2013). Essentially it enables the everyday mobility of individuals but is also crucial for the production and distribution of commodities.

Transport infrastructure investment creates a reduction in travel costs, hence stimulating both production and household consumption. Transport infrastructure investment can also be cited as an essential tool for substantial redistribution effects, which can span amongst all economic groups and regions. Transport infrastructure includes; roads, railways, seaports, waterways, airports, pipelines and on occasion telecommunications (Biehl, 1993). Within the literature the most heavily scrutinised section of transport infrastructure is railways, with the impacts discussed at various spatial levels.

Despite the abundant positive impacts, which can be surmised in a broader economic sense, railways create several negative externalities. These are similar to the environmental impacts outlined in the aforementioned section but additionally comprise noise pollution, safety concerns and general aesthetic detraction.

A large segment of the literature on railway systems focuses on whether it can be used as a feasible planning solution to tackle the rising congestion posed by urban sprawls and automobile traffic (Debrezion *et al.,* 2004). However, many other scholars focus on the impact that railway infrastructure places on land values. Indeed, Grass (1992) suggests that public infrastructure has significant impacts on the pattern of urban development, using the economic theory that areas with higher accessibility lead to a denser settlement. Another avenue of literature focuses on what Diaz (1999) argues as the most significant impact of rail transit, which is the impact on property values. This discourse will be the focus of this paper, but first, the determinants of property values must be established.

2.3 Determinants of Property Values

Before the determinants of property prices are examined, we must first establish what constitutes ‘property’. A range of definitions has been delineated, with variations stemming from different disciplines. For example, Millington (2000, p.7) opines that “the ownership of property is a form of holding money”, while many scholars contend that property ownership carries the ability to enforce

certain rights and duties (Gregory *et al.,* 2011). The range of recognised property rights again ideologically differs, with Western societies viewing property as a tool for alienation, use and exclusion (Singer, 2000). For this study; however, property refers to an area of land occupied by residential, commercial or industrial buildings (Brigham, 1965).

Early studies and theoretical work based on property focused predominantly on the value of land. This can be traced to the seminal work from Von Thünen (1863) who derived the bid-rent theory, stressing the prevalence of transportation costs in defining land values. His work, later supported by Alonso (1964) and Müth (1969), suggested that the price paid for land declines the further the distance from the central trading point or CBD. Accordingly, the dominant factor was considered accessibility to said central trading point. Although land values are acknowledged as contributing factors for determining property prices, there are still crucial distinctions. Richardson *et al.* (1973, p.3) contended that in many studies before 1970 it was "commonly assumed that the demand for a house was derived demand for land and hence that the two gradients (house price and land value) are similar".

Although scholars now recognise that "valuable land may hold poor quality housing" (Richardson *et al.,* 1973, p. 190), accessibility is a factor that remains extremely influential for property prices. The basic accessibly theory follows, that as a location becomes more attractive, demand increases, which in turn increases values. It is widely noted that the CBD is a centre for many activities, thus proximity to said CBD is considered an attractive quality which increases property values. Transport infrastructure investment reduces travel time to the CBD (Fejarang, 1994), hence proximity to transport infrastructure increases the accessibility index of the property. Accordingly, the value of the transport facility is capitalised into the property value (Debrezion *et al.,* 2004). Thus, the nuanced concept of accessibility can be considered any variables that contribute to opportunities of a location for interaction (Martellato *et al.,* 1998).

Although accessibility is an influential determinant for property prices, economists now recognise property as a heterogenous good that encompasses a bundle of idiosyncratic characteristics, which reflect not only its location and land value but equally a number of other amenities such as the neighbourhood and environment (Ajibola *et al.,* 2013). Indeed, Ge and Du (2007) contest that property values are determined by a variety of factors which Kamali *et al.* (2008) categorise into four components; property, neighbourhood, environmental and accessibility variables. Oyebanji (2003) alternatively identifies seven variables, which Olusegun (2013) categorises into three different groups; external, internal and economic factors. The variables include changes in fashion/taste, population, complementary uses and location, technological, institutional and economic factors (*Ibid*).

Despite infrastructure becoming a well-recognised determinant of property prices, with key scholars such as Johnson *et al.* (2005) suggesting the presence of infrastructure leads to an appreciation in

property values, and Hammer *et al.* (2000) arguing that the provision of infrastructure is central to property values, it has garnered surprisingly little academic or empirical attention.

2.4 The Impact of Rail Infrastructure on Property Prices

Railway infrastructure, through accessibility benefits, can affect both land use and value patterns. Therefore, it follows that to conclude anything about the capitalised value impact of a railway station, one needs first to separate the accessibility benefit attributed to the railway station (Debrezion *et al.,* 2004).

Hitherto, proximity to railway stations as a factor that influences property values has drawn relatively little literature attention. Traditional literature considered accessibility as the only influential factor, however, across most recent literature, scholars view railways stations from two angles; as a place in an area and as a node in a transport system (Bertolini and Spit, 1998). In line with section 2.3, this means that stations pose a duality of effects on proximate properties, both amenity and accessibility. New rail systems, alongside increased accessibility, can attract significant area investment and development. Large stations can serve as amenity hubs with retail and leisure. An example is Kings Cross station, which facilitated Coal Drops Yard a rejuvenated shopping centre (Haynes and Savage, 2007).

The majority of studies utilise a hedonic pricing model, which estimates the influence that one factor, amongst many, has on price (Henneberry, 1998). This is used to isolate accessibility benefits by accounting for heterogeneous neighbourhood characteristics. Such model requires considerable information on neighbourhood and location variables, but also information on the properties physical character. Each study varies significantly, shown in table 2.1.

Generally speaking, there is no consistent relationship amongst studies when evaluating property as a whole. However, in most cases, it can be seen that residential property experiences value appreciation. Moreover, the radius impact area of the station is more extensive compared to commercial property.

Table 2.1: Hedonic Model Studies

Country	Author	Study	Outcomes
UK, Europe	Forrest *et al.*, (1996)	Manchester Metro Link	-Indicate no significant price difference whether property was within 1000m, or between 1000-2000m from the station.
UK, Europe	Henneberry (1998)	Sheffield Supertram	-Short term increase of 4% in price for properties closest to stations. -However, he concluded that there was no significant statistical relationship between distance and price.
UK, Europe	Du and Mulley (2007)	Tyne and Wear Metro, Sunderland	-No correlation found between an uplift in land values and the introduction of the metro system.
Finland, Europe	Laakso, (1992)	Helsinki Metro	-An overall impact of 6% increase on properties within 1000m of stations, however, could affect by up to 11% in the best locations.
Turkey, Europe	Celik and Yankaya (2006)	Izmir Subway	-Proximity to railway stations yielded a higher value by a price gradient of $250-300 per square metre.
Portland, North America	Al-Mosaind *et al.,* (1993)	MAX LRT Line	-Only negligible positive influence of proximity the closer the home is to a light-rail transit station in the short-term. -Long term increase of 10.6% for homes within 500m walking distance, which equates to $21.75 per metre price gradient.
Miami, North America	Gatzlaff and Smith, (1993)	Miami Metrorail	-Weak evidence that there was any significant effect to residential values.
Toronto, North America	Bajic (1983)	Spadina Subway Line	-The benefits from the subway have been capitalised into housing prices located in proximity to the railway. -Discount of approximately $2,237 per hour timesaving.
Washington D.C., North America	Grass (1992)	Metro Rail Line	Significant relationship between the Metro and residential property values. Properties closest to the station increased the most.
-	Debrezion *et al.,* (2004)	Numerous railway lines	-Commuter railway lines have the most significant impact on property values (both residential and commercial) at an average of 12%.

Nevertheless, due to the inherently unique nature of property, interaction with railway stations can be highly localised and contextual (Cervero, 1994), with one of the problems being the heterogeneity between stations. For example, service frequency, parking, service catchment area and railway technology (rapid transport) are often not considered (Bowes and Ihlanfeldt, 2001). According to Gatzlaff and Smith (1993) the impacts of railway infrastructure also significantly varies depending on the size of the CBD that the transport reaches.

Although the hedonic pricing model is heavily used by scholars, there are several fundamental drawbacks which render it maladroit for many studies. For example, a significant number of variables are required to sufficiently isolate accessibility impacts, including the physical characteristics of each property and the neighbourhood area. Across a railway line with 38-stations that are all situated in very different economic, social and environmental surroundings, even with twenty variables there would be significant unexplained variance. Furthermore, hedonic modelling frequently omits external economic factors, including taxes, interests' rates and regulation which could have a significant impact on property valuations.

2.5 London Studies

2.5.1 London's Railway Infrastructure

Within a UK context, rail infrastructure is a contentious debate. Deliberations regarding the spatial disposition of rail investment, the environmental and displacement impacts and the substantial costs form the centre of the controversy. The most recent investment plans through High-Speed-Two have added to the dispute, yet it is clear that the infrastructure is necessary for many cities, particularly the capital London.

Despite recent UK transport investment becoming progressively disproportionately focused within London, which consumes over 50% of the UK budget (Parveen, 2017), throughout the past 15-years the city has seen relatively little significant additions to the rail network. Nevertheless, the continued investment is a necessary component when one considers the expected number of passenger journeys on the underground system is increasing year on year. (figure 2.1).

The most recent rail investment was through the London Overground, with both southern and eastern line extensions that were completed in 2010 and 2016 respectively. Preceding this, the Jubilee Line was extended in 1999, to link together central London with Canary Wharf and the greater south-eastern area of London. It has not been since the DLR in 1987 where London has invested in a completely new railway service, which served the rejuvenated docklands area of east London. Built as a light rail system, the network has been extended several times to now carry 121.8 million passenger journeys annually. These upgrades were required to accommodate an ever-expanding population, but they also produced numerous impacts on the wider residential market.

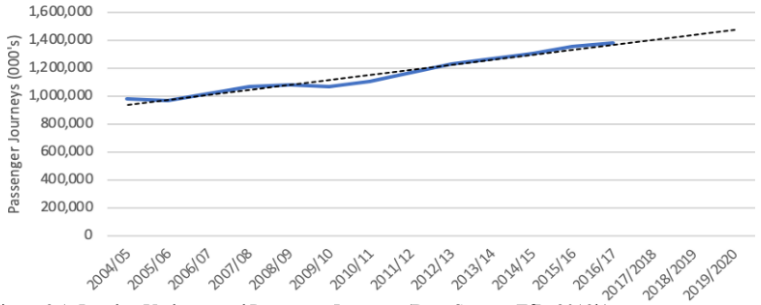

Figure 2.1: London Underground Passenger Journeys (Data Source: TfL, 2019b)

2.5.2 London's Property Market

Despite little transport infrastructure investment, the property market in London has seen unprecedented growth in the past few decades. The unique economic features and global situation of London and the South East have strongly influenced the residential market, which has grown at a higher rate when compared to the rest of the UK. Indeed, this economic influence fits with the categories that Olusegun (2003) outlined, suggesting that economic factors were one of three reasons for property price appreciation.

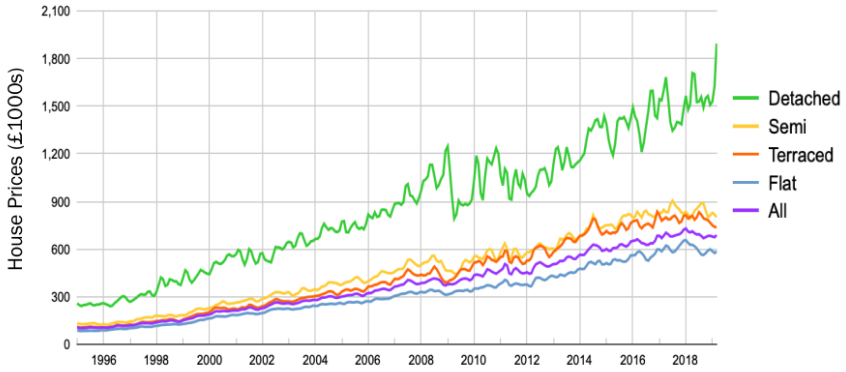

Figure 2.2 Residential Prices in London by Property Type (Source: Home, 2019)

Nevertheless, even within London, there are significant regional variations. For example, prime residential markets which have experienced an influx of highly skilled workers have continued to drive prices, particularly in Western Central boroughs like Kensington & Chelsea and Westminster (figure

2.3). This reflects the multi-tiered market and differences between neighbourhoods, linking to the work of Kamali *et al*. (2008).

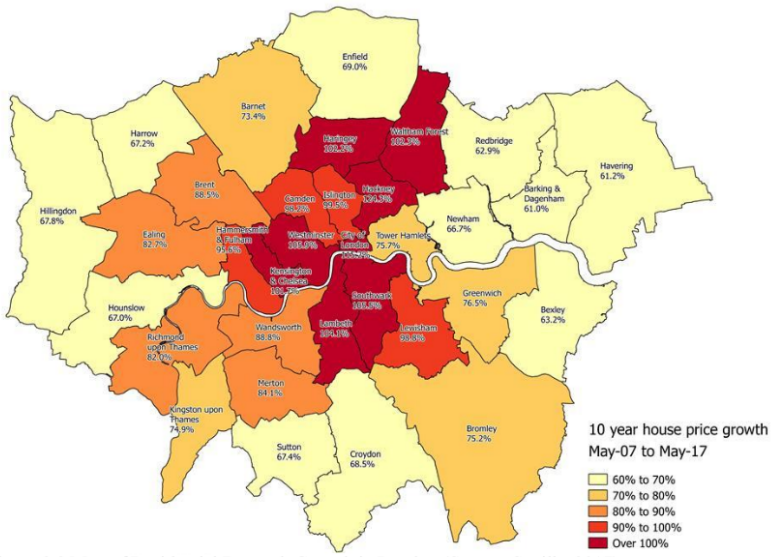

Figure 2.3 Map of Residential Borough Growth in London (Source: Savills, 2017)

Outer London boroughs and markets are largely dependent on overall domestic confidence, which has been relatively stable, except for two instances – the global economic crash and the European Referendum results. However, the growth of these markets has been weaker than the core areas of central London.

2.5.3 London Rail Infrastructure and Property Prices

There have been very few studies that have specifically analysed the changes in house prices with the integration of the new rail infrastructure within London. These studies have been largely focused within London's south-eastern area, where both the JLE and DLR have predominant impacted.

Mitchell and Vickers (2003) analysed the immediate short-term impact of the JLE on land values. They established that residential land values increased by £9bn as a direct result of the JLE which actually cost £3.5bn. Pharoah (2002) instead evaluated the impact that the JLE had on development activity, concluding that for some stations, including Canada Water, there was little activity.

There are only a couple of existing studies that specifically evaluated property prices changes. Ahlfeldt (2013) combines a gravity model which establishes the impact of increasing accessibility on household prices to both the JLE and DLR. He reported that the impact increased property prices by 12% in areas where there was no antecedent access. Chesterton (2000) used a hedonic model but reported no significant conclusion. He cited that less than 50% of the variance for property values was explained by his selected variable, highlighting the complexed nature of both property and the difficulty in trying to isolate specific rail infrastructure impacts. Regardless, these studies, with the exception of Ahlfeldt (2013), only focus on an extension to a line, rather than an entirely new transport infrastructure system. Furthermore, most of the stations were already connected to central London through other rail networks.

2.5.4 Crossrail Studies

Crossrail, however, is a new transport infrastructure network, which will connect some areas that had little previous rail access. Nonetheless, due to the relative infancy and the fact that the rail line is not yet operable, little academic work has been conducted in way of linking property prices.

Most analytical work stems from large consultancy companies, which have focused on a range of impact indicators. Some *(see* Arup, 2014 and KPMG, 2016) examine general impacts of Crossrail such as increased visitor numbers, however, most studies are focused explicitly on the impact for property values. Pre-eminent studies include:

Table 2.2: Crossrail-Specific Studies

Author/Company	Findings
GVA (2012)	-Estimated that by 2026, values from central stations could rise by 35% and outer London stations by 23% above the baseline projection
CBRE (2016)	-Established that since the Crossrail announcement, houses near the stations have increased by 31% above the baseline
Knight Frank (2017)	-Central London properties within a 10-minute walk of Crossrail stations have outperformed the baseline market by 40% from 2008-2016 -The Eastern section has experienced property price increases of 58%, with the highest performing station Forest Gate (82%) -The western section has experienced property price increases of 59%, with the highest performing station Acton Main Line (77%)
JLL (2015)	-From 2014-2020 it is estimated the properties around Crossrail will outperform the market by 19%, with the highest growth coming from Whitechapel
Hamptons (2014)	-Average increase of 34% in house prices near stations along the route between 2009-2013

Across these different studies, the clear general trend shows an increase in house prices across Crossrail Stations, which are the expected results given the other literature regarding rail infrastructure investment and property trends. However, the magnitude of increase varies significantly, ranging from

an average of 40% (Knight Frank) to 19% (JLL). One of the key reasons for these discrepancies is that studies have been conducted over different time periods, which significantly affects results. Indeed, Knight Frank's study was from 2008-2016, which was a period of considerable residential growth.

2.6 Research Gap

The research within this study will help establish a clearer indication of the house price impacts of Crossrail, providing a robust analysis timeframe. The results will be analysed from before the announcement of Crossrail, up until 2019. This also takes into account the adverse economic impacts of the initial European Referendum result, which other early estimations failed to predict.

This study will also update results regarding the scholarly discourse of transport infrastructure. Currently, there are significant variations with results, with studies displaying both positive and negative trends. Furthermore, in contrast to most other studies that have analysed the relationship between rail investment and property prices, this work will not use a hedonic pricing model. Given the drawbacks of this method, namely the vast number of variables required, it is not suitable for analysis of a the 38-station investment.

3. Description of Study: Crossrail

3.1 Background

Crossrail is a 118km railway that stretches longitudinally across London and its environs from Heathrow airport and Reading in the extreme west, to Abbey Wood and Shenfield in the extreme east. Launched as the Elizabeth Line, Crossrail will cut journey times by up to 40 minutes and increase central London's rail network capacity by 10% (Crossrail, 2019), hence relieving congestion at several key stations across the capital. The line strategically connects key retail and business areas, whilst bringing a further 1.5 million people to within a 45-minute commute of the West End and city (*Ibid*).

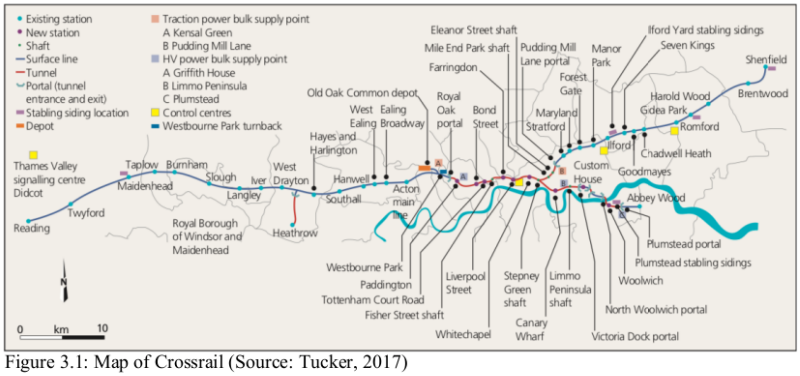

Figure 3.1: Map of Crossrail (Source: Tucker, 2017)

Planning for the project was approved in 2007, with construction beginning in 2009. Crossrail was originally scheduled for completion in December 2018; however, signal system issues have delayed the opening by approximately 18 months to early 2021.

The 2008 Crossrail Act outlined the projects joint sponsors and delivery partners. The mayor of London, through Transport for London (TfL) and the Greater London Authority (GLA), contributed a total of £7.1bn. The government, through the Department of Transport, contributed a loan of £4.9bn, whilst Network Rail funded £2.3bn. Additional finance will be gained through the Crossrail Community Infrastructure Levy, business rate supplements and fare-payers amongst others (figure 3.2) (Tucker, 2017).

Figure 3.2: Crossrail Funding Breakdown (Source: Crossrail 2019)

Despite the significant £17.8bn costs, there are potentially huge economic benefits. The programme will contribute an estimated £42bn to the UK economy through driving housebuilding and business developments creating jobs and business opportunities (*Ibid*).

There have also been a number of redevelopment plans undertaken around new Crossrail Stations. For example, despite a good location, Tottenham Court Road's surrounding market had historically underperformed. Now there are substantial plans to create attractive, pedestrian-friendly public spaces at street level which will boost the immediate market (*Ibid).* Moreover, Canary Wharf Station has been developed with a new concourse, a publicly accessible roof garden (figure 3.3) alongside four floors of retail and leisure facilities which will support the local economic ecosystem.

With regards to the construction works, the most significant challenge was the 42km of underground tunnels, with which 21km are twin bore that include nine new station platforms. Much of the work along the ground-level sections was to electrify the route, demolish or alter several obstructing bridges and redesign stations so that they could accommodate 240m length platforms and increased footfall (*Ibid*).

Figure 3.3: Crossrail Station Design [Top Left: Canary Wharf, Top Right: Paddington, Bottom Left: Liverpool Street, Bottom Right: Abbey Wood] (Image Source: Crossrail, 2019)

3.2 Comparative Projects

In terms of scale, the magnitude and cost of the project make Crossrail Europe's largest infrastructure development. With 42km of new underground tunnels and an estimated 200m annual passengers, there are very few comparable schemes across the globe.

Crossrail will be the largest UK infrastructure project since the channel tunnel construction. In terms of construction cost, the channel tunnel finished at approximately £9bn (1985), however that figure is inflation-adjusted to above £25bn in 2019. Crossrail is set to dwarf other significant UK megaprojects of the recent era, including Heathrow Terminal 5 and HS1. However, if approved, the 560km high-speed two railway route that will link London to Birmingham and eventually other northern cities such as Manchester and Leeds, is expected to cost approximately £60bn, making it by far the biggest project the UK has funded. Outside of Europe, the only current comparable project is the California High-speed Rail. The network links San Francisco to Los Angles, and is expected to cost an estimated £40bn.

3.3 Initial Expectations

Having reviewed both the academic literature and analysed Crossrail in detail, there are a few expectations that can be established. One of the key themes throughout the literature was that accessibility is one of the main attributes contributing to property price increases. Crossrail is cutting

commuting times and enabling another 1.5 million people the opportunity to commute to London in under 45 minutes. Therefore, one would expect that areas where accessibility was originally limited to experience the largest house price increases. Taking both accessibility and area demographics into account, figure 3.4 illustrates the areas that I hypothesise property appreciation will be the most significant.

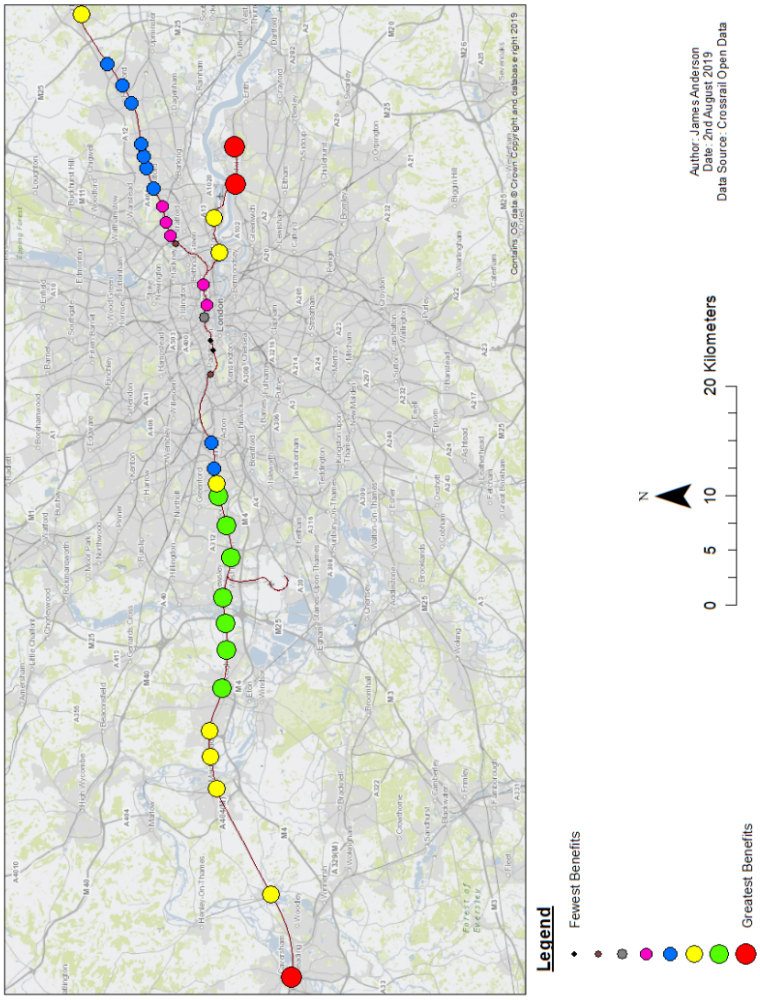

Figure 4.1: Expected Benefits Hotspots Map

4. Methodology

4.1 Methodology

In order to analyse the impact of Crossrail on property effectively, this study, like many others (*see* Knight Frank, 2017; CBRE, 2016, Hamptons, 2014) will split the railway line into four separate sections (illustrated in figure 4.1);

- Western Section - (Reading to Acton Town)
- Central Section - (Paddington to Canary Wharf)
- Eastern (North) Section - (Stratford to Shenfield)
- Eastern (South) Section - (Custom House to Abbey Wood)

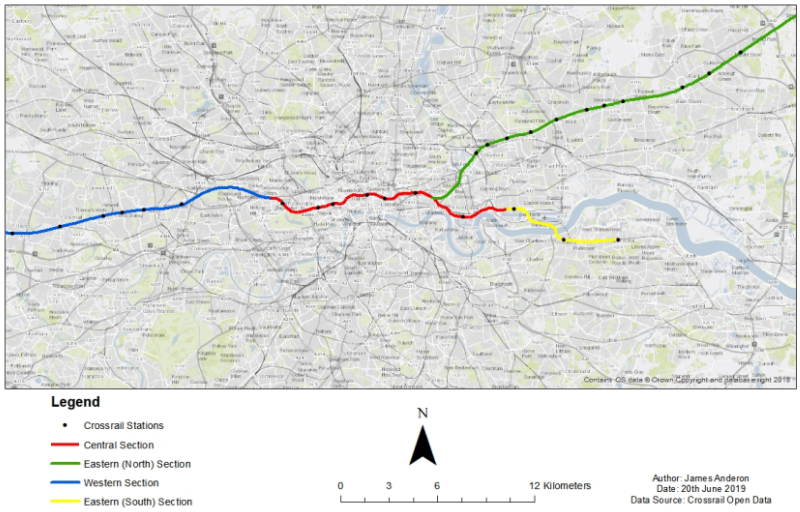

Figure 4.2: Crossrail's Segment Division

These four sections represent different markets that take into consideration idiosyncratic social and economic demographics for each area. Accordingly, the central section aligns with the central property market, whilst the remaining three sections align with the outer London market. This arrangement helps with regards to benchmarking, whilst also accounting for the London Central Activities Zones (CAZ) unique character.

Following an extensive review of similar studies that assess the impact of railway infrastructure development on property (*see* Chesterton, 2000; GVA, 2012; Hamptons, 2014), this study will similarly

establish a ‘zone of influence’ around Crossrail stations locations along the route. The zone of influence used for this study overlays with the approach taken in the Crossrail Community Infrastructure Levy (CIL) study (Buck, 2017). Therefore, the zone refers to a 1-kilometre radius around the Crossrail stations and aims to capture the general geographic area that will be impacted by the introduction of Crossrail. The zone has been confined explicitly to 1-kilmetre so that the overlap is limited in central London stations (figure 4.2). The zone of influence has been subdivided into three categories;

Table 3: Zone of Influence

Zone	Distance	Reasoning
Inner-most	0 – 0.24km	Studies indicate that a 250m walk within a city takes a maximum of 5 minutes, and in theory should add value to a residential property.
Middle	0.25 – 0.49km	This zone reflects an approximate 5-10-minute walk, a convenient walking time to a train station
Outer-most	0.5 – 1km	This zone is considered to equate to approximately 15-minute walking time and reflects a realistic maximum walking distance from a residential property to a station.

This method will hence enable a detailed spatial analysis of Crossrail’s impact, evaluating whether proximity to the station affects property values.

Figure 4.2: Crossrail's Central London Section with 'Zone of Influence'

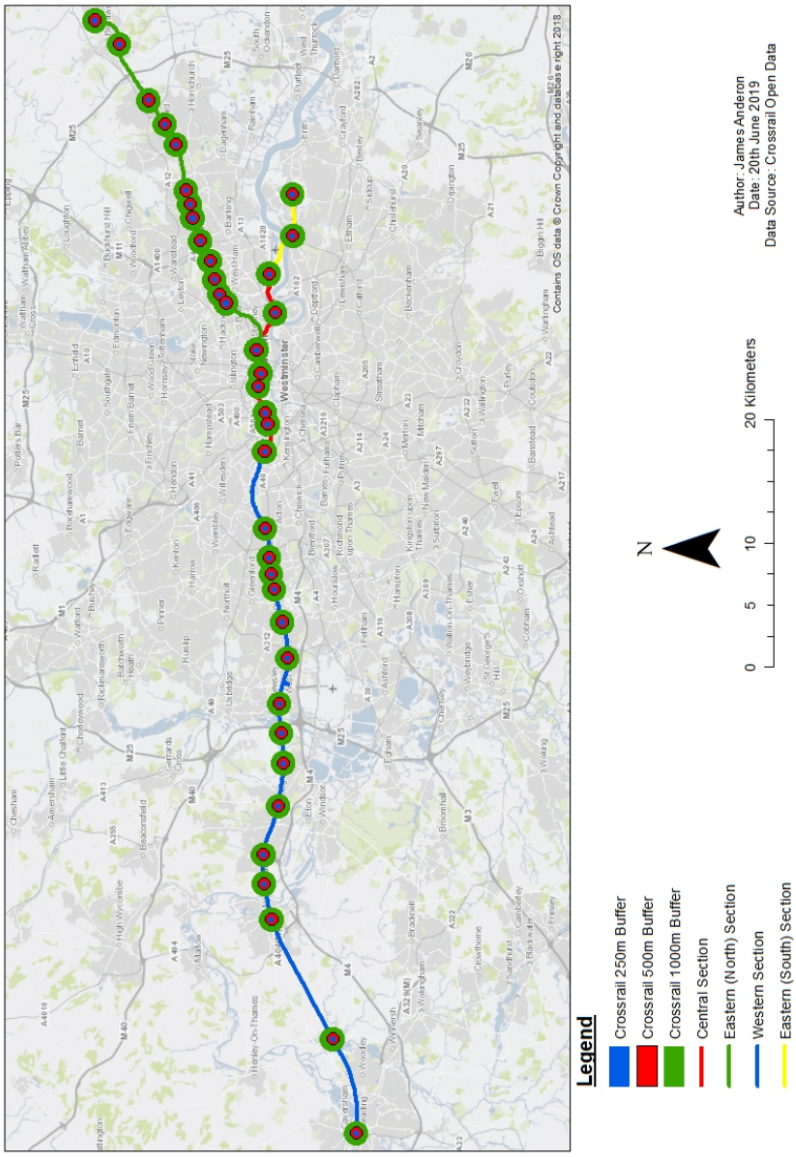

Figure 4.3: Crossrail's Segment Division and 'Zone of Influence'

For the evaluation, postcodes within each zone radii at every station across the route will be extracted and analysed. Heathrow (3 stations) is excluded from this analysis, as the 1km zone still covers the airport area, with no residential property. It must be noted that there is likely to be property effects related to Crossrail beyond these established zones of influence; however, it is expected that these locations will be most strongly influenced.

4.1.1 Control sample

As noted from the reviewed literature, there are numerous factors other than infrastructure that influence the price of property within an area. Indeed, the surrounding neighbourhood and environment play a significant factor in value determinants (Kamali *et al.,* 2008), therefore non-Crossrail factors will have influenced areas regardless of whether they are close to stations.

As a way to counter this, a control sample has been established for each section of the railway line, in a similar fashion to other Crossrail studies (*see* Hamptons, 2014; CBRE, 2016; GVA, 2016). These control samples are aimed to represent areas of relatively similar economic and social demographics with comparable existing journey times into central London. These areas however will not be directly impacted by Crossrail, so that the impact is isolated. Using this method, both neighbourhood and environmental variations will be eliminated. The areas used are in Appendix A.

In combination with data from these areas, growth from the surrounding boroughs and districts is considered, to create a station benchmark baseline that will be the point of comparison. This method isolates the impact of Crossrail, eliminating a range of macroeconomic variables that have influenced property prices in the area.

4.2 Data

In order to successfully execute the outlined methodology, a suitably large dataset that encompasses two different comparison years across all three zones of impact at each station is required. Furthermore, price data for postcodes within the proximity of Crossrail stations needed to be established.

This study collected property price data to the first digit of the inward postcode. This refers to the Sector Postcode and ensures that data is focused into a sufficiently localised area. There are approximately 9,000 sector postcodes within the UK, meaning roughly 200 households to each sector (Royal Mail,

2019). If information was collected to a further degree of precision, at the unit level, it would have created an unrealistic proportion of data for analysis, whilst also an insufficient amount of residential properties will have been sold within both years.

This study is innately longitudinal, given the comparative nature of property price changes. Therefore, prices will be analysed from 2003 through to the current year of 2019. This timeframe encompasses both the years of planning approval (2007) and the construction starting dates (2009) of Crossrail. It also, contrasting to other studies (Hamptons, 2014; JLL, 2015; GVA, 2012), provides a greater timeframe spectrum to see how other areas performed before Crossrail, whilst also including the 2008 economic crisis.

Hence, an unbalanced panel dataset was constructed consisting of all 38 Crossrail stations (Heathrow excluded), separated into three different zones across two different years. Therefore, there are 228 overall station calculations, which have been ascertained from 1,742 postcode calculations.

4.2.1 Data collection

The main data collection source was HM Land Registry, a non-ministerial department of the government that maintains records of residential property transactions. This data is therefore quantitative and secondary, openly available to the public. For some postcodes, HM Land Registry had no property data, in which case Zoopla's house price data was used. The reason the dataset is unbalanced is that in some locations, specifically in central London, sector postcodes contained no residential records.

Because this research does not contain personal or individual house prices, there are no ethical data considerations (Oates *et al.*, 2010).

5. Results

This section of the study will present the results of the methodology, with a brief analysis to ascertain the trends. The section will begin by identifying the absolute changes in property prices from 2003-2019, followed with a break down for each Crossrail section. Thereafter, the results will be assessed relative to the benchmark control sample, which will isolate the impacts of Crossrail.

5.1 Absolute Property Price Changes

The average change in prices of properties that are located within 1km of Crossrail stations varies considerably across the route. As expected, the greatest absolute changes were generated from the central London stations, with an average increase of 197% for prices. Accordingly, the largest increase was located at Bond Street, which increased by 264%. Perhaps surprisingly, the southern part of the East section generated the smallest increases in property prices, with an average of just 111%, although this section only has a relatively small sample size compared to the other segments (3 stations). Figure 5.1 details the difference between each station along the route:

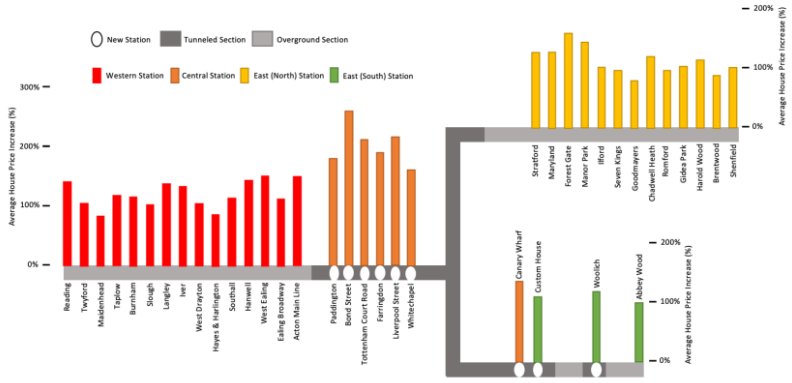

Figure 5.1: Average Absolute Price Changes for Properties Within 1km of Crossrail Stations

The fact that the east (southern) section recorded the lowest increase in house prices was more unexpected when journey time saving is considered (figure 5.2 & 5.3):

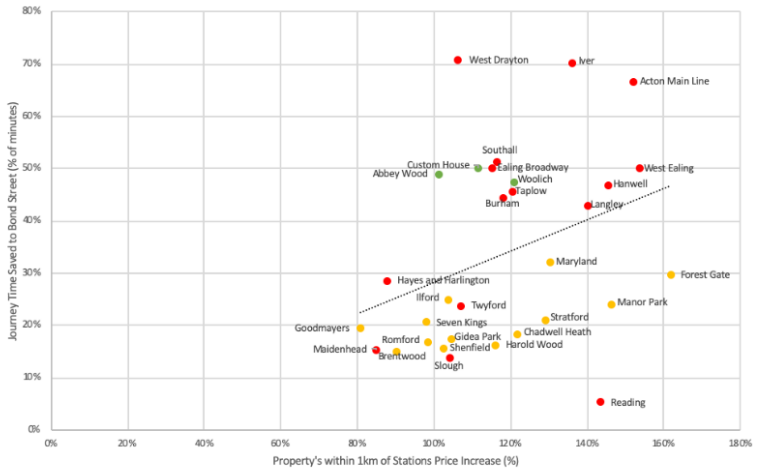

Figure 5.2: Scatterplot of Property Prices against Journey Timesaving Through Crossrail

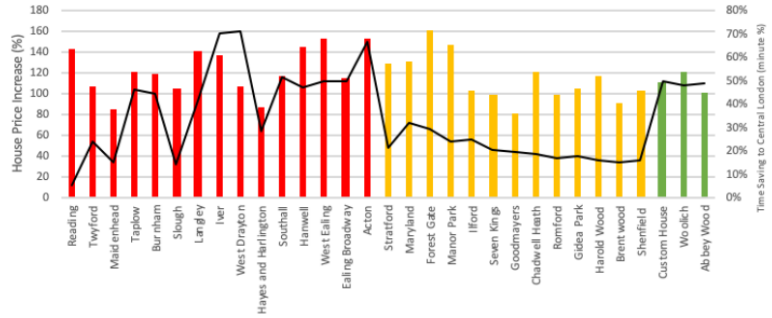

Figure 5.3: Bar Chart of Property Price Increases Against Timesaving Through Crossrail

Indeed, Custom House, Woolwich and Abbey Wood Stations all save approximately 50% travel time into central London with the introduction of Crossrail, however the increase in property prices is only relatively moderate. Nevertheless, across Crossrail it is evident from both figures that there is a positive correlation between time saved and property price increases, which supports the accessibility trend presented from previous literature. However, one problem with both of these figures is that frequency of trains into central London is not considered. For example, the journey from Reading to central London will only save 10% in time, but the number of journeys per hour increases by 100%. Another issue that must be considered is that central London in this instance is considered as Bond Street. Therefore, the journey time savings may be somewhat distorted, particularly for the stations on the

north-eastern section of Crossrail which have pre-existing central line connections directly to Bond Street.

The results from table 5.1 show that the property price impacts of the Crossrail station are generally stronger for houses that are in closest proximity. Other than the north-eastern section, the results were as expected with properties closest to the station increasing in value the most. The results of the northeast section are somewhat surprising compared to expectations, exhibiting the opposite trend of increasing the further from the station.

Table 5.1: Property Price Changes for each Zone of Impact

Segment	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
West	127%	123%	117%
Central	204%	197%	189%
East (North)	111%	115%	119%
East (South)	118%	111%	105%

5.1.1 Western Section

As seen through the aforementioned figures, the western section of Crossrail experienced the second-highest increase in average absolute property prices. Using both figure 5.1 and table 5.2 in Appendix A, which illustrates the breakdown for each station comprising details of the percentage and value increases, one can establish a number of observations. Properties within 250m of Reading station increased the most in value, by 193% which equates to £335,967. The highest overall performing stations however were both located in Zone 2, West Ealing, closely following by Acton Main Line.

5.1.2 Central Section

As previously mentioned, the central section averaged the highest increase in property prices. Table 5.3 in Appendix A, illustrates that the best performing station Bond Street, witnessed the highest overall increase for properties within 0.25km (271%). Other areas of substantial growth are Tottenham Court Road and Liverpool Street. Canary Wharf, however, was significantly below the average for the other stations across the central route

5.1.3 Eastern (North) Section

The northern part of the eastern section witnessed comparatively underwhelming absolute property price increases. Figure 5.4 in Appendix A shows that the most significant increase came from properties

within proximity of Forest Gate with an average of 162% across all impact zones., however areas around the stations Seven Kings, Goodmayes, Brentwood and Romford saw comparatively little growth.

5.1.4 Eastern (South) Section

Figure 5.1 and table 5.5 in Appendix A detail the breakdown of results for the southern part of the eastern section. Although there are only three stations across this section, the results were slightly lower than expectations. The largest increase in values was for properties located within 250m of Woolwich station, however this increase was still only a relatively small 139%. Despite the journey saving benefits, properties within 1km of Abbey Wood increased by just 101% over the past 16 years.

5.2 Benchmarked Property Price Changes

This section will analyse results based on the benchmarks that were established in table 4.2, showing the increase in property prices once the impact of Crossrail has been isolated. With the benchmark considered, the western section experienced the highest increase in relative property prices, whilst the eastern sections were approximately similar to the benchmark. The significant absolute increases experienced by the central section have also been considerably eroded when the benchmark was introduced.

Table 5.6: Benchmarked Property Price Changes for each Zone of Impact

Segment	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
West	23%	19%	12%
Central	15%	8%	0%
East (North)	- 4%	0%	2%
East (South)	-14%	-21%	-27%

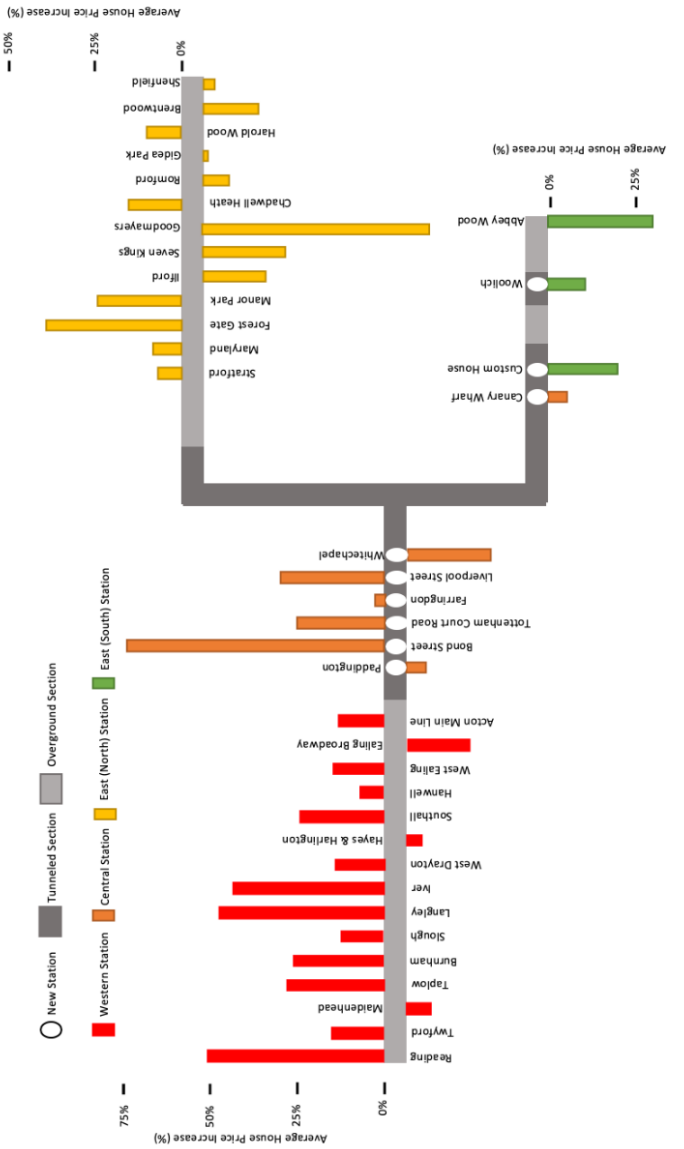

Figure 5.4: Average Benchmark Price Changes for Properties Within 1km of Crossrail Stations

5.2.1 Western Section

The western section of Crossrail largely outperformed the benchmark for the area, with properties around only three stations falling below the baseline. When the benchmark is considered, Reading now records the highest increase above the 1km radius. Furthermore, properties within 0.25km of Reading station have exponentially grown in price, by 101%.

Table 5.7: Benchmarked Property Price Changes Across Crossrail's Western Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Acton Main Line	21%	21%	-3%
Ealing Broadway	-19%	-19%	-16%
West Ealing	19%	19%	6%
Hanwell	6%	6%	8%
Southall	30%	20%	23%
Hayes & Harlington	-1%	-3%	-9%
West Drayton	23%	9%	11%
Iver	44%	44%	44%
Langley	53%	53%	38%
Slough	0%	25%	11%
Burnham	35%	25%	18%
Taplow	33%	33%	19%
Maidenhead	-22%	1%	0%
Twyford	15%	15%	15%
Reading	101%	33%	20%

5.2.2 Central Section

Although the central section experienced the largest increase in regard to absolute price increases, when the benchmark is considered, the increases are more limited. Nevertheless, Bond Street still performs exceptionally well, with increases of 82% to properties within the 0.25km radius, whilst Liverpool street performs well. Other stations though, including Paddington, Whitechapel and Canary Wharf are majoritively below the central benchmark.

Table 5.8: Benchmarked Property Price Changes Across Crossrail's Central Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Paddington	-4%	-10%	-3%
Bond Street	82%	76%	67%
Tottenham Court Road	19%	28%	30%
Farringdon	13%	1%	-5%
Liverpool Street	43%	47%	1%
Whitechapel	-23%	-24%	-26%
Canary Wharf	18%	-15%	-20%

5.2.3 Eastern (North) Section

As mentioned, the northern part of the eastern section displays a variety of results between each station and zone of impact, but averages to an equal increase as the benchmark. This is largely as a result of the significantly higher values that were achieved in some of the wider borough areas, therefore meaning that Crossrail's impact increases values to meet the benchmark. Forest Gate records the greatest increase, with Goodmayes the largest fall.

Table 5.9: Benchmarked Property Price Changes Across Crossrail's Eastern (North) Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Stratford	3%	6%	12%
Maryland	-2%	-2%	29%
Forest Gate	45%	45%	29%
Manor Park	13%	28%	32%
Ilford	-15%	-21%	-19%
Seven Kings	-42%	-15%	-15%
Goodmayes	-50%	-43%	-31%
Chadwell Heath	21%	21%	5%
Romford	-8%	-6%	-9%
Gidea Park	-3%	2%	-3%
Harold Wood	8%	8%	14%
Brentwood	-17%	-17%	-14%
Shenfield	-3%	-3%	-4%

5.2.4 Eastern (South) Section

The results of the southern part of the eastern section are overwhelmingly negative when the benchmark is introduced, with only properties within 0.25km of Woolwich station recording an above-baseline result.

Table 5.10: Benchmarked Property Price Changes Across Crossrail's Eastern (South) Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Custom House	-18%	-18%	-25%
Woolwich	7%	-15%	-25%
Abbey Wood	-31%	-31%	-30%

5.3 Spatial Impact of Crossrail

Finally, the overall results of Crossrail can be evaluated.

Table4.11: Overall Crossrail Impact

	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Crossrail Impact	10.37%	8.53%	4.61%

Indeed, as anticipated, the zone of influence within the closest proximity of the Crossrail station experiences the largest rise in property prices. As the distance from the station increases, the increase in price declines. Crossrail's impact still reaches properties up to 1km away, highlighting the significance of transport infrastructure for some areas.

6. Interpretation and Discussion

This section discusses the results attained from the methodology within context, hence interpreting the significance of the findings in light of existing literature. The section is structured around answering the final three objectives formulated in the introduction, providing a succinct answer to the overall research question and aim.

6.1 Residential Property Prices

The overall changes in residential postcode property prices between the two different comparison years have been as expected, considerable, with the benefits of Crossrail evident for many areas. In absolute terms, properties within 1km of all 38 Crossrail stations have increased by 170% from an average of £269,635 in 2003 to £727,773 in 2019, which represents a stark rise. Even when the baseline benchmark that isolates the impact of Crossrail is considered, properties within proximity of stations have increased by 7.8% more, which represents an additional £40,000 for a £500,000 property. Although the benefits of Crossrail have already been capitalised into residential values, one would expect the impacts to become ever more significant over the coming years as the rail line becomes operable and utilised.

As chapter 5 outlines, when the baseline benchmark is considered, Crossrail's most significant property impacts have been experienced across the Western section of the line. One of the reasons for this impact is that most of the stations along this section were previously isolated in terms of accessibility to the capital. As explored through Debrezion *et al.* (2004), Fejarang (1994) and Kamali *et al.* (2008), accessibility to the CBD is one of the most eminent determinants of property values. Crossrail additions for the western section will cut journey times to central London by an average of 30 minutes, supplying between four and ten trains per hour at peak times. Although the service will be less frequent than the eastern section, cut to travel times and a direct link to central London by not having to change at Paddington, vastly improves the accessibility and commuting journey for the region. Therefore, Crossrail has unlocked the dormant values of many areas that were previously considered tertiary. The results here match other studies including Hamptons (2014), which suggested that the effects of Crossrail in the west were the most extensive, with prices and transaction growth well above local authority averages as buyers were more confident that Crossrail would have a significantly positive effect on the area.

Across the western route, there are significant value differentials between stations, with some stations located in lower value locations such as Southall. Accordingly, although in 2003 the properties in the area start at similar prices to the benchmark (£186,917 and £184,609), property values in Southall have now accelerated to £407,383, pulling away from the 2019 benchmark of £362,854. Other stations that

start in lower value locations, such as Hanwell were significantly below the benchmark and do not appreciate sufficiently to exceed the area benchmark for 2019. Nevertheless, Crossrail has been influential in eroding the gap by facilitating development in the area.

Reading station records the most substantial increase in property values when the benchmark is considered. Crossrail has strengthened the cities position, which already has a strong rail network. Individuals can enjoy the inherent amenities associated with a city, but now make cheaper, quicker and more frequent journeys into the capital, likely attracting strong demand from young professionals. Whilst there is only a small cut in journey times to Bond Street, there are now considerably quicker journeys to the city and canary wharf by eliminating changes.

Both Knight Frank and CBRE studies found that Acton Main Line station experienced the highest increase in house prices across the Western route. Although this study found evidence to suggest this has not been the case, there is still an indication that properties around this station outperformed the market benchmark. There is however evidence to suggest that buyers were initially attracted to both zone 2 stations, Acton Main Line and Ealing Broadway, however, due to the high prices (approximately £750,000), buyers looked beyond the area further west, which explains the buoyant market in locations such as Southall.

The results from chapter 5 highlight that in absolute terms, the properties around central section stations experienced the most significant increase in values at 233%, from an average of £474,241 in 2003 to £1,579,013 in 2019. This considerable growth demonstrates the strength of London's housing market over the past 16 years despite experiencing one of the largest economic downturns in recent history. Accordingly, since the recession the economy has propelled forward through an influx of foreign investment and skilled labour, which has gone far in driving the housing market. This growth, which is demonstrated in section 2.5.2 depicts the resilient, global nature of central locations.

However, when the central benchmark is considered, the increase is significantly eroded, enough to the extent that properties within 500m-1km of the station receive no benefit from Crossrail. The reason for this again links to the argument of accessibility posed by Debrezion *et al.* (2004), Fejarang (1994) and Kamali *et al.* (2008), with all stations already possessing excellent links to other areas of the city. Indeed, each station across the route excluding Canary Wharf already encompasses at least two underground tube lines. Therefore, another railway line will produce fewer marginal accessibility benefits compared to stations on London's outskirts.

Historically, values in areas such as Liverpool Street were significantly lower than the central London benchmark, however they have continued to trend upwards at a much faster rate. For example, in 2003, properties within 500m of Liverpool Street station averaged just £272,322, almost half as much as the

benchmark of £540,356. Currently, the values have accelerated to just under one million, which is much closer to the central benchmark.

Both Whitechapel and Canary Wharf have struggled to match the central London benchmark increase, representing the fact they are not prime residential patches. Previous studies from GVA (2012) outlined that they anticipated Canary Wharf to bridge the gap, but this continued lag reflects both the stronger than expected benchmark growth alongside the limited capacity and opportunities to deliver new developments in the Canary Wharf area.

The northern segment of the eastern section displayed results that were largely underwhelming considering what previous Crossrail research projects had reported. Studies, including Knight Frank (2017) and GVA (2016) detailed this section as the most impacted, with property prices increasing considerably. However, according to the results of this study station areas were largely similar to the area benchmark baseline. The poor performance is surprising considering there has been a surge in residential developments in the east, far more than the other sections. GVA's (2016) report details that over 3.5m sqft of residential floorspace has been constructed from 2008-2016, considerably higher than the other sections (1.5m West and 2.75m Central), demonstrating that there is high residential demand in the area. The benefits of development have not yet capitalised into values; however, one would expect to see an explosive acceleration over the coming years.

Perhaps the main reason that the section comparatively underperformed was because of the relatively abundant central London connections. In comparison to the western section, the east had better pre-existing connections before Crossrail, so the time saving to central London is less significant, as shown in figure 5.2. Linking this to literature, it is therefore evident that the eastern area gains comparatively fewer accessibility benefits through Crossrail which have not been capitalised into values. For example, Stratford station already has five train-lines and can reach Kings Cross in 7 minutes using HS1. Furthermore, because of the vast station area, there is minimal housing within both a 250-and-500-metre proximity.

Another reason, argued by Hamptons (2014) who shared similar findings to the results of this paper, is that the areas immediately surrounding stations are less desirable and that the higher value markets in the west were better positioned to take advantage of the recovering housing market after the recession.

Despite the results of this study not yielding the same overall section findings as others, all studies shared a common station which recorded the highest change in property values – Forest Gate. The largely supply-fixed Victorian conservation area will now benefit from a 12-minute commute to Bond Street and because of the limited space for new developments, house prices have risen significantly.

The southern segment of the eastern section recorded vastly underperforming results, both with regards to absolute property price changes and a significant lag behind the area benchmark. In a similar fashion to the north-eastern section, this area has gained considerable development, with both Custom House and Woolwich adding over 500,000 sqft of residential floor space from 2008-2016 GVA, 2016), however the benefits are yet to be capitalised into value increases. The results, although poor, conformed with both Hamptons (2014) and JLL (2015) studies.

Even though the accessibility benefits are significant, the areas have undergone vast regeneration over the past two decades. The areas were also marred for years with uncertainty over the Crossrail route, which impacted buyer confidence. Furthermore, the housing make-up of the areas surrounding the stations does not lend to house price appreciation. Less than a third of the 4,600 households within 500m of Woolwich station live in privately-owned accommodation, with the majority renting from the Local Authority. Similarly, in Abbey Wood, London's second-largest public housing development, Thamesmead, is within close proximity.

Crossrail therefore appears to have had a two-fold impact on property values. Firstly, improvements in connectivity have generated accessibility benefits that have opened up new districts and reduced travels times, which have both driven up residential sector values. Additionally, Crossrail has attracted significant investment and development activity in otherwise neglected areas, which have led to wider improvements in the area which have unlocked the considerable underlying values of areas. Although some of the most developed areas, particularly both eastern sections, are yet to reap the development benefits, growth would be expected to accelerate in the coming years. This duality of effects can be categorised into accessibility and amenity, which links to the narrative of infrastructure impacts discussed by scholars. The biggest postcode winners stand to be Reading, Bond Street, Forest Gate and Woolwich.

6.2 Spatial impact of Crossrail

As detailed above, Crossrail had a definite impact on residential property postcodes which were in the station vicinity, however the impact differed considerably with distance from the station. Through a review of other studies (*see* Bajic, 1983; Laakso, 1992; Debrezion *et al.,* 2004), the expectations were that greater benefits are attributed to properties closest to the railway station. Indeed, as expected, properties closest to the Crossrail station increase in value by 10.4% above the benchmark, whilst properties that are between 500-and-1000 metres away increased by just 4.6% above the benchmark. By using the results established from table 5.11, one can ascertain that for every 100m from the Crossrail station property values decrease by 0.76%.

Therefore, for a property that has appreciated by £500,000 over the past 16 years, on average it would benefit from an additional £52,000 premium for being within a 250m distance from a Crossrail Station. However, a property up to 1000m would benefit by an average of £23,000. In some circumstances, for example, Reading station, properties within 250m double in appreciation over the past 16 years compared to the surrounding benchmark, highlighting the pull of Crossrail for some areas.

This trend exists primarily through accessibility ease, eliminating some of the friction of travelling to the CBD, but also through the array of amenities that new stations can offer. As seen with Tottenham Court Road and Canary Wharf, new stations can bring vast development's, which contain retail and leisure facilities, hence making the area more attractive. Proximity to both amenity and transportation therefore in theory should increase property values.

Although this is the trend, for some stations, particularly those on the northern segment of the eastern section, properties closest to Crossrail Stations have not always benefited with value premiums. In actuality, properties in the outer zone experienced a 2% premium, whilst those in the inner and middle zones of influence experienced negative or no premium. As mentioned previously, Hamptons (2014) study found evidence to suggest that the areas immediately around the station were less desirable in the east. Furthermore, for some properties located less than 250m away from the station, many negative externalities may become prevalent, including noise pollution, worsened aesthetics and heavier traffic. Therefore, although accessibility is one of the most influential determinants, the marginal benefit of 250m proximity does not outweigh the significantly worse environmental or neighbourhood surrounding determinants (Ajibola *et al.,* 2013).

Nevertheless, the overall spatial trend from this study broadly fits with the theoretical determinants of property prices, and wider literature, including Celik and Yankaya (2006), Al-Mosaind *et al.* (1993), Grass (1992), Bajic (1983).

6.3 Update to literature

The successful completion of the outlined methodology combined with the results discussed above suggests that this study has contributed to the finite literature surrounding both Crossrail and transport infrastructure, by assessing the inherent impact it may have on property prices in surrounding areas.

All five listed Crossrail studies established extremely positive results, ranging from 19% (JLL) to 40% (Knight Frank). This studies results report the equivalent positive correlation; however, the magnitude of correlation was somewhat lower. Although no results will be the same, simply due to the differing timelines, exact methodology techniques and zone of influence proximity measurements, one would

have perhaps expected that the results of this study would be greater simply because of the extended timeframe. An explanation for this is that this study includes two significant political and economic events that negatively impacted the property market. The first was the 2008 economic crisis, which damaged property values. All of the existing Crossrail studies used an analysis date after the crisis, for example, Knight Frank (2008) and Hamptons (2009). The second event was the European Union Referendum results, which negatively impacted the economy far greater than any expectations. Again, each study concluded their timeframe before this event. Other projection studies, such as GVA (2016) and JLL (2015) would have failed to account for such event and accordingly are likely to have value appreciations. Therefore, this study has updated the Crossrail literature by providing an extended timeframe which includes two significant negative events, but also by confirming that the impacts are inherently positive, particularly for areas that were previously starved of accessibility.

This evaluation of Crossrail has also provided an insight into transport infrastructure more generally. Overall, the existing transport infrastructure studies exhibited a positive correlation when evaluating property, however there was no consistent consensus. Accordingly, the impact was frequently held under 10%, and for many that conducted hedonic analysis, much of the variance was unexplained with the scholars chosen variables. Moreover, neither of the three selected UK studies showed any statistical correlation. The results of this study therefore suggest an overall positive trend, but Crossrail has also affirmed many studies conclusions that the impact of transport infrastructure for properties is highly localised and contextual. Indeed, stations such as Goodmayes, which have attracted little investment or wider regeneration development and had a sufficient rail network accessibility previously have experienced few valuation gains.

6.4 Limitations

Several limitations have emerged surrounding both the methodology and data used. The majority of data was collected through HM Land Registry, which although is very reliable and provides excellent coverage, there were some missing postcode areas. Another problem with HM Land Registry is that the dataset is inherently lagged, meaning that some older transactions will have been posted at later dates and some of the newest transactions may not yet be recorded.

Furthermore, the data collected was based on sectoral postcode areas, rather than individual houses. Although this spatial scope is sufficiently detailed for analysis, there are occasions where postcodes overlap into two ‘zones of influence’. Because the ‘innermost’ and ‘middle’ zone are separated by just 250m, the inherent granary characteristics of the postcode mean that this limitation is unavoidable, unless data is collected to an individual property level, which would have yielded far too much information.

Although there is good, reliable coverage of residential property data, the same cannot be said for commercial properties. Due to the disclosed nature of commercial deals, there is no central database with detailed transaction figures. The most renowned database is CoStar, however, there are many studies which question reliability. This therefore limited the ability for this study to extend and evaluate property as a whole, analysing the impacts that Crossrail had on commercial values.

Regarding the methodology, one of the biggest limitations was that the benchmark for each area was not entirely accurate. Although each benchmark was carefully established, taking into account a variety of socioeconomic demographic factors, journey times into central London and the general area environment, it is impossible to completely replicate areas and perfectly isolate the impact of Crossrail. Therefore, it is probable that the areas will have performed differently over the past 16 years, even if Crossrail had never been incepted or implemented. Hedonic modelling is the technique required to completely isolate the impact of Crossrail, hence why several studies utilise it, however there are too many unobserved variations across 38 Crossrail Stations for practical use.

Another limitation to the method was that the 'zone of influence' was established with 'as-the-crow-flies' distance. Although this determines general proximity, depending on the road network it does not necessarily translate to accessibility. Therefore, an alternative measure to establish accessibility would be through practical measures such as a 10-minute walk.

7. Conclusion

By increasing the volume of individuals travelling into central London, the impact of Crossrail will be felt across all environs of greater London, unlocking vast expansion potential. Although commercial office, industrial and retails markets will attract a considerable boost, the most impacted industry stands to be the residential market. Property-owners along the entire stretch of the route will continue to see their homes proliferate in value as their journeys to work become shorter and more convenient, and their neighbourhoods continue to develop and improve.

The values have increased at differing rates depending on the local context, specifically the pre-existing transport networks, local development and socioeconomic demographics. Generally, properties located closest to the station, or in areas that have received considerable transport infrastructure upgrades have appreciated the most. Overall, across the route property values have nearly trebled from 2003 to 2019, increasing by an average of 170%. Therefore, properties around Crossrail have outperformed the market by an average of 7.8% over the past 16 years. Naturally there have been some 'winning' stations, where the surrounding area has been heavily redeveloped and accordingly properties have appreciated considerably. These currently stand to be Reading, Iver, Langley, Bond Street, Tottenham Court Road, Liverpool Street and Forest Gate.

Therefore, the aim of the study has been achieved. In doing so, both the existing Crossrail studies and limited UK transport infrastructure have been updated, providing a reliable report of changes in residential prices across the route.

There are more positive benefits to come from Crossrail. With the service less than 18 months from the rescheduled opening date, property at each station is likely to experience significantly increased demand from buyers and renters once operable. Furthermore, value forecasts, combined with the permitted and potential planning pipeline, sector intelligence and general property market trends suggest that Crossrail's contribution to residential values and wider station area regeneration will increase years beyond the opening of the line.

Crossrail has acted as an example of major transport infrastructure that has supported wider regeneration and accordingly delivered boosts to local housing markets. Therefore, this study, situated within a broader context of literature supports the theory and scholarly argument that adding accessibility should increase residential property values. However, the impacts are extremely localised, and significant change requires stakeholder co-ordination, public realm investment and a forward-thinking local authority approach. Areas of substantial investment and development have satisfied a larger number of property price determinants, by generating an improved neighbourhood an environment. However, in

isolation and where network transports already exist, the impacts can be insignificant, and in some cases negative.

This study has therefore helped provide unique support in answering the overall research question, by introducing a new methodology to scholarly literature and evaluating changes over a prolonged timeframe.

7.1 Future Research

There are several avenues with which this study could be taken in the future. As stated in the limitations section, the study could be extended to commercial property types. As has been evaluated with other studies, commercial real estate reacts differently to the addition of transport infrastructure, so assessing and analysing how much Crossrail has accelerated commercial values would be useful. Furthermore, it would be beneficial to assess the different spatial pull of Crossrail for commercial property, with a much smaller expected zone of influence.

Another suggestion for further study would be to assess the impacts that transport infrastructure has on every aspect of the broader property market, not merely limiting the analysis to value changes. Accordingly, one could evaluate the wider development pipeline, assessing the impact that Crossrail has had on development capacity and delivery. Another avenue would be the impact that Crossrail has on placemaking and how areas around stations are offering different activities and amenities. Finally, to support the argument that Crossrail has an impact on the property market, the number of transactions close to stations could be analysed, to evaluate market activity.

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9. Appendix

Appendix A

Table 4.2: Control Sample Locations

Benchmark Segment	Locations	Reasoning
Central	Belgravia, Knightsbridge, Pimlico (SW1W, SW1X, SW7, SW1)	These locations are affluent areas, which represent a median household income £51,000, which similarly compares to £49,000 for Belgravia and £48,000 for Farringdon. Likewise, both areas share similar social characteristics with regards to crime rate (260 and 305), age and ethnicity structure, health and wellbeing. Both areas are similar however, Crossrail is not a direct influence in the control sample.
Western Section 1	New Malden (KT1, KT2)	Similar travel time to London before Crossrail, with direct trains reaching London Waterloo in 25 minutes. New Malden is similarly situated with reference to central London but also shares similar demographics to a number of stations across the Western section. For example, the mean annual salary is approximately £32,000 compared to £30,000 in Acton. Socially, the areas have similar education levels and ethnicity structures.
Western Section 2	Farnborough (GU11, GU14)	Similar travel time to London before Crossrail, with trains reaching London Waterloo in 40-50 minutes. Demographically, an area such as Maidenhead compares similarly both socially and economically to Farnborough – with owned/mortgage households (68% and 63.5%), 25-64 age population (54.1%, 55.4%), general health at good/very good (86.73% and 85.61%), job seekers allowance rate (1.7% and 2%), and ethnic structure (82.6% and 82.4%) British.
East (North) Section 1	Woodford, Chingford (E18, E4)	The journey time for Woodford/Chingford to reach Tottenham Court Road and central London is approximately 30 minutes, which is similar to a journey from Forest Gate (35 minutes) before Crossrail is operable. The social demographics of the area are also similar regarding ethic makeup (76.11% and 74.98%), general health at good/very good (83.07% and 83.10%).
East (North) Section 2	Croydon, East Barnet (CR0, EN4)	A journey from Romford currently takes a similar amount of time (42 mins) compared to Croydon (41 mins) and East Barnet (45 mins). Again, economically many aspects of these areas are similar. For example, Romford has a median income of £30,000 which is comparable to East Barnet (£32,000).
East (South)	Peckham, Beckton, Silvertown (SE15, E16)	A journey from Abbey Wood to central London currently takes 55 mins, which is similar to Beckon (60 mins) and Silvertown (50 mins). Two of these areas are similarly rejuvenated docklands areas, which accordingly share many similarities.

Table 5.2: Property Price Changes Across Crossrail's Western Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Acton Main Line	160%	160%	136%
Ealing Broadway	120%	120%	123%
West Ealing	158%	158%	145%
Hanwell	145%	145%	147%
Southall	122%	112%	115%
Hayes & Harlington	91%	89%	83%
West Drayton	115%	101%	103%
Iver	136%	136%	136%
Langley	145%	145%	130%
Slough	92%	117%	103%
Burnham	127%	117%	110%
Taplow	125%	125%	111%
Maidenhead	70%	93%	92%
Twyford	107%	107%	107%
Reading	193%	125%	112%

Table 5.3: Property Price Changes Across Crossrail's Central Section Stations

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Paddington	185%	179%	186%
Bond Street	271%	265%	256%
Tottenham Court Road	208%	217%	219%
Farringdon	202%	190%	184%
Liverpool Street	232%	236%	219%
Whitechapel	166%	165%	163%
Canary Wharf	162%	129%	124%

Table 5.4: Property Price Changes Across Crossrail's Eastern (North) Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Stratford	125%	134%	129%
Maryland	120%	120%	151%
Forest Gate	167%	167%	151%
Manor Park	135%	150%	154%
Ilford	107%	101%	103%
Seven Kings	80%	107%	107%
Goodmayes	72%	79%	91%
Chadwell Heath	127%	127%	111%
Romford	98%	100%	97%
Gidea Park	103%	108%	103%
Harold Wood	114%	114%	120%
Brentwood	89%	89%	92%
Shenfield	103%	103%	102%

Table 5.5: Property Price Changes Across Crossrail's Eastern (South) Section Station's

Station	0 – 0.25km	0.25 – 0.5km	0.5 – 1km
Custom House	114%	114%	107%
Woolwich	139%	117%	107%
Abbey Wood	101%	101%	102%

Appendix B

RISK ASSESSMENT FORM
FIELD / LOCATION WORK

UCL

The Approved Code of Practice - Management of Fieldwork should be referred to when completing this form
http://www.ucl.ac.uk/estates/safetynet/guidance/fieldwork/acop.pdf

DEPARTMENT/SECTION BARTLETT SCHOOL OF PLANNING
LOCATION(S) LONDON
PERSONS COVERED BY THE RISK ASSESSMENT 1

BRIEF DESCRIPTION OF FIELDWORK Using secondary data, with analysis done on a computer

Consider, in turn, each hazard (white on black). If **NO** hazard exists select **NO** and move to next hazard section.
If a hazard does exist select **YES** and assess the risks that could arise from that hazard in the risk assessment box.
Where risks are identified that are not adequately controlled, they must be brought to the attention of your Departmental Management who should put temporary control measures in place or stop the work. Detail such risks in the final section.

ENVIRONMENT	**The environment always represents a safety hazard. Use space below to identify and assess any risks associated with this hazard**
e.g. location, climate, terrain, neighbourhood, in outside organizations, pollution, animals.	Examples of risk: adverse weather, illness, hypothermia, assault, getting lost. Is the risk high / medium / low? NO

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ work abroad incorporates Foreign Office advice
- ☐ participants have been trained and given all necessary information
- ☐ only accredited centres are used for rural field work
- ☐ participants will wear appropriate clothing and footwear for the specified environment
- ☐ trained leaders accompany the trip
- ☐ refuge is available
- ☐ work in outside organisations is subject to their having satisfactory H&S procedures in place
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

NO

EMERGENCIES	**Where emergencies may arise use space below to identify and assess any risks**
e.g. fire, accidents	Examples of risk: loss of property, loss of life

NO

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ participants have registered with LOCATE at http://www.fco.gov.uk/en/travel-and-living-abroad/
- ☐ fire fighting equipment is carried on the trip and participants know how to use it
- ☐ contact numbers for emergency services are known to all participants
- ☐ participants have means of contacting emergency services
- ☐ participants have been trained and given all necessary information
- ☐ a plan for rescue has been formulated, all parties understand the procedure
- ☐ the plan for rescue /emergency has a reciprocal element
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

NO

FIELDWORK 1 May 2010

EQUIPMENT	**Is equipment used?**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. clothing, outboard motors.	Examples of risk: inappropriate, failure, insufficient training to use or repair, injury. Is the risk high / medium / low?		

NO

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
☐	the departmental written Arrangement for equipment is followed
☐	participants have been provided with any necessary equipment appropriate for the work
☐	all equipment has been inspected, before issue, by a competent person
☐	all users have been advised of correct use
☐	special equipment is only issued to persons trained in its use by a competent person
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

NO

LONE WORKING	**Is lone working a possibility?**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. alone or in isolation lone interviews.	Examples of risk: difficult to summon help. Is the risk high / medium / low?		

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
☐	the departmental written Arrangement for lone/out of hours working for field work is followed
☐	lone or isolated working is not allowed
☐	location, route and expected time of return of lone workers is logged daily before work commences
☐	all workers have the means of raising an alarm in the event of an emergency, e.g. phone, flare, whistle
☐	all workers are fully familiar with emergency procedures
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

NO

ILL HEALTH	**The possibility of ill health always represents a safety hazard. Use space below to identify and assess any risks associated with this Hazard.**
e.g. accident, illness, personal attack, special personal considerations or vulnerabilities.	Examples of risk: injury, asthma, allergies. Is the risk high / medium / low? NO

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ an appropriate number of trained first aiders and first aid kits are present on the field trip
- ☐ all participants have had the necessary inoculations/ carry appropriate prophylactics
- ☐ participants have been advised of the physical demands of the trip and are deemed to be physically suited
- ☐ participants have been adequate advice on harmful plants, animals and substances they may encounter
- ☐ participants who require medication have advised the leader of this and carry sufficient medication for their needs
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

TRANSPORT	**Will transport be required**	**NO**	**X**	**Move to next hazard**
		YES		**Use space below to identify and assess any risks**
e.g. hired vehicles	Examples of risk: accidents arising from lack of maintenance, suitability or training Is the risk high / medium / low?			

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ only public transport will be used
- ☐ the vehicle will be hired from a reputable supplier
- ☐ transport must be properly maintained in compliance with relevant national regulations
- ☐ drivers comply with UCL Policy on Drivers http://www.ucl.ac.uk/hr/docs/college_drivers.php
- ☐ drivers have been trained and hold the appropriate licence
- ☐ there will be more than one driver to prevent driver/operator fatigue, and there will be adequate rest periods
- ☐ sufficient spare parts carried to meet foreseeable emergencies
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

DEALING WITH THE PUBLIC	**Will people be dealing with public**	**NO**	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. interviews, observing	Examples of risk: personal attack, causing offence, being misinterpreted. Is the risk high / medium / low?		

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ all participants are trained in interviewing techniques
- ☐ interviews are contracted out to a third party
- ☐ advice and support from local groups has been sought
- ☐ participants do not wear clothes that might cause offence or attract unwanted attention
- ☐ interviews are conducted at neutral locations or where neither party could be at risk
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

WORKING ON OR NEAR WATER	Will people work on or near water?	NO	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. rivers, marshland, sea.	Examples of risk: drowning, malaria, hepatitis A, parasites. Is the risk high / medium / low?		

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ lone working on or near water will not be allowed
- ☐ coastguard information is understood; all work takes place outside those times when tides could prove a threat
- ☐ all participants are competent swimmers
- ☐ participants always wear adequate protective equipment, e.g. buoyancy aids, wellingtons
- ☐ boat is operated by a competent person
- ☐ all boats are equipped with an alternative means of propulsion e.g. oars
- ☐ participants have received any appropriate inoculations
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

MANUAL HANDLING (MH)	Do MH activities take place?	NO	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. lifting, carrying, moving large or heavy equipment, physical unsuitability for the task.	Examples of risk: strain, cuts, broken bones. Is the risk high / medium / low?		

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ the departmental written Arrangement for MH is followed
- ☐ the supervisor has attended a MH risk assessment course
- ☐ all tasks are within reasonable limits, persons physically unsuited to the MH task are prohibited from such activities
- ☐ all persons performing MH tasks are adequately trained
- ☐ equipment components will be assembled on site
- ☐ any MH task outside the competence of staff will be done by contractors
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

SUBSTANCES	Will participants work with substances	NO	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. plants, chemical, biohazard, waste	Examples of risk: ill health - poisoning, infection, illness, burns, cuts. Is the risk high / medium / low?		

CONTROL MEASURES **Indicate which procedures are in place to control the identified risk**

- ☐ the departmental written Arrangements for dealing with hazardous substances and waste are followed
- ☐ all participants are given information, training and protective equipment for hazardous substances they may encounter
- ☐ participants who have allergies have advised the leader of this and carry sufficient medication for their needs
- ☐ waste is disposed of in a responsible manner
- ☐ suitable containers are provided for hazardous waste
- ☐ OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

OTHER HAZARDS	Have you identified any other hazards?	YES	If 'No' move to next section If 'Yes' use space below to identify and assess any risks
i.e. any other hazards must be noted and assessed here.	Hazard: Medical conditions resulting from extended display screen use Risk: is the risk		

Risk of incuring visual problems, postural problems and fatigue and stress

CONTROL MEASURES **Give details of control measures in place to control the identified risks**

Frequent breaks
Appropriate Light levels
Freedom of movement required when sitting in for extended periods

Have you identified any risks that are not adequately controlled?	NO	X	**Move to Declaration**
	YES	☐	**Use space below to identify the risk and what action was taken**

Is this project subject to the UCL requirements on the ethics of Non-NHS Human Research? Yes

If yes, please state your Project ID Number 18093702

For more information, please refer to: http://ethics.grad.ucl.ac.uk/

DECLARATION The work will be reassessed whenever there is a significant change and at least annually. Those participating in the work have read the assessment.

Select the appropriate statement:

- X I the undersigned have assessed the activity and associated risks and declare that there is no significant residual risk
- X I the undersigned have assessed the activity and associated risks and declare that the risk will be controlled by the method(s) listed above

NAME OF SUPERVISOR Alex Moss

**** SUPERVISOR APPROVAL TO BE CONFIRMED VIA E-MAIL ****