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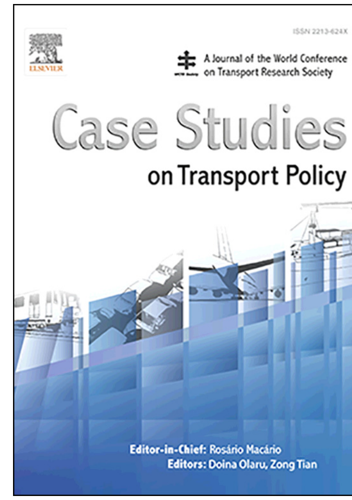

Public transport accessibility and housing value uplift: Evidence from the Docklands Light Railway in London

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Abstract

Public transport infrastructure is essential to city development, improving accessibility and allowing people to engage in activities, allowing travel by environmentally-friendly modes, and also creating economic benefits. This study investigates the impacts of public transport accessibility on development, examining changes in housing prices, and applying hedonic modelling. London's Docklands Light Railway (DLR) is selected as a case study. The findings show that residential properties in station catchment areas of the south-eastern and northern branches of the DLR have a premium respectively of 0.352% and 0.093% per 100m proximity to a station. By assessing inclusive variables, it is found that housing value is also determined by the property's own features and the neighbourhood, particularly the property tenure. The detected housing value uplift implies that the provision of good public transport is crucial in policy making, especially in areas with poor public transport accessibility. Moreover, since transport investment is partly capitalised in housing projects, we suggest that future transport infrastructure investment and housing development should be set within a framework of value capture policies.

Keywords

Transport accessibility; Transport infrastructure; Transport investment; Public transport; Docklands Light Railway; Land value uplift; House prices; London.

Highlights

- The impacts of the DLR south-eastern branch produced a higher premium on house prices compared to those of the northern branch.
- Within station catchment areas, property tenure is most influential in determining housing values.
- Houses that are detached, newly built, freehold and on brownfield sites are likely to be more expensive than their counterparts.
- The regression curves of the average housing price per 100m from the station were analysed, showing that each station catchment area may generate approximately £5-8 million residential value uplift.

1. Introduction

Building extensive public transport systems is now an objective for many cities internationally, with large amounts of funding being used for this purpose. Improving accessibility by public transport is usually the most efficient and only possible way to deliver large volumes of passengers to and from the larger metropolitan cities, and is important to improving access to activities (Cao and Hickman, 2019; Cuthill et al., 2019; Handy and Clifton, 2001; Pagliara and Papa, 2011).

In London, the current transport strategy (TfL, 2017) is seeking to serve a projected growth in population from 8.7 million in 2015 to 10.5 million in 2041. There was an average of 26.7 million daily trips in 2015, with 64 per cent delivered by public transport, walking or cycling; and 36 per cent by private car. By 2041, the target is to achieve 32 million daily trips, with 80 per cent of these delivered by public transport, walking or cycling; and only 20 per cent by private car – hence the requirement for new public transport investment. Major new projects are planned, with capacity and frequency upgrades, new lines such as Crossrail (at a cost of £15 billion) and Crossrail2 (£33 billion), new interchange refurbishments, alongside wider pedestrian, cycling and public realm improvements. Public transport infrastructure is seen as critical to developing the modern and sustainable city:

> "*Transport networks make the city what it is – connecting communities, opening up opportunities and creating the conditions for London's global economy to flourish*."
> (TfL, 2017, p.10).

There are large potential developmental impacts associated with this type of public transport investment, with new projects often leading to increases in property values. Projects are partially justified in terms of the development that might follow. It is stated, for example, that Crossrail 2 can provide capacity for an additional 270,000 people travelling across London and unlock access to 270,000 new homes (TfL, 2017). The provision of housing is an important issue for strategic planning in London, as efficient housing supply can bring diverse social and economic benefits to communities (Forrest, 2012). London has consistently experienced a shortfall of dwellings in the face of demand and high levels of unaffordability, disposable income increases and demographic changes (Maliene and Malys, 2009). In 2017, it was expected that a minimum of 42,000 new housing units per annum would be required to meet the expected demand in London (Savills, 2017), with a large proportion of these required as affordable housing. The narrative is hence to support population growth and provide housing supply through investment in public transport.

Although planners and politicians have assumed that property values are partly dependent on their proximity to stations (Welch et al., 2016), there are limited empirical studies assessing how access to a public transport station affects housing prices in the UK (Banister and Thurstain-Goodwin, 2011; Dabinett et al., 1999; Forrest et al., 1996; Knowles and Ferbrache, 2016), especially undertaken at the local level – such as London (Gibbons and Machin, 2005). Moreover, existing studies found that the relation between transport accessibility to local stations and housing prices is complex, in that the characteristics of the public transport-induced price fluctuations in the housing market and the extent of attracting a premium depend on local contextual features. Understanding the relationships between public transport accessibility and development value, however, is critical in cities, such as London – allowing assessments to be made about appropriate levels of housing supply, optimum locations for new housing development, the potential for value capture, and possibilities for funding infrastructure.

The motivation for this paper is to lend a potential policy-shaping perspective to transport infrastructure investment in London, through determining the relationship of travel accessibility to residential housing prices and hence quantify the relative importance of influential factors leading to land value uplift. The paper attempts to satisfy the overall purpose by addressing three interrelated research questions: 1) what impact does access to a light rail transit station have on housing prices?; 2) how is the relationship between accessibility and housing prices related to the temporal sequence of the delivery of a transport project?; and 3) whether accessibility to a public transport station is the most prominent feature in determining property values or not?

The paper is structured as follows. Section 2 reviews the previous literature; section 3 briefly describes the case study of the Dockland Light Railway (DLR), the data, the variables and the method; section 4 presents the modelling results; section 5 provides contributions, discussions and policy implications as well as stating the limitations of the research; and section 6 draws the conclusions.

2. Literature review

Previous studies have measured the impacts of different types of public transport projects on rental rates or property prices. In spite of mixed findings, many research results show the significance of transport accessibility in affecting housing values. Mainly focusing on the US context, studies have found that properties located close to transit stations have higher values than those built away from station catchments (Al-Mosaind et al., 1993; Benjamin and Sirmans, 1996; Debrezion et al., 2007; Voith, 1993). Hedonic modelling has become the dominant empirical method used, particularly in the US studies, yet this type of approach is less well used in Europe and the UK. Some UK studies demonstrate the significance of extending transit lines in increasing land values (Banister and Thurstain-Goodwin, 2011; Comber and Arribas-Bel, 2017; Gibbons and Machin, 2005; Jones, 2015; Knowles and Ferbrache, 2016), but the price premiums that might result from non-transport effects are not quantified.

Although most of the literature suggests that land values are reduced with distance decay from stations, there is some evidence that negative externalities, such as pollution and noise, significantly reduce property prices in the locations closest to stations (Bowes and Ihlanfeldt, 2001; Brandt and Maennig, 2012; Laakso, 1992), with the highest prices being a certain distance away from the station. For example, Laakso (1992) investigated the housing market in Helsinki before and after transit and found that properties 250–500m from railway stations had a higher value than those less than 250m away. However, this finding deserves scrutiny as the distance to the non-existent station[1] (before it opened) was excluded from the modelling, resulting in uncertainty as to whether the negative externalities were caused by existing locational effects or station proximity.

It is, of course, not solely transport accessibility that affects housing prices. Several studies have highlighted the influence of non-transport contributing factors, including physical features, neighbourhood characteristics and local amenities (Banister and Thurstain-Goodwin, 2011; Bowes and Ihlanfeldt, 2001; Hess and Almeida; 2007; Henneberry, 1998; Huang et al., 2017). Some studies found that property values were insignificantly boosted by transport improvement (Cervero and Landis, 1993; Forrest et al., 1996; Gatzlaff and Smith, 1993), though these were mainly based on analysis in the US context, where urban development is less focused around the public transport system, and perhaps the transit network is fairly limited and with low patronage. For instance, Gatzlaff and Smith (1993) claimed that the insignificant effect of the Miami Metrorail might be due to the car-oriented transport plan. Another possible cause is that transport accessibility is less influential than other non-transport factors that influence housing prices. In some US (Hess and Almeida, 2007), Asian (Huang et al., 2017) and Australian contexts (Mulley, 2014), property and neighbourhood features have been found to be important in determining prices. However, many studies conducted outside the US have issues with acquiring data about detailed internal features (such as age and size of property). Apart from internal features, Du and Mulley (2006) found that proximity to good schools was decisive in choosing home locations in Tyne and Wear. Proximity to schools was also assessed in London (Banister and Thurstain-Goodwin, 2011). Furthermore, Debrezion et al. (2010) examined wider variables such as local demographics and land use density.

In addition, land value capture covers mechanisms for recovering the property value uplift that derives from investing in infrastructure and allowing development in station catchment areas (Mulley, 2014; TfL, 2017). It has its origins in the early Garden City ideas and was implemented in the planning of New Towns in the UK (Hall and Ward, 1998). The station catchment areas where most uplift may occur can be seen as the ‘zone of influence’ (TfL, 2017, p.12). Over the years, the problem empirically has been isolating the impact of the transport investment on property value uplift alongside other issues. The uplift can concern residential and commercial development and sale or rental prices (TfL, 2017). Infrastructure can be funded by capturing the raised values, using mechanisms such as betterment taxes, tax increments and negotiated joint development initiatives via public-private partnerships (Cervero and Duncan, 2002; Mulley et al., 2016). Mulley et al. (2016) investigated a bus rapid transit (BRT) corridor in Brisbane, finding an unbalanced land value uplift where the effects of proximity are significant around older stations, thus suggesting betterment taxes or tax increment financing which has been widely implemented in the US. London is currently considering the most effective mechanisms, including the use of Community Infrastructure Levy (CIL) and Stamp Duty Land Tax (SDLT). However, perhaps both are likely to 'extract only a small fraction of land value gains from transport investment' (TfL, 2017, p.7). Nonetheless, there is much potential to use property value uplift for the public good, particularly if a higher proportion of uplift can be estimated and captured.

The association between transport accessibility and housing values has been assessed mainly in terms of station catchment areas and sale or rental prices, but each area seems to have unique physical characteristics and this complicates efforts to estimate general coefficients of uplift (Banister and Thurstain-Goodwin, 2011). There is no overall agreement concerning the microeconomic benefits. Likewise, selecting independent variables in one study may not be consistent with other studies, these being subject to different approaches taken and the data available for each area. As a result, the differences in identifying and selecting independent variables, together with the varied choices of the hedonic model form (e.g. linear or logarithm), are likely to contribute to the wide-ranging results of empirical studies. Some of the most informative literature and main findings are briefly summarised in Table 1.

To sum up, it is found that firstly, to date, the quantitative examination of the impact of transport accessibility on property values in Europe has not been well established, with most work carried out in the US context. There is currently limited research that uses inclusive variables and concentrates on the impact and relative importance of access to light rail transit stations on residential property prices in London. Secondly, while some researchers used panel data, most ignored the time series when adopting longitudinal data at a specific phase of the project timeline only (such as Bowes and Ihlanfeldt, 2001) or used cross-sectional data (such as Al-Mosaind et al., 1993; Laakso, 1992). This may reduce the accuracy (Hsiao, 2003) and reliability of the results (Mohammad et al., 2013) as failure to incorporate temporal aspects into the hedonic regression model leaves questions about whether the accessibility effect is the "effect of the locations" or the "effect of rail transit" (Ko and Cao, 2013, p.51). Despite a few studies attempting to use time-series data (Forrest et al., 1996), the temporal effect is rarely considered. Additionally, researchers often do not relate the improved accessibility effect to the public infrastructure investment strategies. Accordingly, planners and politicians who are interested in land value capture lack sufficient information to ascertain how and to what extent proximity to a station might lead to housing price uplift. Therefore, the aforementioned research gaps have been addressed in this research.

Table 1

Summary of the key literature.

Researchers	Types of rail transit	Types of housing	Study area	Main findings
Positive effects				
Al-Mosaind et al. (1993)	LRT	Residential	Portland, US	10.6% increase in price within 500m of stations.
Banister and Thurstain-Goodwin (2011)	Metro	Residential	London, UK	1. Increase in housing prices in proximity to stations; 2. £59 million residential value uplift in Southwark; £5.7 million uplift in Canary Wharf.
Benjamin and Sirmans (1996)	Metrorail	Apartment rent	Washington D.C., US	2.5% decrease in rent with 0.1 mile increase in distance from stations.
Debrezion et al. (2007)	LRT, metro, BRT, rail	Commercial and residential	US (unspecified)	1. Commercial properties were more expensive than residential houses within station zones; 2. Average prices of commercial and residential properties within station catchments were 16.4% and 4.2% higher than those outside, respectively; 3. CRT stations were more influential than LRT/HRT/Metro stations in increasing housing prices.
Gibbons and Machin (2005)	Metro, LRT, rail	Residential	London, UK	1.5% decrease in price every 1km increase from stations.
Mulley et al. (2016)	BRT, rail	Residential	Brisbane, Australia	Every 100m and 250m proximity to stations increased property values by 0.14% and 0.36% respectively.
Voith (1993)	Rail	Single-family detached house sales	Philadelphia, US	8.1% increase in average sales price and 7.5% increase in average median price (for all types of housing) proximate to stations.
Negative effects				
Bowes and Ihlanfeldt (2001)	Bus, rail	Residential	Atlanta, US	1. More transport effects than retail effects in determining prices; 2. Lower prices due to negative externalities within 0.25-mile station buffer.
Brandt and Maennig (2012)	Rail	Residential	Hamburg, Germany	1. Up to 4.6% uplift with improvement of rail transit; 2. Lower prices due to negative externalities within 250m station buffer.
Laakso (1992)	Metro, rail	Residential	Helsinki, Finland	Highest land values 250-500m from railway stations, and 500-750m from metro stations.
Insignificant effects				
Forrest et al. (1996)	LRT	Residential	Manchester, UK	Weak impact of rail transit provisions on residential property values.
Gatzlaff and Smith (1993)	Metrorail	Single-family detached house sales	Miami, US	Weak impact of new rail transit announcement on residential property values.
Hess and Almeida (2007)	LRT	Residential	Buffalo, US	Every 0.3m proximity to stations increased average property values by $0.99 (network distance) or $2.31 (straight-line distance). Rail proximity was less influential than property location and characteristics in housing price prediction.
Mulley (2014)	BRT	Residential	Sydney, Australia	Property values were mainly determined by individual property features and neighbourhood.

3. Case study and method

3.1. Case study context

The DLR is an electrically powered driverless light railway system serving the redeveloped Docklands area and east and south-east London (Gibbons and Machin, 2005). It currently has 45 stations and is operated and managed under franchise by KeolisAmey Docklands Ltd (TfL, 2018). The first part of the DLR opened in 1987 (Knowles, 2007). Six extensions have been built since then to assist in the redevelopment of the Docklands area and serve the increased population. With an enhanced operating network, annual passenger numbers for the DLR have experienced a twelvefold increase to 122 million over the past three decades (TfL, 2018).

There are several reasons for selecting a DLR case in London. First, DLR is a particular type of light rail transit (LRT) – overground – which is much cheaper to build than heavy rail systems. In addition, DLR is more unlikely to have as wide an influence on property prices as Underground investment or even tram LRT; however, London has very high property prices internationally (Hamnett, 2009), hence even a marginal change in accessibility might have a large property price impact. Therefore, the DLR case study is probably very different relative to the findings from previous literature (Ingvardson and Nielsen, 2018), for example, in North American (Black, 1993; Cervero, 1984; Kuby et al., 2004).

This paper focuses on the station catchment areas of the south-eastern and northern branches of the DLR (Fig. 1). The south-eastern branch of the DLR consists of two extensions, the London City Airport Extension (LCAE) and the Woolwich Arsenal Extension (WAE). The LCAE has significantly improved public transport links to the airport. While more than 75 per cent of passengers travelled to London City Airport (LCA) by taxi or private vehicle before the opening of the extension, the DLR ridership increased by 45 per cent after one year of operation. The WAE was proposed as a continuation of the previous LCAE, linking the Docklands area to Woolwich and the wider Thames Gateway (Butcher, 2010). Its river crossing feature was intended to reduce the physical barrier of the River Thames, particularly in East London where there are few river crossings. The northern branch Stratford International Extension (SIE) was built on part of the former North London Rail Line (Butcher, 2010). The SIE was prioritised as one of the key public transport schemes in East London following the announcement that London would host the 2012 Olympic Games (Preston and Wall, 2008).

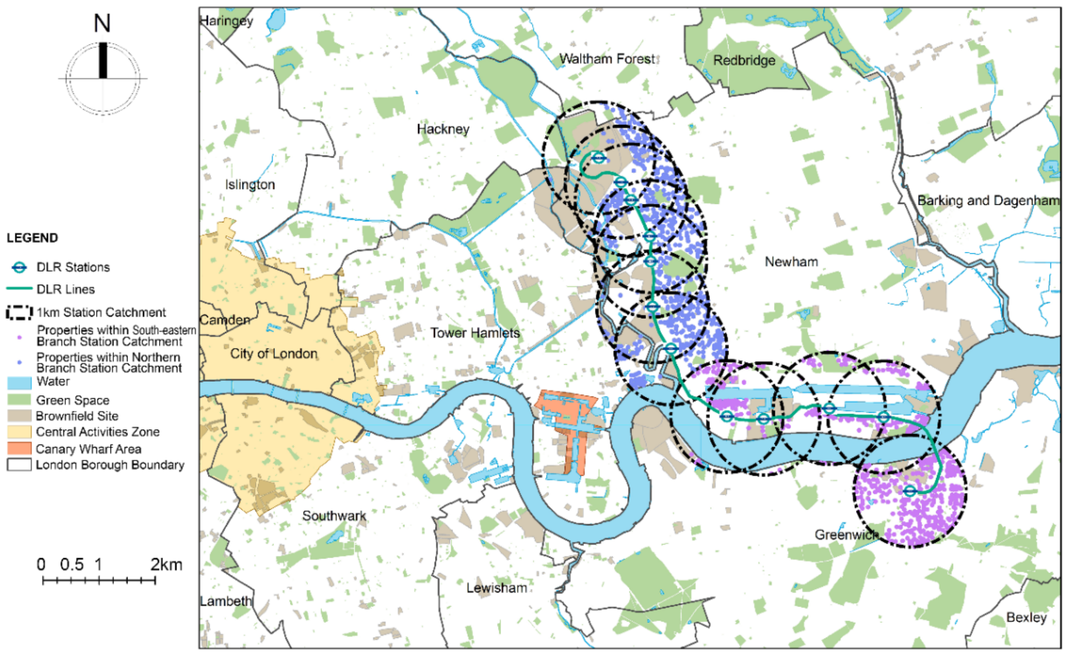


Fig.1. Case study area (source: authors).

The selection of the DLR extensions for analysis is due to multiple reasons. Restricted by the limitation of the database that only contains housing transactions from 1995 onwards, the south-eastern and northern branches of the DLR are two of the few public transport lines in London that it is possible to conduct longitudinal data research on. Apart from the data availability, this is an area that historically lacked dedicated public transport facilities. Consequently, the association between public transport accessibility and housing prices can be inferred from the significant change in the distance to the nearest stations that the opening of new DLR stations brings. Moreover, the housing market within the geographical area has a degree of heterogeneity regarding the accessibility level, property characteristics and neighbourhood facilities, offering the opportunity to determine the relative importance of different contributing factors in the constitution of a housing price.

3.2. Method

The hedonic pricing model, as proposed by Rosen (1974), is based on consumer theory (Lancaster, 1966), and is the most common model for housing price evaluation due to its merits in perceiving the effect of particular variables and less intractability in practice (Xiao, 2017; Xu, 2015). Hedonic regression has advantages in simplicity and practicality for the prediction and feasibility of giving weights to each segment that affects housing prices (Rothenberg et al., 1991). That is, the property price can be interpreted as a function of integrated independent variables (see Equation 1, Du and Mulley, 2006), which include accessibility, property and neighbourhood features. The typical selection of independent variables includes distance to station, type of property, distance to shops and recreational facilities, and demographic statistics. While it has been argued that the estimation based on Equation 1 will give "inconsistent estimation in the resulting coefficients" (Xiao, 2017, p.16), three additional forms of the hedonic model therefore have been developed, including semi-log, log-log and box-cox (Xiao, 2017). In order to investigate the relationship between transport accessibility and housing prices, the following formula is employed in this research.

$$P = f(L,H,N) + \varepsilon \quad (1)$$

Where:

P is the property price;

L is the locational variable;

H is the housing variable;

N is the neighbourhood variable;

ε is the random error.

3.3. Data and variables

Previous studies have identified a diverse collection of contributing factors in determining property values. In this study, the analysis builds upon Banister and Thurstain-Goodwin's (2011) investigation into the Jubilee Line Extension (JLE), using a similar set of variables. A semi-log form of hedonic model is used, rather than the linear one used in their research, bearing in mind that the semi-log has been widely recognised (Debrezion et al., 2007; Gibbons and Machin, 2005; Martínez and Viegas, 2009; Mohammed et al., 2013; Mulley et al., 2016; Weinberger, 2001) and has greater accuracy when interpreting coefficients (Xiao, 2017). Consequently, the relationship between housing prices and locational, housing and neighbourhood variables is shown in Equations 2 and 3, with a description and source of each variable given in Table 2. The key features associated with housing prices within the station catchment were extracted from ArcGIS to conduct the hedonic price regression in R.

South-eastern branch:

$$logP=\beta_0+\beta_1\times PRE_1+\beta_2\times POST_1+\beta_3\times POST_2+\beta_4\times DLR+\beta_5\times LCA+\beta_6\times TfL\_1KM+\beta_7\times RAIL+\beta_8\times BUS+\beta_9\times ROAD +\beta_{10}\times CAZ+\beta_{11}\times CW+\beta_{12}\times FLAT+\beta_{13}\times SEMI+\beta_{14}\times TERR+\beta_{15}\times DETA+\beta_{16}\times NEW+\beta_{17}\times TENURE+\beta_{18}\times SCHOOL$$

$\_250M+\beta_{19}\times BROWNFIELD+\beta_{20}\times PARK+\beta_{21}\times WATER+\beta_{22}\times POP\_DEN+\beta_{23}\times BAME+\beta_{24}\times OTHER+\beta_{25}\times SHOP+\varepsilon$ (2)

Northern branch:

$$logP=\beta_0+\beta_1\times PRE_3+\beta_2\times POST_3+\beta_3\times OTHER+\beta_4\times DLR+\beta_5\times LCA+\beta_6\times TfL\_1KM+\beta_7\times RAIL+\beta_8\times BUS+\beta_9\times ROAD+\beta_{10}\times CAZ+\beta_{11}\times CW+\beta_{12}\times FLAT+\beta_{13}\times SEMI+\beta_{14}\times TERR+\beta_{15}\times DETA+\beta_{16}\times NEW+\beta_{17}\times TENURE+\beta_{18}\times SCHOOL\_250M+\beta_{19}\times BROWNFIELD+\beta_{20}\times PARK+\beta_{21}\times WATER+\beta_{22}\times POP\_DEN+\beta_{23}\times BAME+\beta_{24}\times SHOP+\varepsilon \quad (3)$$

Table 2

Hedonic model variable descriptions.

Variable	Description of measure	Data sources
Dependent variable		
Log_P	Logarithm of property price; adjusted via the Nationwide House Price Calculator	Land Registry
Temporal explanatory variables		
PRE_1	1=property sold before the LCAE construction (2000-2002); 0=otherwise	Land Registry
$POST_1$	1=property sold after the LCAE opens, but before the WAE opens (2006-2009); 0=otherwise	Land Registry
$POST_2$	1=property sold after the WAE opens (2010-2016); 0=otherwise	Land Registry
PRE_3	1=property sold before the SIE construction (2000-2005); 0=otherwise	Land Registry
$POST_3$	1=property sold after the SIE opens (2012-2016); 0=otherwise	Land Registry
Locational attributes		
DLR*	Distance from a DLR station to the property in metres	Ordnance Survey OpenData
LCA*	Distance to LCA in metres	Ordnance Survey OpenData
TfL_1KM*	1=other TfL station within 1 km; 0=no	Ordnance Survey OpenData
RAIL*	Distance to the nearest National Rail station in metres	Ordnance Survey OpenData
BUS*	Distance to the nearest bus stop in metres	Transport for London Unified API
ROAD*	Distance to the nearest road in metres	Ordnance Survey OpenData
CAZ*	Distance to the Central Activities Zone (CAZ) in metres	London Datastore
CW*	Distance to Canary Wharf in metres	London Datastore
Property attributes		

FLAT	1=flat; 0=otherwise	Land Registry
DETA	1= detached house; 0=otherwise	Land Registry
SEMI	1=semi-detached property; 0=otherwise	Land Registry
TERR	1=terraced property; 0=otherwise	Land Registry
OTHER	1=other type of property; 0=otherwise	Land Registry
NEW	1=newly built property; 0=otherwise	Land Registry
TENURE	Tenure of property, 1=freehold; 0=otherwise	Land Registry
BROWNFIELD*	1=property built on brownfield site; 0=otherwise	London Datastore
Neighbourhood attributes		
SCHL_250M*	1=school within 250m; 0=otherwise	London Datastore
SHOP*	1=shopping mall/retail within 1km; 0=otherwise	CoStar database
PARK*	Distance to green space in metres	Ordnance Survey OpenData
WATER*	Distance to lake/river in metres	
POP_DEN*	Population density (persons per hectare)	London Datastore
BAME*	Percentage of population from black, Asian and minority ethnic (BAME) groups	London Datastore

* Calculated in ArcGIS and R

4. Modelling results

4.1. Hedonic model results

The reliability of the data is statistically assessed via normal Q-Q plots and histograms which show that the log-transformed housing price is interpretable as it has a normal distribution. Two separate models were developed to estimate the relationship between housing and transport, which enabled a further comparison of the effects of different public transport infrastructure strategies and diverse localities.

The summary of the regression models is presented in Table 3. F-tests suggest that both models are likely to be statistically significant and the hypothesis that these models cannot explain the logarithmic price is rejected because of the 0.000 probability. Adjusted-R^2 values show that 37.7% and 35.5% of the observations could be explained by the models respectively, hence the hedonic regression models have an acceptable fit.

Table 3

Model summary.

Model	Adjusted R square	Std. error of the estimate	F	Sig.
South-east Branch	0.377	0.130	70.276	0.000
North Branch	0.355	0.130	113.648	0.000

Regarding the multicollinearity diagnostic, the distance to the CAZ was removed due to its high multicollinearity with the distance to Canary Wharf. This occurrence of multicollinearity is reasonable considering that the CBD in London is defined as covering both the CAZ and Canary Wharf (GLA, 2008), and both zones are geographically located west of the studied DLR line. Additionally, the distance to the National Rail stations was removed from both models owing to multicollinearity. The coefficients and statistics of the remaining variables are presented in Table 4.

Table 4

Regression results.

	Model 1: South-eastern branch					Model 2: Northern branch				
	Unstandardised coefficients		Standardised coefficients	t	Sig.	Unstandardised coefficients		Standardised coefficients	t	Sig.
	B	Std. Error	Beta			B	Std. Error	Beta		
(Constant)	5.2033130	0.043		121.963	***	5.1400212	0.027		191.600	***
Temporal explanatory variables										
PRE_1	-0.0257133	0.008	-0.060	-3.135	**					
PRE_3	-	-	-	-	-	-0.0045883	0.005	-0.014	-0.944	*
$POST_1$	0.0015426	0.008	0.004	0.199	*	-	-	-	-	-
$POST_2$	0.0509097	0.007	0.150	7.067	***	-	-	-	-	-
$POST_3$	-	-	-	-	-	0.0897121	0.005	0.255	17.251	***
Locational attributes										
DLR	-0.0000352	0.000	-0.054	-2.702	**	-0.0000093	0.000	-0.014	-0.901	-
LCA	0.0000392	0.000	0.174	3.774	***	0.0000374	0.000	0.254	8.776	***
TfL_1KM	0.0222481	0.015	0.067	1.444	-	0.0567373	0.008	0.120	7.173	***
BUS	0.0001300	0.000	0.055	3.230	**	-0.0000845	0.000	-0.037	-2.746	**
ROAD	0.0003418	0.000	0.021	1.194	*	0.0011542	0.000	0.045	3.358	***
CW	-0.0000200	0.000	-0.140	-4.990	***	-0.0000138	0.000	-0.084	-2.461	*
Property attributes										
FLAT	-	-	-	-	-	0.0017038	0.010	0.005	0.165	-
TERR	-0.0471650	0.015	-0.142	-3.179	**	-	-	-	-	-
DETA	0.1080487	0.029	0.066	3.732	***	0.2021312	0.036	0.069	5.581	***
SEMI	-0.0220108	0.019	-0.027	-1.159	*	0.0263572	0.010	0.032	2.543	*
OTHER	0.1593149	0.033	0.080	4.870	***	0.1688185	0.021	0.103	8.028	***
NEW	0.1251367	0.012	0.176	10.766	***	0.0378315	0.011	0.043	3.386	***
TENURE	0.2062084	0.015	0.625	13.897	***	0.1675134	0.010	0.514	16.444	***
BROWNFIELD	0.0240077	0.034	0.011	0.700	*	0.0636363	0.014	0.059	4.465	***
Neighbourhood attributes										
SCHL_250M	0.0001303	0.000	0.173	7.224	***	0.0061803	0.004	0.018	1.409	*
SHOP	0.0000292	0.000	0.058	2.314	*	0.0000364	0.000	0.058	3.984	***
PARK	0.0001903	0.000	0.091	5.293	***	0.0001202	0.000	0.051	3.860	***
WATER	-0.0000303	0.000	-0.042	-1.388	*	-	-	-	-	-

POP_DEN	-0.0005410	0.000	-0.158	-4.005	***	0.0000808	0.000	0.023	1.525	*
BAME	0.0005481	0.001	0.023	0.804	-	-0.0002928	0.000	-0.012	-0.822	-
n					2630					4291

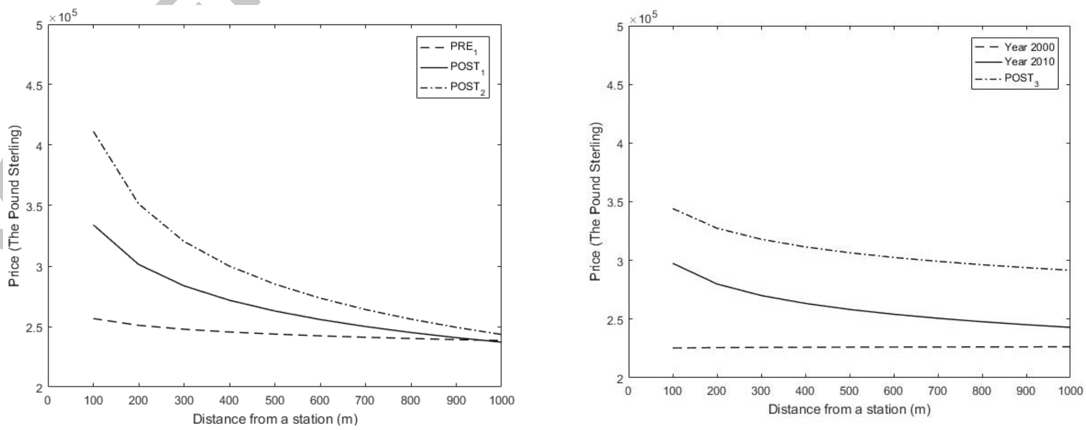
Note: *p<0.05; **p<0.01; ***p<0.001.

Independent variables excluded in the result: deleted due to detecting multicollinearity.

4.2. Temporal explanatory variables

This analysis incorporates temporal explanatory variables to help disentangle the accessibility effect from potential locational factors. In the two models, the independent variables representing the time prior to the delivery of the DLR extensions (PRE_1 and PRE_3) are negative, demonstrating that residential property values in the station catchment areas were less valuable when the public transport system was less accessible. However, with the implementation of the extensions, the housing prices within the area have experienced a rapid increase, as observed from the positive coefficients of $POST_1$, $POST_2$ and $POST_3$. In particular, the coefficient of $POST_2$ is higher than that of $POST_1$ in model 1, implying that the WAE has helped break the physical and cultural barriers of the Thames.

Along with the regression results in Table 4, the best-fit line of the average property price at each development stage is plotted against distance decay. The PRE_1 price line (see Figure 2a) seems fairly stable over the 1km radius of impact, which corroborates the finding that locational factors were nearly negligible before the opening of the south-eastern branch stations. In other words, the increased property value ($POST_1$ and $POST_2$ lines) is most likely due to the improved accessibility effect. Although the SIE has also increased the housing price ($POST_3$ line), close proximity to the northern branch stations had perceived locational benefits before the SIE opened, which was probably because of the presence of the JLE (see Figure 2b: 'YEAR 2000' and 'YEAR 2010'). Since the difference between PRE and POST lines represents the change in housing price before and after the delivery of the public transport system, it is possible to estimate that £51.4 million and £45.7 million residential land value uplifts[3] have been attained in the 1km south-eastern and northern branches areas respectively. These results indicate that each station catchment area may generate approximately £5-8 million residential value uplift, which is comparable with the finding from Banister and Thurstain-Goodwin (2011), who studied a 1km radius of Canary Wharf station and found a £5.7 million housing price increase as a consequence of JLE.



(a) South-eastern branch (b) Northern branch

Fig. 2. Distance decay curve: change in average price

4.3. Locational attributes

Access to public transport is primarily examined as the distance from a station to a residential building. The regression outcomes in Table 4 demonstrate that the distance from a DLR station in the south-eastern and northern branches has diverse effects. In the south-eastern branch, the distance from a station has an expected significant and negative impact on housing prices. With every 100m nearer the transit station, the housing price increases by 0.35 per cent when other explanatory variables are constant. Conversely, the housing price does not show as being statistically significant in model 2 with closeness to a northern branch station. This might be attributed to the presence of the JLE in the area, which is represented by the variable 'TfL_1KM'. The variable 'TfL_1KM' is significant and positive in the northern branch, indicating that a property with multiple stations (Underground and DLR) in its one-kilometre surrounding area has a premium of around 5.67 per cent. This number indicates that residents in the northern branch area are likely to use the Underground as an alternative to the DLR. The presence of other stations provides the likelihood of having various travel choices; indeed the Underground network is much more extensive, with over 10 times more Underground journeys than DLR journeys.

The results obtained from both models are mostly in agreement with each other regarding locational attributes. Coefficients of 'CW' are significant and negative. This has two implications: first, good job accessibility is likely to be associated with increased housing prices; second, it suggests that the several stages of DLR extensions have increased accessibility to Canary Wharf, the Docklands and east London. Although the LCAE was developed to enhance public transport accessibility to the airport, there is a negative link with local housing prices. Both models indicate that residents are willing to pay a premium of 0.37-0.39 per cent for every 100m distance away from the airport. Hence negative externalities, such as noise and air pollution, are associated with proximity to the airport. In both branches, a building located further away from the road transport network tends to be more valuable, suggesting that negative environmental factors such as pollution and noise have a substantial impact on that area.

4.4. Property attributes

Most of the independent variables describing the property characteristics are highly significant in determining residential housing prices and have the expected signs. For both models, the variables 'TENURE', 'DETA' and 'NEW' have the expected positive signs and are of high significance at a 99.9 per cent level of confidence. Among all the property attributes, the variable 'TENURE' is most influential in predicting the logarithm of price, suggesting that a freehold property has a premium of 20.62 per cent and 16.8 per cent respectively over its leasehold counterpart in the south-east and north DLR station catchment areas. Concerning the type of dwelling, a detached house is likely to be more valuable in price, while a terraced house is less expensive. This result is consistent with the findings from other citys' property markets (Mayor et al., 2012) and can be explained by the willingness to pay extra for increased indoor space and privacy. In terms of the age of the property, despite the specific age of each property being unavailable from the UK database, the variable 'NEW' suggests that a newly built house is more expensive than older properties, which is similar to the previous findings concerning the 'age of property' as an independent variable (Mayor et al., 2012). This may reflect that a new build has better interior design or is in better condition. These results confirm the findings of previous investigations that a property's price is subject to its own characteristics (Hess and Almeida, 2007; Mulley, 2014).

In addition to these most common variables, this paper further includes a 'BROWNFIELD' variable, and the results indicate that real estate developed on a brownfield site is positive and significant, especially in the northern branch where more brownfield sites were identified. This finding proves the role of DLR in supporting regeneration and increasing residential property values on existing brownfield sites.

4.5. Neighbourhood attributes

Multiple neighbourhood and socio-demographic variables have been included in the regression to diminish the likelihood of reaching flawed conclusions and to be consistent with previous studies. The results demonstrate that the distance to different landscapes, the presence of local amenities, and demographic characteristics have considerable effects on housing prices.

The environmental variables demonstrate diverse results. The distance of the property from the River Thames is significant and negative. For every 100m closer the building is to the river, a premium of 0.303% is attracted, which could be attributed to the desirable waterside views and amenity attraction. Similar findings have been reported by Mayor et al. (2012) and Xu (2015). However, interestingly, measuring the distance to the park produces the opposite result: being closer to a park reduces housing prices by 1.9 per cent and 1.2 per cent respectively in the south-eastern and northern branch areas. This might be explained by the negative externalities caused by closeness to a park, such as crowds and noise, or even safety when dark, which are generally not so much of an issue at the waterside. In addition, it is unexpected that the presence of schools and shops within walking distance from the property will reduce its price. This might be explained by reason of accompanying negative externalities, in the shape of noise, parking congestion, pollution and security.

5. Discussion and policy implications

The contributions of this paper are mainly threefold. By producing a hedonic pricing model, the analysis finds that the housing price premium associated with proximity to the DLR in east London is statistically significant. The south-eastern branch, where previously there was no public transit link, produced a premium of 0.352 per cent per 100 metres proximity. This is higher than the northern branch's premium of 0.093 per cent, where the DLR runs parallel with the JLE. These results indicate that each station catchment area may generate approximately £5-8 million residential value uplift. This scale of impact is consistent with findings from the US and Australia (Benjamin and Sirmans, 1996; Mulley et al., 2016) and from previous analysis in London (Banister and Thurstain-Goodwin, 2011). However, the northern branch of the DLR has a relatively low impact on price premium. One reason may be that the DLR branch is the only DLR or Underground choice for local residents in the area, whereas people living along the south-eastern branch corridor may use the JLE as an alternative. Fixed rail public transport plays a key role in the regeneration of an area where the public transport system was poor in the past. The DLR is less attractive from the perspective of increases in house value relative to a connection to both the DLR and Underground, as there is a lower level of service and less extensive network. More extensive Underground connections would also be more attractive to residents, as this is a higher specification public transport network relative to the DLR. These findings can help shape the future transport strategy in these and similar poorly connected areas in east London, which are also likely to be suffering from social deprivation problems (Cao and Hickman, 2018). Improved public transport can be delivered to provide reliable and quick services across East London and for crossing the River Thames, and also to help link into the wider public transport network.

Second, the hedonic regression model based on longitudinal data covering all of the intervention areas provides temporal evidence of the effect of light rail investment on economic development. The result shows that in the intervention areas, properties with the proximity to a station have generated a continuous increase in price since operation commenced. Such a refinement of the methodology of the hedonic regression model can help to strengthen the evidence on causality, i.e. that the property value uplift is directly impacted by the changed accessibility effect rather than existing locational positive externalities. This longitudinal data-based analysis provides evidence that some of the land value uplift induced by public transport investment can be captured, using a modified tax regime, to help finance new infrastructure projects.

Third, the analysis has added extra neighbourhood and locational variables as these factors may affect housing prices. It is important to account for these contributing factors when examining the proximity impacts of light rail station relative to residential property value. The findings show that certain types of property (e.g. detached housing) or being near to certain types of amenity (e.g. close to the river) can increase housing prices in east London. Various units of measurement were unified through calculating standardised coefficients to make independent variables comparable (Hess and Almeida, 2007). The results show that tenure is the most prominent feature in determining property values. While the demographic density gathered in the Lower Layer Super Output Areas (LSOA)[2] shows differences between the two models, the results from the northern branch have a higher level of statistical significance, indicating that increasing housing prices may be associated with a higher population density. Therefore, understanding the urban context is important in these types of impact evaluations.

A number of policy reflections and implications can be made following the results. There is no direct link between investment in public transport and development. Any development requires an effective urban planning framework which acts to deliver the development. This quite straightforward conclusion is often missed in a context where planning is commonly put forward as a 'brake' on development – on the contrary, it is the facilitator of development, and can be used to shape development in a manner which helps achieve other policy objectives, including environmental, social and economic. There are implications for development in cities internationally. Although the evidence indeed reveals that areas with historically poor public transport services have enormous potential for economic development and land use pattern change by expanding rail transit systems, there is little use in investing in public transport if the urban form cannot be shaped around the system. Hedonic modelling provides an approach which allows us to isolate the impacts of transport investment on development and value uplift, and this can be an important factor in estimating how much value can be captured via changed tax regimes, to be reinvested in future infrastructure investment. In a city such as London, where land is usually privately owned, it is expensive to compulsorily purchase land before permission is given for redevelopment. Land value capture gives an alternative approach, most likely through a proportion of Stamp Duty being returned, alongside business taxes, to the city authorities. Finally, there is a further complex problem to resolve. In cities such as London, there are many concerns over the affordability of housing and of gentrification of neighbourhoods. The public funding of infrastructure can be a direct contributor to these problems. There is little understanding of the levels of property price increases that are acceptable, and how this might differ according to actor viewpoint and spatially. The current default position in transport appraisal is that all development is positive, yet this is becoming increasingly untenable. It might be possible to develop thresholds that can be used to warn of unacceptable levels of unaffordability and displacement – for example with policy interventions then used to ensure high levels of affordable housing provision. These issues can usefully be the subject of further empirical research.

There are some limitations to the analysis. The selection of housing attributes was limited due to data availability and more detailed assessment could be undertaken on this, and indeed other variables. For instance, different types of public transport systems could be examined to inform the most suitable transport investment for unique areas. Depending on data availability, more housing characteristics (such as floor area) could be explored; this is expected to lead to a better understanding of housing transactions, as well as increase the reliability of the regression analysis. The study selected 1,000 metres as a catchment buffer and this could be used in different ways in future work. This is common practice, following RICS (2002), Cao and Hickman (2019) and many other studies, but clearly this threshold may not be suitable for all locations.

6. Conclusions

This paper aimed to assess the effects of access to a light rail transit station on the change in residential property values by producing a hedonic price model in East London. The housing price premium generated from the proximity to the DLR in east London is comparable with the findings from elsewhere. The south-eastern branch, where historically there was no public transit system, produced a premium which is higher than the northern branch's; here, the DLR runs parallel with the JLE. Results also reveal that the price is affected by other positive and negative externalities. For instance, houses that are detached, newly built, freehold and on brownfield sites are likely to be more expensive than their counterparts, and proximity to the river is preferred while parks and shops are negative amenities. The findings from this study offer considerable scope for shaping policy. Expanding public transport systems are essential to developing neighbourhoods, and to providing access to housing, jobs and other activities. However, we need to be careful that the benefits of public investment are realised by all –

and estimating the potential land value uplift associated with infrastructure investment is a critical first step towards this goal.

Notes

[1] Non-existent station: In Laakso's (1992) research, the effects of housing price within station catchment area were not taken into account in the model before building the station. In other words, the station did not exist at that time. Therefore, it is unclear what factors affect the changes in housing prices.

[2] Lower Layer Super Output Areas (LSOAs): The LSOAs were originally constructed using 2001 Census data from groups of Output Areas (typically four to six) and were constrained by the standard table wards used for 2001 Census outputs. In 2011, these LSOAs had an average of 700 households and 1700 residents. Measures of proximity (to give a reasonably compact shape) and social homogeneity (to encourage areas of similar social background) were also included (ONS, 2015). There were 4,835 LSOAs in Greater London in 2011. The 2011 LSOA map is used as a basic boundary map in the analysis, which is in line with the previous study conducted in London by Cao and Hickman (2018) and Cuthill et al. (2019). The resolutions of all data sets provided are at LSOA level.

[3] Residential land value uplifts: The land values during each DLR implementation phase were estimated from the integral calculus of the lines in Figure 2. The lower and upper limits of the definite integrations were presumed from 50 to 1,000m, as no properties were observed within 50m of station catchment area. The uplifts in the value of residential lands were consequently obtained via subtracting the value after DLR operation from the one before its construction.

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