THE JOURNAL OF TRANSPORT AND LAND USE jtlu.org
VOL. 16 No. 1 [2023] pp. 469–496

Access-based land value appreciation for assessing project benefits

Yadi Wang
University of Sydney and Stantec
yadi.wang@stantec.com

David Levinson
University of Sydney
david.levinson@sydney.edu.au

Abstract: The traditional mobility-oriented travel-time saving benefit assessment method has been repeatedly questioned for numerous intrinsic flaws, motivating the search for alternative benefit assessment approaches. Although a wealth of literature confirms the capitalization effect of access benefits induced by transport improvements to land or real estate value, the access-based land value uplift method hasn't yet been widely recognized and employed as an official tool assisting transport decision-making. The present paper collects 136 empirical studies and aims to disentangle the obstacles hindering the promotion of the access-based assessment method by systematically reviewing methodological design, the access metrics used, and the target real estate sub-markets or land use types upon which access benefits are quantified. First, it was found that almost half of the sampled studies just investigated the general effects of transport operation on real estate prices without incorporating sufficient temporal and locational considerations, thereby failing to isolate project-specific incremental impacts. Second, while the hedonic pricing model remains the most popular model, a trend towards embracing more advanced modelling techniques such as spatial lag, spatial error, and Difference-in-Differences (DID) models to control for bias caused by spatial dependence has been observed. Third, Euclidean distance and distance buffer rings are the most widely used operational measures of access. Primal access measures covering the number of opportunities available at a destination and travel impedance are recommended. Last, over 86% of sampled empirical studies target the residential real estate market. The lack of non-residential land uses in the literature presents a significant research gap that should be addressed.

Keywords: Land use, land value capture, project evaluation, accessibility

Article history:
Received: November 4, 2022
Received in revised form: May 2, 2023
Accepted: May 21, 2023
Available online: December 28, 2023

1 Introduction

Transport improvements go far beyond allowing people and vehicles to travel faster. The current practice of planning for, and evaluating, transport places overwhelming weight on the movement function of transport infrastructure, resulting in wide application of the mobility-oriented transport project evaluation framework, and travel time savings are generally deemed to be the primary performance metric of mobility benefits. A substantial number of

https://dx.doi.org/10.5198/jtlu.2023.2297
ISSN: 1938-7849

The *Journal of Transport and Land Use* is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies.

ex post project evaluations have empirically demonstrated the weakness of travel-time based user benefit assessment, with the main critiques centering on:

- inability to screen out the best option (Lee Jr, 2000, Mackie and Preston, 1998),
- inaccuracy in result (Flyvbjerg et al., 2004, Odeck, 2004, Pickrell, 1989),
- incompleteness in scope (Laird et al., 2005),
- incredibility in pricing the priceless (Ackerman and Heinzerling, 2002), and
- incompetence in generating funding and sustaining the investment cycle.

Instead of saving time, the mission of transport is to connect people with all the resources and opportunities they value, where access metrics measuring the ease of reaching those options should have been considered and incorporated in transport planning and evaluation (Committee of the Transport Access Manual, 2020). The Fundamental Model of Access (as shown by figure 1) (Committee of the Transport Access Manual, 2020) presents a theoretical model of the positive feedback loop among transport systems, access, land use and travel demand activity systems, and financial systems. Transport improvements (like increasing network speed and reducing travel distance) are anticipated to reduce generalized costs of journeys for land, which increases access. The more accessible the land, the more activities will want to occur there, thereby increasing density in the long term as business activities concentrate and denser housing is constructed. More activity creates better opportunities to maximize profitability by exploiting economies of agglomeration. In this case, the access benefits triggered by locational advantages are capitalized into real estate value. Alonso (1964), Mills (1967), and Muth (1969) develop bid-rent theory, an urban economic model where people and companies compete with one another and are willing to pay a premium for land with better access.

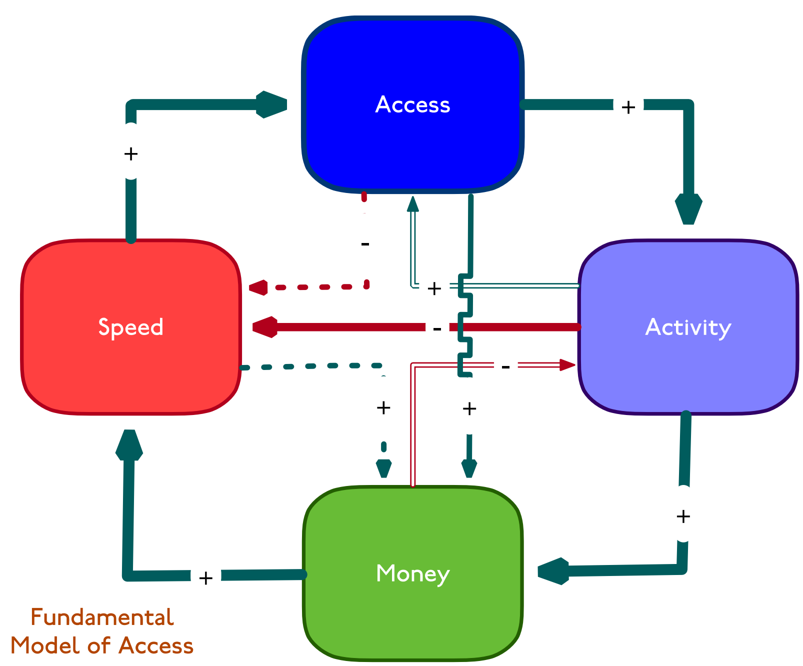


Figure 1. Fundamental Model of Access
Source: Committee of the Transport Access Manual (2020).

We note the policy significance of that, as it is important not only for assessing benefits more accurately, but that the transport provider can capture some of the land value gains accruing to individuals or businesses to fund or finance transport improvements (Zhao et al., 2012), closing the feedback loop between benefits and project implementation.

The traditional travel-time-based benefit valuation method engages changes in travel time as the key measure of project impacts, which are anticipated to be observed and estimated from project construction and through the life of project operation. The prescribed value of time parameters monetizes changes in travel time, where all benefit streams associated with changes in travel time are discounted back to the base year. The key considerations in this benefit valuation system include measurements of project impacts, analysis period (time frame or project stage), the unit dollar value for benefit monetization, benefit streams, as well as capitalization and discount rates.

There is a wealth of literature demonstrating the capitalization effect of access benefits induced by transport improvements to property value, some of which are reviewed in this paper. Although the positive correlation between property price and proximity to transport infrastructure has been found, the access-based land or real estate value uplift method has yet to be widely recognized and employed as an official tool assisting transport evaluation and decision-making. The empirical research design and economic parameters to allow these findings to be directly applied to project evaluation remain insufficient. The present paper discusses the practical practice and gaps in the access-based land value uplift method based on empirical studies and evidence.

The remainder of the paper is framed as follows: section 2 reviews the current practice of transport project benefit assessment; sections 3 and 4 introduce the data and analytical methods adopted; section 5 reports key observations about the practice and gaps based on the literature reviewed; section 6 highlights the concluding remarks and directions for future research.

2 The current practice of transport project benefit assessment

Under the current practice of transport project benefits evaluation, travel time-based user benefits form the bulk of the direct economic benefits of transport projects (Marleau Donais et al., 2019). Nevertheless, this conventional approach has been questioned for numerous intrinsic flaws.

First, in accordance with numerous retrospective transport project evaluations, the *ex ante* estimations on project costs and benefits based on this approach have been repeatedly reported to be highly inaccurate (Andrić et al., 2019, Cantarelli et al., 2012, Cruz and Sarmento, 2019, Flyvbjerg et al., 2004, 2005, Hartgen, 2013, Hoque et al., 2021, Huo et al., 2018, Lee, 2008, Li and Hensher, 2010a, Love et al., 2016, Lundberg et al., 2011, Nicolaisen and Driscoll, 2014, Odeck, 2004, Park and Papadopoulou, 2012, Parthasarathi and Levinson, 2010, Pickrell, 1989, Sebastian, 2005, Voulgaris, 2019a,b, Welde and Odeck, 2011, Wang and Levinson, 2023a). The estimates and verification of project costs are more straightforward and comparable among multiple projects than those of economic benefits. Inaccurate benefit estimates are largely driven by an inaccurate prediction of travel demand, that is traffic flow for road projects and ridership for transit projects. Demand forecasts lay the foundation upon which the traditional evaluation of many types of economic benefits rely. While projecting demand is a complicated mechanism encompassing the aggregate behavior of travelers and commuters (Ceder, 2007), it is even harder to deliver accurate demand forecasts for transit projects than for road projects (Bain and Polakovic, 2005, Cruz and Sarmento, 2019, Flyvbjerg, 2007, Flyvbjerg et al., 2003, 2005, Mackinder and Evans, 1981, Pickrell, 1989, Voulgaris, 2019a).

Second, monetizing economic benefits using non-market valuations (shadow price) potentially weakens the credibility of the estimation results (Ackerman and Heinzerling, 2002). For example, travel time savings account for most of the economic benefits of road projects. Travel time is an intangible resource, which is neither directly tradable nor directly priced by the market (some toll roads or express transport services excepted). Although various methods like considering both stated and revealed preference of value of time have been used to justify the reasonableness of shadow price, pricing unpriced resources repeatedly raises concerns.

Thirdly, both project expenses and advantages are determined using an incremental method, which essentially takes into account the additional costs or benefits relative to the baseline 'no-build' scenario (Florio and Vignetti, 2013, Kelly et al., 2015). Consequently, the precision of both *ex ante* and *ex post* assessments hinges on the consistency and suitability of the chosen counterfactual 'no-build' situation. Notably, in *ex post* evaluations, the continued appropriateness of the counterfactual baseline scenario is limited by the unpredictability of the project's impact on the external environment and its response to these changes. Moreover, the development of the baseline scenario depends on numerous assumptions. Monitoring the validity of these assumptions and timely adjustments by incorporating new insights gathered during the project's lifespan can enhance the resilience of the baseline scenario, though this can be challenging.

Retrospective *ex post* evaluations, as one of the primary approaches to monitoring, generally begin years after project opening accounting for both data collection issues and ramp-up effects (Flyvbjerg, 2003, Li and Hensher, 2010b), imposing time lags on drawing lessons learned and feeding back to new projects. In addition, to ensure the comparability between *ex ante* and *ex post* analysis, they should apply consistent evaluation methods and standards under similar assumptions, which discount the effectiveness and quality of the *ex post* verification.

Fourth, determining a feasible 'do-something' project option based on the traditional method has potentially undermined project success from the early planning stage (Lee Jr, 2000, Mackie and Preston, 1998). As one of the earliest key milestones, various candidate project alternatives are analyzed and compared to screen out the ultimate locally preferred alternative. Project alternatives with the same transport mode are differentiated from each other mainly in route alignment (Wang and Levinson, 2023b). Altering route alignment seems to have subtle impacts on serving capacity, resulting in little difference in usage forecasts. But its impacts on the value of real estate in the vicinity of key transport nodes can be substantial. However, the current evaluation methods fail to capture the direct land value uplift, negating the potential benefit-generating capacity of candidate alternatives and resulting in unequal or unfair comparisons among them.

Fifth, though the primary contribution of transport infrastructure in various modes may be improving access and equity (Geurs et al., 2016), they differ in mode, scale, and the types of benefits generated. Uniformly applying the same benefit assessment approach might miss mode-specific advantages, failing to adequately exploit potential economic benefits that a transport project would generate. For example, compared to the residential and commercial properties in remote suburbs, those at the urban core are more expensive and more sensitive to changes in the transit network, enabling a valuation method based on house price appreciation. However, house price uplift is not one of the critical benefits being independently and directly examined in the traditional travel time savings (TTS) assessment approach and considering both would risk double-counting the benefit.

Sixth, in contrast with housing purchase decisions, travel decisions are provisional, changing frequently and dynamically, requiring fictitious assumptions on factors and events influential in travel behaviors. Real estate purchasing decisions are less frequent and thus more appropriate for evaluating long-term infrastructure investments, which encompass factors directly and indirectly affecting travel behaviors and naturally reflect the weights of each factor based on subjective preferences from individual perceptions. As a result, evaluating transport project benefits based on real estate valuation changes might reduce noise and uncertainty in valuation.

Seventh, network effects arise and can be recognized when the presence of an additional transport service or facility positively impacts the existing network as a whole (Liu et al., 2022, Page and Lopatka, 1999). Although network effects as a result of improved integration and coverage are always claimed to be important in terms of the ability to offer access benefits (Curtis and Scheurer, 2016), they are imprecisely assessed and implicitly included in the current project appraisal method (Laird et al., 2005). Liu et al. (2022) point out that housing markets are sensitive to public transport network effects, showing higher price increments when positive network externalities take place.

Apart from the aforementioned concerns about the technical aspects of the current time savings-based benefit evaluation method, this method is also challenged in its ability to serve the creation of a seamless and sustainable rotation of capital when many large cities across the globe are confronted with financial stalemate in constructing and operating public transport infrastructure. Travel time savings are essentially gains in users' utility which are monetized through welfare analysis by capturing consumers' surplus informed either by users' stated preference (willingness-to-pay) or wage (Jara-Diaz, 1990). The demonstrated economic benefits cannot be directly collected and fed into future projects. The conventional funding sources covering the up-front capital expenditures of transport projects originate from taxation revenues. Considering the absence of a strong linkage between general tax revenues and allocation as well as the fierce competition for public coffers, transport projects cannot secure funding sources when acute issues in other public services like public health and education arise (Ubbels et al., 2001). Special-purpose taxation revenues (such as fuel duty or congestion charges in the US) are partially or entirely earmarked for public transport. The sustainability of the earmarked funding mechanism has been weakened due to the deployment of vehicle electrification and strong public protest against tax rises (Istrate and Levinson, 2011, Zhao et al., 2012). Farrell (1999) mentioned that particular attention has been drawn to the distribution of earmarked grants. The steep growth of the total costs required by the transport sector is incommensurate with the operational revenues generated by user charges so that almost all transport systems across the world are subsidized (Black, 1995). Since maintaining transit services aligns with government objectives (such as congestion reduction and providing transport for low-income people) and serves the public, government subsidies have been continuously offered to cover operating deficits (Black, 1995).

The existing fiscal pressure on investing in the transport sector necessitates the search for alternative financing mechanisms, and among all feasible approaches land value capture (LVC) has been gradually popularized (Zhao and Levinson, 2012). The rationale behind LVC lies in that the land value uplift triggered by access gains as a result of transport improvements shall be seized and redistributed to support future projects (Batt, 2001, Mathur, 2014, Medda, 2012). Property owners who enjoy unearned income as a result of possessing premises in the vicinity of new transit facilities can relinquish windfall fortune without showing a loss (Smith and Gihring, 2006).

Engaging understandable and consistent access metrics is the cornerstone to gear the LVC method from the early planning stage, and thereby introducing and promoting an access-based land value benefit assessment method are in demand. This method is rooted in the consensus that the primary motivation of transport development is facilitating access to desired places instead of shortening travel time, which can be found in studies by Levinson and Wu (2020) and Levine et al. (2019) and was empirically tested by Sun et al. (2016) in Tianjin, Wen et al. (2018) in Hangzhou, Lin and Hwang (2004) in Taipei, Hiironen et al. (2015) in Helsinki, Dewees (1976) in Toronto, Agostini and Palmucci (2008) in Santiago, Hess and Almeida (2007) in Buffalo, Du and Mulley (2012) in Newcastle, and Dubé et al. (2013) in Montreal, and Wang and Levinson (2022) in New York, among others. The value of access derives from its ability to connect places and people, which depends on the location of people and the directness, speed, and, in the case of transit, frequency of the transport network (Istrate and Levinson, 2011). The incremental benefits sourced from transport improvements can be captured by changes in access. As corroborated by a wealth of empirical research, the strong connections between property price and location advantages (places with high access to manifold opportunities) further reinforce the viability of the access-based method (Brigham, 1965, Dubé et al., 2013, Hansen, 1959, Wegener, 2004), where job access is a leading factor influencing buyers' residential property choice (Horner, 2004). Furthermore, integrating access measures and land value when studying transport impacts can capture project benefits that have been largely neglected in the travel time-based approach (Mohring, 1961, 1993). In comparison with travel time and travel-related costs, access is a more inclusive and economically informative measure embracing factors like time, distance, and trip purpose (Páez et al., 2012).

However, the interest in capturing capitalization effects of property or land value uplift spurs a mushrooming volume of empirical studies engaging diverse methods. Those empirical studies differ in methodological design, time windows within which project impacts are observed, the access metrics of transport improvements, and the target real estate sub-markets or land use types upon which access benefits are quantified. We believe the absence of consistent theoretical guidance and applied practice has so far restrained the new method from being deployed as an official tool assisting transport decision-making. This study systematically reviews the existing empirical research about capturing accessibility gains which are triggered by transport initiatives and capitalized in real estate value and contributes to this research topic by disentangling potential obstacles hindering applications access-based land or property value uplift method.

3 Data

The data used in this study primarily comprise the methods and empirical results of peer-reviewed journal articles and research reports which are collected in accord with the search processes shown in figure 2.

To acquire a pool of empirical research that are relevant to the studied issue, two groups of search terms were identified to enable combinations of key words when searching in different database. The first group of key words covers different modes of transport facilities or services, which describe public transport and road transport. The second group of key words targets at capturing considerations in housing or land valuation, including pointer words about property values and types.

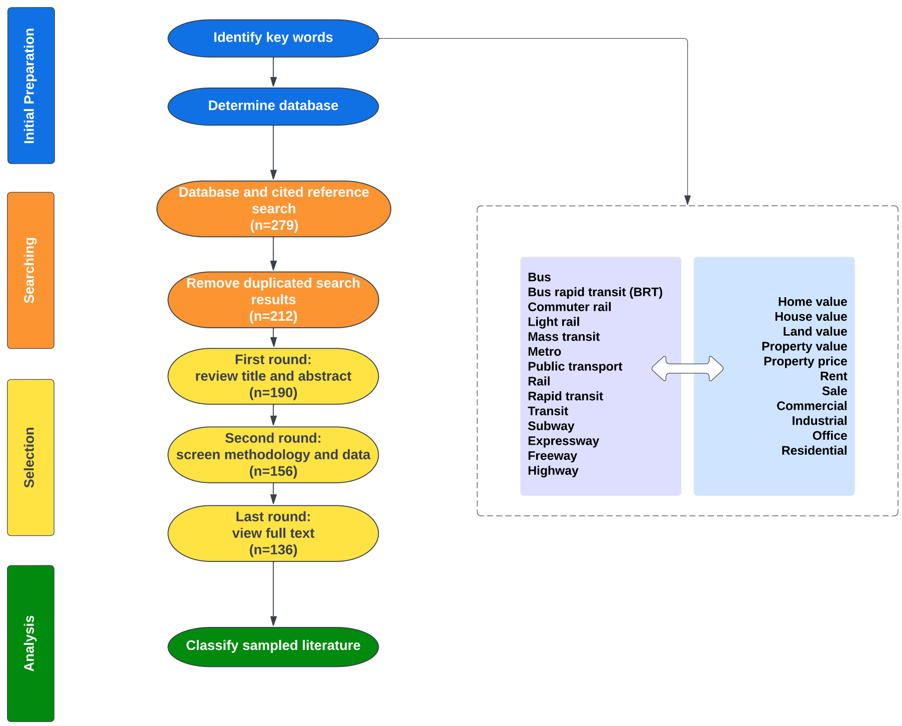


Figure 2. Literature collection methodology and key words used in literature search

Google Scholar was used for the literature search, as it returns far more related results than any library database. The settings of Google Scholar are specified as: 1) 'since 2000' for time range; 2) 'sort by relevance' for result sorting; and 3) 'any type' for source type. The time range is restricted to 'since 2000' to avoid incorporating early studies which may significantly differ from recent studies in study design, methodology and data. Acknowledging that Google Scholar has limited capacity in exclusively returning peer-reviewed scholarly results, we paid particular attention to control for quality of results, ensuring only those from peer-reviewed academic sources are included in the study.

The raw search results returned by Google Scholar comprise 279 empirical studies, which is reduced to 212 after removing duplicates. Three rounds of screening and selections, based on reviewing the title and abstract, methodology and data, and full text, were conducted by the authors, and the exclusion criteria are described as follows:

- Meta-analysis and literature review studies were excluded. The first reason is that these studies synthesize the methodology and findings of multiple empirical studies that were chosen based on tailored selection criteria and time frames, which may differ from the studies we sampled and used. The second reason is that these studies cannot fully explain how each individual empirical study was designed and executed.
- Studies that didn't use quantitative analytical methods were excluded. The reason is that this paper focuses on analyzing access-based land value uplift empirical research

which is expected to test the quantifiable correlation between transport access and property values. In this case, quantitative analytical methods are needed.

- Studies that did not engage property values or land values or rents as dependent variables were excluded. The reason is that studies using other variables (such as land use type) would evaluate changes in transport access differently.

Finally, a sample of 136 empirical studies was obtained for analysis.

4 Methodology

In project appraisal, several key considerations underpin benefit valuation processes, ensure robustness, and justify the final output. The feasibility of applying the access-based method is determined by its capabilities of handling those key considerations (evident by empirical studies).

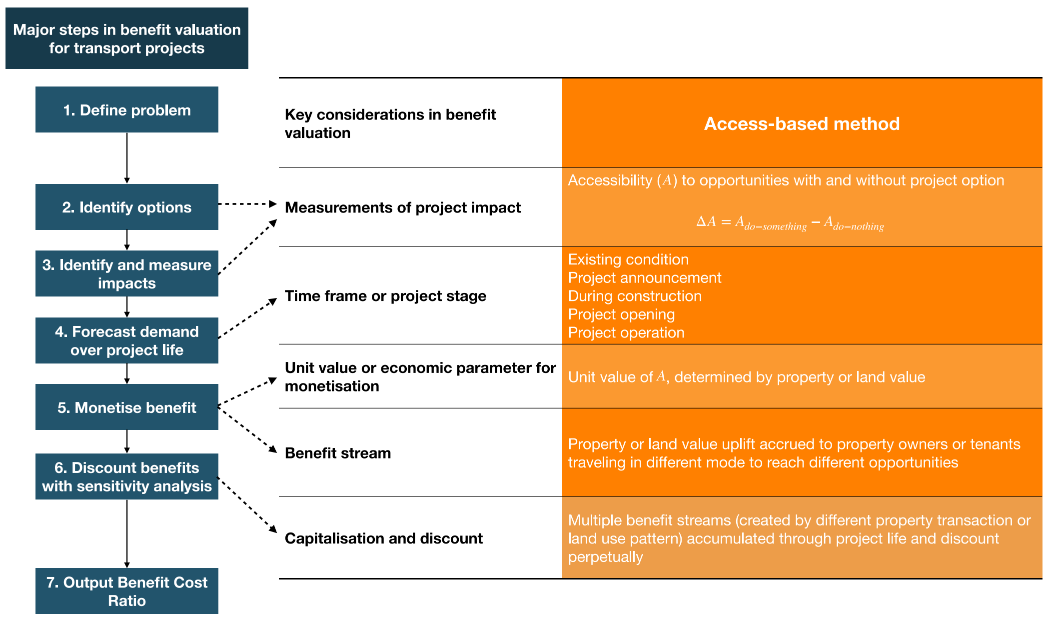


Figure 3. A comparison of the key considerations in benefit valuation between travel time-based method and access-based method.

As shown in figure 3, the evaluation process starts by outlining a series of real and plausible candidate project options deemed appropriate to address the identified needs. Generally, a minimum of three options are required: a 'do-nothing' *base case* option, a 'dominimum' option, and a 'do-something' option. In the next step of identifying and measuring all the possible impacts of each option on the current operation/situation relative to the *base case* scenario, the first key consideration kicks in. In the access-based approach, the **choice of measurements of project impacts** is changes in access (ΔA). Access (synonymous with accessibility) measures the ease of reaching (or being reached by) designated opportunities from a particular origin (Committee of the Transport Access Manual, 2020, Hansen, 1959). Ample empirical evidence corroborates that change in access with and without a project (ΔA) has been captured and capitalized in real estate value. However diverse access indicators have been observed, each study uses its own metrics, making direct comparability difficult. So, the sampled literature is then classified by the access measures used and the extent to which they precisely capture the changes of impact in the 'do-something' case relative to the baseline case.

The next step is estimating future demand for the prospective project, which is closely linked to the scale of the expected benefits of each option. The total benefits should be accounted for all the time periods over the expected project life, leading to the second key consideration about **time frame or project stage**. In the new method, real estate data across different project stages, starting from project announcement, throughout project construction, and sustaining after project completion, can be used to capture changes in property value. As a result, particular attention has been paid to the temporal structure of study design in literature classification.

In benefit monetization (step 5), project-specific impacts identified in previous steps are monetized via multiplying the unit dollar value by the total number of users that are impacted. The amount a user is likely to pay for (or against) the gain (or loss) is the **unit value for monetization**. In the access-based method, the price elasticity of access is determined by real estate value, which can be dynamically updated by the latest property transactions. Further, parameters can be cross-validated and calibrated by employing different econometric models and controlling for any perceived influential factors. The sampled literature are then stratified in accordance with model specification and variables considered.

The last step before outputting the value for money assessment results (such as benefit-cost ratio) is summing up all types of benefit streams, discounting to the present value, and testing sensitivity by using different hurdle rates and analysis periods (expected economic life). The access-based method captures benefit streams derived from real estate transactions about multiple land use types, which is also affected by the type of transactions – sales and rental – with different time features. Hurdle rate refers to the minimum expected rate of return at which the project remains break-even, which generally acts as a discount factor when computing the present value of future benefit steams generated by the study transport project. The sampled literature is then examined in terms of real estate types and transaction types.

5 Key observations about the practice and gaps based on the current literature

Figure 4 visualizes the geographical distribution of the sampled studies. The sampled literature comes from 34 countries across the globe, though no relevant empirical study about Africa has been observed in the last two decades. The United States (US) and China rank the top two counties with 36 and 30 studies respectively, followed by Australia with 10, South Korea with 8, and Canada with 6. Empirical studies in developing countries located in South America, Southeast Asia, and South Asia were found to account for 36.5% of the sampled studies. Particularly, it is noted that more than one empirical study has occurred in Colombia (4), Thailand (3), and Malaysia (2). The rapid growth of public transport system construction in developing countries fosters research on the interplay between transport infrastructure and the local real estate market.

Among all the public transport projects investigated, light rail and metro or subway occupy the predominant proportion, followed by Bus Rapid Transit (BRT) (table 1). Studies follow the planned deployment of infrastructure. For example, urban subway systems were opened in 36 cities in mainland China, although more than 300 cities primarily relied on traditional bus systems to serve residents' daily commuting needs (Yang et al., 2020).

Accordingly, although studies dedicated to buses are sparser than that of other transit modes, investigating the impact of access gains induced by enhanced conventional bus services on the real estate market is not outmoded.

Further, highway infrastructure, although receiving less attention than transit infrastructure as per table 1, brings about benefits more than satisfying people's travel demand. The heavy dependence of commercial and industrial development on the road network confers that the capitalization effect of highway infrastructure penetrates all types of land use in the real estate market. The impact of active transport investment has received little attention Mogush et al. (2016).

Table 1. Number of sampled studies by transport mode and study design

		Transport Project Mode						
		BRT	**Bus**	**Highway**	**Light Rail**	**Metro/Subway**	**Other Rail**	**Total**
Design 1	**A1**	-	2	-	1	1	-	4
	C2	-	-	-	-	-	-	-
	O3	-	-	-	-	-	-	-
	Total	10	2	8	9	15	11	55
Design 2	**A&C**	-	-	-	4	1	-	5
	A&O	-	-	-	-	-	-	-
	C&O	1	-	3	8	14	1	27
	All stage	5	-	1	5	2	-	13
	Total	6	-	4	17	17	1	45
Design 3	**A&C**	-	-	-	1	-	-	1
	A&O	-	-	1	1	-	1	3
	C&O	2	-	1	5	7	-	15
	All stage	2	1	3	7	3	1	17
	Total	4	1	5	14	10	2	36
	Total	20	3	17	40	42	14	136

[1] Announcement stage
[2] Construction stage
[3] Operation stage

5.1 Measurements of project impacts and time frame

The major challenge in evaluating the effect of transport intervention on real estate prices is the consequence of the confounding impact of other variables existing in the study region and varying over time, thus resulting in specification problems in model design. This problem can be alleviated by customizing temporal and locational considerations in study design. The three general types of study design observed in the existing literature are listed as follows, with their count of observations being summarized in table 1.

- Design 1 takes one project stage for analysis and covers properties in the areas potentially impacted by the project or even the entire corridor, which can be written as equation 1;
- Design 2 takes at multiple project stags for analysis and compares the price of properties in the areas potentially impacted by the project or even the entire corridor between different stages, including a temporal (T_i) control indicator, which can be written as equation 2; and
- Design 3 takes multiple project stages for analysis and compares the price of properties in treatment and control areas between different stages, including both a temporal and a spatial (L_i) control indicator, which can be written as equation 3.

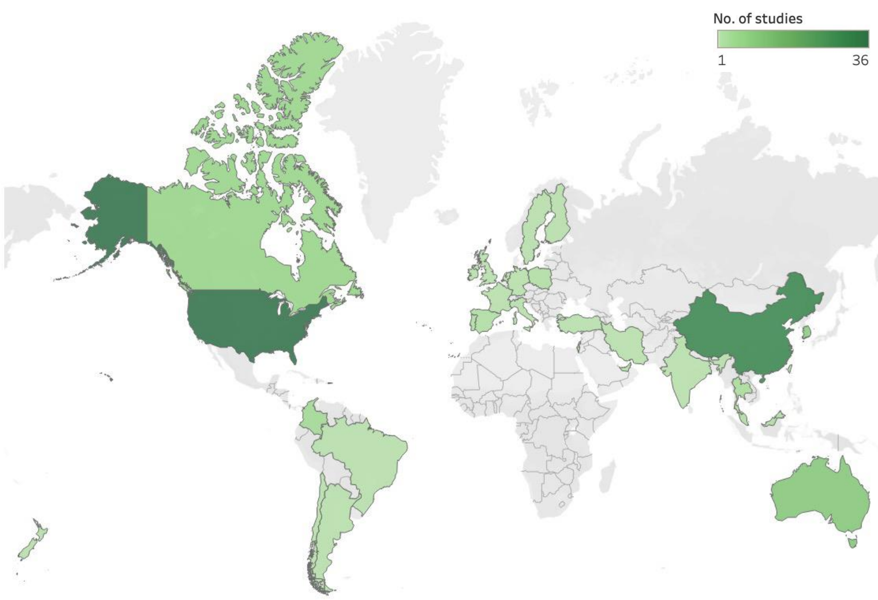


Figure 4. The number of empirical studies by country

$$P_i = f(\mathbf{A}_\mathrm{i}) \tag{1}$$

$$P_i = f(\mathbf{A}_\mathrm{i}, T_i) \tag{2}$$

$$P_i = f(\mathbf{A}_\mathrm{i}, T_i, L_i) \tag{3}$$

where:
P_i is the price of parcel i,
$\mathbf{A}_\mathrm{i}$ denotes a series of independent variables indicating the access of parcel i,
T_i is a temporal control indicator variable assigned with a value of 1 if the price of parcel i is measured after a transport intervention (only in Study Design 2 and 3),
L_i is a locational control indicator variable assigned with a value of 1 if parcel i locates in the treatment area, (only in Study Design 3)

As shown by table 1, roughly two-fifth of sampled studies adopted the first type of design and aim to capture general effects of transport facilities on property price without considering any changes in locational factors due to the studied transport project, thus is least appropriate to quantify project-specific incremental impacts. Specifically, a positive correlation between property price and proximity to public transport stations is found, but the real estate price premium directly attributable to spatial advantages caused by the studied project cannot be accurately estimated. These studies are unable to distinguish between historic access benefits embedded in the price and the value of new access resulting from an infrastructure investment. The value of new access may be lower than a unit of historic access, if diminishing returns to access exist (Iacono and Levinson, 2016, 2017).

However, transport projects experience several stages, starting from project conceptualization, the official announcement, construction, opening, and post-opening. Changes in real estate property values happen well in advance of the opening of the transport facility as participants from both demand and supply sides in the real estate market initiate speculation on the prospective gains, capitalizing expected future property uplift.

The second study design considers temporal effects (γT_i) and formulates a simple comparison about the price of properties locating next to the studied transport project before and after transport investment, which has been taken by 33% of sampled studies. In this case, it is expected that observations on the same study object (property) are available across many years. Mohammad et al. (2013) pointed out that panel data may outperform cross-sectional and time-series datasets in terms of the ability to calibrate for impacts caused by omitted or unobserved time-invariant factors. The starting point of study time window to observe real estate price changes should be carefully decided to capture access benefits capitalized in prices as much as possible. All the research using this design compare price changes between construction and operation stage, but that fewer than half extend the observation time window to time stages before construction.

A strong precondition underlying the before and after comparison is that the properties covered remain comparable regardless of the intervention, which somehow overlooks the fact that real estate price change are triggered by joint impacts, including the intervention and other extraneous factors (Salon et al., 2014). Appropriately isolating the differential impacts of the project on the base and project scenarios is crucial because it influences the attribution of incremental economic benefits to the studied project option.

In the last type of design which was embraced by fewer than a quarter of the sampled studies, two groups of properties are considered, one group from the control area without major transport improvements and the other group from the treatment area with access benefits induced by the transport project. This quasi-experimental design, with the presence of (θL_i) in equation 3, gauges the impact of the transport intervention on real estate prices by contrasting the average price change in unaffected regions over time against that in the affected regions over time, which is also known as a Difference-in-Differences (DID) method.

In terms of the establishment of the evaluation baseline, choosing control (untreated) regions that are comparable to treatment regions is particularly important to observe the actual impact of transport-related externalities in real estate prices over time. Some studies collect data about properties located in the entire affected transport corridor and define dwellings located within a pre-defined distance radius, such as a 1-kilometer radius adopted by Agostini and Palmucci (2008) and a 800-meter distance by Filippova and Sheng (2020), as the treatment group and the remaining as the control group. It is presumed that the causal relationship between transport infrastructure and property prices wears off after a specific point, though that assumes at least some of the result.

Propensity score matching (PSM) method is a widely utilized alternative to decide the treatment and control groups, which could handle the issue caused by high dimensionality of property attributes. PSM methods choose control groups by pairing each (or a group of) treatment parcel with a (or a group of) control parcel of similar observable attributes, where the level of similarity (propensity score) is computed with a logistic regression model (Dehejia and Wahba, 2002). The authors insist that comparing the values of properties with identical (or similar) propensity scores but distinct locational attributes form a less biased evaluation of the intervention impact.

5.2 Unit value for monetization

The valuation and monetization of benefits require a set of economic parameters or unit monetary values that are fairly representative, standardized in the unit of account, and regularly adjusted. Those economic values of benefits are essentially capitalized in property price or land value, which could be evaluated using the hedonic pricing model.

In hedonic theory, the differentiated good – e.g., the house – is decomposed to a bundle of commodities and characteristics that differ between specific goods (houses). The hedonic pricing model is a regression model fitted to identify the statistical relationship between property price and the set of attributes affecting it (Lancaster, 1966, Rosen, 1974, Sheppard, 1999). As shown by figure 5, the slope of the line showing the cumulative number of studies employing hedonic modelling gets steeper since 2009, indicating its wide use in this specific research topic. The coefficient output by a hedonic model reveals the economic value of each non-monetary characteristic of a property from the lens of property value and thus can be incorporated into benefit assessment, such as the access benefits provided by transport infrastructure. In addition to the study design outlined in the previous section, the validity and robustness of economic parameters estimated by hedonic models largely hinge on model specification, which involves the explanatory variables used to explain the dependent variable—property price.

The prices of parcels are likely to be affected by nearby parcels, suggesting that property prices are not spatially independent. Concerns about spatial autocorrelation arise when a standard linear least squares method is coupled with hedonic pricing model because of the violation of the default assumption about homoscedasticity and no auto-correlation. As observed in figure 4, a tendency towards using more advanced spatial hedonic model by employing multilevel, spatial lag/error, and geographically weighted modelling techniques has been observed. Multilevel models distinguish the differences at parcel-level and community-level by outputting different error terms. A spatial lag method aims to directly incorporate spatial autocorrelation in the modeling process by considering spatial weights and the degree of spatial dependency. The residual error term in a spatial error model is decomposed into two components: an evenly distributed and spatially independent part and a spatial component. A tendency towards embracing more advanced modelling techniques, as indicated by the upward slope of the cumulative number of observations on spatial lag/error and DID model, can be observed from figure 5.

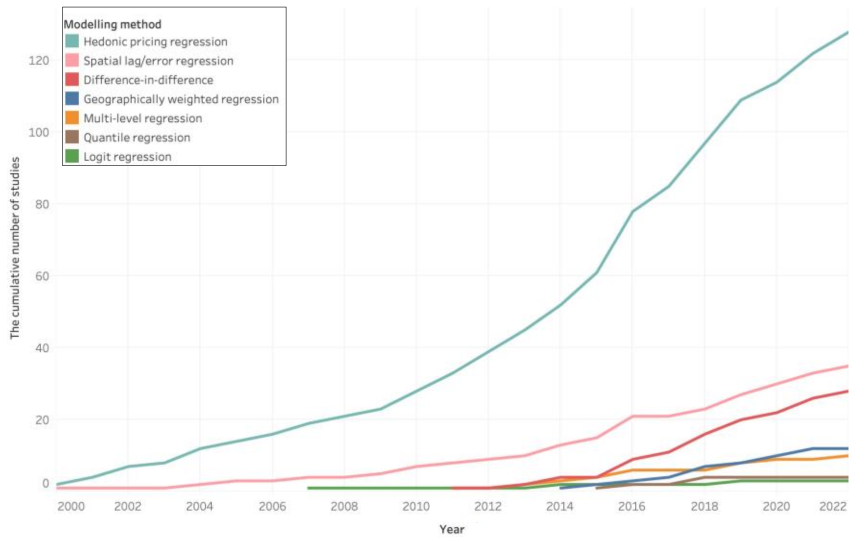
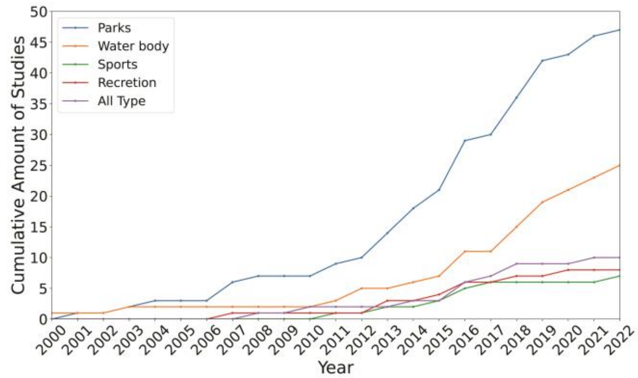


Figure 5. Cumulative number of studies by modelling method 2000-2022

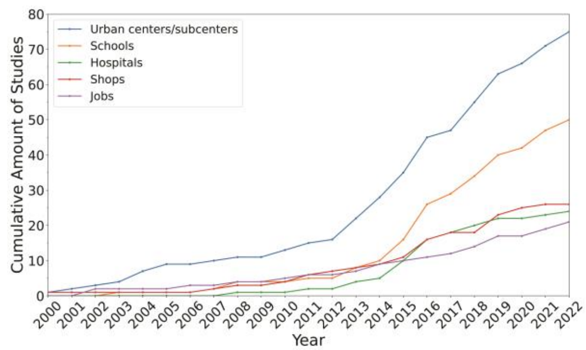
5.2.1 Hedonic pricing model specification

From a pool of candidate properties available in the market, the property meeting the buyer's budget constraints while satisfying her needs is most likely to be chosen. Figure 6 summarizes the cumulative number of attributes incorporated in modelling in the sampled empirical studies, which are stratified into six major categories. Among all factors affecting the value of land, the geographical location determining the access of the land to surrounding opportunities is the most important one (Alonso, 1964, Mills, 1967). Distance gradients for the price of properties have been recognized by Muth (1969) and Mills (1967) in the model of urban land use and spatial distribution, where housing prices are expected to drop with the distance from the urban core.

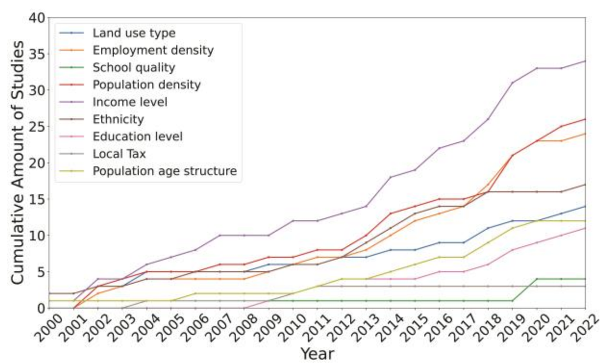
As shown by sub-figure 6f in figure 6, the access to transport services (access to a station or interchange, e.g.,) is used as an indicator of locational advantage. It is also the most frequently used variable in hedonic pricing models, as indicated by the highest cumulative number of observations shown by the y-axis. It is noted that more than half of the sampled studies did not consider access to competing transport modes (alternative transit facilities or roadways other than the studied one), overlooking the fact that access gains offered by other modes are also capitalized into real estate values (Damm et al., 1980). In addition, although cycle paths and walkways may be constructed jointly with transit projects to solve the first/last mile problem and support access to public transport services, it is observed that active transport modes are generally unaccounted for by the current empirical literature.



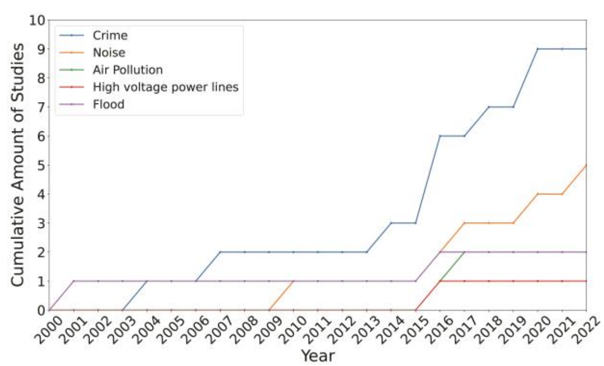
(a) Amenity



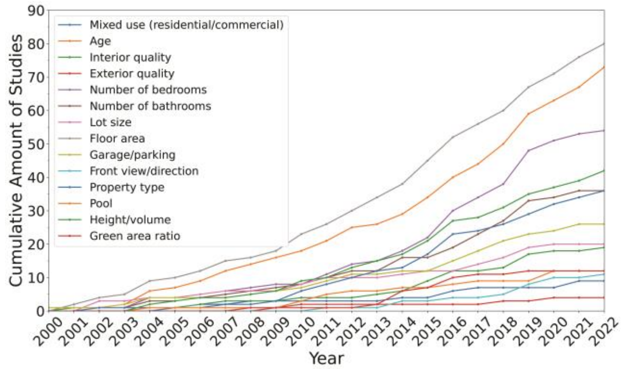
(b) Basic needs



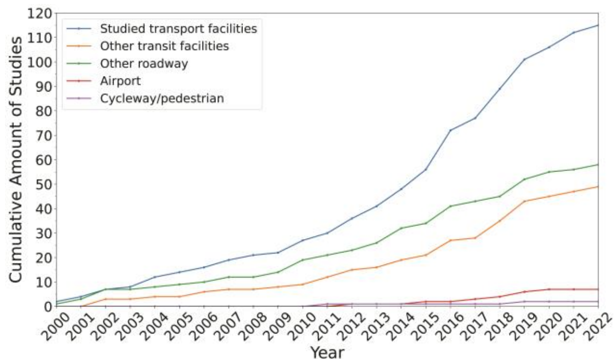
(c) Demographic/socioeconomic



(d) Negative externalities



(e) Structural



(f) Locational

Figure 6. Cumulative number of attributes by category

The proximity to transport services is essentially a surrogate measure of access to people's needs because the purpose of going to a train station or highway is to reach the ultimate destinations. So, another set of variables – the proximity to places or opportunities that fulfill people's basic needs (figure 6b) and amenity (6a) needs – is incorporated to further identify properties' locational advantages. One typical measure of the locational attribute is the distance to the central business district (CBD) in a monocentric city or the closest subcenter in a polycentric city (figure 6b), as a proxy of a property's position advantage relative to the whole urban area. The spatially centralized opportunities and activities available at the urban center allow distance to CBD to be a synthetic access measure (Heikkila et al., 1989). Further, access to parks and water bodies, ranked the top two attributes in the amenity category, could reveal people's willingness to pay for positive environmental externalities. Goodman (1978) and Linneman (1980) empirically found that neighborhood attributes are important factors affecting properties' value, which can be broadly categorized as demographic, socioeconomic (figure 6c, and negative externalities (figure 6d). Income level appears to be the most common metrics involved to address concerns about neighborhood quality, followed by employment density, population density, and ethnicity. Ethnicity is an intriguing factor involving a bundle of traits (such as language and religion) shared by a community. For example, Daniels (1975) tested if people of color tend to pay a premium to locate in a white community. Concerns about negative externalities are scarcely encompassed in modelling. In comparison to other negative impacts, crime continuously attracts attention because public transit may facilitate various crimes (Brantingham et al., 1991).

Property-specific characteristics (figure 6e) covers structural attributes (e.g., floor area size and the number of bedrooms) and availability of supporting facilities (like parking spaces). The availability of garages is a key factor influencing housing purchase decisions. Essentially, based on the model specifications of the analyzed studies, it can be inferred that all factors influencing site selection are rooted in people's concerns about accessibility, and that all variables included in the hedonic model can be converted into access metrics.

$$P_i = f(\mathbf{A}_{B,i}, \mathbf{A}_{N,i}, \mathbf{A}_{H,i}, \mathbf{A}_{D,i}, \ldots, \mathbf{S}, \mathbf{Y}) \tag{4}$$

P_i is the price of property i,
$A_{B,i}$ is access to the locational characteristics of property i with respect to basic living needs (e.g., access to jobs, shops, education, etc.),
$A_{N,i}$ is access to the quality of the surrounding neighborhood of property i,
$A_{H,i}$ is access to the interior and exterior structural attributes of property i,
$A_{D,i}$ is access to social groups or communities with specific qualities i,
S is the control variables for spatial effects not otherwise captured,
Y is the control variables for temporal effects.

However, it is observed that the sampled studies generally did not incorporate all the aforementioned variables. On the one hand, the choice of explanatory variables has great influence on the model's goodness-of-fit which indicates its ability to explain the movement in housing prices. On the other hand, omitting key variables could reduce the accuracy and reliability of specific model parameters, resulting in misvaluation of the consumers' marginal revealed willingness to pay (Wooldridge, 2015).

5.2.2 Measures of access to opportunities

Being close to desired opportunities, and away from undesired ones, provides intangible gains, which are of great value but do not come with a market price. The way the access attributes are defined and measured has great impacts on the unit monetary value output by the hedonic regression model. It is observed from the literature that different types of operational measures of access have been engaged, these include:

1. **Euclidean distance** measures the straight-line length between two points, providing a straightforward indication of physical distance, which is the most frequently used method.
2. **Buffer ring** is a measure based on Euclidean distance. It classifies whether a feature of concerns falls in a pre-determined distance buffer and generally operates as a dummy variable.
3. **Network distance** is the distance between origins and destinations when travelling along the existing transport network such as road or transit network.
4. **Travel time** is the duration of time spent travelling between origins and destinations (or surrogate destinations) using a specified transport mode. For example, the auto travel time to the closest motorway entry point, or the bus travel time to the closest employment hub.

5. **Primal access** (shown in Equation 5) measures the number of opportunities (O_j) can be reached within a specified cost function ($f(C_{ij})$), which is also called 'opportunity-denominated' access.

The general function for primal access (Levinson and Wu, 2020) can be written as:

$$\mathbf{A_i} = \sum_{j=1}^{J} g(\mathbf{O_j})\, f(\mathbf{C_{ij}}) \quad (5)$$

where $\mathbf{A}_i$ is the matrix of accessibilities at origin i, $g(\mathbf{O}_j)$ is a matrix weighted opportunities at destination j, and $f(\mathbf{C}_{ij})$ is a matrix of weighted impedances (typically travel costs and travel times) for travel between i and j.

Roughly two-thirds of studies used Euclidean distance, followed by distance buffer ring observed in 55%, network distance in 23%, primal access in 17%, and travel time in 12.5% of sampled studies, respectively. It should be noted that many studies used more than one type of access measure, so the sum of the percentage values exceeds 100%. In comparison to network distance and travel time, Euclidean distance provides the least information. It neglects the fact that people travel along a transport network where the actual travel distance differs significantly from the straight-line distance (Levinson and El-Geneidy, 2009). Aside from that, Euclidean distance is a mode-insensitive measure. For example, the Euclidean distance between a property and the town center is a constant value, which fails to reflect the level of convenience provided by different transport modes. Given such, this measure can hardly capture the real contribution of improvements in transport network to reduce spatial separation. Network distance provides a more realistic proxy of the movement trajectory between an origin and a destination. But travel choices are affected by confounding factors where distance has limited capacity to explain people's behavior. Zahavi and Talvitie (1980) pointed out that travel time and money costs greatly influence travel behavior. Both measured and reported travel times are used to represent travel experiences.

However, access measures are expected to consist of two fundamental factors: the cost incurred to overcome the spatial impedance to reach the opportunity and the quality or number of opportunities (Páez et al., 2012). The first three measures only cover the first component but omit the second one, thereby classified as 'impedance' instead of 'access.' As shown by equation 5 primal access comprises two parts, the number of opportunities available at place j and an impedance function $f(C_{ij})$ accounting for factors (distance, travel time or money costs) that hinder travel from i to j (Committee of the Transport Access Manual, 2020). With respect to the consideration of travel impedance, many types of impedance function are available. For instance, in a cumulative opportunity measure, the cost of travel C_{ij} is accounted for in dichotomous form (see Equation 6), where a value of 1 is assigned if travel time by a specific mode (e.g., bus) is shorter than some specified threshold (e.g., 30 mins) and 0 otherwise.

$$f(C_{ij}) = 1 \; if \; C_{ij} \le t, else \; f(C_{ij}) = 0 \quad (6)$$

The time-weighted cumulative opportunity measure considers that the value of an opportunity wears off with increase in travel cost. The impedance weighting function $f(C_{ij})$, in this case, often takes on the form of a negative exponential.

5.3 Benefit evaluation and monetization

5.3.1 Land-use type and transaction type

It is observed in figure 7 that over 86% of empirical studies on capitalization effects paid attention to residential properties, fewer than 20% targeted commercial properties (including office), and roughly 6% of studies involved but were not dedicated to industrial properties. In the real estate market, residential property transactions are more active and frequent than transactions about other kinds of land uses, providing a huge volume of consistent and acquirable data for statistical analysis. Residential sales data appears to be more often used than rental data, where the difficulty in obtaining the latter restrains the exploration of rental premium. Assessing changes in rental income reveals the willingness- to-pay of people who actually benefit from enhanced transit access (Wang et al., 2016).

Although it is reported that rental price increment is higher in the commercial rental market than in the residential market (Debrezion et al., 2007, Mohammad et al., 2013), commercial properties received less attention. The feasibility and practicality of capturing land value uplift in the commercial real estate market may discourage the exploration of commercial properties in this topic. For example, the joint development land value capture strategy has been successfully applied in Hong Kong. The local transit agency collaborates with property developers to jointly develop the land awarded by the local government at lower 'before rail' prices, and then value uplift in all types of property as a result of transit-oriented development is ploughed back by claiming a fraction of capital gains from property-related transactions, which is subsequently redistributed to future transit development (Mathur, 2019). The replicability of this strategy is heavily subject to local policy and legislation, which is popular in Asian countries but rarely applied in Western countries (Istrate and Levinson, 2011).

In addition, commercial gentrification, which refers to the upgrading of various local businesses by displacing the original lower value local stores (Lin and Yang, 2019), is likely to be induced by public transport infrastructure construction or improvement and affect the local commercial property market. The positive externalities resulting from commercial gentrification are typically value appreciation in commercial properties, but there are also negative externalities like depriving original merchants (shoppers) income when they are forced to relocate (shop) elsewhere (Lim et al., 2013). Should both the downsides and upsides of commercial gentrification (if any) be properly accounted for in benefit assessments, the justifiability of the assessment results would be strengthened.

Industrial land use received the least attention. Industrial site selection relies more heavily on port and aviation infrastructure. Considering that, the current study restricts its research scope to roadway and public transport infrastructure, limiting the number of observations about the capitalization effects of industrial properties.

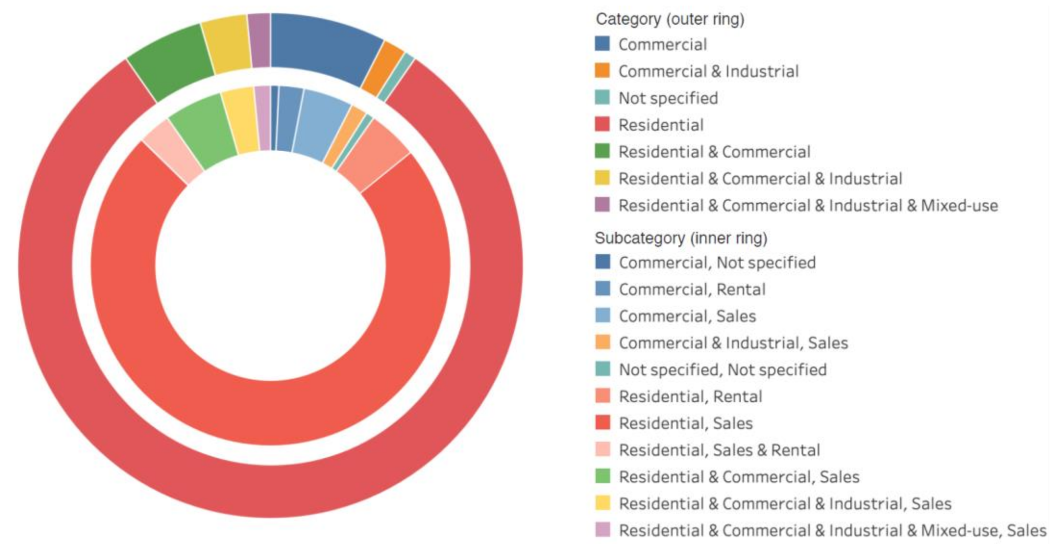


Figure 7. The proportion of real estate sub-market and the proportion of rental vs. sales in each sub-market

5.3.2 Housing price.

The raw value of the dependent variable includes the price per property or per standardized areal unit (e.g., m^2 or $feet^2$) and the differences between the price before and after the transport intervention (typically in a repeated-sales approach). In the first form, the inclusion of absolute prices is intended to disentangle how each independent vector can explain the housing prices. The differenced values for the same sets of properties assists in attributing the changes in property prices to the relevant independent variables. It's important to clarify that in the latter approach, the independent variables are typically presented in their original absolute values rather than as differences. This differs from the first-difference method, where both the dependent and independent variables are transformed into difference values.

The functional forms of the dependent variable include the absolute value form or the log-transformed ratio-scale form, and the latter form is more commonly found in the sampled studies. The functional forms logically vary the interpretation of the coefficients. The diverse measures of housing prices, including asking prices, sales prices, and assessment values, have pros and cons when engaged in hedonic pricing model (Henneberry, 1998). Asking prices (or listing prices) are the prices quoted by sellers when properties are listed for sale, which represent a starting point of subsequent price bargain and thus is likely to differ from the ultimate sales price. The sales price of a property represents the final settlement price in a transaction, providing a more accurate indicator of the property's true market valuation than the listing price (Debrezion et al., 2007). Although asking prices have been criticized for their divergence with sales prices (Cheshire and Sheppard, 1989), they are argued to be plausible alternatives to sales prices when the availability of the latter is limited (Du and Mulley, 2007). Han and Strange (2016) find that among settled property transactions, the proportion of transactions closed at listing prices is nontrivial and that listing prices affect and navigate home buyers' behavior. In addition, the representativeness of asking price varies with the relative consumer and seller bargaining power in local housing market. For instance, at times when the bargaining power of purchaser is weak in the real estate market in Beijing (Zhang and Wang, 2013) and Guangzhou (Salon et al., 2014), there is a high likelihood of closing a deal at the asking price offered by the seller. Some markets like Australia use an auction, and do not have 'asking prices' as such, though there may be a 'reserve price.'

6 Concluding remarks and future challenges

The traditional travel-time based user benefit assessment method has been repeatedly questioned for numerous intrinsic flaws. The present paper aims to disentangle the obstacles hindering a general access-based land or property value uplift method by systematically reviewing methodological design, the access metrics of transport improvements, and the target real estate submarkets or land use types upon which access benefits are quantified.

First, it is observed that the US and China rank as the top two countries in terms of the total number of empirical studies published in this research field. The observation that developing countries account for roughly 36.5% of empirical studies demonstrates that the rapid growth of public transport system construction in developing countries has encouraged research on the interplay between transport infrastructure and the local real estate market. In addition, among all the transport projects investigated, light rail, metro or subway, and BRT occupy the largest share, where conventional bus services, as well as roads and highways and active transport facilities received less attention despite their wide use.

Furthermore, in the aspect of study design, nearly half of the sampled studies solely examined the overall impact of transport facilities on property prices, without accounting for any changes in location-related factors caused by the studied transport project. This approach is generally considered less suitable for capturing the project-specific incremental effects. For studies that considered temporal effects, the observation time window is rarely extended to time stages before construction, overlooking the fact that changes in real estate property values may happen well in advance of the opening of the transport facility as participants from both the demand and supply side in the real estate market anticipate the prospective gain. Considering that real estate price changes are triggered by joint impacts, including the studied transport intervention and other extraneous factors, choosing control regions that are comparable to treatment regions is important to isolate the differential impacts of the project on the base scenario and project scenario. However, it is common to distinguish treatment and control regions by a pre-defined radius, which assumes the causal relationship between transport infrastructure and property prices wears off after a specific distance and fails to handle the inherent high dimensionality of property attributes.

Third, although the hedonic pricing model remains the most popular model for identifying the statistical relationship between property price and the set of attributes affecting it, some studies have enhanced the method by embracing more advanced modelling techniques such as spatial lag/error and DID model to control for bias caused by spatial dependence have been observed.

Fourth, with respect to model specification, the locational features of a property, which are indicated by proximity to transport services, amenity, and places that fulfill people's basic needs, are the most frequently used variables in hedonic pricing models to capture access benefits. Euclidean distance and distance buffer ring are the most widely used operational measures of access, measures which are mode-insensitive and neglect the fact that people travel along a transport network. Access measures are expected to consist of two fundamental factors (Wu and Levinson, 2020): the cost incurred to overcome the spatial impedance to reach the opportunity and the quality or number of opportunities. In this case, although adopted relatively rarely in comparison to other access measures, primal access measures covering the number of opportunities available at a destination and an impedance function accounting for factors (travel time or money costs) that hinder travel should be employed.

Last, over 86% of empirical studies on capitalization effects paid attention to residential properties, fewer than 20% targeted commercial properties, and roughly 6% of studies considered, but were not dedicated to, industrial properties. Property sales data appear to be more frequently applied than rental transaction data. Further, it is observed that asking prices, sales prices, and assessment value have all been used as measures of housing prices. This bias towards residential land uses in the literature presents a significant research gap that should be addressed.

The biggest challenge confronted by the new method is that access measures have not been as widely applied a transport system performance metric as travel time. So, introducing access as a standardized performance measure (Committee of the Transport Access Manual, 2020), establishing uniform guidance and precise metrics on access measures, and considering it as a criterion in transport investment decisions can promote the development and recognition of the access-based benefit assessment approach.

References

Ackerman, F. and Heinzerling, L. (2002), Pricing the priceless: Cost-benefit analysis of environmental protection, University of Pennsylvania Law Review 150(5), 1553–1584.

Agostini, C. A. and Palmucci, G. A. (2008), The anticipated capitalisation effect of a new metro line on housing prices, Fiscal Studies 29(2), 233–256.

Alonso, W. (1964), Location and land use: Toward a general theory of land rent., Publications of the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University, Harvard University Press, Cambridge.

Andrić, J., Mahamadu, A.-M., Wang, J., Zou, P. and Zhong, R. (2019), The cost performance and causes of overruns in infrastructure development projects in Asia, Journal of Civil Engineering and Management 25, 203–214.

Bain, R. and Polakovic, L. (2005), Traffic forecasting risk study update 2005: Through ramp-up and beyond, Proceedings of ETC 2005, Transport Policy and Operations - Road Finance Design and Maintenance Traffic and Revenue Forecasting. https://trid.trb.org/view/846461

Batt, H. W. (2001), Value capture as a policy tool in transportation economics: An exploration in public finance in the tradition of Henry George,’ American Journal of Economics and Sociology 60(1), 195–228, https://onlinelibrary.wiley.com/doi/abs/10.1111/1536-7150.00061

Black, A. (1995), Urban mass transportation planning.

Brantingham, P. J., Brantingham, P. J. and Wong, P. S. (1991), ‘How public transit feeds private crime: notes on the 'Vancouver Skytrain’ experience, Security Journal 2(2), 91–95.

Brigham, E. F. (1965), The determinants of residential land values, Land Economics 41(4), 325–334.

Cantarelli, C., van Wee, B., Molin, E. and Flyvbjerg, B. (2012), Different cost performance: different determinants?: The case of cost overruns in Dutch transport infrastructure projects, Transport Policy 22, 88–95.

Ceder, A. (2007), Public transit planning and operation: Theory, modelling and practice, CRC Press.

Cheshire, P. and Sheppard, S. (1989), British planning policy and access to housing: some empirical estimates, Urban Studies 26(5), 469–485.

Committee of the Transport Access Manual (2020), Transport Access Manual: A Guide for Measuring Connection between People and Places, Committee of the Transport Access Manual, University of Sydney.

Cruz, C. O. and Sarmento, J. M. (2019), Traffic forecast inaccuracy in transportation: A literature review of roads and railways projects, Transportation (Dordrecht) 47(4), 1571–1606.

Curtis, C. and Scheurer, J. (2016), Planning for public transport accessibility: An international sourcebook, Routledge.

Damm, D., Lerman, S. R., Lerner-Lam, E. and Young, J. (1980), Response of urban real estate values in anticipation of the Washington metro, Journal of Transport Economics and Policy pp. 315–336.

Daniels, C. B. (1975), The influence of racial segregation on housing prices, Journal of Urban Economics 2(2), 105–122.

Debrezion, G., Pels, E. and Rietveld, P. (2007), The impact of railway stations on residential and commercial property value: A meta-analysis, The Journal of Real Estate Finance and Economics 35(2), 161–180.

Dehejia, R. H. and Wahba, S. (2002), Propensity score-matching methods for nonexperimental causal studies, Review of Economics and Statistics 84(1), 151–161.

Dewees, D. (1976), The effect of a subway on residential property values in Toronto, Journal of Urban Economics 3(4), 357–369.

Du, H. and Mulley, C. (2007), The short-term land value impacts of urban rail transit: Quantitative evidence from Sunderland, UK, Land Use Policy 24(1), 223–233.

Du, H. and Mulley, C. (2012), Understanding spatial variations in the impact of accessibility on land value using geographically weighted regression, Journal of Transport and Land Use 5(2), 46–59.

Dubé, J., Thériault, M. and Des Rosiers, F. (2013), Commuter rail accessibility and house values: The case of the Montreal south shore, Canada, 1992–2009, Transportation research. Part A, Policy and Practice 54, 49–66.

Farrell, S. (1999), Financing European transport infrastructure: policies and practice in Western Europe, Springer.

Filippova, O. and Sheng, M. (2020), Impact of bus rapid transit on residential property prices in Auckland, New Zealand, Journal of Transport Geography 86, 102780.

Florio, M. and Vignetti, S. (2013), The use of ex post cost-benefit analysis to assess the long-term effects of major infrastructure projects, Working Paper 2723381, Centre for Industrial Studies.

Flyvbjerg, B. (2003), Megaprojects and risk: An anatomy of ambition, Cambridge University Press, Cambridge.

Flyvbjerg, B. (2007), Cost overruns and demand shortfalls in urban rail and other infrastructure, Transportation Planning and Technology 30(1), 9–30.

Flyvbjerg, B., Holm, M. K. S. and Buhl, S. L. (2003), How common and how large are cost overruns in transport infrastructure projects?, Transport Reviews 23(1), 71–88.

Flyvbjerg, B., Holm, M. K. S. and Buhl, S. L. (2004), What causes cost overrun in transport infrastructure projects?, Transport Reviews 24(1), 3–18.

Flyvbjerg, B., Holm, M. K. S. and Buhl, S. L. (2005), How (in)accurate are demand forecasts in public works projects?: The case of transportation, Journal of the American Planning Association 71(2), 131–146.

Geurs, K. T., Dentinho, T. P. and Patuelli, R. (2016), Accessibility, equity and efficiency, in Accessibility, Equity and Efficiency, Edward Elgar Publishing.

Goodman, A. C. (1978), Hedonic prices, price indices and housing markets, Journal of Urban Economics 5(4), 471–484.

Han, L. and Strange, W. C. (2016), What is the role of the asking price for a house?, Journal of Urban Economics 93, 115–130. https://www.sciencedirect.com/science/article/pii/S0094119016300018

Hansen, W. G. (1959), How accessibility shapes land use, Journal of the American Institute of Planners 25(2), 73–76.

Hartgen, D. T. (2013), Hubris or humility? Accuracy issues for the next 50 years of travel demand modeling, Transportation (Dordrecht) 40(6), 1133–1157.

Heikkila, E., Gordon, P., Kim, J. I., Peiser, R. B., Richardson, H. W. and Dale-Johnson, D. (1989), What happened to the EBD-distance gradient? Land values in a policentric city, Environment and Planning A 21(2), 221–232.

Henneberry, J. (1998), Transport investment and house prices, Journal of Property Valuation and Investment .

Hess, D. B. and Almeida, T. M. (2007), Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York, Urban Studies (Edinburgh, Scotland) 44(5/6), 1041–1068.

Hiironen, J., Riekkinen, K. and Tuominen, H. (2015), The impact of a new subway line on property values in Helsinki metropolitan area, in FIG Working Week, pp. 17–21.

Hoque, J. M., Erhardt, G. D., Schmitt, D., Chen, M., Chaudhary, A., Wachs, M. and Souleyrette, R. R. (2021), The changing accuracy of traffic forecasts, Transportation (Dordrecht) pp. 1–22.

Horner, M. W. (2004), Spatial dimensions of urban commuting: A review of major issues and their implications for future geographic research, The Professional Geographer 56(2), 160–173.

Huo, T., Ren, H., Cai, W., Shen, G., Liu, B., Zhu, M. and Wu, H. (2018), Measurement and dependence analysis of cost overruns in megatransport infrastructure projects: Case study in Hong Kong, Journal of Construction Engineering and Management 144.

Iacono, M., & Levinson, D. (2016), Mutual causality in road network growth and economic development, Transport Policy, 45, 209-217.

Iacono, M., & Levinson, D. (2017), Accessibility dynamics and location premia: Do land values follow accessibility changes?, Urban studies, 54(2), 364-381.

Istrate, E. and Levinson, D. M. (2011), Access for value: Financing transportation through land value capture, Technical report, Brookings Institution Metropolitan Infrastructure Initiative.

Jara-Diaz, S. R. (1990), Consumer's surplus and the value of travel time savings,' Transportation Research Part B: Methodological 24(1), 73–77. https://www.sciencedirect.com/science/article/pii/019126159090033U

Kelly, C., Laird, J., Costantini, S., Richards, P., Carbajo, J. and Nellthorp, J. (2015), Ex post appraisal: What lessons can be learnt from EU cohesion funded transport projects?, Transport Policy 37, 83–91. https://www.sciencedirect.com/science/article/pii/S0967070X14002108

Laird, J. J., Nellthorp, J. and Mackie, P. J. (2005), Network effects and total economic impact in transport appraisal, Transport Policy 12(6), 537–544. https://www.sciencedirect.com/science/article/pii/S0967070X05000909

Lancaster, K. J. (1966), A new approach to consumer theory, Journal of political economy 74(2), 132–157.

Lee, J.-K. (2008), Cost overrun and cause in Korean social overhead capital projects: Roads, rails, airports, and ports, Journal of Urban Planning and Development 134(2), 59– 62.

Lee Jr, D. (2000), Methods for evaluation of transportation projects in the USA, Transport policy 7(1), 41–50.

Levine, J., Grengs, J. and Merlin, L. A. (2019), From Mobility to Accessibility: Transforming Urban Transportation and Land-Use Planning, Cornell University Press, Ithaca.

Levinson, D. and El-Geneidy, A. (2009), The minimum circuity frontier and the journey to work, Regional Science and Urban Economics 39(6), 732–738.

Levinson, D. and Wu, H. (2020), Towards a general theory of access, Journal of Transport and Land Use 13(1), 129–158.

Li, Z. and Hensher, D. A. (2010a), Toll roads in Australia: An overview of characteristics and accuracy of demand forecasts, Transport Reviews 30(5), 541–569. https://doi.org/10.1080/01441640903211173

Li, Z. and Hensher, D. A. (2010b), Toll roads in Australia: An overview of characteristics and accuracy of demand forecasts, Transport Reviews 30(5), 541–569.

Lim, H., Kim, J., Potter, C. and Bae, W. (2013), Urban regeneration and gentrification: Land use impacts of the Cheonggye stream restoration project on the Seouls Central Business District, Habitat International 39, 192–200.

Lin, J.-J. and Hwang, C.-H. (2004), Analysis of property prices before and after the opening of the Taipei subway system, The Annals of Regional Science 38, 687–704.

Lin, J.-J. and Yang, S.-H. (2019), Proximity to metro stations and commercial gentrification, Transport Policy 77, 79–89.

Linneman, P. (1980), Some empirical results on the nature of the hedonic price function for the urban housing market, Journal of Urban Economics 8(1), 47–68.

Liu, Z., Li, Y. and Ming, Z. (2022), Transit network effects and multilevel access premiums: Evidence from the housing market of Shanghai, China, Cities 129, 103841.

Love, P. E., Ahiaga-Dagbui, D. D. and Irani, Z. (2016), Cost overruns in transportation infrastructure projects: Sowing the seeds for a probabilistic theory of causation, Transportation Research Part A, Policy and Practice 92, 184–194.

Lundberg, M., Jenpanitsub, A. and Pyddoke, R. (2011), Cost overruns in Swedish transport projects, Working Paper 5694, Centre for Transport Studies Stockholm.

Mackie, P. and Preston, J. (1998), Twenty-one sources of error and bias in transport project appraisal, Transport Policy 5(1), 1–7. https://www.sciencedirect.com/science/article/pii/S0967070X98000043

Mackinder, I. and Evans, S. (1981), Predictive accuracy of British transport studies in urban areas, Transport and Road Research Laboratory (TRRL)

Marleau Donais, F., Abi-Zeid, I., Waygood, E. O. D. and Lavoie, R. (2019), A review of cost–benefit analysis and multicriteria decision analysis from the perspective of sustainable transport in project evaluation, EURO Journal on Decision Processes 7(3-4), 327–358.

Mathur, S. (2014), Innovation in Public Transport Finance Property Value Capture, Transport and Mobility, Ashgate Publishing Ltd, Farnham.

Mathur, S. (2019), An evaluative framework for examining the use of land value capture to fund public transportation projects, Land Use Policy 86, 357–364.

Medda, F. (2012), Land value capture finance for transport accessibility: A review, Journal of Transport Geography 25, 154–161.

Mills, E. S. (1967), An aggregative model of resource allocation in a metropolitan area, The American Economic Review 57(2), 197–210.

Mogush, P., Krizek, K. J. and Levinson, D. (2016), The value of bicycle trail access in home purchases, in Accessibility, Equity and Efficiency, Edward Elgar Publishing, pp. 193–209.

Mohammad, S. I., Graham, D. J., Melo, P. C. and Anderson, R. J. (2013), A meta-analysis of the impact of rail projects on land and property values, Transportation Research Part A: Policy and Practice 50, 158–170.

Mohring, H. (1961), Land values and the measurement of highway benefits, The Journal of Political Economy 69(3), 236–249.

Mohring, H. (1993), Maximizing, measuring, and not double counting transportation improvement benefits: A primer on closed- and open-economy cost-benefit analysis, Transportation Research Part B: Methodological 27(6), 413–424. https://www.sciencedirect.com/science/article/pii/0191261593900142

Muth, R. F. (1969), Cities and housing; the spatial pattern of urban residential land use..

Nicolaisen, M. S. and Driscoll, P. A. (2014), Ex-post evaluations of demand forecast accuracy: A literature review, Transport Reviews 34(4), 540–557.

Odeck, J. (2004), Cost overruns in road construction—what are their sizes and determinants?, Transport Policy 11(1), 43 – 53.

Page, W. H. and Lopatka, J. E. (1999), Network externalities, Encyclopedia of Law and Economics 760, 952–980.

Park, Y.-I. and Papadopoulou, T. (2012), Causes of cost overruns in transport infrastructure projects in Asia, Built Environment Project and Asset Management 2, 195–216.

Parthasarathi, P. and Levinson, D. (2010), Post-construction evaluation of traffic forecast accuracy, Transport Policy 17(6), 428–443. https://www.sciencedirect.com/science/article/pii/S0967070X10000594

Pickrell, D. (1989), Urban rail transit projects: Forecast versus actual ridership and costs. final report, Technical report, Transportation Systems Center, Cambridge, MA (USA).

Páez, A., Scott, D. M. and Morency, C. (2012), Measuring accessibility: positive and normative implementations of various accessibility indicators, Journal of Transport Geography 25, 141–153.

Rosen, S. (1974), Hedonic prices and implicit markets: Product differentiation in pure competition, Journal of Political Economy 82(1), 34–55.

Salon, D., Wu, J. and Shewmake, S. (2014), Impact of bus rapid transit and metro rail on property values in Guangzhou, China, Transportation Research Record 2452(1), 36–45.

Sebastian, M. (2005), Cost and time overruns in public sector projects, Economic and Political Weekly pp. 154–168.

Sheppard, S. (1999), Chapter 41 hedonic analysis of housing markets, in Applied Urban Economics, Vol. 3 of Handbook of Regional and Urban Economics, Elsevier, pp. 1595–1635. https://www.sciencedirect.com/science/article/pii/S1574008099800108

Sims, S. and Dent, P. (2005), High-voltage overhead power lines and property values: a residential study in the UK, Urban Studies 42(4), 665–694.

Smith, J. J. and Gihring, T. A. (2006), Financing transit systems through value capture: An annotated bibliography, American Journal of Economics and Sociology 65(3), 751–786.

Sun, H., Wang, Y. and Li, Q. (2016), The impact of subway lines on residential property values in tianjin: An empirical study based on hedonic pricing model, Discrete Dynamics in Nature and Society 2016, 1–10.

Ubbels, B., Nijkamp, P., Verhoef, E., Potter, S. and Enoch, M. (2001), Alternative ways of funding public transport: A case study assessment, European Journal of Transport and Infrastructure Research 1(1), 73–89.

Voulgaris, C. T. (2019a), Crystal balls and black boxes: What makes a good forecast?, Journal of Planning Literature 34(3), 286–299. https://doi.org/10.1177/0885412219838495

Voulgaris, C. T. (2019b), Trust in forecasts? correlates with ridership forecast accuracy for fixed-guideway transit projects, Transportation (Dordrecht) 47(5), 2439–2477.

Wang, Y., Feng, S., Deng, Z. and Cheng, S. (2016), Transit premium and rent segmentation: A spatial quantile hedonic analysis of shanghai metro,' Transport Policy 51, 61–69.

Wang, Y., & Levinson, D. (2022), Time savings vs. access-based benefit assessment of New York's Second Avenue Subway, Journal of Benefit-Cost Analysis, 13(1), 120-147.

Wang, Y. and Levinson, D. (2023a), The accuracy of benefit-cost analysis for transport projects supported by the Asian Development Bank, Asian Transport Studies, 9, 100104.

Wang, Y. and Levinson, D. (2023b), The overlooked transport project planning process-What happens before selecting the Locally Preferred Alternative?, Transportation Research Interdisciplinary Perspectives, 19, 100809.

Wegener, M. (2004), Overview of land-use transport models, in D. A. Hensher and K. B. (Eds.), eds, Handbook of transport geography and spatial systems, Handbooks in Transport; 5, Elsevier, Amsterdam, Chapter 9, pp. 266–290.

Welde, M. and Odeck, J. (2011), Do planners get it right? The accuracy of travel demand forecasting in Norway, European Journal of Transport and Infrastructure Research 11, 80–95.

Wen, H., Gui, Z., Tian, C., Xiao, Y. and Fang, L. (2018), Subway opening, traffic accessibility, and housing prices: a quantile hedonic analysis in Hangzhou, China, Sustainability 10(7), 1–23.

Wooldridge, J. M. (2015), Introductory econometrics: A modern approach, Cengage learning.

Wu, H. and Levinson, D. (2020), Unifying access, Transportation Research Part D: Transport and Environment 83, 102355.

Yang, L., Chau, K., Szeto, W., Cui, X. and Wang, X. (2020), Accessibility to transit, by transit, and property prices: Spatially varying relationships, Transportation Research Part D: Transport and Environment 85, 102387.

Zahavi, Y. and Talvitie, A. (1980), Regularities in travel time and money expenditures,
Transport Research Record (750), 13–19.

Zhang, M. and Wang, L. (2013), The impacts of mass transit on land development in China: The case of Beijing, Research in Transportation Economics 40(1), 124–133.

Zhao, Z., Iacono, M., Lari, A. and Levinson, D. (2012), Value capture for transportation finance,' Procedia - Social and Behavioral Sciences 48, 435–448. Transport Research Arena 2012.
https://www.sciencedirect.com/science/article/pii/S1877042812027590

Zhao, Z. J., & Levinson, D. (2012), Introduction to the special issue on value capture for transportation finance. Journal of Transport and Land Use, 5(1), 1-3.