

Access, amenity, and agglomeration: What can we expect from rapid transit projects?

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Abstract

Investment in rapid transit infrastructure is undergoing a renaissance in cities throughout the developed world with development of heavy rail, bus rapid transit and light rail projects. Urban rapid transit projects often pose a conundrum for transport agencies seeking to write robust business cases. Conventional project appraisal methods focus on transport user benefits, but are often less able to capture wider economic benefits arising from land-use change in the rapid transit corridor, including commercial and residential intensification, improvements to public amenity and associated benefits from productivity and consumption-based agglomeration economies.

This paper presents a new approach to ex-ante evaluation of rapid transit projects based on expected uplifts in property values around transit stations. We begin with a relatively simple insight: that a package of positive and negative effects will be capitalised into nearby property values. For example, rapid transit infrastructure that improves transport accessibility or reduces vehicle noise and emissions will enhance property values. In addition, changes in property values will also reflect changes in expectations for future redevelopment and agglomeration potential.

In this paper, we develop a flexible approach for evaluating project benefits based on the potential for property value uplift around transit stations. We use reference class forecasting – i.e. identifying a range of scenarios based on observed outcomes following similar projects – to understand the wider economic benefits of new rapid transit infrastructure. We apply this approach to a case study of a light rail project in Auckland, New Zealand, identify its strengths and weaknesses, and compare it with more conventional approaches to project appraisal. Finally, we discuss how it can be applied to project evaluation in other cities.

1. Introduction

There is a growing body of empirical literature showing positive property value impacts from rapid transit infrastructure. However, these empirical findings have not yet been widely applied to inform ex-ante project evaluation procedures. Property value impacts have been forecast for a limited number of recent projects, but in most cases this analysis has not contributed to formal project appraisal and its wider use is hampered by a lack of a consistent methodology.

This paper investigates the potential for using property value impact analysis as a more central tool for ex-ante appraisal of rapid transit projects. The promise of this approach is that property value uplift offers an already monetised 'value' that reflects many economic benefits arising from a project, including some wider economic benefits that may be difficult to assess through conventional methods. Commuter rail, light rail and bus rapid transit lines can support land-use change and intensification, agglomeration economies, and improvements to amenity and the public realm. Property value analysis may be useful in obtaining monetised values for such benefits.

While outcomes for property value uplift can only be precisely assessed in ex-post appraisal, application of proxy land value uplift values from previous comparable projects may assist in ex-ante appraisal. This paper outlines a method using reference class forecasting techniques to identify and apply proxy values to assess economic benefits from new and improved infrastructure. We apply the method to a sample case study of a light rail project in Auckland, New Zealand.

This paper is structured as follows: in section 2 we briefly discuss theoretical literature on the links between transport infrastructure and property value. We find that rapid transit infrastructure can raise property values through accessibility, amenity, agglomeration and land-use change. In the third section, we review empirical studies on property value impacts from rapid transport infrastructure. We isolate the key variables determining the range of reported impacts and structure a reference class to establish proxy values. In section 4 we discuss how proxy values obtained through our reference class analysis can be used for project appraisal. We then apply our method to several hypothetical light rail projects in Auckland, New Zealand. Finally, in section 6 we discuss the strengths and weaknesses of this approach relative to conventional transport appraisal techniques.

2. Rapid transit investment, property value impacts and economic benefits

This section reviews literature on the relationships between transport infrastructure and property/ land values. We outline a framework illustrating the key mechanisms linking rapid transit investment and property value uplift (Figure 1). Our framework traces the mechanisms by which changes in transport accessibility and environmental amenity around transport infrastructure lead to second-order effects on property development and land-use change. These effects are all reflected in property values.

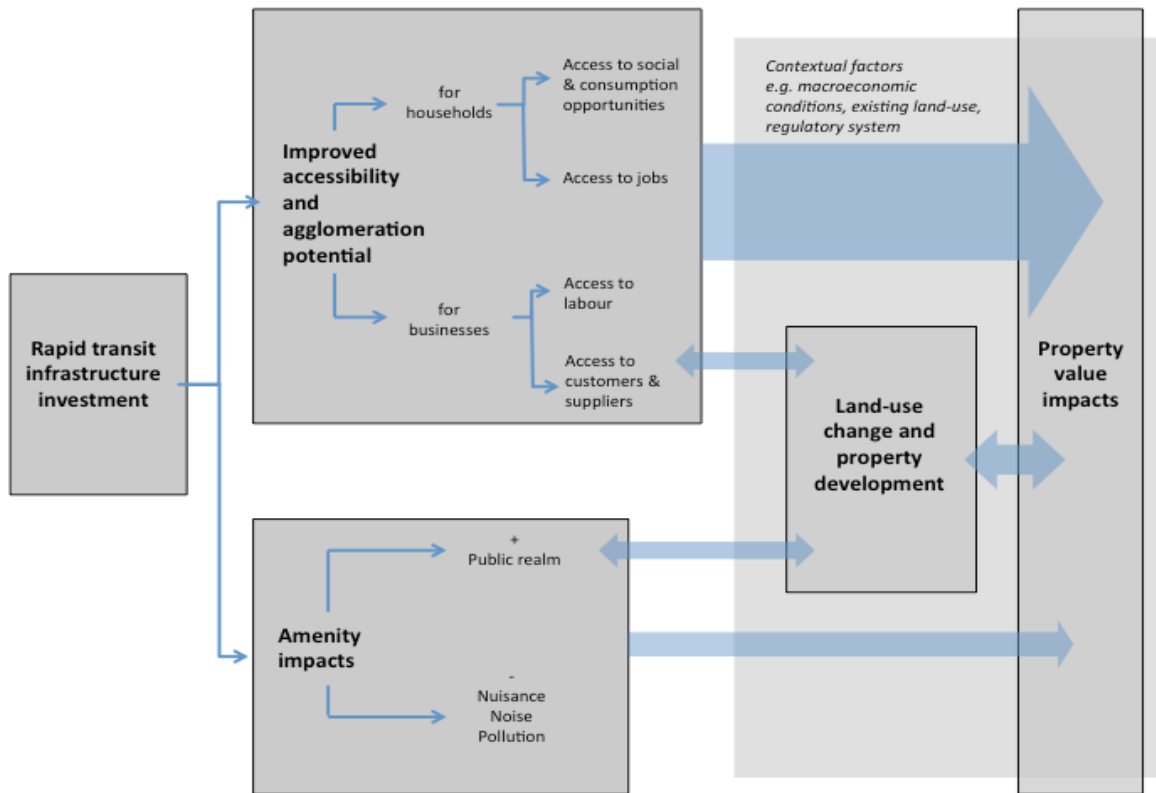
The primary mechanism by which an urban transport infrastructure improvement might increase property value is through the increased accessibility for particular locations enabled by the infrastructure. For example, a new rail line connecting a central business district (CBD) with residential suburbs can mean residential properties near stations benefit from improved accessibility to high-paying employment opportunities. Likewise, CBD-based firms near stations may enjoy better access to wider labour markets.

Urban economics spatial equilibrium models and bid-rent theory explain differential urban land rent as a function of transport costs to certain beneficial locations within a city such as a CBD (Alonso 1964, Muth 1969). In a traditional mono-centric city where employment is concentrated in the CBD, residential land values can be expected to decline with distance from the CBD as commuting costs rise. Conversely, higher residential land values close to the CBD reflect transport time-savings capitalised into higher land values. New rapid transit infrastructure that reduces commuting costs to employment centres can be expected to result in residential property purchasers bidding-up prices to reflect improved accessibility. For CBD commercial office and retail property affected by new rapid transport infrastructure, purchasers can be expected to bid up the price of property in these central locations that benefit from improved accessibility to labour markets, suppliers and customers (McCann 2001).

Improved accessibility can have second-order impacts by increasing the potential for agglomeration externalities that can further contribute to property value uplift. Transport accessibility supports agglomeration externalities at particular locations by enabling a greater ease of interaction between higher numbers of people and firms, increasing the 'economic mass' accessible from a location or its 'effective density' (Venables 2007). The property value impacts from agglomeration externalities are likely to be most significant for CBD locations in large congested cities where new rapid transit infrastructure can allow firms to benefit from denser concentrations of business activity (Chatman and Noland 2014) and

easier access to a larger proportion of the city's labour pool (Prud'homme and Lee 1999). Rapid transit infrastructure may have particular advantages in supporting central city agglomeration economies by enabling larger and denser employment centres than those supported by car-based transport systems with higher spatial demands for road and parking infrastructure (Hazledine et al 2012). There is emerging empirical evidence suggesting that agglomeration economies in dense commercial centres are reflected in land value premiums (Koster 2013).

Figure 1: Conceptual framework linking rapid transit infrastructure investment and property value impacts



In addition to accessibility and associated agglomeration mechanisms driving property value uplift from rapid transit investment, a secondary mechanism linking rapid transit projects with property values is through amenity impacts. Rapid transit infrastructure can create both positive and negative effects on local amenity. For example, a new rail line through a residential area may introduce noise or visual intrusion that negatively impacts property values. Conversely, infrastructure can improve amenity through improvements to public realm/ urban design accompanying the infrastructure or by reducing externality effects of superseded transport infrastructure. A light rail line, for example may improve the amenity of a street by reducing local air and noise pollution from high volumes of buses. As with the accessibility and agglomeration impacts, amenity impacts of rapid transit infrastructure can be very different from those of road-based transport infrastructure. Non-invasive infrastructure such as light rail or underground rail can deliver high levels of passenger transport capacity with lower levels of amenity impact than road infrastructure with equivalent passenger-carrying capacity.

Finally, rapid transit infrastructure can impact property values and the wider economy through land-use change and intensification. As illustrated in Figure 1, land-use change can be understood as a second-order impact arising not directly from new rapid transit infrastructure, but from its accessibility and amenity impacts. Land-use change through property development can occur because developers perceive the location to be more

attractive for development following the introduction of infrastructure and because higher property/land prices incentivise land-use change. Figure 1 shows multiple feedback interactions between property prices and land-use change and between land-use change and accessibility and amenity. Land-use change and property development can increase local accessibility by increasing the levels of local services and jobs available and impact amenity through improvements to the built environment.

The relationships outlined above between rapid transit infrastructure and property value impacts do not represent automatic causal links. While new infrastructure can guarantee accessibility and amenity changes, the subsequent link to property value uplift depends on multiple contextual conditions. Transport infrastructure is a necessary but not sufficient condition for increasing property values and development (Banister and Berechman 2001). For example, the regulatory environment supporting land use change, the general economic climate of the city, property market conditions and availability of finance will all influence the extent to which accessibility and amenity improvements translate into property value uplift (GVA Grimley 2004, Williamson et al 2012).

3. Property value impact analysis for project evaluation

There is a rapidly expanding empirical evidence base supporting the strong relationships between rapid transit investment and localised property value uplift hypothesized by urban economic theory. However, property value analysis has not yet been extensively applied for the purposes of ex-ante project evaluation. This section briefly examines why property value analysis may be useful for evaluation purposes. It compares the approach with conventional evaluation methods and outlines some examples where property value analysis has been used to date in supporting business cases for rapid transit projects.

3.1 Comparison with conventional approaches to project evaluation

Transport project evaluation methods are well-established and a common framework for appraisal is now used across the developed world (Mackie and Worsley 2013). Conventional good practice for economic evaluation in Australia, New Zealand, UK, USA and Germany, among other countries, is based on cost-benefit analysis supplemented by other analytic techniques to capture non-monetised components. In New Zealand, for example, the New Zealand Transport Agency's *Economic Evaluation Manual* establishes a standardised approach for project evaluation.

Project evaluation using property value analysis differs from conventional appraisal in focusing on benefits as reflected in localised property value uplift rather than modelling transport user benefits and other externality effects. While property value analysis may be most appropriately treated as a supplementary tool, rather than as an alternative method, it is useful to contrast the approaches to understand the types of benefits and costs captured by each. Table 1 lists the broad categories of benefits assessed by conventional evaluation methods (based on Mackie and Worsley 2013) and assesses whether these benefits may be captured by local property value impacts arising from rapid transit projects.

As outlined in section 2, urban economic theory suggests that changes to accessibility, productivity or environmental amenity resulting from rapid transit investment will be reflected in property values in affected locations. However, Table 1 highlights that some types of benefits considered by conventional evaluation methods are unlikely to be reflected in property values. For example, changes in localised environmental externalities such as air and noise pollution will be reflected in property values but global externalities such as climate change effects from carbon emissions will not. Some types of transport benefits such as road safety or the public health effects of walking and cycling uptake are also unlikely to be reflected in local property values.

Table 1: Comparing types of benefits considered by conventional and land value analysis approaches to project evaluation

Type of Benefit		Are benefits from rapid transit projects captured by:	
		Conventional appraisal	Property value analysis
Transport user benefits	Travel time savings	Yes	Yes
	Reliability, comfort and crowding	Yes	Yes
	Safety	Yes	No
	Health and fitness	Yes	No
Wider economic benefits (WEB)	Agglomeration	Yes (if WEBs modeled)	Yes
	Imperfect competition	Yes (if WEBs modeled)	Yes
	Land-use change/ regeneration	Infrequently	Yes
Environmental benefits	Noise pollution	Yes	Yes
	Air pollution	Yes	Yes
	Carbon emissions	Yes	No
	Environmental capital	No	No

3.2 Previous use of property value impact analysis for project evaluation

Here, we briefly consider three examples where property value analysis has been undertaken ahead of a project construction and has to varying extents contributed to project decision-making. In all cases the analysis was not part of formal project evaluation procedures and in two cases a key motivation was to investigate the potential for project financing using property value capture mechanisms.

GVA Grimley (2012) forecast property value uplift impacts from the £15.9 billion London Crossrail project, due to open in 2018. A review of academic studies on property value impacts of rail infrastructure was used to identify a ‘value uplift factor’ applied to 500m and 1000m radii ‘zones of influence’ or catchment areas around stations. Uplift factors of 27.5% - 30% were applied to baseline residential property values and 0.5%-27.5% applied to commercial property. The study forecast £5.5 billion of property value uplift between 2012 and 2022.

The Canadian Urban Institute (2010) forecast property value uplift resulting from a planned light rail line in Hamilton, Ontario, Canada. A 400m radius around stations was used as the catchment around 16 stations on the 14km route and an uplift factor of 2% applied to baseline values. An uplift factor of 4% was applied to properties within one street block of stations, while higher values of 8%-14% were applied to vacant land. The study forecast \$CAD280 million of additional property value around the stations over a 15 year period. Capital costs for the project were estimated at \$CAD1billion.

Siemens AG/ City of Turku (2012) forecast property value uplift for a planned 40km light rail system in the Finnish city, costing an estimated €770–€820 million. Uplift factors of 2%-3% were applied to properties within 800m of the stations. Sensitivity testing applied a wider range of uplift factors to developed land (0–11%) and undeveloped land (0–34.5%). The study predicted total property value increase above baseline levels of €480–€850 million under conservative estimates and up to €1.68 billion under higher-impact scenarios.

While no consistent, widely agreed framework for analysis has emerged to date, there are a number of methodological similarities between these studies. All three apply differential property value uplift factors to commercial and residential properties. All methods use a review of academic literature to determine uplift factors. However, there is considerable variation in the size of catchments and level of uplift applied to baseline property values.

4. Developing an evaluation tool using reference class forecasting for property value uplift factors

In this section we briefly outline a general framework for property value analysis before discussing the use of reference class forecasting techniques to specify uplift factors for application across a range of different projects.

4.1 A method for project evaluation using property value analysis

Consistent with the previous practice (outlined in section 3.2) we identify a five-step process for using property value analysis to evaluate rapid transit projects:

1. Identify the project's zone of influence or catchment area
2. Identify baseline property values within the catchment
3. Identify appropriate value uplift factors to apply to properties in the catchment
4. Apply value uplift factors to properties in the catchment
5. Compare total property value uplift (benefits) with project costs.

Our innovation in this process is most relevant to Step 3 in the use of reference class forecasting techniques to systematically identify appropriate value uplift factors based on the particularities of the project and its context. The other steps in the process involve relatively straightforward methodologies and are discussed briefly in our case study in section 5.

4.2 Reference class forecasting for property value uplift factors

In determining value uplift factors for ex-ante evaluation of new rapid transit infrastructure, other studies have all referred to empirical ex-post assessments of property value impacts from projects in different contexts (Canadian Institute of Urbanism 2010, Siemens AG/ City of Turku 2012, GVA Grimley 2012). We follow this method and systematise it in line with reference class forecasting techniques.

Reference class forecasting involves taking 'an outside view' on the estimated costs or benefits of a particular project for the purposes of reducing inaccuracy and bias in the context of decision-making uncertainties (Flyvbjerg 2009). Flyvbjerg explains that: "the outside view is established on the basis of information from a class of similar projects ... [and] places the project in a statistical distribution of outcomes from this class of reference projects" (Ibid., p. 354). The technique is suggested as particularly applicable to forecasting transport infrastructure construction costs, but in this instance we apply the technique to forecasting levels of benefits from transport infrastructure.

Reference class forecasting generally involves three steps: establishing a reference class of comparable projects, comparing forecast levels of benefits or costs of the project being evaluated against the distribution of levels found in the reference class, and finally adjusting forecasts for the project to better reflect the reference class. We broadly follow this approach and establish a reference class 'long-list' of rapid transit projects where property value uplift factors have been determined. We then further filter our long-list into reference class 'short lists' based on two key variables we understand to be central in impacting levels of property value uplift: rapid transit infrastructure type and property type. Finally, we determine a distribution of likely outcomes for property value uplift to be used as guidance for project

evaluation, taking into account other secondary factors such as city size, geographic region and detailed project characteristics.

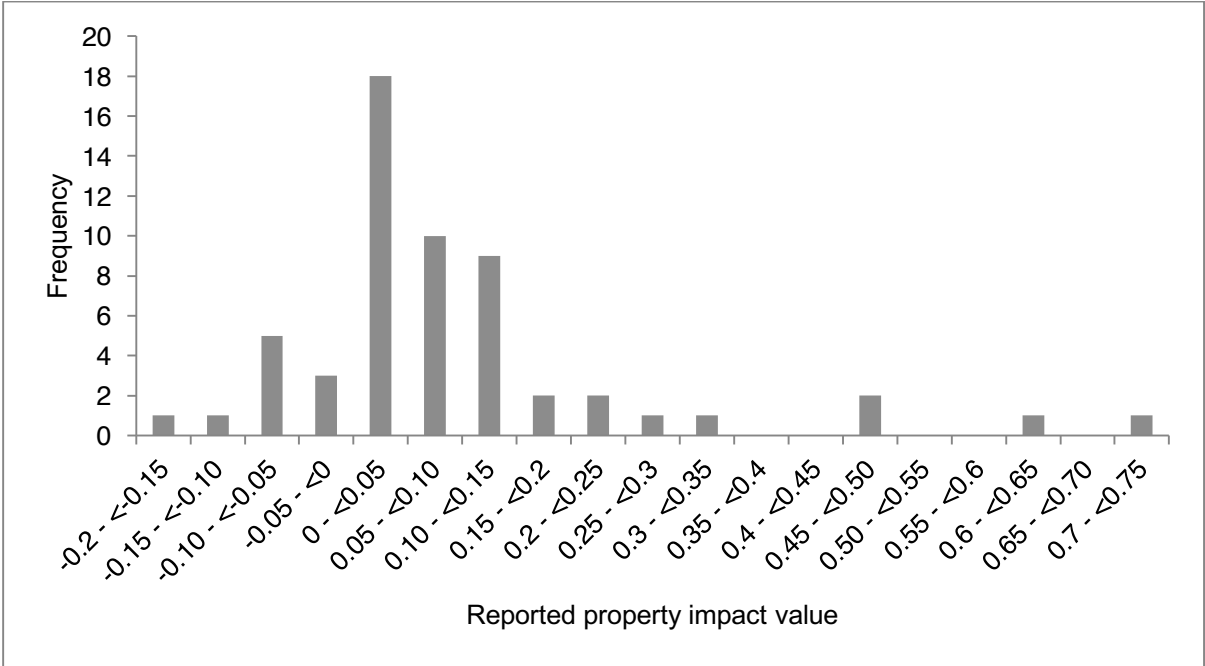
We collate a reference class of rapid transit infrastructure property value impacts by reviewing academic literature on the topic. We confine our literature search to studies published after 1995 and to those that specify percentage property value uplift factors attributable to the construction of new (or substantially improved) rapid transit projects. We consider relevant rapid transit projects to include urban commuter rail, metro rail, light rail and bus rapid transit infrastructure. We include both studies of individual lines and broader systems including multiple rapid transit lines within a single metropolitan area. Our search aimed to provide findings from a broad diversity of geographic contexts (including global location and city size), impacts on different types of property (residential and commercial) and impacts arising from different types of rapid transit infrastructure.

Our literature search result in a collation of 36 studies that document 40 rapid transit projects/ systems in 25 cities throughout North America, Europe, East Asia, Australia and South America. We collect 61 distinct property impact values, with some studies reporting multiple values based on different property types or infrastructure projects. The studies are dominated by findings from North America, with 45 of the 61 values from 21 projects in North American cities. The studies report property impact values from projects in a range of city sizes, with the largest having a population of 25.4 million (Seoul, Korea) and the smallest a population of 1.1 million (Buffalo, USA). The 61 property impact values obtained include 10 from commuter rail projects/ systems, 12 from metro rail, 29 from light rail and 10 from BRT projects.

The 61 property impact values in the reference class reflect either a single average value reported for a project or, if multiple values were reported, a simple average of minimum and maximum reported values if multiple values were provided for a single infrastructure project. The range of reported property impact values was large, from a minimum of -30% impact on property values around a station to 300%. The range of the 61 average values used in the reference class was -21%-150%, with the majority positive values. The distribution of property impact values in the reference class is illustrated in Figure 2 (2 highest and 2 lowest values excluded). Reassuringly, it appears to follow a normal distribution, which Mohammad et al (2013) interpret as evidence that there is no bias against publishing negative results. The majority of the values fall between 0 - 15%. 12 of the 61 values reflected negative property value impacts and only 7 of the averaged values reflected property value uplift of more than 25%. The mean of the 61 values was 11.8% and the median 5.0%. The impact values included in the reference class are derived from studies with a range of methodologies with the majority assessing impact through hedonic price modeling at a single point in time and other studies assessing impact by undertaking 'before/after' analysis over a range of time periods. 'Before/after' analyses tended to focus on a relatively short time period around investments – ten years or less.

These findings are consistent with other meta-analyses. Mohammad et al (2013) conduct a meta-analysis of 23 empirical studies on the property value impacts of rail infrastructure (not including BRT), including 102 observations. They observe a wide variation in estimated property value impacts from -45% to more than 100%. They report a mean from 102 observations of 8.0% and a median of 5.4%. Debrezion (2007) conduct a meta-analysis on studies of the property value impacts of rail stations (again, not including BRT). They report results from 57 observations and similarly report a wide range of property impact values from -61%-145%. They report a mean uplift value of 8.6%. These two meta-analyses report findings that are broadly in line with values found in our reference class. Our average uplift of 11.8% is slightly higher than the 8.0% and 8.6% reported in these analyses and our median value of 5.0% is very similar to the 5.4% reported by Mohammad et al (2013).

Figure 2: Distribution of property impact values in the reference class



These average uplift values could be used as central points of reference for ex-ante project evaluation purposes. However, the very wide variation of observed values suggests caution should be used in applying average values and other explanatory variables should be investigated to improve the reliability of forecasting (Williamson et al 2012). We therefore recommend a second step in reference class analysis, reducing our reference class of 61 values to sub-sets of values and their distributions for different types of rapid transit infrastructure (for example Light Rail and Commuter rail) and different types of property (residential and commercial). These “short lists” can then be narrow further to account for other variables of interest, such as city size and structure or scheme characteristics. However, we note that defining a tightly focused reference class is challenging due to the small number of studies in some categories.

Mohammad et al (2013) assess 21 contextual factors and 7 methodological factors that vary across studies of rail infrastructure impacts on property values. They isolate five factors that are highly significant in explaining the wide variation in findings: measurement of property or land values, the type of property (commercial or residential), the type or rail infrastructure, the distance from the station and a methodological factor of whether cross-sectional or longitudinal data is used. Debrezion’s (2007) meta-analysis investigates how seven variables explain variations in study findings and consistent with two factors identified by Mohammed et al (2013) also find that property type and infrastructure type, alongside demographic factors in the station catchment, are highly significant in explaining variation.

Based on the findings of these meta-analyses, analysis of our own reference class, availability of information within studies and applicability to ex-ante forecasting we isolate two variables that must be considered when refining a reference class: property type and infrastructure type. Other variables are also likely to be of interest, depending upon the project. This is designed to enable more reliable application of property impact values depending on the context of the project under evaluation.

First, an analysis of our reference class found significant variation in the range and distribution of property value impacts according to whether the type of property measured was residential or commercial (Table 2). Average uplift values were found to be higher for commercial than for residential property, although a considerable range of values were reported and the sample of studies on commercial property impacts was much lower. Two

studies from the overall reference class are classified as ‘other’ in Table 3 as they reported impacts on industrial and un-zoned vacant land.

Table 2: Property value impacts in the reference class by property type

	Overall	Residential	Commercial	Other
Average	12%	7%	17%	71%
Median	5%	5%	2%	71%
Max	150%	64%	91%	150%
Min	-21%	-17%	-21%	-9%
Count	61	46	13	2

Higher values for commercial property are also found by the two other meta-analyses on the topic and in other reviews of the literature (GVA Grimley 2004). Mohammad (2013) finds that commercial property tends to exhibit significantly higher property/ land value changes, with a premium of between 24 and 31 percentage points for commercial over residential property. Debrezion (2007) finds that uplift for property within 400m of a rail station averages 4.2% for residential, but is almost four times higher at 16.4% for commercial property.

Second, analysis of rapid transit infrastructure type also found variation in the property value impacts of commuter, metro, light rail and bus rapid transit projects (Table 3). Average uplift values were highest for commuter rail and light rail at 17%, with BRT and Metro projects showing significantly lower impacts at 2% and 3% respectively.

Our analysis of the impacts of rapid transit infrastructure type is somewhat consistent with previous literature. Mohammad’s (2013) meta-analysis finds that commuter rail has the highest positive impact on property values, although comparison of heavy and light rail shows little variation between the two and the potential negative noise and other externalities of overground heavy rail are suggested as countering its potentially greater accessibility advantages. Debrezion (2007) also finds a premium for commuter rail over metro or light rail, suggested as reflecting its speed and accessibility advantages. In contrast to our findings, no significant difference is found between metro and light rail. Neither of these two meta-analyses compares BRT with rail-based systems. Salon and Shewmake (2011) review the literature and report lower uplift values for bus-based systems compared to rail. Cervero and Duncan (2002) and Ma et al (2014) compare property value impacts of rail and BRT-based infrastructure within Los Angeles and Beijing respectively and find significantly lower impacts from BRT lines.

Table 3: Property value impacts according to infrastructure type

	Overall	Commuter rail	Metro rail	Light rail	Bus Rapid Transit
Average	12%	17%	3%	17%	2%
Median	5%	5%	5%	10%	3%
Max	150%	91%	27%	150%	10%
Min	-21%	-7%	-21%	-17%	-11%
Count	61	10	12	29	10

4.3 Specifying proxy property impact values for project evaluation

We recommend the following process for defining an appropriate reference class for analysis and defining proxy values for property value uplifts following a specific rapid transit project. First, filter the long list of project evaluations according to type of rapid transport infrastructure and property type. Second, if the projects in the short list include some that are located in cities with substantially different population sizes or urban forms, filter them out. Third, summarise the results from the remaining reference class into a range of potential

values for property value uplift, distinguishing between values for residential and commercial property and including an average value and a confidence interval. In defining an appropriate reference class for a particular project, consideration should be given to both narrowing the reference class to the most comparable projects but also including sufficient values to ensure a reasonable sample size.

5. Applying our method to a case study

In this section, we apply the method outlined in section 4 to a case study in Auckland, New Zealand's largest city.

5.1 Project background

We consider three hypothetical Light Rail Transit (LRT) alignments in Auckland: a Western Bays line running from the city centre to Mount Albert via Point Chevalier; a Tamaki Drive line running from Britomart to St Heliers along the waterfront; and a Botany to Manukau line running between Botany and Manukau town centres. Potential alignments and station locations are depicted in Figure 3. While Auckland Transport is considering options for developing LRT corridors, these alignments are not currently under investigation. However, all three have been discussed as potential corridors, or, in the case of the Western Bays line, have historically been used as a tram corridor.

5.2 Step 1: Identifying catchment areas

For defining a catchment area within which property value impacts are relevant, previous empirical studies have used either threshold distances around stations (usually a simple radius mapped around a station) or estimated rates of decay in property value premiums with increasing distance from stations. For the purposes of ex-ante project evaluation, a threshold measure is likely to be most tractable.

Based on our review of empirical studies and previous meta-analyses we identify an 800m radius around stations as appropriate for this light rail case study as illustrated in Figure 3. While property value impacts may extend further and are commonly reported beyond 1000m distant from stations, decay rates with distance are also frequently reported and the most significant impacts are likely to occur within 800m (Mohammad et al 2013, GVA Grimley 2004). Although some previous studies suggest smaller catchment areas are relevant for commercial property (Debrezion 2007, GVA Grimley 2004), our review of empirical studies finds no consistent evidence on different catchment areas according to property type and thus we use an 800m catchment for both residential and commercial property. A more precise method for defining catchment areas could use street/ pedestrian network distance, rather than straight line distance from stations.

5.3 Step 2: Identifying baseline property values

Baseline property values within the catchment areas are a key input into our analysis. High values tend to indicate that locations are intensely used or in high demand and, hence, that the potential for economic benefits from improved accessibility are likely to be relatively high. GVA Grimley (2004) recommend the use of property transaction records or government property valuations used for tax purposes. Empirical studies have used various datasets including sales transactions, listed sales prices and valuations for property tax assessment. For the purposes of this case study, we have estimated current land values as a function of two key variables that have been found to have a significant effect on property values: proximity to the city centre (DCBD) and proximity to the coast (DCOAST)¹. We model

¹ See for example Grimes and Liang (2007), Donovan (2011), and Nunns et al (2015), as well as a range of other hedonic price studies of Auckland property prices.

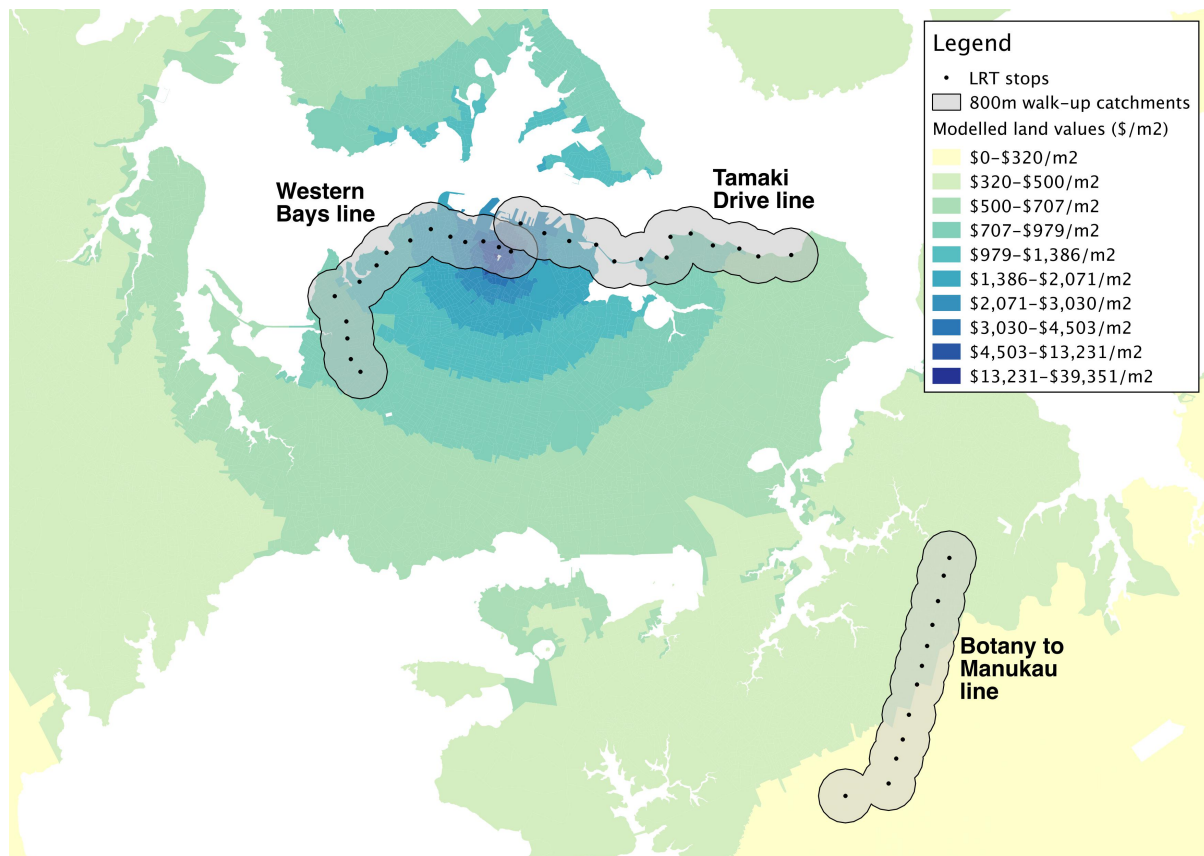
residential and business land values at a detailed geographic level based on the results of a simple hedonic analysis of Auckland land valuation data². We find that these two explanatory variables explain roughly 52% of the variation in land values. Equation 1 describes our model of land values in a given meshblock (LV_i).

Equation 1: A simple model of Auckland land values

$$LV_i = 1.024 * \exp (13.255 - 0.730 * \ln(DCBD_i) - 0.048 * \ln(DCOAST_i))$$

Modelled land values deviate from actual land values in some areas, especially where other localised amenities/ disamenities are present. Nonetheless, this simple model of land values reflects the value placed on proximity to employment and other opportunities in the city centre, and to the coast, which reflects environmental amenities. After modelling land values at a meshblock level, we allocate land values to commercial or residential property based on the ratio of residential population to jobs from the 2013 Census³.

Figure 3: Walk-up catchments and modelled land values around three hypothetical LRT lines



²We estimate the following ordinary least squares (OLS) regression model on Auckland residential and business land values:

$$\ln(LV_i) = \beta_0 + \beta_1 \ln(DCBD_i) + \beta_2 \ln(DCOAST_i) + u_i$$

We obtained the following estimates of the model parameters: $\beta_0=13.255$; $\beta_1=-0.730$; $\beta_2=-0.048$. We also estimated a correction factor of 1.024 to use when transforming from logged land values [$\ln(LV_i)$] to dollar values [LV_i]. All coefficients were statistically significant at the 1% level. However, we caution that these results are influenced by the exclusion of a number of other explanatory variables.

³ For example, in area with 100 residents and 100 jobs, we would assume that 50% of land was used for housing and 50% of land was used by businesses. This is an indicative figure only.

Table 4 summarises the total land area and estimated land values within catchments around each of the three LRT lines. As indicated by the above map, the land around the Western Bays line is likely to be most valuable – indicating the relatively high demand for residential and commercial uses in these areas and, potentially, relatively high potential for redevelopment provided that it was zoned appropriately.

Table 4: Land areas and values around three hypothetical LRT lines

Line	Track length (km)	Total property area (ha)	Estimated residential land value	Estimated commercial land value
Western Bays	9	821	\$8.3bn	\$6.6bn
Tamaki Drive	9.6	518	\$3.0bn	\$3.6bn
Botany to Manukau	8.8	893	\$1.7bn	\$1.2bn

5.4 Steps 3 and 4: Identifying and applying property value uplift factors

Based on our reference class forecasting method outlined in sections 4.2 and 4.3, we identify an appropriate range of property value uplift factors by establishing a short list of values from comparable projects. We filter our reference class ‘long list’ to isolate property impact values for light rail infrastructure, commercial and residential property types and values from comparable cities (filtering for North American and Australian projects). This results in 14 values for residential property uplift factors and 6 values for commercial property. The values represent findings from 9 projects in 8 North American cities (Golub et al 2012, Duncan 2010, Goetz et al 2010, Rewers 2009, Cervero & Duncan 2002a, Cervero & Duncan 2002b, Cervero & Duncan 2002c, Clower & Weinstein 2002, Chen et al 1997). We obtain an average uplift factor for residential and commercial property of 7% and 24% respectively. We establish a range of values based on median, 25th and 75th percentile values. Our low, medium and high impact scenarios use property uplift factors of 2%/ 6%/ 11% and 5%/ 18%/ 29% for residential and commercial property respectively. We apply these uplift factors to baseline property values in the LRT catchments to obtain an indicative range of potential benefits from the project (Table 5).

Table 5: Potential range of benefits from three LRT lines

Line	Low scenario	Medium scenario	High scenario
Western Bays	\$0.5bn	\$1.7bn	\$2.8bn
Tamaki Drive	\$0.2bn	\$0.8bn	\$1.4bn
Botany to Manukau	\$0.1bn	\$0.3bn	\$0.5bn

5.5 Step 5: Comparing project benefits and costs

Finally, we consider – at a high level – whether these projects are likely to pass a cost-benefit test. One simple method is to consider whether per-kilometre benefits, proxied by property value uplift, are likely to exceed per-kilometre costs to construct LRT. We assume that separated LRT in existing road corridors costs approximately \$60 million per kilometre to construct, and \$20million per kilometer for vehicle and operating costs (discounting future costs to today’s dollars). (Actual project costs will vary depending upon technical specifications and route characteristics.) Based on the figures reported in Tables 4 and 5 above, we have calculated an indicative range of benefit-cost-ratios for these three lines.

Table 6 suggests that the Western Bays line is most likely to provide economic benefits that exceed its costs. Other lines do not perform as strongly. In the case of the Botany to Manukau line, this is due largely to the relatively low land values in the area, which signal a lack of demand for more intensive uses or for accessibility improvements to high value

commercial centres. In the case of the Tamaki Drive line, land values are higher, but the catchment area is smaller due to the fact that it runs directly on the coastline.

Table 6: Potential range of benefit-cost ratios for three LRT lines

Line	Low scenario	Medium scenario	High scenario
Western Bays	0.7	2.3	3.9
Tamaki Drive	0.3	1.1	1.8
Botany to Manukau	0.1	0.4	0.8

6. Discussion

This paper has sketched a method for undertaking property value impact analysis for the purposes of ex-ante evaluation of rapid transit infrastructure. The method is designed to be flexibly applied to a range of different project types across various urban contexts. The method makes use of a rapidly growing empirical literature on property value impacts from rapid transit infrastructure and contributes to a much narrower, but also growing range of studies that attempt to apply these findings to ex-ante evaluation of projects. The method follows the broad framework established by these previous studies but advances it by using reference class forecasting techniques to systematically select comparator projects for evaluation purposes.

There remain various ways in which the method may be further refined and developed. For example, the reference class established remains reasonably small and more reliable forecasts for project evaluation will be more firmly established alongside developments in the empirical literature. There are various details of the methodology that could be further investigated and small changes may have significant impacts on the findings of project evaluation using the method. For example, benefit-cost ratios produced with the method will depend heavily on the level of underlying property values and whether land or property values are used as baseline measures.

While the method remains experimental at this stage, there is considerable promise for the approach as it overcomes well-recognised shortcomings of conventional appraisal methods. The tool accounts for a broad range of local amenity, accessibility and wider economic impacts of infrastructure on the basis of real prices paid in property markets as opposed to modelled prices that underpin benefits valued by conventional transport appraisal. Property value analysis tools fit within a broader set of emerging techniques for measuring wider economic benefits from transport infrastructure. As a 'micro-scale' assessment tool, rather than macro (national scale) or meso (urban regional scale) technique for evaluation (Banister and Thurstain-Goodwin, 2011), it may be particularly well-suited to rapid transit projects, which have benefits that tend to be more spatially concentrated around infrastructure than those arising from road-based transport projects.

However, as the assessment tool operates at the micro-scale, there are uncertainties about the extent to which benefits measured can be considered net benefits to society, or spatial redistributions of benefits toward urban locations served by the new infrastructure. The method lends support to projects that serve urban areas with high underlying property values, with risks that this could favour investment in locations occupied by relatively high-income residents or in areas that already benefit from relatively good transport infrastructure, while not recognising the benefits of more transformational projects. There also remain questions about how the method may sit alongside existing appraisal. At this stage, the method remains experimental and should not be used alone for project assessment. It may however, valuably complement other project evaluation methods.

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