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A meta-analysis of the impact of rail stations on property values: Applying a transit planning lens

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ABSTRACT

Access to transit infrastructure is valuable. In areas surrounding rail stations, some of that value gets absorbed by property markets. Since 1970, over 200 case studies worldwide have explored the extent to which transit access impacts property value uplift. However, findings from this body of research vary widely. In an attempt to explain this variation, previous meta-analytic studies have focused on testing the roles that built environment elements, temporal factors, and modelling techniques play in shaping the observed relationship between proximate positioning from rail stations and property pricing. This study expands on these meta-analyses by introducing the first examination of how transit service elements – e.g. frequency, fare, reliability – impact rail-induced residential property value uplift. It further contributes to the literature by expanding the range of geo-comparability of uplift findings across four continents, examining the potential effects of the Global Financial Crisis of the late 2000s, and adding 10 new variables of potential influence not only under the banner of 'transit service', but pertaining to neighborhood socio-demographics and housing policy as well. Findings reveal that factors of geography, housing data type, race and ethnicity, rent control policies, rail type, transit cost, and transit network expanse all significantly affect rail access uplift magnitude ranging from depreciating effects of 7.4 percentage points to appreciating effects of 9.6 percentage points. Beyond helping to explain variation across the literature, these findings can be a useful tool for policymakers combatting trends of increasing market-driven displacement from transit-rich areas, those pursuing financing mechanisms for transit infrastructure, and to transit planners concerned with how their decisions may affect matters of housing equity for the communities they serve.

1. Introduction

We derive value from transit services. That value can take many forms. For example, time savings (Bajic, 1983; Leclerc et al., 1995), direct financial savings (Lewis-Workman and Brod, 1997; Dunphy et al., 2004), optionality (Weisbrod, 1964), sentiments of pride and belonging (Hidalgo and Yepes, 2005), or simply comfort and convenience (Fu and Juan, 2017). Whatever its source, a portion of that value gets absorbed by property markets and is reflected in pricing. The extent to which this relationship manifests is impacted by, among other things, our ease of access to transit systems. One determinant of that ease is spatial distance: proximity.

The body of literature discussing the impact that proximity to transit stations has on property pricing, a phenomenon that will be referred to from here on out as a 'transit access premium', is extensive. Since 1970, over 200 studies have been published on the subject, most focusing specifically on rail. The access premiums found within these rail studies vary widely. Some have identified

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slightly negative premiums (Du and Mulley, 2007; Nelson, 1992; Landis et al., 1994); meaning that being located proximately to rail stations has a depreciating effect on property price. Others have found no significant evidence of a premium at all (Gatzlaff and Smith, 1993; Clower and Weinstein, 2002; Adair et al., 2000). The lion's share of studies, however, have uncovered positive access premiums. Yet even within this group, there exists a sizable range of findings. Some studies have uncovered positive rail access premiums below 2% (Cervero and Duncan, 2002; Gu, 2007; Lewis-Workman and Brod, 1997) while others have found premiums in excess of 40% (Cervero, 2006).

How does one explain such wide variation in premium magnitudes found across the rail access literature? Despite a rich collection of case study findings, few have tried to systematically put these studies in conversation with one another in such a way as to provide generalizable conclusions about the nature of transit's relationship with property markets. To date, only four attempts at such an analysis have been made. These efforts, all of which utilize a meta-analytic regression approach, have focused on explaining the variation in the effect size of premiums through examination of built environment contextual factors, temporal factors, modelling techniques, rail type (e.g. light, heavy), property type, and treatment. Surprisingly, none have assessed how variations in the conditions of transit service might impact associated premium magnitudes. This work, which also deploys a meta-analysis methodology, chiefly concerns itself with filling this gap in the literature.

Building on the four previously conducted rail access meta-analyses, this work contributes to our understanding of the transit-access/property market relationship in the following ways: it includes premiums spanning four decades, 1980 to 2020, where the most previously looked at was three; examines the potential impacts of the Global Financial Crisis of the late 2000s; and widens an otherwise US-centric body of research to include 18 countries across four continents. Finally, this work's primary contribution comes from its expansion of the field's collection of premium-influencing variables with the introduction of 10 new moderators pertaining to demography, housing policy, and, most extensively, transit service – e.g. frequency, fare, reliability. By introducing these features of transit planning, this work answers the call made by Landis et al. (1994) and Xu and Zhang (2016) for an increase in the applicability of premiums research outside of scholarship. It also positions transportation planning practitioners as active agents in a relationship within which they have previously been treated as passive or reactionary.

This study finds that factors pertaining to geography, housing type, race and ethnicity, rent control policies, rail type, transit cost, and transit network expanse all significantly affect rail access premiums ranging in absolute value magnitude from 0.21 to 9.6 percentage points.

The relevance of transit access research like this has most commonly been framed in terms of 'value capture' – a public financing mechanism that facilitates the recovery of some or all of the value that public infrastructure generates for private landowners (Smith and Gihring, 2006; Sharma and Newman, 2018; Cordera et al., 2019). Ending the discussion there fails to highlight that understanding the specific ways these factors impact the transit-access/property-market relationship is vital to the ongoing struggle for equitable urbanity. The dynamics explored here host socio-spatial implications regarding market-driven displacement and gentrification (Baker and Lee, 2019), current widespread trends in the suburbanization of low-income communities (Bailey and Minton, 2018; Allard, 2017), and, consequently, increased transportation subsidization of the wealthy.

This paper is structured in the following way. Section 2 showcases primary findings from the literature. Beginning with a discussion of case studies, it highlights points of disagreement as well as those of general consensus. The section then turns its attention to summarizing the meta-analysis literature. Section 3 looks at model design addressing inclusion criteria, definition of moderators, and meta-analyses as a methodological approach more broadly. Section 4 presents results. Section 5 concludes with a discussion of the implications of findings as well as uncovered opportunities for future research.

2. Literature review

2.1. Case study literature

Rather than catalog the specific rail access premiums uncovered by the many case studies under this research umbrella – an effort already undertaken by several others (Diaz, 1999; Goetz et al., 2009; Du and Mulley, 2007; Hess and Almeida, 2007; Forouhar and Hasankhani, 2018) – this section is instead dedicated to an exploration of how rail access premium studies differ as well as what commonalities exist across them. This serves to establish a foundation upon which to build a comprehensive meta-analysis model.

2.1.1. Explaining difference

Perhaps the most stark divergence in magnitude among premium findings exists along the lines of property type. Rather intuitively, the land-use classification of the property in question – residential versus commercial, for example – influences access premiums. The same is true of whether one is discussing sale prices or rental prices, single versus multi-family housing, and whether one is using price data associated with actual transactions or from an assessor's database. While the ways that these different typologies perform in relation to one another is not completely uniform, commercial access premiums are generally much larger than residential property premiums, and multi-family premiums tend to be larger than single-family premiums. Their prominence within the literature varies as well. Due largely in part to data availability, transaction data is used more often than assessor's data, and the number of studies dedicated to housing sales far outweigh those of housing rentals or commercial property sales (Duncan, 2008). These variables influence the calculation of premiums, and therefore need to be acknowledged in any discussion of variation among premiums within the literature.

Contextual factors of time and place also have a hand in premium determination. It is reasonable to propose that in our present day, sustainable modes may be more highly valued than in times past as efforts toward Environmental Justice and Going Green gain popularity (Kumar et al., 2012). This temporal influence may also be interacting with geographical ones. Though examples of this line of research hail from every rail-hosting corner of the globe, certain regions have dominated the literature at different points in time. Prior to 2010, rail access premium studies were primarily US-centric. To put that claim into perspective, of the 66 studies used as inputs within this meta-analysis, 64% of those published prior to 2010 analyze US rail networks. Of those published between 2010 and 2020, analyses of Chinese rail networks make up the largest share of studies, accounting for 32%. This shift in focus comes as no surprise as Asia-Pacific nations, China in particular, have expanded their rail transit offerings through the addition of both new stations and the opening of entirely new systems at a rate far eclipsing any other region of the world over the last decade (International Association of Public Transport, 2019; Zhou and Zhang, 2021). This place-time relationship across the literature may serve as a further explanatory factor of the range of access premiums measured.

The influence of geographical context doesn't end there. Mobility behavior, a crucial piece in the access premium puzzle, varies from one place to the next. Different levels of dependence on, affection for, as well as comfort and familiarity with transit services across much of Europe and Asia over car-centric locales in the US and Australia, for example, likely contribute to varied values placed on living proximately to rail services across these areas (Taylor and Fink, 2013).

Neither the impacts of time and differences in travel behavior, nor the differences in data type, fully explain the wide range in positive rail access premiums found. Differences in measurement methods and analytical models play a part as well. In tackling the question of how proximity to rail stations impacts property price, different studies have taken to measuring 'proximity' in different ways. Some have measured proximity continuously in linear distance extending outward from a station to the point at which an impact is no longer discernible (Hess and Almeida, 2007; Golub et al., 2012; Lewis-Workman and Brod, 1997). Others have applied distance bands radially surrounding a station. Each band exclusionary of the one prior, for example 0–250 m followed by 251–500 m, and all properties within a given band assumed to experience the same premium (Xu and Zhang, 2016; Mayor et al., 2012; Dubé et al., 2014; Zhang et al., 2014).

A third 'proximity' measuring technique applies a single radial buffer and measures the average value difference of properties within that station-area catchment buffer – i.e. treatment group – compared to those beyond it – i.e. control group (Diao et al., 2017; Martinez and Viegas, 2009; Du and Mulley, 2007). Adding nuance to this approach, some studies have used a propensity scores matching technique to determine treatment and control areas (Yen et al., 2019; Perdomo, 2011). Rather than assume that just because an area falls beyond a certain distance from a station that it makes for a suitable control spatiality, this method uses a probit model featuring neighborhood characteristics to match statistically comparable areas near stations to those outside station catchment zones. The different assumptions about the uniformity of premiums across space that these measurement techniques make likely contribute to the wide range of premiums found.

Similarly, a multitude of analytical strategies have been deployed in the effort to unpack the question of value impact. Three different model types dominate the literature. Hedonic price modelling is used most widely. This highly versatile method allows for the attainment of many observations of property values but is highly susceptible to failings of omitted variable bias (Diao et al., 2017). In an effort to mitigate this susceptibility, several studies have deployed a repeat-sales approach (McMillen and McDonald, 2004; Welch et al., 2018; Ge et al., 2012; Zhou et al., 2021). This model compares sale prices of the same property across different time periods. Studies that use this model compare the changes in sale prices of properties proximate to rail stations to the changes in sale prices of properties falling outside of a determined station access zone. Though this model avoids the endogeneity issues of the hedonic price model, it falls subject to sample selection bias, suffers from generally low numbers of available observations (Wang and Zorn, 1997), and fails to account for the influence that any renovations or improvements to the property made between measurement cycles have over its change in value.

In recent years, a difference-in-differences (DID) approach has gained popularity (Gibbons and Machin, 2005; Mohammad et al., 2017; Im and Hong, 2018; He, 2020). This quasi-experimental approach allows for the treatment of proximate access to a rail station to serve as an exogenous shock, capturing both observed and unobserved impacting factors. The limitations of this model lie in its data and condition requirements. Its appropriate use calls for property sale data from before a station was introduced to a neighborhood as well as after it became operational and that the composition of treatment and non-treatment groups before and after the station-access shock remain stable (Dubé et al., 2014). Case studies that have examined both a DID model and a hedonic price model subject to the same study parameters find that DID modelling techniques demonstrate lower access premiums (Mohammad et al., 2017; Trojanek and Gluszak, 2018). Any attempt at a cross-study comparative analysis of access premiums would need to include accommodations for modelling variations such as these.

2.1.2. Drawing from convergence

It has been widely observed within the case study literature that the relationship between rail access and property price is subject to a nuisance effect. This effect suggests that being situated within roughly 250 m of a station may in fact be a dis-amenity. This has been attributed to station-area noise – both people and train generated, heightened levels of pollution, and an increase in the presence of 'loiterers' linked to the perception of increased crime (Chen et al., 1998; Golub et al., 2012; Ke and Gkritza, 2019).

Consistent findings have also been made with respect to the proximity limit at which access to a rail station no longer has an impact on property values, and at which specific point within this impact zone access premiums reach their peak. Irrespective of varied location contexts and analyses methods, premiums were nearly never observed to extend beyond 2 km from a station. Most commonly, the upper extent of impact zones was measured to be 1.6 km with steep decreases in premiums occurring after 1–1.2 km (Chalermpong, 2007; Duncan 2011; Zolnik, 2020). Similarly, shared findings of premium peaks around 500 m from stations, about a five minute walk, abound (Wen et al., 2018; Martinez and Viegas, 2009; Wang, 2016).

Both the pedestrian environment surrounding stations and the type of rail service available at stations further impact access premiums. The quality of the journey from property to station – influenced by the presence of elements like tree canopy coverage, attractive street furniture, high visibility crosswalks, varied and small-scaled commercial offerings, lighting, etc. – consistently has a positive effect on access premium size (Duncan, 2011; Xu and Zhang, 2016). Additionally, premiums associated with commuter rail service tend to be significantly larger than those linked to light rail or metro service (Landis et al., 1994; Cervero and Duncan, 2002; Zhong and Li, 2006). One justification for this may be that many commuter rail services are co-located with highway infrastructure access points; a reality that only about 50% of case studies account for. Scholars such as Voith (1993) have found that access to other, non-transit mobility facilities is also capitalized into property values. In this sense, commuter rail accessible properties may be reaping the value uplift effects of both rail and highway proximity. It could also be attributed in part to a larger competitive advantage with alternative modes. Trips taken via commuter rail tend to be longer than trips taken on light rail or metro services and more closely align with peak congestion travel times (Yu and Machemehl, 2010). As a result, the car alternative for these trips may be particularly unappealing – the costs (financial, comfort, convenience, etc.) associated with long drives, parking, and heavy traffic may make the train mode choice an exceedingly valuable option.

A second tier of less widely explored factors that nonetheless offer shared findings across the case study literature are similarly worth drawing upon to inform the design of a robust meta-analysis of rail access premiums. These include attention paid to the influences that neighborhood demographics, relation to central business districts (CBD), and perception of distance have over the construction of value. Among studies that included income in their analysis, there is general agreement that neighborhood income characteristics of the station area have a significant impact on access premiums. The directionality of that impact varies, however. While some studies have found that higher income areas experience larger premiums (Brandt and Maennig, 2012; Siripanich et al., 2019), others have found that premiums are larger in lower income areas (Forouhar and Hasankhani, 2018; Wang, 2016). Conversely, great uniformity has been found regarding the way that neighborhood racial and ethnic composition influence rail access premiums. Across studies from North America, Europe, the Middle East, and Southeast Asia alike, the larger the percentage of minority or foreign born persons in a station area neighborhood, the smaller the premium (Pan et al., 2014; Landis et al., 1994; Dziauddin et al., 2013; Cervero and Duncan, 2002; McMillen and McDonald, 2004; Brandt and Maennig, 2012).

The case of consistent findings of significance accompanied by varied directional impact on premiums applies to station proximity to a CBD. Some – for example Efthymiou and Antoniou's (2013) study of Athens and Ma, Ye, and Titheridge's (2014) study of Beijing – have found that for stations outside of the CBD, premiums decrease as distance from the CBD increases. Others, particularly those from US cities that experienced post-industrial urban flight the likes of Hess and Almeida's (2007) study of Buffalo, found that premiums increase as station distance from the CBD increases.

Finally, perception of closeness was occasionally explored and found to be more impactful over access premiums than actual closeness with respect to travel time to station (Armstrong, 1994). This idea evolved in more recent studies and took the form of examining the difference in transit premiums measured along a street network distance from stations versus a straight-line (Euclidean) distance. Network distance measurements commonly render smaller access premium values than straight-line distance measurements (Hess and Almeida, 2007; Dziauddin et al., 2013). This is counter-intuitive. While 500 m, for example, of street network distance from a station may take 5 min to traverse on foot, 500 m of straight-line distance almost always corresponds with more than 500 m of actual on-foot travel. With both distances falling beyond the nuisance effect impact area, the shorter distance should render a higher premium. The fact that it does not speaks to the power of perception – homeowners may be perceiving the travel times of straight-line distances and street network distances differently. The research team of Krizek et al. (2012) found that for journeys of 1 to 5 min, traveler estimates of trip time along network distances were only 51% accurate and tended to be overestimations while straight-line trip time estimates were 63% accurate and tended toward underestimations. Similar findings rang true for journeys 6 to 10 min in length. This relationship between distance measurement type and perceived travel time no doubt interacts with questions of proximity-dependent value, and therefore premium magnitudes.

2.2. Meta-analysis literature

A handful of scholars have tried to combine the disconnected pieces of this rail access premium puzzle to provide a systematic, causal explanation of the variation in findings across the case study literature (Debrezion et al., 2007; Hamidi et al., 2016), and to explore how factors potentially omitted from the case study literature might contribute to the nuance in our understanding of transit infrastructure-impacted property pricing (Mohammad et al., 2013; Park et al., 2016). They have each deployed meta-analyses as their method of choice in this endeavor.

Meta-analysis is a regression approach that synthesizes previous studies focused on a common research question to derive conclusions about that body of research (Haidich, 2010). In addition to being well suited to identifying sources of diversity of findings across related studies (Cook et al., 1992), this approach offers the benefits of the ability to enhance the power of small or inconclusive studies (Turner et al., 2013) and to detect deficiencies in the design, analysis, and interpretation of research (Ioannidis and Lau, 1999). This approach is not, however, without its limitations. Because the analysis is dependent on other research as its primary inputs, it is highly susceptible to publication bias – an occurrence in which the results of research impact the likelihood of that research to be published, and therein, made most readily available (Dickersin, 1990). Though often a difficult task due to inaccessibility, this issue may be circumvented through the inclusion of unpublished research within the meta-analysis input data (Melo et al., 2009).

Despite the many benefits of a meta-analytic research methodology, only four efforts at this type of analysis with respect to rail transit access premiums have been undertaken to date. Due to differences in variable definition and regression design, the impact coefficients found within these studies cannot be cross-compared directly. However, the significance and impact directionality of the moderators featured in each are indeed comparable and are summarized in Table 1. As a collection, they each feature a different set of

Table 1
Rail access premium meta-analysis literature summary.

Study	Geo.	Studies Used	Total Obs.	Premium Interpretation	Moderators Analyzed	Lu	Z	M	Di	Dt	T	B	Tr	Ph	A	Sd	Significant Moderators	Reference Case for Dummy Moderators and Impact Direction	
Debrezion et al., 2007	US	–	55	Property value premium experienced within 400 m of a station	12	x	x	x	–	–	x	–	x	–	x	x	Commercial Property	Residential Property	+
																	Commuter Rail Mode	Light Rail	+
																	Accessibility Variables	Models without	–
		–	57	Property value premium experienced every 250 m closer to station													Commercial Property	Residential Property	–
																	Commuter Rail Mode	Light Rail	+
																	Bus Rapid Transit Mode	Light Rail	–
																	Semi-log Model	Linear Model	+
																	Accessibility Variables	Models without	–
																	Race or Income Variables	Models without	–
Mohammad et al., 2013	Asia Europe North America	23	102	Land/property value premium experienced 501–805 m from a station compared to land/properties more than 805 m away	28	x	–	x	–	x	x	x	x	x	x	–	Study of Property Value	Study of Land Value	–
																	Commercial Property	Residential Property	+
																	Commuter Rail Mode	Light Rail	+
																	Stabilized System	Systems<1 yr old	–
																	Accessibility Variables	Models without	–
																	Europe	North American studies	+
																	East Asia	North American studies	+
																	Cross Sectional Data	Panel or Time Series	–
																	Semi-log Model	Linear Model	–
																	Double-log Model	Linear Model	–
Hamidi et al., 2016	North America	45	81	Single-family property value premium experienced every 100ft closer to a station	9	–	–	x	–	x	x	x	x	–	–	–	Distance to station	n/a	+
																	Squared station distance	n/a	–
																	Published after 2002	Published 2002 or before	–
																	Compactness Index	n/a	+
Park et al., 2016	US	52	139	Property value premium experienced within 400 m of a station	17	x	x	–	x	–	–	x	–	–	x	–	Distance to Institutions	n/a	–
																	Population Density	n/a	–
																	Dwelling Density	n/a	–
																	Ratio of Industrial Use	n/a	–
																	Street Density	n/a	–
																	Land-use Diversity Index	n/a	+

Moderator Categories Featured Meta-analyses.
Lu: Land-use Typology, **Z:** Zoning Distinction, **M:** Regression Model Type, **Di:** Distance Measurement Distinctions, **Dt:** Data Type, **T:** Time effects, **B:** Built Environment Characteristics, **Tr:** Transit Mode Distinction, **Ph:** Phase of Transit Intervention, **A:** Non-transit Accessibility, **De:** Socio-demography.

strengths worth highlighting and learning from.

Beyond pioneering the use of a meta-analytic approach to analysis of the impact of proximity to transit stations on property values, Debrezion et al.'s (2007) work offers impressive clarity in its model design and recommendations for how best to interpret meta-analysis findings. This work also explores two different treatments of an access premium – one treating distance from a station as continuous and another using a single station-area buffer. This both allows for comparison across the two most widely used measurement methods within the case study literature and provides practitioners wishing to make use of these findings with options of varied applicability.

Drawing from Debrezion et al.'s study, Mohammad et al. (2013) introduce additional explanatory moderators into their analysis, widen their input dataset by including land sale pricings, and expand the geographical lens of relevance applied to this line of research by incorporating studies from not only North America, but Europe and Asia as well. This piece also succeeds in avoiding publication bias by including unpublished research as model inputs.

Three years after Mohammad et al.'s work, two additional meta-analyses were published that both placed specific focus on the contextual influences that the built environment and urban form may have over the relationship between transit access and property value. Hamidi et al. (2016) propose that both population size and density of case study cities may be impacting access premiums – a reasonable assumption based on the notion that both the number of participants in the property market and density of those participants could shape demand within that market. Park et al. (2016) similarly embrace the potential power of built environment factors by testing a wide range of New Urbanist design ideals as access premium moderators. Including population and compactness measures, as Hamidi et al. did, Park et al.'s study adds to the literature an exploration of land-use diversity and roadway density, and expands on Mohammad et al.'s already impressive number of observations collected as input cases.

Despite different contributions with respect to best practices, there are a number of commonalities across the findings from this body of literature. For example, in every meta-analysis that featured it as a moderator, the mode classification of commuter rail was always found to have a significant and positive impact on access premiums (Debrezion et al., 2007; Mohammad et al., 2013). Variables measuring accessibility for non-transit vehicles – for example highway access – were similarly consistently significant, regularly demonstrating negative impacts on premium magnitudes (Debrezion et al., 2007; Mohammad et al., 2013; Park et al., 2016). Finally, in all cases that accounted for them, both zoning characteristics (Debrezion et al., 2007; Mohammad et al., 2013; Hamidi et al., 2016; Park et al., 2016) and semi-log as compared to linear model treatment (Debrezion et al., 2007; Mohammad et al, 2013) proved significant.

The rail access premium meta-analysis constructed within this study builds upon a foundation largely informed by these four works.

3. Methodology: Meta-analysis design

3.1. Input studies

To be included within this meta-analysis, case studies had to adhere to the following criteria. No access premium based on an examination of fewer than five rail stations, or that did not include housing characteristics (e.g. property size, number of bathrooms, property age, etc.) was included. All premiums were based on residential zoning and sale pricings. Only premiums based on property values were used. This excluded the few case studies that derived access premiums from analyses of land values. These choices were based on the performance of rental, non-residential, and land-value treatments in prior studies and the belief that these treatments represent fundamentally different markets (Ahlfeldt et al., 2019; Hilber and Vermeulen, 2016). In most analyses that include these elements, they take on outlier qualities – e.g. land-value access premiums have been found to reach magnitudes of as much as 120% (Cervero and Duncan, 2002).

The case study premiums included all applied to fully operational transit systems. While some studies have found that value absorption of rail investment into the housing market is realized as early as the announcement phase of a project, findings are not consistent as other studies find high volatility in both capture magnitude and significance level during all pre-operational phases (Gatzlaff and Smith, 1993; Billings, 2011; Golub et al., 2012; Ke and Gkritzka, 2019). Though transit takes many forms, only premiums pertaining to rail-specific modes were included here. This was done because different modes have distinctly different scopes of influence with respect to how access to them is internalized by the property market. For instance, while rail stations generally experience a nuisance effect within 250 m of a station resulting in a depreciation of property values, bus stations are generally found to either not have a discernible access premium at all, or to only have a measurable impact up to about 300 m (Mulley and Tsai, 2016). Finally, only studies in which premium standard errors were provided or calculable were included, as these were required for weighting within the meta-analysis regression.

In order to be able to conduct this meta-analysis and draw findings from its result, all input premiums needed to be measured in comparable units. This comparable unit consisted of two parts. Firstly, all premiums needed to take the form of a percentage change in property value. While many were calculated this way in their original case studies, several premiums were reported as changes in monetary values (e.g. in $US). In these cases, conversion was necessary. This was accomplished by comparing the property values at the station-area point of interest to the average property values at points determined to be outside of the station-area impact zone. This segues into the second part of the determination of a comparable premium unit. In this study, the access premium was defined as the value of properties situated 500 m from a rail station – specifically, *at* 500 m not *within* 500 m – compared to those situated beyond 1.6 km from a station. The selection of these distances as points of interest for comparison was based on findings from the case study literature. These findings identified that 500 m represents the point at which premiums tend to experience their peak value while 1.6

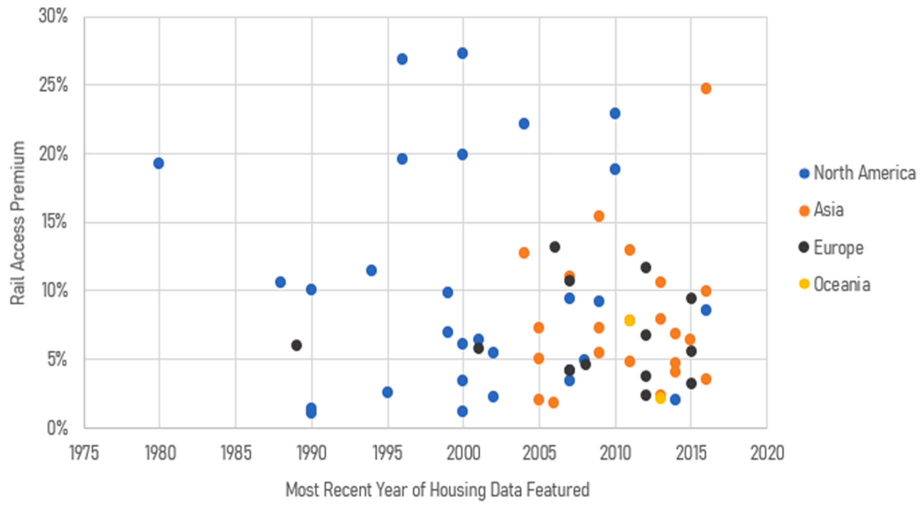

Fig. 1. Rail access premium by most recent year of housing data used in case study.

km represents the point at which most studies no longer experienced a discernable impact of station proximity on property prices. This premium definition can be internalized in more tangible terms in the following way: the difference in property value that comes from living about a five minute walk away from a station versus a twenty minute walk away from one. Case studies in which insufficient information was provided to calculate this comparable unit were excluded from the analysis.

This dependent variable definition and set of inclusion criteria resulted in a collection of 66 premiums gathered across 46 studies that ranges from 1.1% to 27.3%. How this range behaves temporally and geo-spatially is depicted in Fig. 1.

Among the case study inputs that make up this meta-analysis, 18% were not published in academic journals. This cohort includes findings from working papers, dissertations, conference proceedings, and non-academic reports most often submitted to municipal transportation departments. Inclusion of these studies serves to avoid the potential impacts of publication bias in the analysis (Berlin and Ghersi, 2005).

3.2. Moderators

Rail access premiums are contributed to by a large host of factors. Some have their rooting in the physical world – contextual factors, while others exist in the analytical framework used to measure these premiums – methodological factors. Modelled in Fig. 2 is an agglomeration of all of the contributory factors that past meta-analyses have explored in some form or another. In blue are the primary contributions of this meta-analysis to the collective moderator web. These represent moderators that have not previously been tested. The rationale behind the introduction of these new moderators and their anticipated impacts on access premiums are the focus of this subsection. How they, as well as all other moderators used within this analysis, are defined is specified in Table 2.

The following logic led to the inclusion of a new moderator within the impact grouping of 'Housing Market Influencers'. Surely the amount of available housing supply, local purchasing models and requirements (e.g. restrictions on owning more than one property, credit-dependent loan eligibility), and policies that dictate price setting freedoms (e.g. rent control, land for sale by public entities) all influence the sale prices of property; proximate to rail stations or otherwise. Of these elements, a focus was placed on rent control policy – which here encompasses both rent caps and rent stabilization policies – for three reasons. Firstly, feasibility of data acquisition. Mohammad et al. (2013) highlight the difficulty associated with finding housing market influencing information across a large range of case studies spanning several decades. Fortunately, policies the likes of rent control tend to be archived as a part of public record and remain largely unchanged over long stretches of time. These characteristics contributed to data accessibility.

Secondly, rent control has the rather universal objective of avoiding both fast and large upward shifts in housing costs within at least a portion of the housing market. This universality – both in objective and execution, as these policies tend to be set at the level of local (city-level) government – allows for reasonable comparison across both time and geography. Finally, any findings associated with rent control policies on rail access premiums can, in principle, be acted upon by practitioners with some immediacy (not to side-step due process, of course). In that sense, the implementability of rent control strengthens its value as a moderator. Given the restrictive influence that rent control policies are designed to have on potential profits garnered from participating in ownership within the housing market, it is anticipated that this moderator will have a depreciative impact on rail access premiums.

With respect to transit characteristics, nearly all of the meta-analyses that deal with rail access premiums delineate premiums by the type of rail offered at the stations under study. Most typically this results in the categories of light, heavy, and commuter rail. While this treatment is certainly reasonable and necessary – a claim supported by consistent findings of significance, especially of the commuter rail classification – it is not a sufficient encapsulation of the variance in transit quality that could be impacting the value associated with proximate access to transit service. To gain a more detailed understanding of this relationship, this meta-analysis

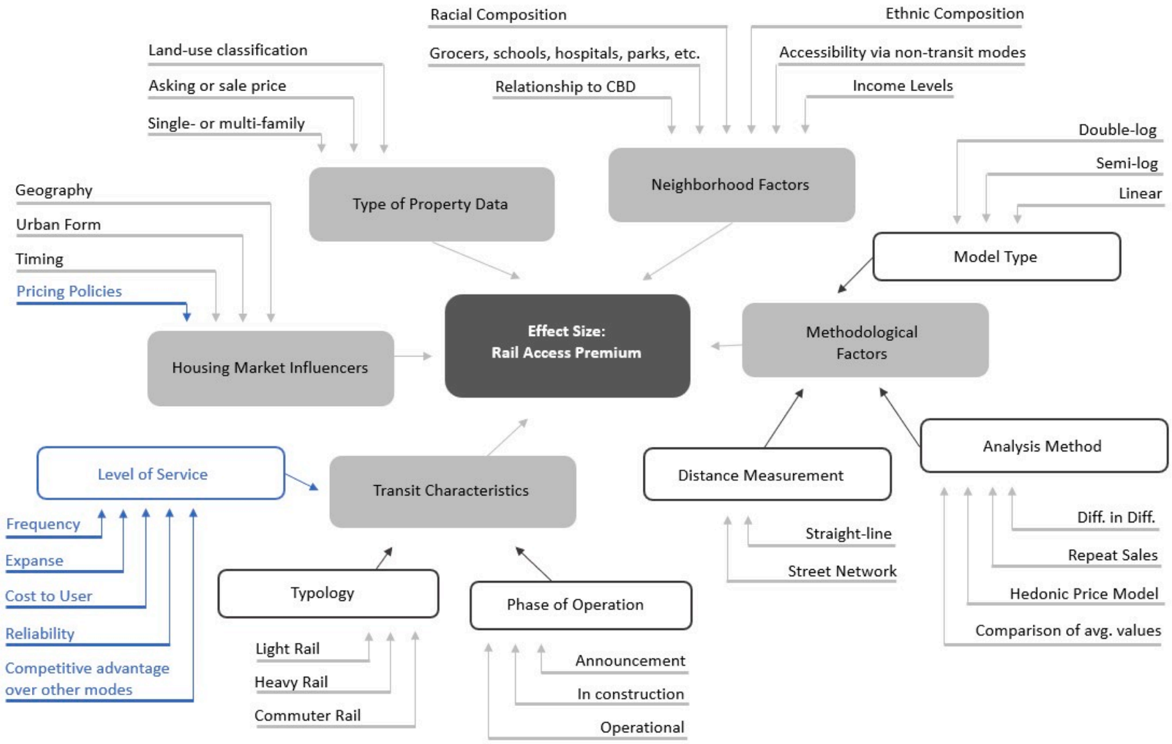

Fig. 2. Framework of factors that affect the impact that proximity to a rail station has on property value.

includes moderators associated with frequency, expanse, fares, reliability, and comparative advantage of transit over other modes.

High frequency demands less stringent trip planning from travelers and offers shorter average wait times. There is also a higher degree of emotional comfort that comes from access to high frequency service. Unsurprisingly, missing a train or bus in conditions of poor frequency is associated more closely with negative emotions such as anxiety and anger than doing so under high frequency conditions (Van Lierop et al., 2018). Against this backdrop, this analysis anticipates a positive valuation placed on access to higher frequency service, and, subsequently an appreciating effect on premiums. The moderators associated with testing this hypothesis are divided into four groups: frequencies of 3 min or less, 4 to 6 min, 7 to 10 min, and the reference group of frequencies greater than 10 min. This choice was based on past findings that only 'high' frequency service, a classification defined in the literature by ten minute or better headways, has a significant effect on surrounding property values (Gallo, 2018).

The number of destination points one can reach when travelling by transit affects the level of desirability and usefulness of that service (Guerra and Cervero, 2011). Similarly, the ease with which you access transit services affects their value. In an attempt to capture this, the moderator of number of same-mode stations within a system was included in the analysis. While not all stations provide access to the same density of destination points of interest, it is reasonable to assume that the larger the number of stations the generally more expansive the reach of a potential trip, the greater the trip flexibility, the more plentiful the transfer options, and the less obstructive a service change or interruption (due to greater rerouting optionality). This value – a network effect (Mulley et al., 2017) – is proxied by the variable defined as 'available connections'; each station representing a point at which to connect with the network. Only same-mode stations were included because different modes tend to be priced differently, and because intermodal transfers are internalized differently – specifically, much less favorably – than intramodal ones (Liu et al., 1997).

The cost of transit service likely influences its attractiveness. In this analysis, cost takes the form of 'expenditure share': annual transit costs as a percent of mean annual income within the city featured in each case study during the first year of housing data used. Annual transit costs were calculated by using the full price one-way fare of each service studied during the first year of housing data used. That fare was assumed to be expended twice a day per weekday. While this determination of annual transit costs most closely embodies a middle-income, white, male, traveler strictly using transit for their work commuter – see (Mauch and Taylor, 1997; Handy and Tal, 2005; Chakrabarti and Joh, 2019) for research on how gender and income, race, and parenthood influence transit travel behavior, respectively – because this moderator serves as a representative proportion and is calculated the same way across all case study inputs it is not distorted by this single traveler profile embodiment. It is anticipated that expenditure share will have a depreciating effect on premiums. This is influenced by the following hypothesis: the higher the expenditure share on transit the presumably more attractive its mode competitors (e.g. bike, walk, drive, rideshare), and the less enticing the use of transit the less valuable is living proximately to a station.

Congestion further speaks to the cross-modal competitive value of transit access. Heavy roadway congestion decreases travel speeds and increases trip times for road-using travel modes, namely cars. Therefore, congestion increases the appeal of modes that are

Table 2
Definitions of moderators used in this meta-analysis (Total N = 66).

Moderator	Definition	N
Neighborhood Factors		
Income°	1 if income controls included, 0 if not	24
Race, ethnicity, citizenship°	1 if race, ethnicity, or citizenship controls included, 0 if not	11
Access to other transport	1 if study controlled for access to non-transit mobility infrastructure (e.g. highway on-ramps), 0 if not	38
Neighborhood amenities	1 if neighborhood amenity controls included, 0 if not	41
CBD	1 if study analyzed stations in the CBD, 0 if not	43
Model Parameters		
Transaction property data‡	1 if used transaction prices used, 0 otherwise	54
	Reference: data from assessor's pricing inventory	12
Network catchment°	1 if street network distance measurement used, 0 otherwise	18
	Reference: straight-line distance measurement used	48
Single-family	1 if only single-family properties analyzed, 0 otherwise	15
Multi-family	1 if only multi-family properties analyzed, 0 otherwise	9
	Reference: mixed housing style dataset	42
Analysis Methods		
Semi-log model	1 if semi-log model used, 0 otherwise	33
Double-log model	1 of double-log model used, 0 otherwise	8
	Reference: linear model used	25
Difference-in-differences	1 if difference-in-differences model used, 0 if not	10
Rail Modes		
Heavy rail (metro)	1 if heavy rail service analyzed, 0 otherwise	36
Commuter rail	1 if commuter rail service analyzed, 0 otherwise	8
	Reference: light rail service	22
Temporal Factors		
2010-2020‡	1 if property data is from 2010 or later, 0 otherwise	24
	Reference: property data from before 2010	42
Geographical Factors		
Europe	1 if study is of Europe, 0 otherwise	13
Asia: excluding East Asia	1 if study is of Asia: excluding East Asia, 0 otherwise	8
East Asia	1 if study is of East Asia, 0 otherwise	14
Oceania‡	1 if study is of Oceania, 0 otherwise	2
	Reference: study is of North America	29
Settlement Factors		
Population density°	1000 people per square mile in study city during first year of property data used	–
Rent control‡	1 if city studied hosted any rent control policies that limited either the rate or extent to which rents could increase during timeframe of property data used, 0 if not	17
Transit Service		
Expenditure share‡	Annual transit costs (assume 2 trips per weekday) as share (percent) of average annual income during first year of property data used in city studied	–
Age of service°	# of years between start of service studied and first year of property data used	–
Available connections‡	# of same-mode stations within the system studied during first year of property data used	–
Urban core driving speed‡	Average peak period driving speed in urban core of city studied during first year of property data used measured in miles per hour	–
Frequency: under 5 mins‡	1 if service studied offered peak-period frequency of under 5 mins, 0 if not	29
Frequency: 5 to 10 mins‡	1 if service studied offered peak-period frequency of between 5 and 10 mins, 0 if not	23
	Reference: service studied only offers peak-period frequency greater than 10 mins	14

‡ These variables have not been used in previous rail access meta-analyses.
° These variables have been used in previous rail access meta-analyses, however, not to the level of detail that is featured here.

not subject to roadway conditions. This includes nearly all rail transit, though some tramlines run in mixed roadway traffic. To capture this relationship, average driving speeds during peak travel times of day within a city's urban core – a representation of congestion levels – were included in the model. This information was sourced from a combination of TomTom Traffic Index data, INRIX traffic data, World Bank data, and direct data requests from municipal planning and transportation departments. It is anticipated that this moderator and rail access premiums interact inversely.

The competitive advantage offered by bicycle travel was not included as a moderator for two reasons. The first is the difficulty that comes with sourcing a metric that represents the quality of bike infrastructure across a span of four decades. The second is that biking and transit use are, generally, though there are exceptions, complementary modes, not full substitutes. That is to say, cyclists also tend to be transit users. (Singleton and Clifton, 2014). As a result, though quality cycling infrastructure may increase the attractiveness of the bike mode for a given traveler, it does not necessarily diminish the value that that same traveler extracts from living close to transit.

The final new moderator under the umbrella of 'level of transit service' featured in this model is service age. This variable is defined as the number of years between the operational start of the service in question and the first year of housing data used by each respective case study. This moderator serves as a proxy for reliability. While most consistently true within the US context, older systems tend to fall victim to reliability issues more frequently than younger systems and suffer slower repair speeds. In the absence of access to on-time performance data or rolling stock information for all systems within the input cohort during the timeframe in which they were studied, age of service was deemed a suitable, if not ideal, proxy for service reliability. Under the belief that poor reliability lessens the value of transit access, this moderator is anticipated to have a depreciating effect on premiums.

Though not a new moderator, it is worth making clear that the temporal factor of housing data sourced 2010 or later, compared to the reference case of pre-2010, was used to account for the potential impacts on the property market attributed to the Global Financial Crisis of the late 2000s; specifically spanning 2007 to 2009. This temporal factor, selected for the universal nature of its felt impact, was also used by Zhang and Yen (2020) in their examination of bus-specific access premiums.

3.3. Regression model

The interaction between these moderators and the rail access premiums found in the case study input dataset was examined using a random-effects meta-analytic model. A random-effects treatment was deemed best suited given that most of the input studies report just one premium estimate each, vary substantially in their model design, and that these inputs represent a sample – as opposed to the entirety – of the premiums literature (Hunter and Schmidt, 2000; Borenstein et al., 2010; Cheung, 2014). Within this random-effect model, effect sizes were weighted by the inverse of the square of the standard errors of each case study in accordance with recommendations by Stanley and Doucouliagos (2015) and as done by both Debrezion et al. (2007) and Mohammad et al., (2013) in their rail access premium meta-analyses. The resultant regression model is shown by Equation (1).

$$P_i = \alpha_0 + \boldsymbol{N}_i'\boldsymbol{b}_1 + \boldsymbol{M}_i'\boldsymbol{b}_2 + \boldsymbol{A}_i'\boldsymbol{b}_3 + \boldsymbol{R}_i'\boldsymbol{b}_4 + D_i b_5 + \boldsymbol{G}_{ij}'\boldsymbol{b}_6 + \boldsymbol{S}_{ij}'\boldsymbol{b}_7 + \boldsymbol{T}_{ij}'\boldsymbol{b}_8 + \varepsilon_i \quad (1)$$

where:

P_i = effect size (percent) of the impact of railway station proximity on property values experienced 500 m from a station compared to 1.6 km or more in study *i*.

α_0 = constant term.

N_i = meta-regressor of neighborhood factors in study *i*.

M_i = meta-regressor of model parameters factors in study *i*.

A_i = meta-regressor of analysis method factors in study *i*.

R_i = meta-regressor of rail mode in study *i*.

D_i = meta-regressor of temporal factors in study *i*.

G_{ij} = meta-regressor of geographical factors of city *j* in study *i*.

S_{ij} = meta-regressor of settlement factors in city *j* hosting study *i*.

T_{ij} = meta-regressor of transit service factors in city *j* hosting study *i*.

ε_i = model disturbance term.

Bold terms denote vectors of variables and parameters.

4. Results and discussion

The results of modelling the effect of rail access on property values for properties located at 500 m from a station compared to those located 1.6 km or more from a station are shown in Table 3. The coefficients rendered within this table represent modifications upon the reference case. The reference case is the following: a light rail system in a non-rent-controlled North American city whose premium pertains to assessor's housing data priced before 2010, does not account for neighborhood factors (demography, access, amenities, or CBD closeness), was measured using straight-line distance, was not modelled using a DID method, and features peak period frequency of 1 train or fewer every 10 min. On average, the value of a residential property subject to these reference conditions situated 500 m from a station is 18.8% higher than an otherwise comparable property situated 1.6 km from a station.

4.1. Previously examined moderators

Inclusion of station area neighborhood composition with respect to race, ethnicity, or citizenship has a significant negative impact on rail access premiums. Studies that account for any of these three demographic factors demonstrate, on average, premiums 6.0 percentage points lower than those that do not. The only other meta-analysis to test the moderating power of any of these factors – Debrezion et al. (2007) include race as a moderator – similarly found it to be significant and to have a depreciating effect on access premiums.

Studies that included these factors most likely did so because of a known racial, ethnic, or xenophobic tension in the area of interest.

Table 3
Effect of rail access on property values located 500 m from a station compared to those 1.6 km or more from a station.

Factor Type	Moderator	Coefficient	t-stat
	Constant	0.1878*	(2.46)
Neighborhood Factors			
	Income	0.0001	(0.01)
	Race, ethnicity, citizenship	−0.0598*	(−2.06)
	Access to other transport	0.0111	(0.59)
	Neighborhood amenities	0.0236	(1.07)
	CBD	−0.0252	(−0.88)
Model Parameters			
	Transaction property data	−0.0521*	(−2.00)
	Network catchment	−0.0031	(−0.15)
	Single-family	0.0310	(1.01)
	Multi-family	0.0453	(1.52)
Analysis Methods			
	Semi-log model	0.0183	(0.79)
	Double-log model	0.0345	(0.94)
	Difference-in-differences	−0.0401	(−1.88)
Transit Modes			
	Heavy rail	0.0402*	(1.97)
	Commuter rail	0.0958*	(2.17)
Temporal Factors			
	Property Data from 2010 to 2020	−0.0495	(−1.73)
Geographical Factors			
	Europe	−0.0269	(−0.76)
	Asia: excluding East Asia	−0.0137	(−0.34)
	East Asia	−0.0742*	(−2.18)
	Oceania	−0.0857	(−1.55)
Settlement Factors			
	Population density	0.0014	(1.50)
	Rent control	−0.0527*	(−2.15)
Transit Service			
	Expenditure share	−1.431*	(−2.61)
	Age of service	−0.0003	(−0.71)
	Available connections	0.00021*	(1.99)
	Urban core average driving speed	0.0008	(0.35)
	Frequency: every 4 mins or less	−0.0516	(−1.23)
	Frequency: every 5 to 10 mins	−0.0234	(−0.66)
	Observations	66	
	R-squared (between-study variance explained)	0.31	

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

This tension could be influencing premiums in two ways. On the one hand, transit in these areas may be hyper-stigmatized as being a service specifically for marginalized minority groups, and, as a result of this stigma, other groups may devalue the service and access to it. On the other hand, racist or xenophobic preferences regarding the choice of one's neighbors may be depreciating the housing market in areas with a larger share of minority residents irrespective of a positive valuation of transit service by property buyers. The body of literature that explores this interaction between housing markets and ethno-racial prejudice is extensive, widely international, and hosts findings that frequently support this claim. For examples, see Taylor (2019) for North American context, Flage (2018) for European context, Seekings (2008) for Sub-Saharan African context, Munir et al. (2021) for South Asian context, and dos Santos Oliveira (1996) for Latin American context.

Interestingly, while earlier meta-analyses found a significant effect of access to non-transit roadway infrastructure on premiums, no significant impact of that moderator is found here. It is possible that the inclusion of the congestion-related moderator 'urban core average driving speed' present in this model and absent from all others dilutes the potential effects of this factor. That is to say, while proximate access to a highway may be valuable to a driver, that value decreases sizably if that driver faces consistently heavy traffic.

Access to commuter rail is associated with higher premiums than access to light rail systems; 9.6 percentage points higher on average. Similarly, heavy rail systems also render higher access premiums than light rail systems; an average of 4.0 percentage points higher. This aligns with the findings of past meta-analyses. One possible explanation for this is that light rail services may be viewed as comparatively less permanent. Given that many light rail tracks across the world have been dug up or paved over and replaced by roadways, this is a reasonable perception. Another, as previously mentioned, may be that some light rail services operate in mixed traffic. In doing so, they lose some of their mode-competitive advantage which could depreciate their access value. A third explanation may lie in the nature of light rail service. Light rail systems generally provide more of a local service than either heavy or commuter rail, stopping more frequently and running at slower speeds. Finally, whether based in reality or not, commuter rail may be being associated with higher quality features – more comfortable seating options, cleaner cars and stations, less on-board crowding due to larger vehicles and lower rider-to-car ratios. Such an association could result in its appreciated access premiums.

Geographical comparison of effect sizes reveals that all regions from which premium data was collected – Europe, Asia, and

Oceania – are associated with lower premiums than those hosted by North America. Though each geographical moderator is negative, only the influence of East Asia proves significant. Rail access premiums in East Asia are, on average, 7.4 percentage points lower than those in North America. This may, at least in part, be attributed to the drastically varied travel behavior exhibited across the two regions. Whether due to preference or urban form – almost assuredly both – the combined mode share of walking and biking across much of East Asia dwarfs that of even the most pedestrian-centric North American cities. Compare, for example, the 2020 combined walk-bike commute share of 11% in New York City to that of 40% in Shanghai. Living proximately to transit may be less valuable if one's trip needs are well served by foot travel.

It is worth highlighting that several moderators found not to have a significant effect on the impact that access to rail stations has on property values in this work were similarly deemed insignificant in past meta-analyses. Here, being located within a city's central business district does not significantly impact premiums. The same was found by Mohammad et al. (2013). Single and multi-family housing distinctions were found to be insignificant by Debrezion et al., (2007), as is the case here. Finally, Park et al. (2016) tested how using street network measurement techniques as opposed to straight-line measurements might influence premiums. In neither their study nor in this one was a significant effect revealed.

4.2. Newly introduced moderators

Focusing on the moderators newly introduced within this study, the following results were found. The type of price data used – transaction sale price versus assessor's listed sale price – impacts premium effect size. Specifically, premiums measured using prices of actual transactions are 5.2 percentage points lower, on average, than those measured using assessor's data. This effect on premium size aligns with the anticipated impact of this moderator as assessor prices – a value generated in the absence of buyer/seller negotiations – generally reflect an upper bound estimate of a property's value to prospective buyers outside of a handful of high demand, highly competitive housing markets (Cypher and Hansz, 2003).

On average, studies of station access value situated in cities and time periods where rent control policies exist host premiums of an average of 5.3 percentage points lower than those that do not. The directionality of this impact aligns with expectations. In these areas, while living 500 m from a rail station may indeed be a valued access amenity, the extent to which that value can be absorbed by the housing market and financially profited from may be bounded.

Expenditure share, the portion of an average annual income spent on transit within a given city, also has a significant and negative impact on access premium size. Every 1 percentage point increase in annual expenditure share of transit is associated with a 1.4 percentage point decrease in access premium. Phrased differently, the more expensive a transit service relative to income, the less valuable living within walking distance of a station becomes. Part of this relationship may be that in cases where transit is more costly, the competitive advantages of other modes – namely walking, cycling, and ridesharing – increases substantially and may even outweigh those of transit.

The only other transit service element that has a significant impact on access premiums is the number of available connection points within the transit network. For every 10 additional stations, premiums are, on average, 0.21 percentage points higher. It is important to understand that this particular impact on premiums occurs on a systemwide scale. The addition of 10 stations anywhere within a transit systems network has a 0.21 percentage point uplift on station-proximate properties across the entire network; even those far away from the new station sites. That is not to say that access to all stations is uniformly useful or important; indeed some stations – for example those serving multiple lines – may be of greater access value than others. This finding represents an average across a system.

The age of transit service does not render statistically significant impact on access premiums. This may be the result of this moderator encapsulating dual, competing effects: reliability effects and maturity effects (Zhang and Yen, 2020; Trojanek and Gluszak, 2018; Arnold et al., 2017). The reliability logic here, as previously discussed, is that older systems may be more susceptible to delays brought on by malfunction or general lacking maintenance. The maturity logic, conversely, suggests that older systems may more positively have their value absorbed by the property market as their service quality has been tried and tested and their ability to contribute to value retention of properties surrounding them through times of general market crisis proven. Disentanglement of these effects, allowing for the measurement of their influence individually, is needed to best paint a full picture of transit service elements' impacts on access premiums.

Surprisingly, none of the moderators relating to service frequency demonstrate a significant impact on access premiums. This could be because only the effect of best peak-period frequency available was tested. Perhaps all-day average frequency is what property owners internalize the value of instead. Additionally, the cut off point for what is considered high and low frequency utilized here is 10 min. While this choice was informed by past findings of significant value and behavioral difference at this threshold, it is possible that a difference in value of access to transit service sizable enough to affect property prices fluctuates at a lower frequency point; perhaps somewhere between 10 and 15 min. Furthermore, though none of the varied levels of high frequency service render a significant impact on premium values, there is something valuable to be gained from this result. It suggests that planners can aim to provide the best frequency possible without fear that doing so will contribute to premium-driven displacement. This is empowering information to the transit planning practitioner who may not have much say in zoning regulations or housing policies, but cares about the equity implications of their work.

4.3. Interpretation

Through a set of test cases, one may best gain a practical sense of how these results can be useful – for example, to a homeowner living in an area slated for a new rail station wanting to estimate the value uplift they can expect, or a researcher tasked with explaining variation in premium size across studies. While interpreting the forthcoming test cases, keep in mind that 500 m from a rail station, the site where this work calculates transit access premiums, reflects the distance at which premiums are their highest; the value uplift peak.

As stated at the opening of this section, the reference case for this analysis is a light rail system in a non-rent-controlled North American city whose premium pertains to assessor's housing data. On average, the value of a residential property subject to these conditions situated 500 m from a station is 18.8% higher than an otherwise comparable property situated 1.6 km or further from a station.

If instead these conditions were applied to a heavy rail system (+4.0 percentage points) with 145 stations (+0.21 percentage points per 10 stations) whose fare corresponded with an average annual transit expenditure share of 6.7% (−1.4 percentage points per one percent share), and which was situated in an environment hosting pronounced racial tensions (−6.0 percentage points), this meta-analysis suggests that an access premium of 10.4% could be expected. These augmentations to the reference case reflect Chicago in the year 1999 and apply to the case study analysis of the city conducted by McMillen and McDonald (2004). This case study analyzed housing data from 1997 to 1999 and found an access premium of 9.8% at 500 m from a station compared to at 1.6 km or further from a station.

Using this meta-analysis model, the case of light rail in Beijing in 2009 based on transaction data would render an average access premium of 5.5%. This case would be comprised of the following parts in comparison to the reference case: East Asian geographical context (−7.4 pp), 187 stations (+0.21 pp per 10 stations), a transit expenditure share of 3.3% (−1.4 pp per 1% share), and the use of transaction data (−5.2 pp). The team of Zhang et al. (2014) ran an analysis of this case under these conditions using housing data from 2006 to 2009. They too calculated an average access premium of 5.5% at 500 m from a station compared to at 1.6 km and beyond.

A test case of commuter rail in Europe rounds out this demonstration of applicability. A look at Lisbon in 2007 calls for the following changes to the model's reference scenario: commuter rail (+9.6 pp), transaction data (−5.2 pp), 168 stations (+0.21 pp per 10 stations), 8.1% annual transit expenditure share (−1.4 pp per 1% share), and the presence of rent control policies (−5.3 pp). For this case, the model returns an estimated 10.1% access premium. Martinez and Viegas (2009) found an access premium of 10.7% at 500 m from a station – compared to 1.6 km and beyond – in their analysis of Lisbon's commuter rail-proximate properties in 2007.

In this way, findings from this study can be tailored to one's specific context of interest and inform access premium estimates.

5. Conclusion

Utilizing a random-effects meta-analytic methodology, this work examines the impact that being located 500 m, compared to 1.6 km or more, from a rail station – termed a 'rail access premium' – has on residential property sale prices. This model finds that elements of demography, data type, place, and planning all impact rail access premium magnitudes. The following significant relationships are revealed. Premiums based on the inclusion of neighborhood racial, ethnic, or citizenship composition are lower than those that exclude area demographic information by 6.0 percentage points on average. Transaction informed premiums are generally 5.2 percentage points lower than those based on assessed sale prices. Premiums in East Asia are an average of 7.4 percentage points lower than those in North America. Cities hosting any form of rent control policy generally feature premiums 5.3 percentage points lower than those that do not. On average, commuter rail premiums and heavy rail premiums are 9.6 and 4.0 percentage points higher than light rail premiums, respectively. Finally, with every one percentage point increase in annual expenditure share on transit, premiums decrease an average of 1.4 percentage points, and for every 10 additional stations within a network, premiums are 0.21 percentage points higher.

The finding that ethno-racial context influences property prices is not surprising, as it has been explored and confirmed time and time again in a wide geographical range of urban settings. What is interesting is that that relationship holds true even when the amenity of transit access is introduced into the equation. This finding speaks to the need for a closer look at the intersection or race, transit, and wealth accumulation via property ownership. While the findings rendered here make clear that *accounting for race* matters in the transit-access/property-market puzzle, a greater understanding of exactly to what extent specific station-area *racial composition* is causal of property devaluation may allow policy makers to determine a precise percentage to which homes within minority-dominant, transit-proximate areas are being under-appraised. Such knowledge could form the base of a set of concrete, Reparative actions.

In addition to allowing for direct comparison of markets across geographical regions, the revelation that place directly impacts access premiums is of value in that it too highlights areas in which further research would be a powerful contribution to the field. While this piece was not able to feature any premiums gathered from South America or Africa, these regions have introduced several new rail systems since 2010, and as these systems age, their value uplift may solidify and become more readily measurable. A greater representation of the Global South within the case study literature would make for a more comprehensive meta-analysis and could provide increasingly fine-grained information on how transportation infrastructure and housing costs interact subject to varied contexts.

The finding that cities hosting rent control policies experience lower premiums of 5.3 percentage points is useful beyond explaining variation in premiums found across the case study literature. Drilled down to its core, it suggests that if your objective is to limit the risk of low-income communities or existing residents being priced out of their transit-proximate homes, the introduction of rent control policies not only directly at the site of interest – perhaps in the form of a Station Area Overlay District – but also at a more general city-wide scale should indeed perform favorably even if that protective policy does not apply directly to the focal site. In this sense, rent control for some increases staying power for all.

The choices that transit planners make – some implementable in the short-term, others more distant – necessarily impact housing costs. This work's significant findings associated with rail type, service cost, and network expanse suggest that transit planners should not be sidelined in matters pertaining to housing pricing. Rather, those in the field of housing and field of transit should collaborate in their efforts, be they focused on infrastructure financing or supporting equitable housing landscapes.

Circling back to matters of related further research, recent analysis conducted by the team of Zhou et al., (2022) has found that in areas relatively distant from rail stations (~1.2 km) where bike sharing serves as a complement to transit services, a positive bike-induced housing price premium is observed. This overlap in area of influence suggests that future studies of transportation network-impacted housing price premiums should consider looking at mobility systems more comprehensively, assessing them in their multi-modal rather than single mode forms. In doing so, the 1.6 km cut-off used within this meta-analysis to reflect the point at which properties no longer experience direct transit premium impact may need to be reconsidered; likely expanded.

Finally, with the rising global popularity of Bus Rapid Transit, increased research attention to how this mode influences property values could be of great use to practitioners presently planning for entirely new systems and services soon to be implemented, and therefore, well-timed for premium-impacting decisions. Case study research of BRT access premiums is currently being championed by Corinne Mulley and her collaborators at the University of Sydney. The only known meta-analysis dedicated specifically to BRT access premiums has been conducted by Zhang and Yen (2020). With 181 cities worldwide now hosting BRT service – 42% of which began operation in the last decade alone – and 210 km of dedicated BRT right-of-way being added annually to the global total (Global-BRTdata, 2021), continued work in this realm could be hugely influential over the world's station-area property values of the next ten years, and likely well beyond.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tra.2022.06.013.

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