

1 **Title:**

2 How does the extension of existing transport infrastructure affect land value? A case study of the Tyne
3 and Wear Light Transit Metro system.

4 **Abstract**

5 This paper seeks to investigate the timing of land value uplift associated with an extension to an
6 existing light rail transport system. It seeks to understand the amount of land value increase on
7 residential properties at different stages of the infrastructure delivery process of the Tyne and Wear
8 Metro (TWM) system in the North East of England. This is to shed light on the potential use of land
9 value capture methods for subsequent extensions. Whilst there has been substantial international
10 research into transport related land value capture methods, this tends to take place in atypical capital
11 cities with buoyant land markets and/or entire transport systems. This is reflected in England, where
12 research is less frequent in major conurbations outside of Central London, which are more typical of
13 urban areas in this country. In response, the intention is to shed new light on this situation by updating
14 historical research into the impact of the TWM. Its primary focus is the longitudinal performance of
15 the 2002 Sunderland Metro Extension (SME). This historical appraisal of impact is important to
16 understand when and how much uplift is generated. This in turn helps to evidence any justifications
17 for subsequent extensions and funding via Land Value Capture. This study uses a time based analysis
18 to quantify differences in property prices before, immediately after and fifteen years after the
19 Sunderland Metro Extension (SME) was constructed. The results show that property values increased
20 immediately after the extension becomes operational, though no significant results were found 15
21 years later.

22 **Key words:** Land value uplift, land value capture, transport accessibility, metro and light rail,
23 Longitudinal study.

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38 1. Introduction and rationale for study

39 Demand for mobility continues to increase in the international urban climate. Increasingly, locations
40 are seeking to extend existing transport infrastructure to connect, and sustain, functional economic
41 areas. However, most infrastructure projects are not profit making. Traditionally, investment in new
42 transport infrastructure has required substantial funds from central government to be viable (Du and
43 Mulley, 2007b; Pike et al, 2019). However, this situation exists against a broad backdrop of reduced
44 government funding due to austerity and changing government ideology associated with reduced
45 degrees of state intervention (Muldoon-Smith and Sandford, 2021). Although there are exceptions to
46 this rule, for example, the Belt and Roads Initiative in China, 4G Roads and Highway Initiative in
47 Columbia, and Nigeria's Lagos-Kano Railway.

48 In England, transport infrastructure has traditionally been funded through Central Government grant
49 and traditional taxation methods. Over 85% of transport infrastructure in the pipeline for 2016-2021
50 is being funded via these methods. However, this will be the last era of this type of funding with state
51 influence, particularly in provincial locations, reducing dramatically under narratives of devolution,
52 fiscal decentralisation and more recently the impacts of Covid (Muldoon-Smith, 2019, Institute for
53 Fiscal Studies, 2020). Already, in recent years, subdued economic growth has limited the availability
54 of existing taxation for public transport infrastructure because it is difficult to justify the enactment of
55 increased taxes (PwC, 2018). The increasing challenge for national, regional, and local governments
56 (particularly in mature urban locations) is to explore and utilise more entrepreneurial and self-
57 sustaining funding models (Fuller, 2018; Pike et al, 2019).

58 Consequently, land value capture (LVC) mechanisms have become an area of increasing interest. For
59 example, as a means of funding public transport infrastructure through new tax revenue associated
60 with additional value, as opposed to increased taxation associated with existing assets. In short, the
61 premise of LVC is to utilise the increased value of nearby land because of increased accessibility
62 through investment in transport infrastructure. In 2016, it was estimated that landowners pocketed
63 £9.3 billion of the £12.3 billion of land value uplift that was generated via infrastructure improvements
64 (CPRE, 2017). LVC methods, in the main, can be separated into two forms. The first is related to
65 development rights around transport sites, which can be either sold or leased to generate and capture
66 value. The second is typically through taxation of properties situated on land, where tenants or
67 landlords who benefit from new infrastructure pay additional contributions. This additional taxation
68 can be captured in a one-off payment or continually depending on the duration of the value uplift and
69 the pragmatic choice of the local government. In England this would be via Council Tax (for residential
70 properties) or Business Rates (for commercial and industrial properties).

71 An understanding of when land value increase occurs upon residential properties at different stages
72 of the infrastructure delivery process is essential (Mohammad et al, 2013). This is because any design
73 of an appropriate LVC mechanism should be predicated by an identification of when, and how, much
74 uplift is generated. This is perhaps the most crucial aspect of LVC mechanisms. As the LVC must
75 capture the uplift at the correct time to enable a successful funding strategy. For example,
76 mechanisms implemented after construction start may miss a significant portion of the generated
77 uplift, as value uplift effects can occur as early as a government's commitment to a scheme. Studies
78 that have been undertaken seem to have a degree of disagreement (Yen et al, 2018) between whether
79 value uplift occurs before construction (McDonald and Osuji, 1995), immediately afterward
80 (Mohammed et al, 2013) or potentially sometime later once the infrastructure is established (Du and
81 Mulley, 2007b).

82 Light rail (the category within which the TWM resides), has been shown to exhibit positive uplifts in
83 both residential and commercial properties within the catchment area of stations (Cervero, 2004;
84 Duncan, 2008; Pan and Zhang, 2008; Xu et al, 2016). However, carrying on the theme of lack of
85 consensus, literature is full of studies failing to find any uplift (Hass-Klau et al, 2004), and even negative
86 impact from light rail stations (Bollinger et al, 1998; Weinstein and Clower, 1999).

87 However, in England, most of the research has taken place in and around the atypical Central London
88 land market where underlying land value is buoyant and land markets are responsive (Li and Love,
89 2020). Previous studies have found positive effects on property value from the London Victoria line,
90 the Jubilee Line, the Channel Tunnel Rail Link and substantial positive effects from the Docklands Light
91 Rail (see Chesterton, 2000 for a meta study of these lines), causing increases from £70,000 an acre in
92 1981, to £4.9 million an acre in 1988. There is less research into suboptimal, but more typical, locations
93 outside of Central London that have land markets which are less buoyant and potentially less
94 responsive to change (Crocker et al, 2000; Hass-Klau et al, 2004). Indeed, little evidence of land value
95 uplift from new light rail infrastructure has been identified. This is an important gap in knowledge, as
96 O' Brien and Pike (2015) note the increased importance of regional infrastructure outside of central
97 locations which is needed to sustain economic development. While (Plimmer, 2017) notes the
98 importance, but also difficulty, of funding infrastructure in regional and sub-regional locations.

99 Early studies on the TWM (Pickett, 1984), Manchester Metrolink (Forrest et al, 1996) and Sheffield
100 Supertram (Crocker et al, 2000) failed to find evidence of land value uplift because of light rail
101 infrastructure. However, more recent studies by Du and Mulley (2007; 2007b; 2012) did identify
102 positive premiums on land value on the TWM, but, importantly, not around the extension. It can be
103 theorised that such locations may take longer to register impact from new infrastructure or that the
104 impact could be less pronounced in less buoyant locations. For example, in 1984, no significant land
105 value uplift was found along the original TWM line. However, in the subsequent studies in 2006 and
106 2007, significant land value uplift was identified around some of the stations which had been served
107 by the original line since 1980 (for 27 years).

108 This suggests that the beneficial impacts from metro systems may take rather a long time to occur
109 outside of primary economic areas. As such, the empirical research presents the opportunity to test
110 this theory, as the SME has now been in operation for approximately 17 years at the time of study.
111 Building upon Du and Mulley (2007b) findings, this study aims to consider the longer-term impacts of
112 the Sunderland Metro Extension (SME), to deduce whether extensions to long standing metro systems
113 can have a positive impact on land value. In addressing this, a case study of the TWM system in North
114 East England incorporating a time-based analysis of additional census points was constructed. This is
115 to shed new scientific light on the funding of extensions to existing transport systems and the lack of
116 consensus around the timing of value uplift in the academic community.

117 The remainder of this paper presents the underlying methodology for the paper, detailing the case
118 study and hypothesis, time frame, method design and limitations. It then considers the results, testing
119 the model, presenting findings and implications. The final part of the paper revisits the hypothesis and
120 presents limitations to the study and some opportunities for further research.

121 **2. Methodology**

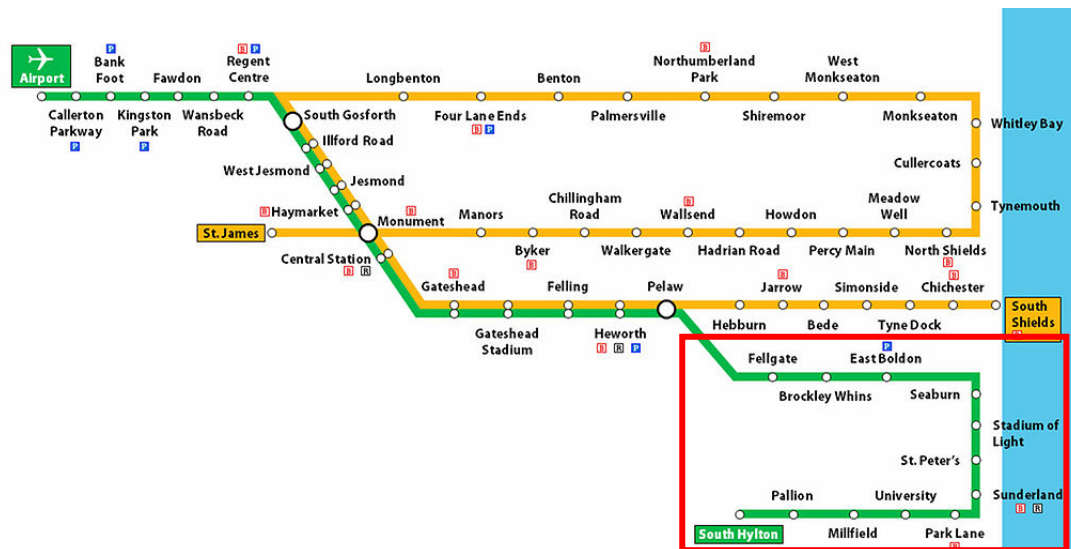
122 **2.1 Case Study and Hypothesis**

123 The hypotheses to be tested is:

124 *'Land value uplift from metro extensions does occur over a fifteen-year period after the system*
125 *becomes operational.'*

126 The original research of Du and Mulley (2007b) predominantly concentrated on where land value
127 capture occurred, this hypothesis focuses on when value capture occurred (Pagliara and Papa, 2011).
128 This focus is adopted to test the contention of Du and Mulley (2007a; 2007b) that value change in the
129 SME may take longer to materialise.

130 In order to carry out this research, quantitative data was collected relating to the TWM system. The
131 system is operated and maintained by Nexus, the region's key public transport provider. It connects
132 Newcastle upon Tyne, Sunderland, Gateshead and South Tyneside. The metro system was planned in
133 the 1970's and the system's structure was mostly built at this time, whilst incorporating much of the
134 existing Victorian rail infrastructure in the region. The system was opened in 1980 (the "Original Line"),
135 followed by an extension to Newcastle International Airport in 1991. The system was further extended
136 to South Tyneside and Sunderland, which was constructed and then opened in June 2000 and 2002
137 (the "Sunderland Extension"), respectively. At the time of study (2018), the original line has been in
138 operation for 38 years and the Sunderland Extension has been operated for 16 years. A map of the
139 Tyne and Wear Metro System is exhibited as Figure 1.



141 Figure 1. Map of the Tyne and Wear Metro (i.e., the Sunderland Metro Extension outlined in red)

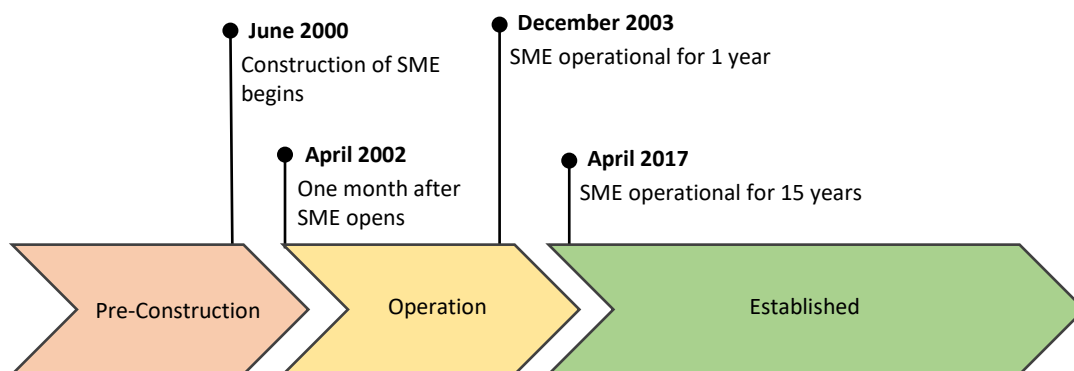
142 To do this, we use a hedonic 'global' model to assess the impact on the SME. Within this choice of
143 method, we recognise the recent work engaging with the issue of local spatial variance – that is
144 insensitivity to impact of specific variables at different points on the transport line (Dziauddin, 2015).
145 As value uplift research has continued to advance, recent studies have sought to trial new methods of
146 measuring the impact of transport accessibility on local land values (Yenn et al., 2018). These have
147 included:

- 148 • Billings (2011) – incorporating a richer set of control variables in analyses.
- 149 • Cao and Porter-Nelson (2016) – location quotients to address spatial dependence.
- 150 • Du and Mulley (2007; 2007b) – geographic weighted regression to analyse spatial impacts.
- 151 • Yenn et al. (2018) – difference in difference model to analyse spatial impacts.

152 However, the focus of this paper is not on the 'local' impact upon where value uplift occurred. Rather,
153 the intention is to reflect upon when value uplift occurred across the current lifetime of the SME.
154 While we concede the volatility in hedonic models (Lieske et al, 2019). One of the ways of improving
155 this situation, especially in time-based studies, is to improve the underlying transaction data and
156 incorporate a systematic time element into it. This is to present an initial staging post for time-based
157 enquiries into infrastructure extensions while remaining consistent with the original method used by
158 Du and Mulley (2007a). Consequently, the authors are careful to be sceptical in their approach to the
159 findings, conceding that there is scope for variance and bias within the global model. Indeed, there is
160 scope to make further methodological innovation, and these options are considered in the concluding
161 section as opportunities for further research. For example, in relation to spatial variance, impact of
162 scale, urban design features and the incorporation of commercial real estate stock.

163 2.2 The Hedonic Model and Timeline

164 The timeline of study was selected to examine the lack of consensus around when value uplift
165 occurred (Figure 2). Data was collected across all stations along the Sunderland Metro Extension. As
166 this study utilises a global hedonic model (as opposed to a local model), the selection of the stations
167 themselves are not explicitly important. The most important factor is the establishment of a property
168 transaction data set that reflects time, supported by a suitable variety of data for the independent
169 variables. As this will explore the interrelationship that exists between land value and the exogenous/
170 endogenous property factors.



172 NB: the underlying data for this study was captured at the following time periods. 1) Census in 2011 2) House price
173 transaction data from Land Registry recorded in the following three census points:1999-2000, 2002-2003 and 2017-18.

174 Figure 2. Indicative timeline displaying the key events leading to the construction and operation of the
175 Sunderland Metro Extension.

176 Hedonic price model is applied for data analysis and the SPSS software package was adopted to
177 identify the significance of the results through the analysis of variance. All stations along the
178 Sunderland metro extension line were selected and property transaction data was collected within a
179 catchment zone of 800 metres. The independent variables in the study were limited to property type,
180 number of bedrooms (Sirmans et al, 2006), percentage of unemployment and higher managerial
181 positions (Office for National Statistics, 2020), and distance to Sunderland and Newcastle City Centres.
182 This conscious limitation occurred because the intention was to focus on the best fit of data to the
183 catchment area. For example, the Census based 'unemployment' and 'higher managerial' figures were
184 the only ones available at the catchment area geography. Rather than adding additional proxy data
185 sets into the model (with various data attributes and granularities). While there were additional
186 variables that may impact property value, they were only available at the municipal level, while
187 information on 'age' and 'quality' of property does not exist. However, this is returned to in the

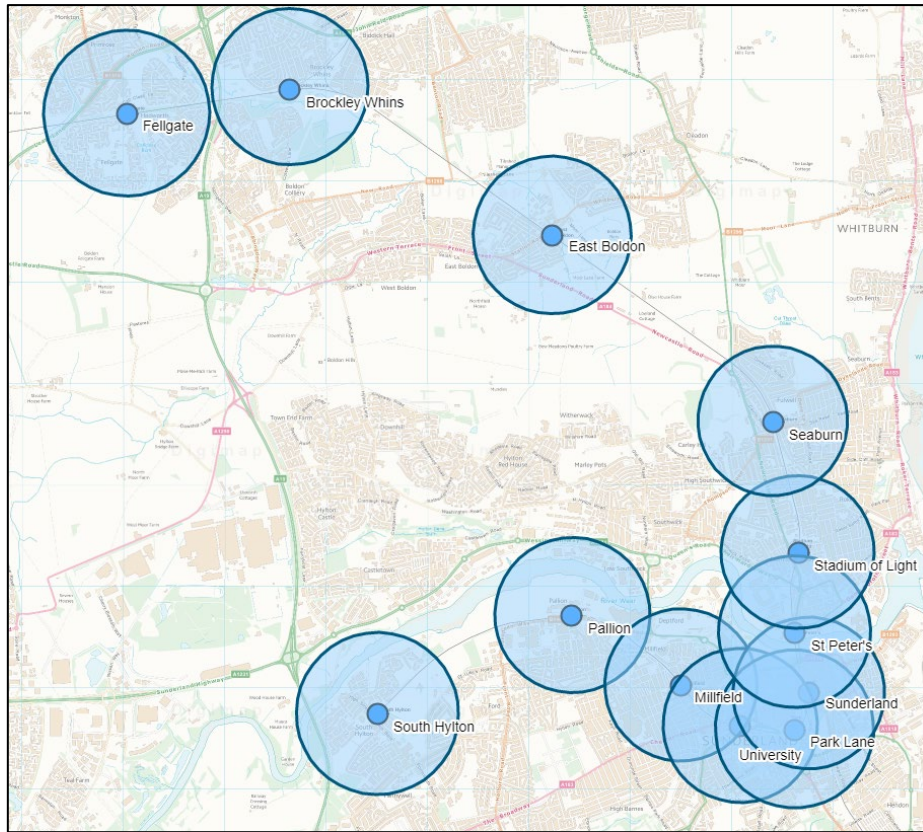
188 conclusion where the potential for the inclusion of additional independent variables is explored (for
189 example proximity to green space and urban design features) alongside methodological innovation.

190 Thus, as put forward by Du and Mulley (2007b, p.12), property prices are a function of a group of
191 variables:

$$192 \quad P_i = f(H, N, T) \quad \text{Eq. (1)}$$

193 *Where H, N and T is a vector of – (H) property features, (N) neighbourhood environment and (T)*
194 *transport accessibility.*

195 In the hedonic model, it is necessary to define the catchment areas for the residential property
196 transaction data, as this represents the properties that have access to the metro extension. Figure 3
197 shows the radius within which the transacted property price data was collected within the identified
198 timeline. Similar to many previous studies, the property transaction data located within 800m of the
199 selected stations have been grouped into the catchment area. This selection method is based on two
200 key themes that have emerged from the literature: first, that 800m is a walkable catchment area for
201 rail based public transport (Yen et al, 2018) and second, that property prices appear to be greatest up
202 to a distance of 800m from the transport station (Mohammad et al, 2013). As illustrated by the figure,
203 the catchment areas overlap in Sunderland City Centre, providing an almost linear catchment area.



205 Figure 3. Map showing the stations of the Sunderland Metro Extension and the catchment area of
 206 each station
 207

208 **3. Data and Variables**

209 **3.1 Data Description**

210 Table 2 summaries the details of each variable included in the model. The following subsections then
 211 present information of each variable in turn, outlining the data and the collection method.
 212 Additionally, Table 3 was also developed to show the price variability of different types of properties
 213 across the three delivery stages of the assets. Across the different unit types, the variability ranges
 214 from 30.85% to 46.09%, indicating that the property price data is dispersed approximately 32-48%
 215 around the mean values. This high degree of variability can be explained by the number of bedrooms,
 216 percentage of unemployment, percentage of higher managerial positions, distance from Sunderland
 217 City Centre and distance from Newcastle City Centre. Taking a 2-bedroom terraced property in areas
 218 of 0-2.9% unemployment as an example. The variability is calculated 18.23%, which is less than half of
 219 the lowest variability attributed to terraced housing. The remaining 18.23%, discussed in proceeding
 220 sections, can be attributed to the other independent variables in the model.

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Table 2. Summary of the variables collected for the Hedonic Price Model

Vector	Variable	Type	Description	Data Source
Land Value (P _i)	PRICE	Continuous	Transacted price adjusted by House Price Index (HPI)	Land Registry
Property (P)	BEDROOM	Continuous	Number of bedrooms	Land Registry
	FLAT	Dichotomous	=1 if flat; =0 otherwise	
	TERR	Dichotomous	=1 if terraced; =0 otherwise	
	SEMI	Dichotomous	=1 if semi-detached; =0 otherwise	
	DETA	Dichotomous	=1 if detached; =0 otherwise	
	BUILD	Dichotomous	=1 if new build; =0 otherwise	
Neighbourhood (N)	%UNEMP	Categorical	% of long term unemployment. (1 = 0%-2.9%; 2 = 3%-5.9%; 4 = 6%-8.9%; 5 = 9-11.9%; 6 = 12%+)	2011 census
	%HMAN	Categorical	% of higher managerial positions. (1 = 0%-2.9%; 2 = 3%-5.9%; 4 = 6%-8.9%; 5 = 9-11.9%; 6 = 12%+)	
Amenities (A)	distSUN	Categorical	Distance from Sunderland City Centre (1 = 0 mi–0.9 mi; 2 = 1 mi–1.9 mi; 3 = 2 mi–2.9 mi; 4 = 3 mi+)	GSI
	distNEW	Categorical	Distance from Newcastle City Centre (1 = 9 mi–9.9 mi; 2 = 10 mi–10.9 mi; 3 = 11 mi–11.9 mi; 4 = 12 mi+)	
Transport accessibility (T)	extPRE	Dichotomous	Property sold between Jan 1999 and Mar 2000 (1=yes; 0=no)	Land Registry
	extOPE	Dichotomous	Property sold between Apr 2002 and Dec 2003 (1=yes; 0=no)	
	extEST	Dichotomous	Property sold between Apr 2017 and Aug 2018 (1=yes; 0=no)	

Table 3. Variability in price of unit types at different infrastructure delivery phases

Unit	extPRE		extOPE		extEST	
	StdDev	Variability	StdDev	Variability	StdDev	Variability
Flat	31903	32.41%	40624	42.68%	29806	39.46%
TERR	38806	39.86%	44786	44.41%	44645	46.09%
SEMI	42780	30.85%	57336	39.47%	49844	34.32%

226 3.2 The Dependant Variable

227 The transacted property price is the dependent variable in the hedonic price model as gathered from
 228 the Land Registry, a database holding all residential transactions in England. Land value is therefore
 229 represented in the transacted value of property. This is because, in England, land value (and tax) is a
 230 capitalised representation of the buildings constructed on top of it. As opposed to other countries that
 231 may utilise a purely land value tax system or split rate system combining differential tax rates for land
 232 and property. Therefore, it is important to note, throughout the rest of the paper, that residential

233 transaction value (of property) is taken as a reflection of land value in the English institutional context.
234 This data set is one of the key opportunities for improvement on previous research. In property related
235 analysis, the transacted sale price is considered as the ideal data to represent the property's value as
236 it provides the true market value of the property (or in this case, the land) at the date of sale, giving
237 the most accurate representation of the land's value (RICS, 2019). In this case the transaction related
238 data set is also the most recent data available, b) has greater longitude and C) is the most accurate.
239 The previous research from Du and Mulley (2007; 2007b) used an online website which listed
240 properties for sale. The data was therefore partial because it only included those properties deposited
241 on the website and limited by only detailing advertised price which includes expectation of value
242 rather than real value – this is the least representative measurement of value (RICS, 2019). An
243 alternative method would have been to use Council Tax bands (the basis for residential property tax
244 in England) however these are based on out-of-date valuations (decades old).

245 All properties sold between January 1999 to June 2000, April 2002 to December 2003, and April 2017
246 to August 2017 within the station catchment areas were used for the time-based analysis. This
247 provided 2957 records of transacted properties.

248 **3.3 Property Data**

249 The data for all property transactions in Sunderland since 1995 was downloaded from the database
250 and imported to excel, which was then filtered by date to give property transactions within the three
251 timeline phases. A House Price Index has been introduced to adjust for the price change over time due
252 to fluctuations in the property market and due to inflation. This was calculated using January 1999 as
253 a base and taking the average house price sale of each month within the time frame of the study. The
254 postcode of each station was then entered into a postcode matching tool that identified all of the
255 property postcodes within 800m. This was then used to filter out all properties outside of the
256 catchment areas. Three key property attributes were gathered from the Land Registry database for
257 the analysis including the number of bedrooms, the property type (flat, terraced, semi-detached or
258 detached) and the build (whether the property is a new build). These attributes cover some of the key
259 endogenous factors that are used in the marketing of residential property, which represents the most
260 'desirable' factors that may influence the value of the property. The property size is therefore limited
261 and captured by the number of bedrooms variable. The property type and status of build are
262 controlled by dichotomous/dummy variables, where 1 = present and 0 = not present. The variables
263 FLAT, TERR and SEMI represent a subgroup of variables relating to the property type, wherein 1
264 represents a property of that type, e.g. a property with the TERR variable equal to 1 would represent
265 a terraced property.

266 **3.4 Neighbourhood Data**

267 The neighbourhood data is used to capture the external characteristics of the area that may influence
268 the transacted price of the properties. The purpose is to try to standardise these characteristics, so
269 the effect of transport accessibility can be isolated and observed. The data selected for this study is
270 the percentage of people 'Long term unemployed' and the percentage of people in 'Higher managerial
271 and professional occupations'. These are grouped into five (5) categories: 1 (0% - 2.9%), 2 (3% - 5.9%),
272 3 (6% - 8.9%), 4 (9% - 11.9%) and 5 (12% +). As in the study by Du and Mulley (2007b), these two
273 factors capture the household status of the area.

274 These attributes provide an indication of the area's demographic classification, as they are one of the
275 most widely-used standard socio-economic classifications in the UK. These variables are derived from
276 the Office for National Statistics (ONS) UK census at the electoral ward level for the year 2011. Similar

277 to the property attributes, a batch geo-coding tool was used to identify the postcodes within each
278 ward, and then matched with the postcodes of each property transaction to attribute the values
279 accordingly.

280 **3.5 Amenities**

281 Access to amenities has been captured by the distance from the property to the Central Business
282 District (CBD), which has been considered as Newcastle City Centre and Sunderland City Centre. The
283 data was grouped into four (4) categories, with each representing a 1-mile distance from the CBD.
284 Following the bid-rent model, these are the destinations that most people living in the Tyne and Wear
285 area are likely to require access to, as they are major employment areas and 'commercial hot spots'.
286 These are basic variables to assess the impact of proximity to the CBD, measured by taking the distance
287 from the postcode of each property to the postcode of the city centre, based on the longitude and
288 latitude co-ordinates of each. It would be expected that there is a varying relationship between the
289 amenities variable and house prices at different stages of the project. Prior to construction, property
290 values would be expected to be higher as distance decreases as there is no metro link to provide
291 increased accessibility. After the extension becomes operational, the magnitude of this relationship
292 would be expected to decrease, as the increased accessibility would make land outside of the city
293 more desirable by the bid-rent model.

294 **3.6 Transport Accessibility**

295 As previously identified, three separate periods are used in the investigation to represent the extent
296 and nature of accessibility to a metro station, each representing a phase of the infrastructure delivery
297 process within which land value uplift may occur. This has given rise to 3 (three) separate dummy
298 variables, identified as extPRE (Pre-Construction), extOPE (Operation) and extEST (Established), which
299 represent a subgroup denoting the phase of infrastructure delivery process. In other words, we
300 present when there is no transport access (extPRE), whether there is transport access (extOPE) and
301 whether there is established transport access (extEST). ExtOPE is the reference point for this analysis,
302 where we can observe the results with no transport accessibility (extPRE) and with established
303 transport accessibility (extEST) in comparison.

304 The interaction terms of the transport accessibility are used to measure the difference in property
305 price between properties in the catchment area and given as a dichotomous value, where 1=present
306 and 0=not present. There is only one catchment area, therefore there are 3 interaction terms
307 (properties within 800m in the years 1999-2000, 2002-2003 and 2017-2018). As each property
308 transaction inputted into the model has to have an extPRE, extOPE and extEST designation, we use '1'
309 or '0' to indicate which stage the property is at. E.g. if the property was transacted in 1999 then extPRE
310 = 1, extOPE = 0 and extEST = 0. If transacted in extOPE then extPRE = 0, extOPE = 1 and extEST = 0.

311 **4. Findings**

312 The results from the multiple regression model indicate that there is a clear positive relationship
313 between the SME and property values within the catchment area. Immediately after the extension
314 became operational, property values displayed an increase of £10,750 from the pre-extension values.
315 However, once the extension had been operational for fifteen years, property values showed an
316 increase of only £3,654 in comparison with the pre-extension values, which is a decrease of £7,056 in
317 comparison with the values displayed immediately after the extension became operational. However,
318 these latter results were not significant

319 Further analysis revealed that exogenous factors should be considered as a rational predictor for the
320 increase in value caused by the metro stations. When constraining the variables of the regression
321 model to the endogenous factors (I.e. property type and number of bedrooms), the percentage of
322 value uplift appears to remain constant. As the mean price of the property increases, so does the
323 increase from transport accessibility at the pre-extension phase. This suggest that the value uplift is
324 not affected by the internal features of the property. Conversely, when considering the exogenous
325 factors, there are clear associations between the data. In areas of low unemployment (below 6%), the
326 value uplift is approximately 12%-14%. In areas of high unemployment (above 6%), value uplift is
327 between 7.4%-8%, suggesting a clear relationship between the variables. This is also evident for
328 distance from the CBD, areas located closer to the CBD (0 mile to 0.9 mile) experience a shallower
329 uplift to those located further away (1 mile to 1.9 mile) through the bid-rent model.

330

331 **4.1 Equation based on Hedonic Model**

332 It is first essential to establish the best equation for the model. By employing a stepwise approach,
333 each variable has been considered for addition or subtraction from the set of
334 independent/explanatory variables. This can improve the R-square value of the model. The equation
335 for the study has been identified and is defined as:

$$336 \quad P_i = B_0 + B_1\text{FLAT}_i + B_2\text{TERR}_i + B_3\text{BUILD}_i + B_4\text{BEDROOM}_i + B_5\%\text{UNEMP}_i + B_6\%\text{HMAN}_i + B_7\text{distSUN}_i + \\ 337 \quad B_8\text{distNEWC}_i + B_9\text{extOPE}_i + B_{10}\text{extEST}_i \quad \text{Eq. (2)}$$

338 Where, P_i represents the transaction price of property i ; B_0 , where B_0 represents the constant; $B_x V_i$,
339 where B_x represents the the coefficient of the variable for property i . As previously explained, FLAT,
340 TERR, SEMI and DETA are a group of dummy variables that represent a subgroup relating to the
341 property type. When computing the multiple regression model, one dummy variable should be
342 omitted from the study to provide a 'reference class.' The coefficient values are then calculated based
343 on the omitted variable, i.e. a coefficient of 10000 for DETA would represent a £10,000 premium on
344 the price of detached properties from that of a semi-detached property, and vice versa. This is also
345 true for the transport accessibility variables. In this case, the extPRE variable has been omitted as a
346 base. This results in the value of extOPE (immediate operation) and extEST (established operation)
347 being calculated in reference to no accessibility to transport (extPRE).

348 **4.2 Regression Model**

349 **4.2.1 Model Testing**

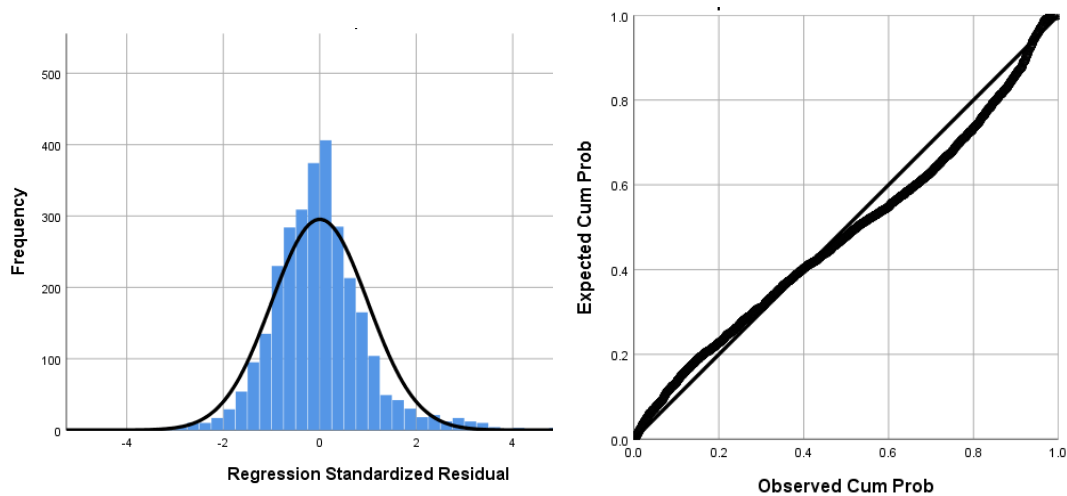
350 In multiple regression analysis, the variability of the dependent variable is expected to be high, as
351 there are multiple independent variables influencing the result. This should be a particular case for
352 this study, as a 1-bedroom flat will sell for much less than a 3-bedroom semi-detached house within
353 similar areas. This is confirmed in Table 3 above.

354

355 Multicollinearity can negatively affect regression-based analysis. An effective method of assessing it
356 is the Variance Inflation Factor (VIF). A VIF of 10 indicates a strong multicollinearity. Table 4 indicates
357 that the VIF of all independent variables in the regression equation are less than 2, indicating that no
358 independent variables are highly linear dependent, concluding that multicollinearity is not an issue in
359 this study.

360

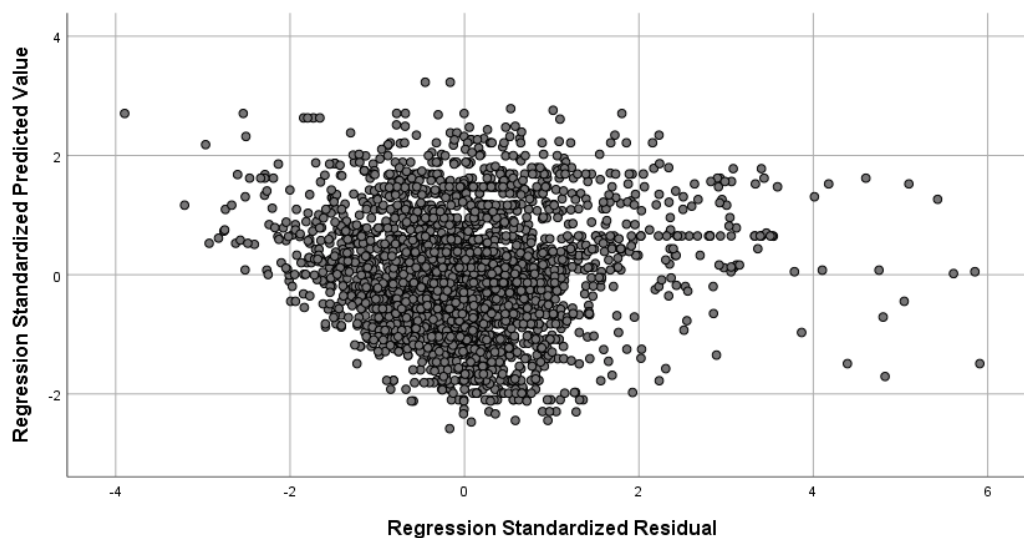
361 It is acknowledged that regression assumes that results should be normally distributed. This can be
362 examined by using the histogram and Q-Q-Plot (see Figure 3). As indicated, the regression results of
363 this study are normally distributed.



365 Figure 4. Histogram (left) and Q-Q Plot (right) showing normal data distribution

366 Testing of homoscedasticity is also essential for regression modelling. This can be achieved by plotting
367 the standardised residuals against the predicted values of Y. As shown in Figure 4, there is no particular
368 pattern to the distribution of variances, suggesting that homoscedasticity is present.

369



371 Figure 5. Homoscedasticity of data results

372

373 4.3 Results

374 The estimation results of the hedonic regression are presented in Table 4. A significant regression
375 model was found of $t(10, 2946) = 241.424, p < .05, R^2 = .449$ with the dataset. Overall, the model fit
376 is represented by an adjusted R-square of 0.449, showing that 44.9% of the variation in the data is
377 being explained. The unexplained variation is likely due to data limitations which led to the exclusion

378 of additional variables that may impact the value of property, including property attributes (number
 379 of bathrooms, car parking spaces, size in m²) and amenities data (location to nearest schools, parks
 380 and other desirable areas). As this is a not a log model, the estimates are interpreted as the true
 381 measure of the dependent value, i.e. 29486.795 is equal to £29,486.80. The percentage of estimates
 382 provides the increase in house price on average for each variable, when all other variables are
 383 constant.

384 Table 4. Results of the multiple regression analysis

Parameter	Estimate	Percentage of estimate / mean price	t value	VIF
Constant	29486.795	N/A	5.056 *	
FLAT	-51826.306	N/A	-16.780 *	1.355
TERR	-35870.589	N/A	-22.340 *	1.260
BUILD	42153.467	38.27%	10.474 *	1.093
BEDROOM	17268.271	15.68%	18.323 *	1.080
%UNEMP	-4426.657	4.02%	-5.399 *	1.710
%HMAN	21043.463	19.10%	16.297 *	1.929
distSUN	1755.990	1.59%	2.542 *	1.073
distNEW	5839.930	5.30%	6.630 *	1.371
extOPE	10750.878	9.76%	6.774 *	1.394
extEST	3654.789	3.32%	1.850 non-sig	1.393
Mean Price		110149		

385 * = significant at 5% level for one tailed tests

386 In this hedonic price model, the endogenous factors are considered to be the variables that directly
 387 represent the property, including property type (FLAT, TERR, SEMI AND DETA) (whether the property
 388 is a new build) and the number of bedrooms. As the variable SEMI was dropped, the estimates for
 389 FLAT, TERR and DETA are in reference to the price of a semi-detached house. The price of a flat is
 390 £51,826 less expensive than a semi-detached house and a terraced property is £35,870 less expensive
 391 than a semi-detached house. Unsurprisingly, the data shows a new build premium for the properties,
 392 estimated at £42,153 or 38.27% of the mean property price. Finally, the estimate for number of
 393 bedrooms is £17,268 (15.68%) of the mean property price. This shows that each additional bedroom
 394 is worth £17,268, which takes up 15.68% of the mean property price.

395 The dummy variables extPRE, extOPE and extEST capture the property price difference at the various
 396 stages of the infrastructure delivery process. As in the property type subgroup, a variable has been
 397 omitted to provide a reference variable, which was extPRE. The estimates of extOPE and extEST
 398 therefore represent the estimated effect of SME accessibility on property values for the respective
 399 phase of the infrastructure delivery process, using extPRE as a base. ExtPRE represents the pre-
 400 construction phase of the extension line (Jan 1999 - May 2000), extOPE is immediately after the
 401 opening of the extension line (Apr 2002 – December 2003), and extEST represents the established (or
 402 longer-term) operation of the metro (Apr 2017 – Aug 2018).

403 As indicated by the regression model, the estimates for the variables BUILD, BEDROOM, %HMAN,
 404 extOPE and extEST were expected to be positive ($\beta_3, \beta_4, \beta_6, \beta_9, \beta_{10} > 0$) while FLAT, TERR, %UNEMP,
 405 distSUN and distNEWC were expected to be negative ($\beta_1, \beta_2, \beta_5, \beta_7, \beta_8 < 0$). To test whether the actual
 406 results can match expectations, a comparison of the outcomes and expectations has been undertaken,

407 for a purpose of identifying an alternative hypothesis (i.e. β_x (or H_1) $>$ or $<$ 0) and whether the outcome
408 is significantly different from 0. If the result is not significant or $\beta_x = 0$, the alternative hypothesis is
409 rejected, and the null hypothesis is accepted. The variables that do not match the expected outcome
410 are marked in bold.

411 Considering the internal factors, FLAT and TERR were expected to have a negative value because the
412 regression equation uses SEMI as a reference group, and flats and terraced properties should have a
413 lower value than semi-detached properties. The BUILD and BEDROOM variables were expected to
414 have a positive value on the constant, due to a new build premium that would be expected on all
415 properties and the added value that is accrued from extra bedrooms in a property. As shown by Table
416 7, the actual estimates for these variables match the outcomes.

417 Regarding the neighbourhood or the socio-economic factors, it is expected that %UNEMP would be
418 negative and %HMAN would be positive. This is anticipated as, generally, it would be expected that
419 areas which possess lower percentage of unemployment and higher percentage of higher managerial
420 positions would be regarded as more desirable neighbourhoods to live in and therefore increasing the
421 price of properties in that area – with the converse relationship also expected to be true. Again, Table
422 7 indicates that these expected relationships match the actual outcomes from the regression model.
423 The %UNEMP variable confirms that property price estimates decrease as the percentage of
424 unemployment rate increases within the neighbourhood. For every one-point increase in the
425 %UNEMP variable (i.e. every 2.9% increase in unemployment), property price decreases by £4,426.
426 Conversely, the %HMAN variable is significant in confirming that property price estimates increase as
427 the percentage of higher managerial positions increase. As a result of one-point increase in the
428 %HMAN variable (i.e. every 2.9% increase in higher managerial position), property price increases by
429 £21,043.

430 In terms of amenities, it was predicted that as the distance from Sunderland City Centre and Newcastle
431 City Centre increases, the property price would decrease. This follows the premise of the bid-rent
432 model, in that as distance from the desirable area increases the price paid for the land will decrease
433 due to less demand. However, Table 7 indicates that the actual outcome from the regression model
434 does not fit these expectations. For every 1 mile further from Sunderland City Centre and Newcastle
435 City Centre, property values increase by £1755 and £5839, respectively.

436 When considering the results for each phase of the infrastructure process, it was expected that both
437 extOPE and extEST would present positive values. This would suggest that properties with access to
438 either a newly operational metro station or an established metro station would have greater property
439 values than those without access, all else held constant. Both expected results were confirmed in the
440 outcomes presented in Table 7. However, what is somewhat surprising is that the impact on property
441 prices due to newly operational metro stations is almost three times the amount than that of
442 established stations (£10,750 compared to £3,654).

443 **4.3.1 Implications**

444 Findings show that the B values of the variable extOPE is greater than 0, which was proven to be
445 significant ($p < 0.05$). This means that land value uplift does in fact occur immediately after the metro
446 extension line becomes operational. This is different from the historical research which a) found no
447 immediate change in value and b) hypothesised that value increase may come later. The estimate of
448 the regression model also shows that in terms of transport accessibility, property values sharply
449 increase immediately after the SME. Before decreasing once the line becomes established, at the

450 extPRE phase, property values were recorded at an average of £113,523. As identified from the
451 regression model, the estimated increase at the extOPE phase is £10,750.

452 This suggests that an introduction of the newly operational metro stations caused an increase in
453 property values of 9.53%. At the extEST phase, the increase in property values was estimated at
454 £3,655. Put simply, after the metro station becomes operational, property values suffer a -5.71%
455 decrease from the uplifted property value, all else held constant. However, from the extPRE to extEST
456 phase, there is still an overall increase of 3.22% to property values. However, as confirmed by the
457 regression estimate, these findings were not significant, and therefore cannot be accepted.

458 **5. Discussion and Conclusion**

459 Previous research considered a timeframe appropriate to measure short-term impacts of changes of
460 accessibility on land values, as measured by changes in property prices. This paper progressed this
461 original research to test a hypothesis that any impact may take longer to feed into house prices. A
462 time-based study was conducted as opposed to a control group to compare properties without access
463 (before the extension construction) and with access (immediately after and fifteen years after). The
464 prices were adjusted using a house price index to bring all values in line with the present value, which
465 meant that the 'time' aspect was the variable measuring transport accessibility.

466 This study hypothesised that land value uplift for extension lines occurs over a fifteen-year period as
467 opposed to immediately after the line becomes operational. The results obtained from the regression
468 model showed that in fact the greatest uplift in land value appeared to occur immediately after the
469 line becomes operational. An average increase of £10,750, or 9.76%, accrues for properties at the
470 extOPE phase, whereas no significant uplift was found at the extEST phase. This concludes that land
471 value uplift does not in fact occur over a long period of time in the Tyne and Wear region, but rather
472 immediately after the extension line opens. This potentially disproves the contention from Du and
473 Mulley (2007a; 2007b), and the underlying hypothesis in this study, that uplift in value may occur later
474 once the infrastructure is established. It also sheds light on the ambiguity found in literature around
475 when value uplift occurs. Findings support the contention of (Mohammad, 2013) that value uplift
476 occurs immediately after construction, indicating some insight into when land value capture
477 mechanisms should be implemented. However, the authors caveat this contention by arguing that all
478 locations, and underlying land and property markets are unique and demand their own analysis
479 (Levinson and Istrate, 2011).

480 When considering the endogenous factors affecting property values, the regression model identified
481 that there has been little effect on the premium generated by transport accessibility. The different
482 property types (flat, terraced and semi-detached) and number of bedrooms (1, 2, 3 and 4) made little
483 impact on land value uplift at the extOPE phase. All property types exhibited an increase of 7.80%-
484 8.30%, and similarly the number of bedrooms exhibited an increase of between 9.68%-10.59%. This is
485 an additional finding to the original research that did not consider property differentiation but
486 suggests, in any event, that the endogenous factors are poor predictors of land value uplift in this
487 case and would therefore not be required when identifying areas for land value capture
488 implementation.

489 Further analysis beyond the hypothesis and a consideration of limitations and opportunities for
490 further research is required to fully understand this situation but it could be contended that this
491 different reading of events immediately after construction could be down to the quality of the
492 underlying transaction data, which better reflects the market conditions at this time. However, there
493 is a large amount of unexplained variation in the data. Hence the conclusions should be viewed

494 circumspectly. In order to reflect on this variation, there is scope for further analysis to measure access
495 to transport as aerial distance to metro stops in combination with the time variable, or by including
496 control groups outside the catchment area. In addition, different catchment area sizes (rather than
497 the singular catchment area used in this study) could be deployed.

498 Furthermore, the property transaction data set was relatively rich in its currency, the Census data was
499 restricted by its decennial nature. Although exhaustive in its coverage and geographic granularity, a
500 weakness of the research is that this data is being used as a proxy over a long period of time. The next
501 Census takes place in 2021 and should be included in any subsequent research. In addition, this paper
502 relates to residential properties only. Although a more heterogeneous property type, there is also
503 considerable scope to model potential uplift to existing commercial properties. The Valuation Office
504 Agency have recently made freely available national rateable valuation information that can be geo
505 referenced to local areas. Historically, this information has not been available in the public domain.
506 This may help to determine whether value capture from commercial property would be worthwhile,
507 as it provides the opportunity to capture value from potentially higher value properties around key
508 areas of Tyne and Wear for further infrastructure projects.

509 Furthermore, for the purposes of this study, a prescribed set of variables were included to compute a
510 hedonic price model. Instead, the emphasis was placed on developing a time-based data set. There is
511 a long list of variables that could impact the value of property which may have implications for value
512 uplift generated by the extension to metro lines, particularly at the local level. As this study identified
513 some impact from exogenous factors, it is recommended that a more comprehensive set of exogenous
514 factors are tested to fully understand the relationship with a view to developing rational predictors
515 for identifying areas benefitting from transport accessibility and therefore potential land value capture
516 methods. For example, in this study, it appears that unemployment can be considered a predictor
517 variable to identify areas for land value capture. Although, due care should be taken in this area due
518 to the potential gentrification impacts of targeted value uplift strategies in areas of high
519 unemployment.

520 In addition, the study focused on three points in time, immediately before, after, and once established.
521 This was an appropriate means of testing the contention of Du and Mulley (2007a; 2007b), that value
522 uplift occurred later and to test the findings from literature that value uplift occurs immediately before
523 or after construction. In this study, house price change between the census points is accounted for via
524 a House Price Index that calculates the present value at each census point in the study – adjusting for
525 inflation. However, there is opportunity going forward to also investigate each individual year within
526 the date range, to investigate any variability between respective date ranges and to open the
527 possibility of additional local methodological enquiry.

528 For example, although many studies have identified a 'positive' uplift in land value through improved
529 accessibility, some have identified both an uplift and downlift around different stations within the
530 same public transport system (Tsai et al, 2017). This was caused by specific local contextual factors,
531 which prevented certain areas of land from producing the beneficial impacts from the infrastructure
532 investment. Hence, it is important for further research to look at not only the global impact of an
533 extension over time per se, but also the dynamics between stations – this is to analyse and counter
534 any potential bias in the global model. Taking this geographical theme forward. It is recommended
535 that further methodologies be used to understand the SME extension further. Geographic weighted
536 regression (GWR) offers scope for additional research (Efthymiou & Antoniou, 2013; Mulley, 2014;
537 Dziauddin et al, 2015; Wu et al, 2018; Dziauddin, 2019; Locurcio, 2020; Munshi, 2020) – while the
538 difference in difference model can also be used to counter spatial autocorrelation (Forouhar &
539 Hasankhani, 2018). GWR is based on a global regression model, such as a hedonic price model, which

540 is then modified by GWR to calibrate local regression parameters. The distance between data points
541 is weighted through the geographical coordinates of the data (Du & Mulley, 2007b). Using the GWR
542 method, there is scope for the internal heterogeneity of land value across the TWM system to become
543 clearer. The information can be overlapped on a GIS to clearly present the spatial dispersion of land
544 value uplift. In previous studies, both positive and negative impacts on land values were recorded
545 around different stops in the TWM (Du & Mulley, 2007b) and further afield on the Buffalo light rail
546 system (Hess & Almeida, 2007) and the Brisbane ferry system (Tsai, et al, 2017). This identified that
547 while, on the global level, uplift across all stations was identified, specific local contextual factors
548 prevented some stations from producing beneficial impacts from the investment.

549 Notwithstanding these limitations, the authors hope that these findings will also help inform the
550 debate into, and scrutiny of, 'the everywhere else' – those locations around the world with sub-
551 optimal conditions. In this sense, the findings are considered to have broader relevance in relation to
552 debates involving the economic, social, political, and environmental dimensions of urban and regional
553 (subnational) change, uneven development, and territorial evolution. The research also provides a
554 basis for policy makers, governments and practitioners when evaluating ideas for financing and
555 funding transport infrastructure systems in sub-optimal locations. For those transport and property
556 professionals involved in the day-to-day management of transports systems, infrastructure
557 development and real estate assets in the developed world, findings identified in this research will
558 help contribute to more knowledgeable and effective practice regarding transport infrastructure
559 development. Also, the developed approach will provide city leaders and property professionals with
560 an insight into dealing with the demands of accelerating urbanisation in the less developed world.
561 Such locations have the potential to learn from and avoid the pitfalls and complications seen in more
562 mature urban areas. With direct pertinence for the empirical research area, the TWM system is
563 currently being considered for further extension. The North East Joint Transport Committee
564 responsible for strategic transport stated that: 'Some communities across the region were
565 disadvantaged because they do not have access to the rail network. Let's put any financial surplus
566 towards understanding the future of the network and where we can expand' (Councillor Carl Johnson,
567 2019).

568 The approach developed in this study has the potential to lead to a better understanding of the factors
569 determining land value changes in the TWM system – particularly in relation to when it occurs. This
570 can inform the type of land value capture mechanisms that would be appropriate to fund any
571 subsequent extension. It can help tailor the financial planning of infrastructure within the landscape
572 of fiscal uncertainty that demand intricate alignment of complex capital and revenue funding streams
573 within locally specific conditions. As Levinson and Istrate (2011) state, there is no pre-conceived silver
574 bullet for the selection and implementation of best practice for LVC mechanisms through accessibility
575 value creation. Echoing Knowles & Ferbrache (2016), for an LVC mechanism to be effective,
576 accessibility value must be measured and married with local planning and fiscal policy in order to
577 successfully capture land value uplift at the correct place and time.

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