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A supply-constrained approach to land use forecasting based on development feasibility modelling and land value uplift

Lee Jollow[1], Brent Winter[2]

[1] National Lead Investment and Economics, Etheus: Lee.jollow@etheus.com.au

[2] Director Investment and Economics, Etheus: Brent.winter@etheus.com.au

Abstract

Alternative land use forecasts are required for transport projects estimating urban renewal benefits from land use change. A limitation of some current approaches is they do not explicitly account for supply-side constraints, which may overstate the land use outcomes that could be achieved in practice. This professional practice paper presents an approach that constrains land use forecasts based on wide area development feasibility modelling and isolates the incremental land use uplift based on the change in land values because of the project. It identifies several advantages, limitations, and opportunities for refinement of this approach, drawing on professional reflections from the authors' applied experience with light rail on the Gold Coast.

1. Introduction

1.1 A conceptual framework for transport-induced land use change

Transport investment can provide a step change in transport capacity, connectivity and amenity that is sufficient to enable changes to planning controls (such as rezoning[1], height limits and floor space ratios) and/or influence where people live and work. This is particularly the case for mass transit modes such as rail, light rail, and bus rapid transit.[2]

There are established approaches in transport economic appraisal guidelines to estimate a range of urban renewal benefits from land use change where these conditions are met. These benefits include higher value land use, second-round transport benefits, public infrastructure cost impacts and sustainability impacts from reduced heating and cooling of more compact dwellings.[3]

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[1] Zoning refers to types of permittable land use for a location, including different categories of residential, commercial, mixed use of industrial purposes and densities.

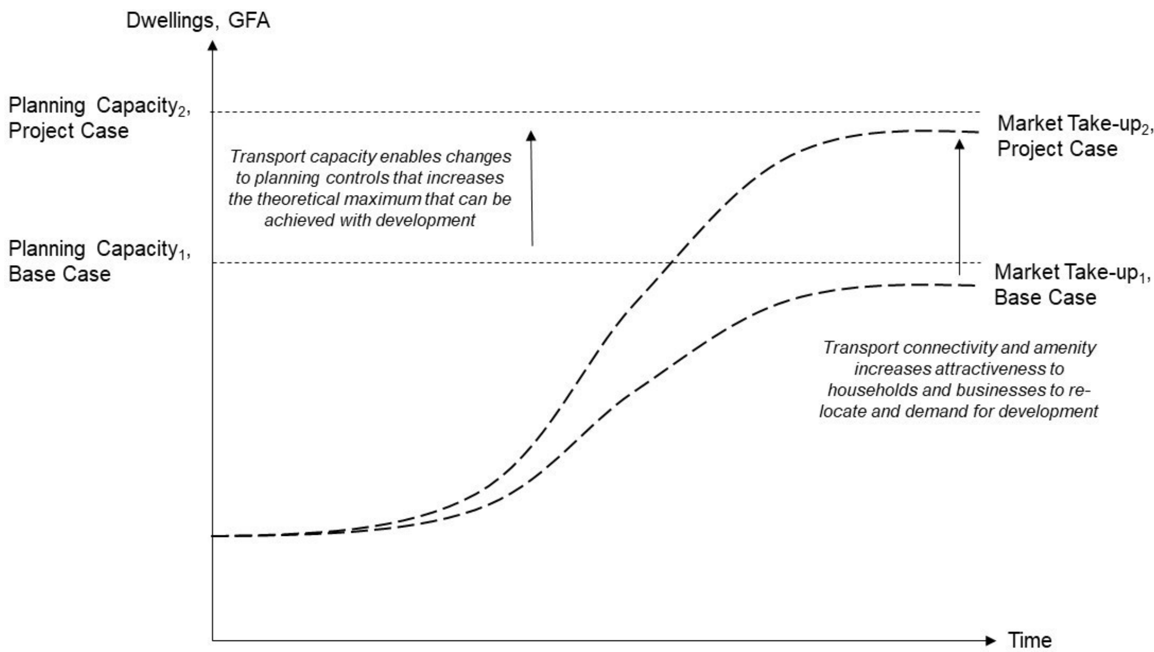
[2] See, for example: Infrastructure and Transport Ministers, "Australian Transport Assessment and Planning, Framework: F0.2 Integrated transport & land use planning", available at: https://www.atap.gov.au/framework/integrated-transport-land-use-planning/index, accessed 19th July 2023; Infrastructure and Transport Ministers (2021) Australian Transport Assessment and Planning Guidelines, Module 08 Land-use benefits for transport initiatives, pp5, 8, 14; Infrastructure Australia (2021) 'Guide to economic appraisal', p44.

[3] Infrastructure and Transport Ministers (2021) Australian Transport Assessment and Planning Guidelines, Module 08 Land-use benefits for transport initiatives, pp14ff; Infrastructure Australia (2021) 'Guide to economic appraisal', pp 45-46 & Appendix C.

Estimating urban renewal benefits requires alternative land use forecasts, first excluding the transport project being assessed (base case[4]) and then including it (project case). Typical outputs of land use forecasts in this context include dwellings by type (attached and detached), population, commercial gross floor area (GFA) and jobs (full time equivalent). Future forecast years will normally be determined by the transport demand modelling.[5]

Figure 1 shows a conceptual framework for how mass transit may increase planning capacity or market take-up of dwellings and GFA to increase population and jobs within the walking catchment of mass transit stations.[6]

Figure 1: Conceptual framework for transport-induced land use change



Source: Jollow, L and Winter, B. (2023).

1.2 Land use forecasting approaches for transport economic appraisal

There are several approaches to land use forecasting outlined in Australian transport economic appraisal guidelines, but no consensus on the single best approach. Identified alternatives include land use attractiveness models, land use and transport interaction (LUTI)

[4] The base case is the counterfactual against which all changes are incrementally measured. It is generally "do minimum" rather than "no nothing" and therefore includes committed/funded future infrastructure investment and ongoing expenditure to maintain minimum service standards. See Infrastructure Australia (2021) "Guide to economic appraisal, Technical guide of the Assessment Framework", pp17-18. The development feasibility modelling approach presented in this paper includes current land values in the Base Case, which are reflective of current planning controls and the connectivity/amenity of current infrastructure, noting that land value uplift generally occurs from credible announcement rather than construction or operations (and therefore land values should account for committed/funded future projects).

[5] In the example, land use forecasts were prepared in 5-year increments to 2041.

[6] In the development feasibility approach, transport connectivity and amenity are reflected in land values which are expected to increase with the introduction of mass transit and therefore result in more development being estimated to be feasible. Mass transit investment may also increase land values through enabling rezoning or generate economies of scale for developers through increased height limits or floors space ratios, thereby increasing the scale of development at a particular location.

models[7], dependent development frameworks, computable general equilibrium models, Geographic Information System (GIS) based methods, and urban simulation models[8]. Development feasibility modelling, which is the subject of this professional practice paper, is identified as a sub-set of GIS-based methods.

Land use attractiveness and land use and transport interaction (LUTI) models have been applied most commonly in Australian transport appraisal, but a key limitation is they "generally do not consider supply-side constraints very effectively by themselves".[9] This means that land use forecasts may not be achieved in practice without alleviating these constraints, for example, through further investment beyond what is assumed in the base case or directly attributable to the transport infrastructure being assessed. This could potentially overstate the base case land use forecasts, which are the starting point of the assessment, and/or overstate the land use uplift attributable to the project being assessed. Further, "some are proprietary models or have licensing requirements" and "require significant expertise to operate"[10] making the results difficult to interpret or replicate.

A development feasibility approach introduces additional supply-side constraints and is therefore being presented as a potential alternative or supplement to these approaches. As with all current land use forecasting approaches there will be tradeoffs, so this paper seeks to unpick the advantages, limitations, and opportunities to assist in charting a course for future research of refinement of guidelines.

1.3 Professional reflections from Gold Coast light rail

To support the findings of this paper, the authors have included professional reflections based on their applied experience from Gold Coast light rail. This focuses on analysis of publicly available information to make the examples more useful for general application while maintaining project confidentiality.

The Gold Coast example is informative because the city has an extensive light rail network, with plans for future extensions. This includes:

- Existing 21-kilometre light rail network with 19 stations from Helensvale to Broadbeach South.[11]
- Construction is underway to extend light rail by 7 kilometres with 8 stations from Broadbeach South to Burleigh Heads (expected completion in 2025).[12]

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[7] Note that LUTI models are land use attractiveness models integrate with a transport model.

[8] For descriptions of each of these models, including strengths and weaknesses, see Infrastructure and Transport Ministers (2021) Australian Transport Assessment and Planning Guidelines, Module 08 Land-use benefits for transport initiatives, pp10-11.

[9] Ibid, pp10-11.

[10] Ibid, pp10-11.

[11] G:link, available at: https://ridetheg.com.au/, accessed 18th August 2023. Total light rail network distance from Helensvale to Broadbeach South based on GoldLinQ, "Gold Coast Light Rail Stage 3, Broadbeach to Burleigh Head", available at: https://www.gclr3.com.au/goldlinq/gclr3, accessed 23rd August 2023.

[12] Queensland Government Transport and Main Roads, "Gold Coast Light Rail (Stage 3a) Broadbeach South to Burleigh Heads, construct light rail", available at: https://www.tmr.qld.gov.au/projects/gold-coast-light-rail, accessed 18th August 2023.

- Investigations are underway from Burleigh Heads to Coolangatta via Gold Coast Airport.[13]

Light rail generally provides the step-change in capacity, connectivity and amenity required to catalyse land use change because of:[14]

- Frequent ‘turn-up-and-go’ services with high-capacity vehicles.
- Reliable and smooth journeys on rails in high-amenity vehicles.
- Opportunities for complementary place-making such as public plazas, green space and active transport infrastructure around light rail stations.
- Longer-term asset lives with rails and raised stations (50-100 years).[15]

The Gold Coast also has several features which make it suitable for light rail, including:

- Natural amenity from beaches, waterways, and national parks.
- A mix of land uses that are activated throughout the day (not just during peak commuting times) including universities, commercial centres, healthcare facilities and Gold Coast Airport.
- Areas of relatively low-density development and car dependency where existing planning capacity is not being taken up by the market (including the area currently under investigation from Burleigh Heads to Coolangatta).

It should be noted, however, that the focus of this paper is on the conceptual framework of the development feasibility modelling approach. The assumptions presented in this paper are location-specific and would need to be tailored for each specific project to match prevailing local market conditions, land uses and planning controls.

2. Land use forecasting approach

A key strength of the development feasibility approach to land use forecasting is that it addresses key economic appraisal guideline requirements around attribution of land use change to the project[16] by introducing additional supply-side constraints. Attribution is clearly demonstrated by applying the same development feasibility modelling to both the base case and project case, and only changing land values as a result of the project while controlling for other factors.

As illustrated in Figure 2, below, a four-part framework was developed which includes:

- **Sourcing baseline land use forecasts:** Generally, government forecasts prepared for a large area such as a region or state, comprised of smaller boundaries based on Australian Bureau of Statistics (ABS) statistical areas (SAs).
    - Development feasibility is used as a means of testing supply-side reasonableness of forecasts.

[13] Queensland Government Department of Transport and Main Roads, “Gold Coast Light Rail Stage 4”, available at: https://www.tmr.qld.gov.au/projects/gold-coast-light-rail-stage-4, accessed 18th August 2023.

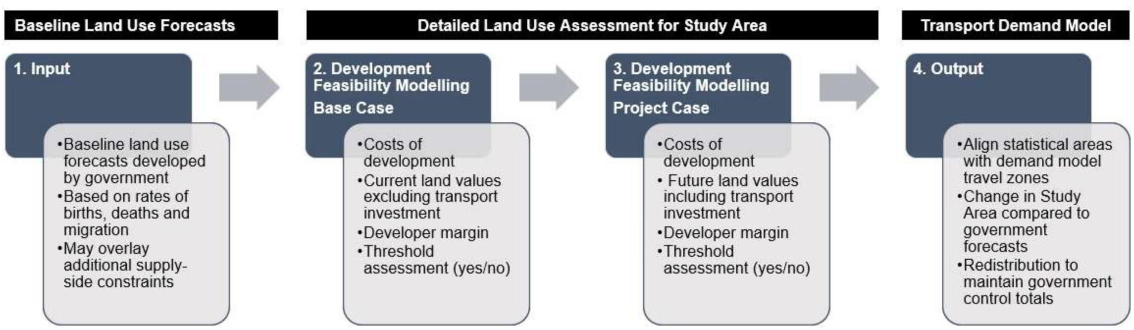
[14] Australasian Railway Association (2021) ‘The Renaissance of Light Rail, Research Paper’, available at: https://ara.net.au/wp-content/uploads/The_Renaissance_of_Light_Rail.pdf, accessed 3rd August 2023.

[15] Transport for NSW (2016) “Principles and Guidelines for Economic Appraisal of Transport Initiatives”, Table 77, p308; Australian Transport Council (2006) “National Guidelines for Transport System Management in Australia, Part 4: Urban Transport”, p44.

[16] Infrastructure and Transport Ministers (2008) “Australian Transport Assessment and Planning Guidelines, Module 08: Land-use benefits of transport initiatives”, p44.

- **Wide area development feasibility modelling for the base case:** Estimates the costs of development assuming current land values to determine whether a threshold rate of return is exceeded (i.e., development occurs) or not (i.e., development does not occur).
    - Where forecasts are unable to meet profitability targets, these are deducted from the base case forecast.
- **Wide area development feasibility modelling for the project case:** Repeats the same modelling, but including additional developer returns where land values increase as a result of the project. This results in additional development being assessed as feasible, concentrated around stations.
    - Land value uplift is modelled based on several inputs including existing literature, and original land value uplift modelling specific to the Gold Coast.
- **Outputs for transport demand models:** Cover larger areas such as regions to account for behavioural change because of the transport project. This requires:
    - Aligning boundaries between the detailed land use assessment and transport demand model, which may use different travel zones.
    - Re-distribution of baseline land use forecasts outside the study area[17], so that region-wide control totals are maintained. For example, if the land use assessment is higher (or lower) in the study area, then there would be a corresponding reduction (or increase) outside the study area so that the totals are the same for the region.

Figure 2: Land use forecasting framework



Each of these steps is discussed in more detail in the following sections.

2.1 Baseline land use forecasts

Transport economic appraisal generally uses government land use forecasts for both the base case and project case, with only the transport infrastructure differing between these two cases. In the Gold Coast case study, the latest population and dwelling forecasts were sourced from

[17] Land use assessments are generally relatively data intensive and so are prepared for smaller study areas concentrated around the transport infrastructure alignment and station. In the example, this covers SA2s between Burleigh Heads to Coolangatta via Gold Coast Airport.

the Queensland Government Statistician's Office (QGSO) 2018 edition medium series at SA2[18], and employment projections were from Transport and Main Roads (TMR)[19].

One challenge with using government land use forecasts is that they are generally not fully supply-side constrained, which means that further investment or changes to planning controls may be required to achieve them in practice. For example, the QGSO 2018 population forecasts are based on core assumptions of fertility, mortality, and migration as well as assumptions about living arrangements and propensities for household formation and timing of dwelling construction.[20]

In the Gold Coast example, a key input was the City of Gold Coast's Planning and Urban Growth Model[21], which uses the same baseline government land use forecasts but incorporates additional Local Government Infrastructure Plan (LGIP) assumptions and additional constraints layers including vegetation protection, ecological values, stormwater and drainage corridors, slope, bushfire and landslide hazards, heritage, airport environments, coastal erosion, extractive resources, floodings, land use buffer requirements, tenure-related constraints, easements and licenses. These inputs were also more granular and enabled development feasibility modelling at the lot level.

It is noted that a potential outcome of using a constrained base case in transport economic appraisal is inconsistency with the base case for conventional transport projects, which tend to adopt government forecasts without further constraint. Although inconsistency on its own is not necessarily a limitation, it means that transport benefits for projects forecasting land use change tend to be lower because these are calculated using the lower base case scenario. However, this should be offset by additional land use benefits which need to be given equal weight in decision making as this should reflect the underlying objectives of the project. For comparability, it may be desirable to also include a sensitivity test that calculates transport benefits alone based on unconstrained government land use forecasts.

Another challenge is the timing of government land use forecasts being developed relative to project development. For example, QGSO 2023 population projections have recently been released (June 2023) but the 2018 household and dwellings projections remain the current edition[22]. However, these do not account for the impacts of COVID-19. As such, projects should be aware of the timing of new releases and have contingencies in place to deal with the implications of these updates including scenario testing.

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[18] QGSO, "Housing and dwelling projections", available at: https://www.qgso.qld.gov.au/statistics/theme/population/household-dwelling-projections/regions, accessed 21st August 2023.

[19] The Department of Transport and Main Roads (TMR) Employment projections based on QGSO with National Institute of Economic and Industry Research (NIEIR) small area allocation (2015 edition) employment projections.

[20] Queensland Government Statistician's Office, "Queensland Government dwelling projections, 2018 edition: Methodology", available at: https://www.qgso.qld.gov.au/issues/8381/qld-government-dwelling-projections-methodology-2018-edn.pdf, accessed 21st August 2023.

[21] For a general description see Saad (2021) "Next generation Planning & Urban Growth modelling – it's a PUG's life", prepared for the Institute of Public Works Engineering Australasia SEQ Branch Conference Caloundra, 24-26 February 2021. Note that assumptions in this paper, including LGIP, may vary from the latest version of the model.

[22] QGSO, "Population Projections, Regional", available at: https://www.qgso.qld.gov.au/statistics/theme/population/population-projections/regions, accessed 21st August 2023.

2.2 Base case wide area development feasibility modelling

Land and property development generally constitutes a prolonged and risky undertaking. The timeline for a typical low-density or medium-density suburban project spans 3-5 years from inception to completion. Consequently, these projects consider both prevailing market dynamics and enduring perspectives encompassing factors such as pricing, vacancy rates, interest rates, employment opportunities, and job market expansion, among others.

Instances arise where development parcels are strategically held and 'banked' until more favorable market conditions materialise. This can notably impact transport appraisal, a domain exceedingly sensitive to temporal variables as a result of discounting future cashflows. Although overarching population growth rates may underpin housing demand over the long term, immediate and intermediate market conditions frequently lead to the prioritisation of specific locations, thus complicating transportation planning and service provision.

Development feasibility modeling adopts a discounted cashflow methodology to appraise the viability of a given project. This approach evaluates the inflows and outflows associated with developing a designated site, contingent upon the attributes of the proposed dwellings. Its objective is to ascertain the profitability of developments and furnish proactive insights into critical thresholds across an array of potential factors. It is generally applied at a micro level to specific sites and development opportunities; however, using tools from QGIS[23] and R programming language[24] it was adapted on a lot-by-lot basis across a wider area.

To do this, government forecasts from the City of Gold Coast's Planning and Urban Growth Model and overlaid at a lot-level. Where forecasts suggested dwelling increases occurred, site acquisition costs, construction 'hard' costs, and project 'soft' costs were deducted from the estimated end sale value. Where the margin was less than the target developer return adjusted for risk, these were deducted from the forecast to form the Base Case. Low, medium, and high scenarios were also derived to bookend best and worst-case forecasts.

Table 1 below presents notional assumptions for wide area development feasibility modelling considering the following:

- Construction costs (e.g., Rawlinsons Australian Construction Cost Handbook[25] and RLB Construction Cost Calculator[26]).
- Development 'soft costs' like architecture, engineering, project management, accounting, legal and financing (published sources and advice from industry partners).[27]

[23] See QGIS, "A Free and Open Source Geographic Information System", available at: https://qgis.org/en/site/, accessed 31st August 2023.

[24] See R Project, "What is R?", available at: https://www.r-project.org/about.html, accessed 31st August 2023.

[25] See, for example, Rawlinsons Cost Management, "Rawlinsons Australian Construction Handbook 2023 – Edition 41", available at: https://www.rawlhouse.com.au/publications/2023-australian-construction-handbook, accessed 23rd August 2023.

[26] See, for example, Rider Levett Bucknall (RLB), Construction Cost Calculator", available at: https://www.rlb.com/ccc/, accessed 23rd August 2023.

[27] See for example, Rawlinsons Cost Management, "Rawlinsons Australian Construction Handbook 2023 – Edition 41", or various publicly available feasibility reports through the council or State Government websites.

- Sales data (e.g., from RP Data[28] or Colliers Research[29]).
- Minimum risk-adjusted rate of return for a developer to invest in a project.

Table 1: Notional assumptions for wide area development feasibility modelling

Parameter	Value
Hurdle margin (risk-adjusted) for developer investment	16%-22%
Construction cost (/m^2 GFA)	\$2,800 (house/semi-detached), \$3,200 (commercial/retail), \$4,900 (unit)
Soft costs (depending on type of development)	15% (house/townhouse) - 30% (unit/commercial)
House/semi-detached size (m^2 GFA) 3 / 4 / 5 / other bedroom proportions (% of total)	150 60% / 30% / 5% / 5%
Unit size (m^2 GFA) 1 / 2 / 3 bedroom proportions (% of total)	105 15% / 50% / 45%
Quality splits	60% medium finish / 40% high finish
Time horizon (depending on estimated cost)	3-5 years

2.3 Project case wide area development feasibility

The only change in the project case is the uplift in land value attributable to the project, with development feasibility re-estimated while holding all other variables constant and then added to the base case land use forecasts where this was sufficient to overcome the target margin. In the Gold Coast example, a land value uplift curve was developed based on:

- Australian research into public transport projects and their impacts on land values.
- Hedonic regression model assessing the impact of previous stages of Gold Coast light rail on unimproved land values.
- Geographically weighted regression to explore local factors unique to the Gold Coast.

It is noted that the regression models presented are one of several different ways to estimate the change in land values for the purpose of development feasibility modelling and should be treated as indicative rather than being the focus of this paper.

2.3.1 Literature review

A literature review of research into the land value impact of mass transit projects is presented in Appendix A, focusing on light rail. This showed that:

- Transport connectivity and amenity alone can result in land value uplift of 30% within 200 metres of a light rail station. Land value impacts can persist for up to 2 kilometres from a light rail station.
- Complementary changes to planning controls provide a further opportunity to increase land values by as much as 63% (rezoning) and 79% (increased floor space ratios).

As shown in Figure 5 below, land value uplift from these studies was plotted against the distance from light rail stations to form an indicative light rail curve as the starting point of the analysis. This was then compared to the subsequent regression modelling results to allow further calibration to develop the final land use uplift curve.

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[28] Core Logic, "RP Data", available at: https://www.corelogic.com.au/software-solutions/rp-data, accessed 28th August 2023.

[29] Colliers, "Gold Coast Market Overview 2022", available at: https://www.colliers.com.au/en-au/research/gold-coast-market-overview-june-2022, accessed 28th August 2023.

2.3.2 Hedonic regression modelling

To calibrate and further refine the uplift curve, a hedonic regression model was developed using unimproved land values for more than 33,000 properties covering an area from Helensvale to Broadbeach South.[30] The sample was cleaned to removed property fragments (e.g., foot path easements and strata spaces), control for known zoning anomalies, and restricted to a catchment of 1,600m from light rail stops (roughly twice the typical 800m transport walking catchment). The final sample reduced to around 9,900 properties.

Unimproved land values were preferred over final sales values because they:

- Focus solely on the underlying productivity of the land and key features such as access, obstacles, proximity to services and amenity.
- Avoid the challenges of controlling for extreme variations in property price at the site level (e.g., sales process for similar units in the same building differing by 50%-100% depending on aspect and floor).
- Can input directly into economic cost-benefit analysis without the further treatment to control for property idiosyncratic factors (e.g., aspect, age, development sites and proximity to negative externalities).

Road network distances from properties to potential sites were then calculated using GIS software applied to the Gold Coast road network. This approach was preferred over linear distance because of the Gold Coast's numerous physical obstacles that limit real world pedestrian accessibility to public transport (i.e., Nerang River and canals/waterways). Future stages of the light rail would face similar constraints from physical features like Tallebudgera Creek and other waterways, Currumbin Creek and parklands, and Gold Coast Airport, which constrain the potential routes for accessing public transport.

The regression model was as specified as follows:[31]

$$\textbf{Equation 1: } \log(\alpha) = \beta + \log(\gamma) + \log(\delta) + \log(\mu) + \log(\theta) + \varepsilon$$

Where α is log of unimproved land value ($/sqm), $\beta$is a categorical variable of the land zone[32] designation, δ is the log distance to the coast, μ is log of the distance to waterways[33], θ is the log of the distance to a light rail (on-road meters), and ε is an error term.

A log-log specification estimates an exponential relationship between land values and the other variables. Of note, the estimated model fit (R^2) was 78.1%, and the overall model (F-test) and individual variables (t-tests) were all estimated to be statistically significant at more

[30] Data was provided to authors through a special data request through Gold Coast City Council. See Queensland Government, "2023 Land Valuations", available at: https://www.qld.gov.au/environment/land/title/valuation/annual, accessed 28th August 2023.

[31] The case study also considered proximity to green space as a variable, but this was too prevalent in the model area to a significant differentiator. It would also be possible to test the inclusion of additional socio-economic variables, but this was not undertaken as part of the case study. A log-log specification was selected over others because it aligns with the shape of the indicative land value curve from the literature review and performed best against standard regression model tests including overall 'model fit' (R^2), the statistical significance of the model (F-test) and the significance of individual parameters (t-tests). For example, comparative R^2 values are 0.7811 (log-log), 0.6548 (log-level) and 0.5381 (level-level); and comparative F-statistic values are 3904 (log-log), 2076 (log-level) and 1,275 (level-level).

[32] Zoning refers to permittable land uses by purpose (e.g., residential, commercial and industry) and density.

[33] Note this is separate from proximity to the coast as it covers inland waterways/canals.

than a 99% confidence level[34]. Figure 4 shows the relationship between unimproved land values and proximity to light rail. Contrary to expectations from the initial literature review, this only estimates land value uplift of around 10% within a 200m radius of light rail.[35]

2.3.3 Geographic weighted regression

Given the result above, geographically weighted regression (GWR) analysis was used as an exploratory technique to understand how uplift might change depending on local factors. GWR fits the model to each data point using the total dataset weighted by distance, estimating different parameters by location. This can use helpful to identify other local factors that drive land values other than what is specified in the model.

Given that the light rail proximity parameter at each location is a curve, Figure 3 below shows a simplified map showing the implied uplift in land values within 200 metres of light rail[36]. The original parameter results are presented in Appendix B. This analysis suggested that areas where proximity to light rail is the most significant driver of land value are those that are:

- Close to the coast and waterways (with high amenity).
- Opportunities to densify within current planning controls (given current low to medium density uses).
- Opportunities to improve the consistency of height limits (which vary significantly) while maintaining existing character (e.g., through gradation).
- Includes social infrastructure like Griffith University and healthcare-related industries (including the Gold Coast University Hospital).

2.3.4 Land value uplift curve

Figure 4 below shows a comparison between the hedonic regression modelling, which is effectively an average for the whole of the Gold Coast, versus the upper bound of the GWR results[37], which has similar local characteristics to the area being investigated between Burleigh Heads to Coolangatta (e.g., high-amenity coastal lifestyle, spare planning capacity and attractors such as Southern Cross University and Gold Coast Airport).

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[34] Based on 9,847 degrees of freedom, F-statistic of 3904 and t-value of -5.548 for the light rail station proximity parameter of -0.04.

[35] Rearranging Equation 1 results in an equation of $((\Delta\alpha+\alpha)/\alpha) = e^{\wedge}(-0.04 * log ((1+\Delta\theta)/\theta)$ where Δ represents change. For example, 200 metres from a light rail stop relative to a maximum distance of 1,600m corresponds to a change of -1,400 metres.

[36] Additional model tests such as Akaike Information Criterion and local R-squared values were considered in developing the GWR approach but their inclusion is too detailed for this professional practice paper which focuses on the development feasibility modelling framework. It is noted that the functional form including dependent and independent variables are the same as the hedonic regression modelling above, applying a Gaussian kernel.

[37] Based on the midpoint of the highest category, which estimates a 25% to 37% uplift within 200 metres.

Figure 3: GWR results of the model applied to Gold Coast unimproved land values (% uplift)

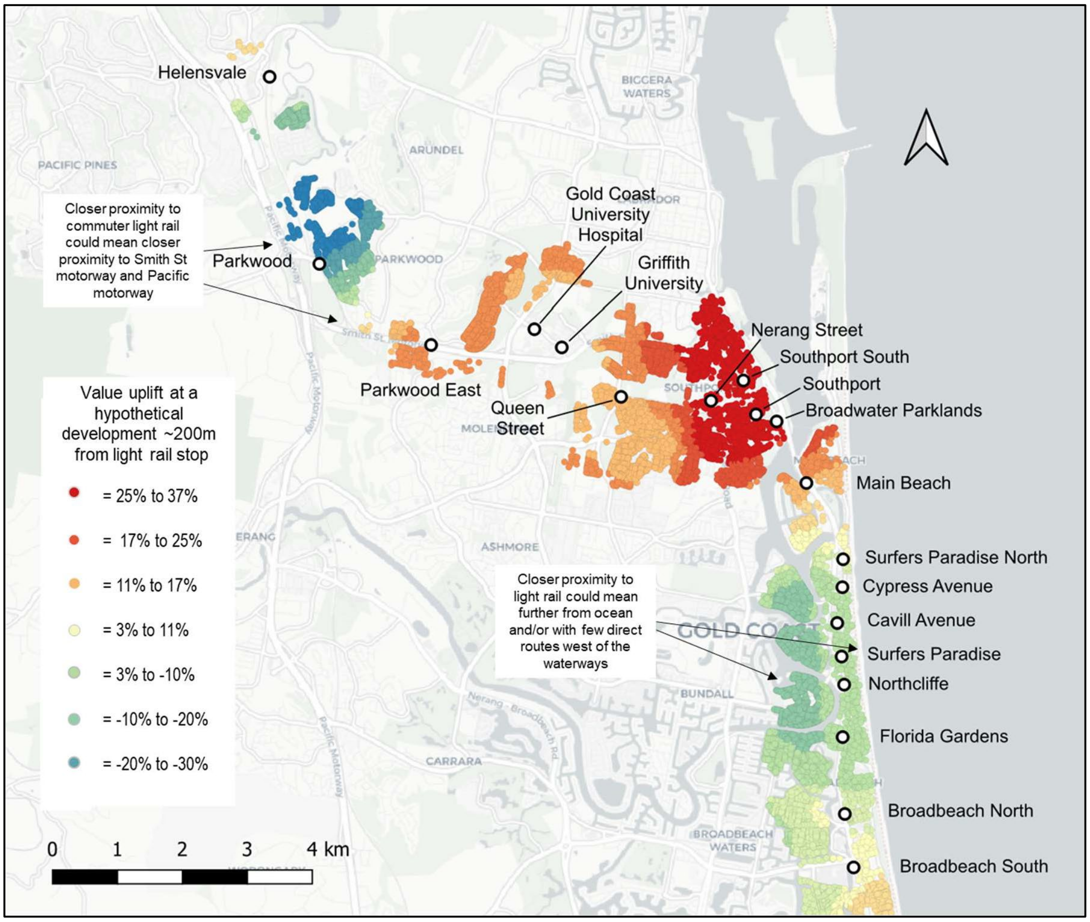
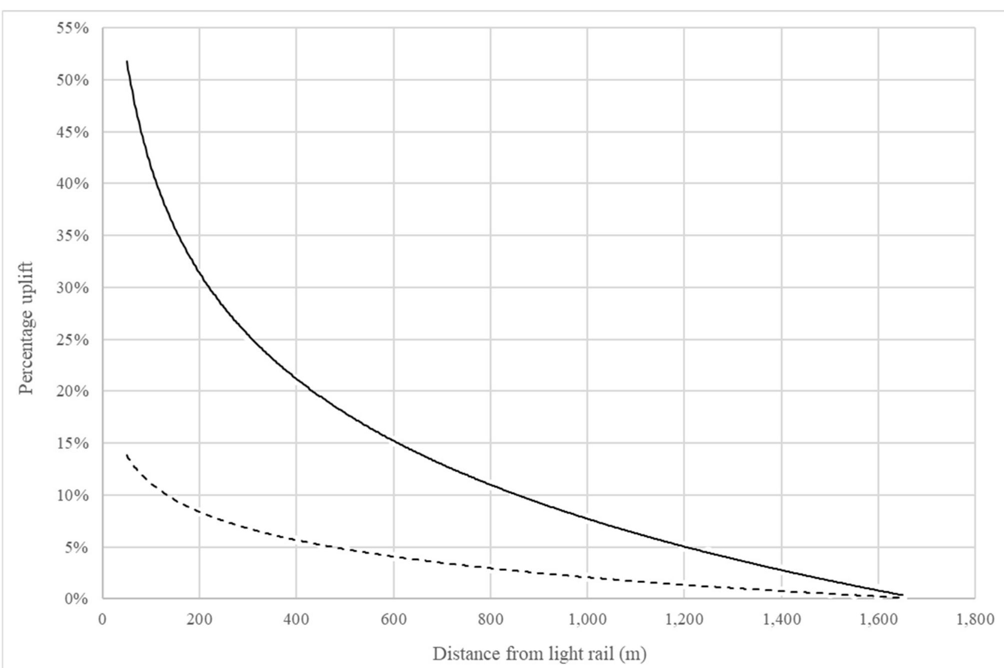


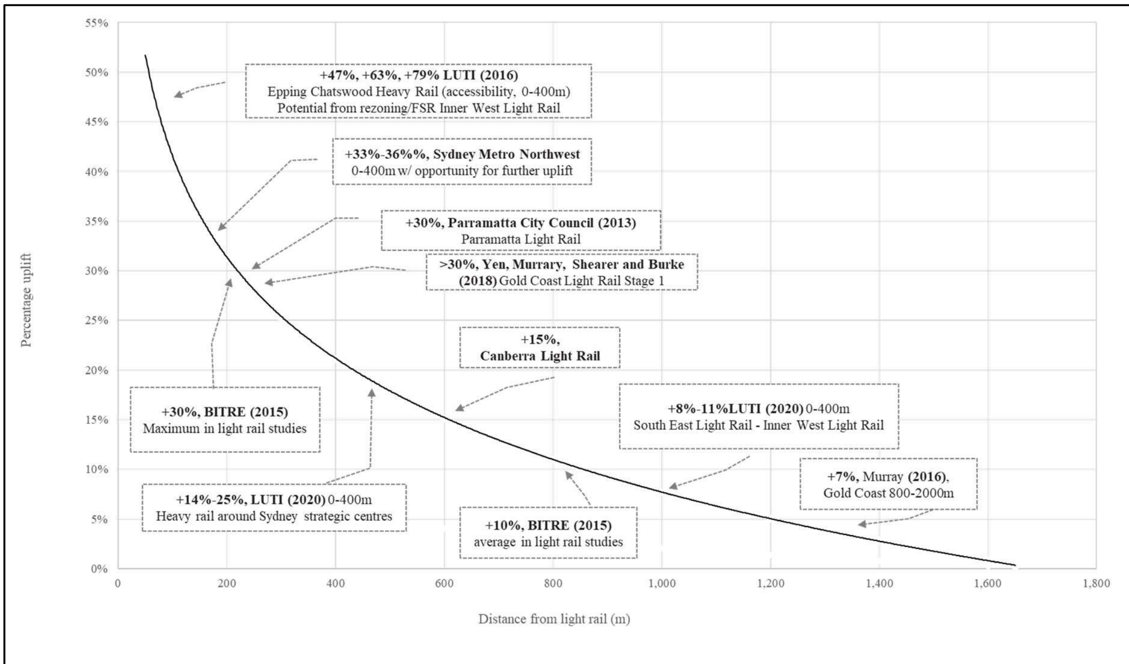
Figure 4: Hedonic regression (dashed) vs. geographic weighted regression (solid)



Source: Jollow, L. and Winter, B. (2023) based on unimproved land values from the Qld Valuer General.

Figure 5 shows how the GWR results are more aligned with benchmarks from the literature review, with an implied uplift of around 30% within 200 metres of light rail.

Figure 4: Estimated land value uplift curve (dahsed line) w/ literature benchmarks



The selection of a final uplift curve inherently involves some subjectivity, given that results from other areas with light rail need to be assumed for new areas without light rail. This is why a multi-tiered approach is prudent, including understanding the key characteristics of each of the precincts in the study area, literature review, modelling, and testing results with key stakeholders through workshops and project governance processes. Further refinement to the curve may also be warranted, for example, to cap the exponential uplift within a certain distance of the light rail station or to better calibrate the curve to comparable studies from the literature review. This is why sensitivity testing is also critical to understand the impact of changing land value uplift inputs to the development feasibility modelling.

2.3.5 Value reinvestment

A potential limitation of the development feasibility modelling approach is that it is relatively binary (yes/no) and dependent on government land use inputs for a temporal element. In the absence of additional mechanisms, this may arbitrarily act as an upper bound given the approach does not explicitly account for changes to planning controls (e.g., zoning, height limits or floor space ratios) or potential land amalgamation.

A key consideration in the development feasibility modelling approach was the treatment of estimated developer returns in excess of the threshold. In some cases, the land uplift model estimated a significant increase in value due to the project, but the realisation of this value was limited by existing planning controls and other factors.

In practical terms, developers are profit maximisers that will extract as much value as possible. As a result, gaining development approval often involves negotiation between planning authorities and developers, who have access to various tools aimed at achieving positive outcomes. These tools might include bonuses for additional floor space, contributions to social housing or amenities, and more. These incentives are commonly used to promote profitable and much-needed housing development, while also giving back some of the generated value to the public in various ways.

To address this, a reinvestment mechanism was introduced into the model. This mechanism assumes that a certain percentage of the excess value generated would be reinvested in further development in two ways:

- Feasible developments that lead to additional dwellings in a feasible site, up to a specified limit.
- New developments built near the projected development, which could arise from consolidating multiple sites near the project (and might be necessary for a feasible project to take place), or spare planning capacity that is not taken up in the government forecasts.

Once again, it is critical to scenario test the impact of changing these sorts of assumptions and to test the reasonableness of these outcomes with stakeholders with local planning expertise. In practice, realisation of these sorts of visionary land use outcomes will require co-ordination with planning agencies and complementary place-making.

It is also possible to further refine this approach through more detailed bottom-up assessments of planning controls and development opportunities. Although, this is relatively onerous for larger areas and so is more likely to be appropriate for larger scale projects seeking an investment decision rather than at the strategic planning stage.

2.4 Outputs to the transport demand model

Detailed land use assessment, including development feasibility modelling, can be relatively data intensive and so is generally focused on a smaller study area around the stations. In the Gold Coast case study, this covered the ABS SA2 boundaries[38] between Burleigh Heads (end of the light rail extension in construction) and Coolangatta via Gold Coast Airport (the Queensland-NSW border). The outputs of the detailed land use assessment are themselves inputs to transport demand modelling undertaken at the region or state level. This requires alignment of boundaries and redistribution of government land use forecasts outside the study area to maintain region or state-wide control totals.

2.4.2 Alignment of boundaries

The first challenge is the misalignment of boundaries between government land use forecasts and transport demand modelling. Boundaries from government land use forecasts are aligned with ABS statistical areas, but transport demand models generally have their own travel zone boundaries which extend beyond the statistical area boundaries.

As such, it is necessary to map the study area boundaries as closely as possible and potentially impose rules of thumb where there is significant misalignment. In the case study, this included identifying outliers where there were negative values or declining growth and manually setting these to the underlying forecasts. The difference was then proportionally reallocated across the remaining travel zones in the study area.

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[38] See ABS, "Statistical Area Level 2 (SA2)", available at: https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/main-structure-and-greater-capital-city-statistical-areas/statistical-area-level-2, accessed 21st August 2023.

2.4.1 Re-distribution of land use forecasts outside the study area

If study area forecasts are below government forecasts within the study area, as typically occurs in the base case with development feasibility modelling, then there will need to be additional growth of the same amount accommodated outside the study area. In the example, this additional growth was accommodated in nearby SA2s with the greatest remaining capacity (based on the difference between planning capacity and government forecasts).

If study area forecasts are above government forecasts within the study area, as often occurs in the project case with mass transit investment, this growth will need to be re-allocated from elsewhere outside the study area. In the case study, growth was reduced in nearby SA2s with the most optimistic growth.

3. Key findings and opportunities for further refinement

A key advantage of the development feasibility approach to land use forecasting is attribution of uplift to the specific transport infrastructure being assessed. This is achieved by applying the same development feasibility modelling to both the base case and project case scenarios, with the only change in the project case being the land value uplift directly attributable to proximity to mass transit stations.

A potential outcome of this approach is inconsistency with the base case for conventional transport projects, which tend to adopt government forecasts without further constraint. This means that transport benefits for projects with land use change may be lower than conventional transport appraisal because they are calculated using a constrained base case. For comparability, it may therefore be desirable to include a sensitivity test that calculates transport benefits alone based on unconstrained government land use forecasts.

The key limitations of the example development feasibility approach presented in this paper are it is generally data intensive, may be relatively binary (yes/no) or static, and does not directly account for planning control changes as follows:

- Different parts of the assessment considered between 10,000 to more than 30,000 lots. This level of analysis may not be appropriate for all stages of project development or scale of projects.
- Development feasibility modelling is applied to government land use forecasts to determine whether a threshold return is exceeded (yes/no). This means outputs are highly dependent on the government land use forecasts which:
    - May not be fully constrained, even with the inclusion of development feasibility modelling. As such, it may still be necessary to account for additional supply-side constraints. In the case study, this included vegetation protection, ecological values, stormwater and drainage corridors, slope, bushfire and landslide hazards, heritage, airport environments, coastal erosion, extractive resources, floodings, land use buffer requirements, tenure-related constraints, easements, and licenses.
    - Effectively imposes an upper bound on the outcomes of the development feasibility modelling without the introduction of additional mechanisms. In the case study, this included assuming re-investment of a proportion of returns exceeding the threshold, to add an additional temporal element and proxy developer incentives (e.g., bonus floor space ratios), land amalgamation, and rezoning or height limit increases.
- Although the value of transport connectivity and amenity is generally reflected in land values from the time of credible announcement of a mass transit project, development

feasibility modelling based on current land values may not fully account for future base case investments or nuances in service provision such as changes to service frequency or travel times (that is, the hedonic land value modelling is based on the existing light rail network and so implicitly assumes the same service outcomes).

The approach presented in the case study was strategic in nature and there are several areas where the approach could potential be refined or supported by more detailed underpinning analysis as part of a future research agenda including:

- Further consideration of alternative functional forms and variables for the regression modelling, including additional socio-economic variables or the use of dummy variables for light rail station distances (e.g., by 100 metre increments).
- Introducing additional temporal elements to the modelling, including consideration of real changes in costs and prices or other trends over time. This could also include more detailed consideration of the impacts of future base case projects on unimproved land values.
- Considering alternative scenarios for government land use inputs to the development feasibility modelling, including consideration of a high growth scenario and/or ultimate planning capacity.
- Preparing complementary planning control analysis and/or bottom-up analysis of opportunity sites identified through stakeholder workshops, including consideration of site-specific assumptions, land amalgamation opportunities, and likely developer incentives or changes to planning controls enabled by the project (e.g., rezoning, more consistent height limits, and bonus floor space ratios). Planning controls (and planning control changes enabled by mass transit projects) may be incorporated into the development feasibility modelling framework, either as an assumption underpinning government land use forecasts used as an input, or by incorporating these as an additional supply side overlay (i.e., ensuring forecast land use uplift does not exceed planning control limits).
- Incorporating transport service characteristics into hedonic land value modelling to better reflect nuances in service provision compared to existing routes on which land value modelling is based. This could include integration of transport demand modelling outputs into the hedonic land value model.

It is also possible to 'de-risk' certain elements of the analysis contributing to a higher risk-adjusted rate of return being assumed for developers. In particular, this could be achieved by providing more certainty around elements such as planning control changes, developer incentives and delivery of complementary place-making scope (e.g., including these in stakeholder agreements, benefits realisation strategies and/or project funding requests). This could be supported through multi-agency agreements or other governance processes for benefits realisation.

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Appendix A Literature review

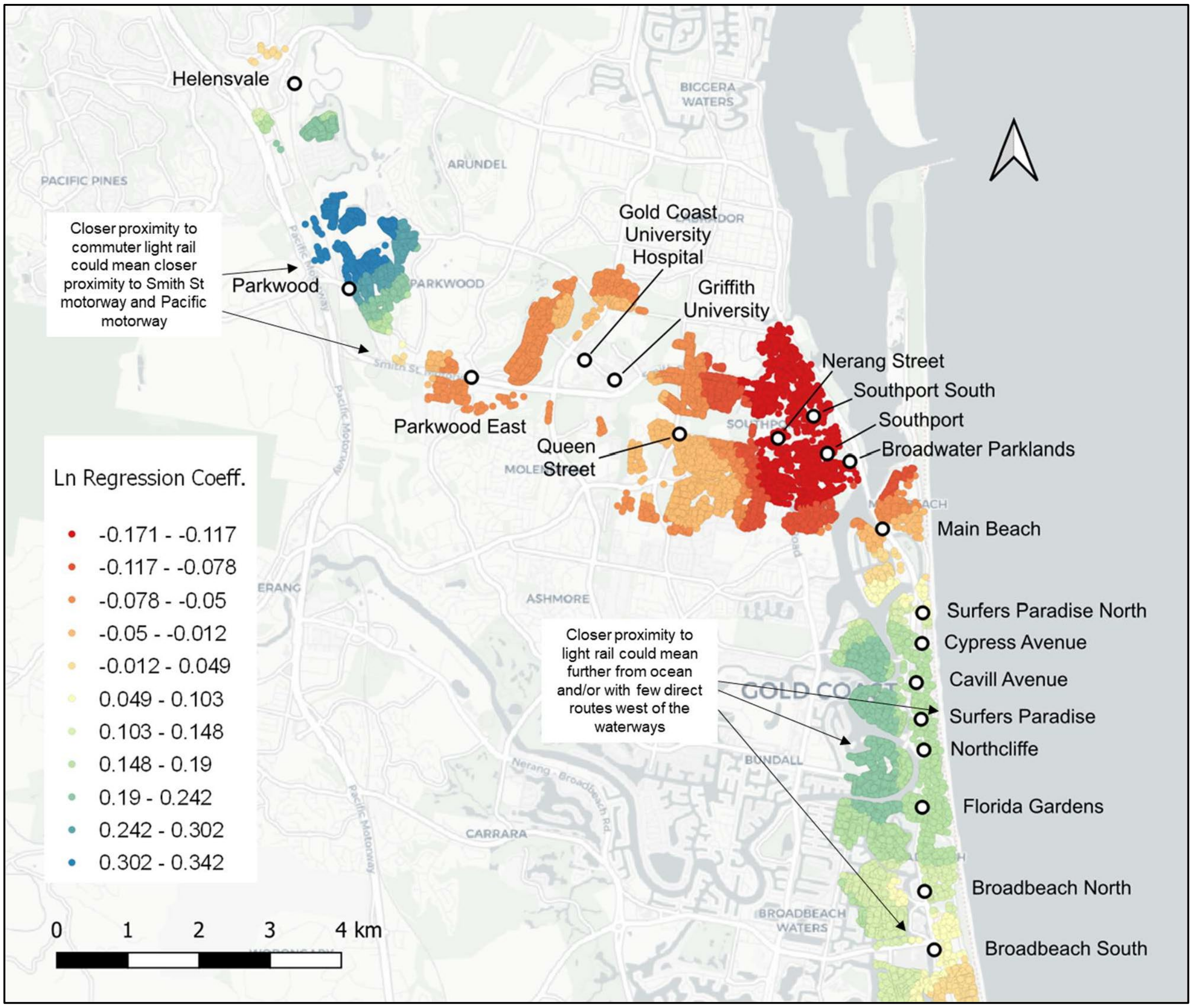
Table A.1: Comparison of land value uplift from light rail in publicly available literature

Study	Value	Comment
Parramatta City Council (2013)	• **Parramatta Light Rail:** 30% uplift in property values along the corridor.	• Economic modelling by Hill PDA and PwC for the feasibility assessment. Land use forecasts from Final Business Case in 2016 are not publicly available.
BITRE (2015)	• **Light rail literature:** Average 10% and up to 30% land value uplift	• Review of Australian and international literature.
LUTI Consulting and Mecone (2016)	• **Epping to Chatswood Heavy Rail:** o +48% (0-400m) from accessibility o +18% (potential) from rezoning o +299% (potential) from FSR • **Inner West (Dulwich Hill) Light Rail**: o +7% (0-400m) from accessibility o +63% (potential) from rezoning o +79% (potential) from FSR	• Hybrid log-linear and log-log model of unimproved land value controlling for zoning, distance (main road, coast, CBD, activity centre, ABS socio-economic indices for areas). • 1,600m walking catchment with dummy variables for different distances. • Zoning changes assumed to increase to highest and best use and floor space ratio assumed to increase from corridor average to 4:1
LUTI Consulting (2020)	• **Sydney Heavy Rail Network:** 14%-25% uplift at heavy rail stations in strategic centres (0-400m) • **Sydney Metro Northwest:** 33%-36% uplift around metro rail stations (0-400m) and several further positive impacts expected • **Dulwich Hill Extension to the Inner West Light Rail**: 10%-11% uplift (0-400m) and further uplift expected • **Sydney South East Light Rail:** 8%-10% uplift (0-400m) and further uplift expected	• Land value uplift at heavy rail stations in strategic centres is based on analysis of Figure 10 in the report. Centres such as Macquarie include mixed uses (e.g., retail, business park, residential) and a university precinct. • Maximum Sydney Metro Northwest land value uplift measured from minimum in 2013 (-5.4%) to maximum in 2018 (30.9%). The report notes that further land value uplift is still expected as a result of the extension from Sydney Metro City & Southwest. • One of the key outcomes from the South East Light Rail was pedestrianisation of George Street. The report identifies that once Randwick Council's planning strategy is adopted, further land value uplift is likely.
Murray (2016)	• **Gold Coast Light Rail Stage 1**: Average 9% within 1200m and average 8% within 2000m between 2014 (final year of construction) and 2015 (first year of operation), including: o +13% (0-400m) o +6% (400m-800m) o +7% (800m-2,000m)	• Global hybrid log-linear and log-log model for the entire City of Gold Coast from 2001 to 2015. Includes 202 independent variables taking into account the various sub areas, coastal distance, zoning and property type controls, and 108 time and distance interaction terms (total 2,105,497 observations). • Could be additional impacts beyond the first full year of operation in 2015.
Major Projects Canberra (2020)	• **Canberra Light Rail:** The increase in the unimproved value of blocks within the light rail corridor between 2011-2018 is 35.2%, which is 15% higher than the average value across the ACT (21.7%).	• Post completion review based on observed land value increase in the light rail corridor.
Yen, Mulley, Shearer and Burke (2018)	• **Gold Coast Light Rail Stage 1:** >30% uplift attributable to light rail (0-800m).	• Post-completion review of sales data for residential properties along the corridor. Compared areas within 800 metres of the stations with a control area containing locations a little further away but still in the same vicinity. • Applied a longitudinal methodology to see when the value uplift occurred from 1996, when planning of the system first started, through to the latest 2016 data.

Sources: Parramatta Council (2013), LUTI Consulting and Mecone (2016), LUTI Consulting (2020), BITRE (2015), Murray (2016), Major Projects Canberra (2020) and Yen et al. (2018)

Appendix B Geographic weighted regression parameters

Figure B.1: GWR results of the model applied to Gold Coast unimproved land values (log-log parameters)



Source: Jollow, L. and Winter, B. (2023) based on Equation 1 and unimproved land values from Queensland Valuer General.