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The impact on neighbourhood residential property valuations of a newly proposed public transport project: The Sydney Northwest Metro case study

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ABSTRACT

The development of new and upgraded transport infrastructure projects are driving economic benefits for business, the environment and society. Major transport projects can fundamentally reshape the very fabric of urban development. However, they are also incredibly expensive to build and can represent a significant burden on the public purse. A vexed question is how the broader benefit of improved transport infrastructure in operation might usefully be leveraged to contribute to the capital investment cost. The Transit-Oriented Development impact of new transportation infrastructure on the value of local property is gaining increasing attention as a potential source of capital contribution. This study investigates the extent of value uplift in property brought about by the announcement and construction of a major transport infrastructure development in Sydney, Australia. A Hedonic Price Model approach is used to assess data on the market valuation of nearby properties and relevant Census data over two distinct project stages: project announcement (2008–2012), and project construction (2013–2019). Findings of the case study show that the impact of rail transit on property prices is significant, but are generally negative at the announcement stage and positive at the construction stage. At the construction stage, residential prices rose an average of 0.037% for every 1% reduction in the distance to the nearest metro station. Of the three models considered for the Hedonic Price Model the Log-linear model (elastic model) has been shown to perform best in representing the relationships in this particular case.

1. Introduction

The location and construction of rail transit systems is an essential consideration in the planning and development of any burgeoning metropolis (Mohammad et al., 2013). An effective urban rail transit system can help reduce reliance on and use of private cars and promote sustainable urban growth (Cervero et al., 2002). An urban rail transit system will also change the spatial layout of the relevant city, and as a consequence impact the value of those residential and development areas newly served by the rail corridor (Wang, 2009). Indeed the entire real estate market of a city can be impacted by such an increase in the supply of residential property, and the added interconnectivity of suburbs provided by the development of a more integrated rail and transport network (Srinurak and Mishima, 2017). The Transit-Oriented Development (TOD) theory seeks to maximize the volume of residential and other properties within walking distance of public transport. TOD has now been applied in the planning decisions of numerous metropolitan contexts, including Hong Kong, Tokyo, and Mexico City (Nasri and Zhang, 2014; Renne and Listokin, 2019).

Based on bid rent theory, which refers to how the demand for real estate increases the shorter the travel distance is to the nearest central business district, access to goods and services is the main factor influencing the development value of land (Alonso, 1964). It is the improved access, provided by new rail transit options, that most directly influences the increase in property values in and around a TOD-impacted area. In Australia, TOD has become a central planning tool of local and regional planning authorities. For example, the Metropolitan Plan for Sydney 2036 (Alonso, 1964) placed added emphasis on a 'City of Cities' concept, where key suburbs would develop as satellite central business districts, linked by improved public transport services, including rail (Newman, 2005). The Future Transport Strategy 2056 (Transport for NSW, 2018) committed in excess of AU $50billion for transport infrastructure projects in New South Wales alone. This commitment reflects the high cost of rail transit system construction, with current costs around AU$400million per kilometre of rail line and a further approximately AU$20million for each new station.

The high cost of rail transit system construction places a significant burden on the public purse. As a result, there is increasing interest in the use of private investment in public transport infrastructure construction projects, and other alternative sources of potential funding. One significant proposal has been to leverage the uplift in property values from the provision of a local rail transit system, to contribute to the costs of the development

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through a levy or other such income-generating instrument (Newman, 2005). An effective method of estimating the potential uplift in property values would very usefully inform public planning agencies on the potential contribution that such an uplift might contribute to development and construction costs, and to private investors who might be considering a joint public-private project arrangement.

A number of empirical studies have been undertaken to examine the actual and potential value uplift in TOD-impacted property prices (Zhong and Li, 2016; Wagner et al., 2017; Pilgram and West, 2018; Mohammad et al., 2013; Camins-Esakov and Vandegrift, 2018). However, key gaps in the research literature still remain. Notably, this study will contribute to the literature in two significant ways: (*i*) there are no previous studies that focus on the impact of the latest Sydney metropolitan rail developments – this study focuses on the local Sydney residential property market and the particular circumstances of that setting as they relate to the relative significance of externalities; and (*ii*) little attention previously has been paid to estimating value uplift in entirely new rail lines and stations still to be constructed, where the externalities in play will be reduced and more evident – this study was undertaken prior to the recent completion of the case study rail transit system.

The remainder of this study is structured as follows: Section 2 reviews the relevant literature and key previous studies; Section 3 provides the theoretical framework for a Hedonic Price Model (HPM) to investigate the potential impact of a Sydney Northwest Metro Line (SNML) on TOD-impacted residential property prices; Section 4 discusses the empirical results of the estimated HPM; and the study concludes in Section 5 with a summary of findings and suggestions for further research.

2. Related works

2.1. The impact of rail transit systems on property value

Investigating the link between public transportation infrastructure and residential property value has been a focus of research for more than five decades. Alonso (1964) first proposed the bid rent theory, which provides a theoretical basis for the study of how transport infrastructure and residential property values are related, in 1964. Since then, a broad range of case studies have been conducted on various locations to investigate whether and how the provision of road, rail, bus and other transportation services impact the housing market. Due especially to the punctuality, speed and low emissions of rail transit systems, the land and residential property values around rail stations has been found repeatedly to significantly increase, particularly near the entrance and exit points to the station. For example, Pan (2013) investigated residential property values near the Houston metro rail transit line in Texas. Results show that the opening of the rail transit line generated a significant premium to the local residential property values. Zhang et al. (2016) also demonstrated that residential values in general increased for every kilometre of new rail track constructed in a metropolitan area. Murat Celik and Yankaya (2006), Tian (2006), Zhang et al. (2007), Mulley et al. (2018), Hopkins (2018), and Wen et al. (2018) have all reached similar conclusions regarding the impact of transport infrastructure projects on increasing the value of residential property. However, other studies have found the exact opposite impact.

In a case study of the Tide Light Rail system in Norfolk, Virginia, Wagner et al. (2017) highlighted the potential negative impact of light rail on property prices. Pan (2013) also found negative impacts on property value when located too close to a rail station. That research demonstrates that properties within a quarter mile radius of a rail station can be impacted adversely. Elsewhere, a case study of the Hudson-Bergen Light Rail in Bayonne, New Jersey found no significant impact on residential property values from the development of the 8th Street station Camins-Esakov and Vandegrift (2018). Chen and Haynes (2015) and Andersson et al. (2010) have studied the impact of high-speed rail transit systems on residential property value and compared the impacts between cities. Chen and Haynes (2015) conducted a case study in China. Andersson et al. (2010) conducted a case study in Taiwan. Both of these studies have shown that the impacts are varied and depend to a significant extent on the size of the population being served and other local conditions.

Research into the impact of other forms of transport infrastructure have also varied in their conclusions. A study by Shen et al. (2017) concluded that TOD-impacted properties around bus stations in Seattle, Washington, were significantly impacted positively, with the greatest impact within 0.5 km of the stations. Deng et al. (2016) conducted a case study of the Bus Rapid Transit system in Beijing, and found that surrounding property values increase the closer the property is to a station. Efthymiou and Antoniou (2013) conducted a comparative study of different kinds of transport facility. That study indicates that metro, tram, suburban rail, and bus stations have a positive impact on property value, where national rail stations, airports, and ports have negative impacts on residential property value. Further variation in the impact of transport infrastructure on property values, depending on local conditions, have been reported for end of ride bicycle facilities Welch et al. (2016), and for road and highway construction Martínez and Viegas (2009), Seo et al. (2018).

2.2. Time and space factors

Instead of general research about the impact of the rail transit on residential property prices, in recent years a growing number of studies have tried to focus on some specific characteristics of these impacts. Among those characteristics, time effects and space effects are most commonly studied. The life cycle of a rail line project is lengthy and has different stages. Previous studies have usefully divided the life cycle into four key stages: pre-planning, planning, construction, and operation (Yan et al., 2012). Yan et al. (2012) conducted a case study of the new light rail system in Charlotte, North Carolina. Results show that this rail transit system has negative influences on property values before the operational stage, but when the light rail is operating there is a more positive reaction in rising property values. Agostini and Palmucci (2008) investigated the same light rail system in further detail and found that property values actually increased at both the announcement of station location (planning) and commencement of work on site (construction) stages. However, higher interests rates masked these earlier stage rises in value. Yiu and Wong (2005) also found that value expectations had a positive impact long before the completion of the Hong Kong tunnel. A similar conclusion has been reached by Ruan and Yin (2014).

Due to the added challenges of a longitudinal study, it is common to consider value variations at a single-project stage. For example, studied the influence of a newly-proposed rail transit project in Hong Kong and found positive evidence that the anticipated benefits of transport improvements are capitalized into property values at an early stage. It is also the case that the value uplift from a new rail line may be quite apparent at the beginning of the operation stage, but will likely wane over time as other factors also impact the value (Wang, 2009). Many studies also find that the extent of the impact varies from one place to another. For example, studies of the spatial extent of the impact of rail line stations on residential property values by Wang (2009) found the generalised radius of influence of railway stations to be 1.5 km, but that the radius of influence varied between stations. Feng et al. (2011) determined that the radius of influence of rail transit stations on residential buildings is 2 km, and that the residential property values depreciated exponentially with increasing distance from rail transit. In addition to the changing radius of influence, in early literature especially, the concept of a sub-market was common. Different geographic locations and economic developments were typically employed to differentiate between such sub-markets. Some studies classified submarkets subjectively, depending on their own experiences (Su and Feng, 2011). More advanced methods, such as the spatial model and geographically weighted regression analysis method, are widely used in other related studies. Sun et al. (2016) have found that the impacts of the rail transit system are more significant on the urban fringe than at the heart of an urban area. Su and Feng (2011), Gu and Zheng (2010), Ma et al. (2010) and Su et al. (2015) have reached similar conclusions in related studies. Karlsson (2011) conducted a case study of general public transportation facilities in Iceland and reached an opposite conclusion. That study found that by improving traffic conditions between the central business district (CBD) and other areas nearby, a large marginal effect on local housing values could be achieved when compared with the performance in remote areas. However, research results varied considerably across the different study cases. Research undertaken by Hewitt and Hewitt (2012) concluded that the impact of a rail transit system on property value is spatially dependent and may be affected by specific regional factors. We can observe then, that time and space effects are two of the main factors that govern the impact a rail transit system has on property value, and that those effects are different in different cases, locations, social and economic circumstances.

2.3. Economic conditions and other influential factors

Residential property values are affected by many factors, including location, accessibility, the immediate environment, and so on. Some factors also affect each other. For that reason, and in addition to the study of rail transit system direct impacts on property value, some studies focus on other related factors which might also have influence on property values. For example, it is reasonable to anticipate that the immediate economic circumstances of local residents can affect the type and scale of the impact a rail transit system will have on property values. Forouhar and Hasankhani (2018) performed comparative studies on the influence that rail transportation can have on surrounding properties, based on the general level of income for different neighbourhoods. That study found that the rail transit line brings apparent premiums to properties in low-income neighbourhoods, but has a negative impact in high-income neighbourhoods. One explanation for this could be the greater reliance on private over public transport, that can typify the higher-income residential areas. In stark contrast, Hess and Almeida (2007) reached exactly the opposite conclusion. That study found that the light rail stations in Buffalo, New York have positive impacts on property value in high-income station areas while having negative impacts on low-income station areas. The underlying causal factor for this reversal has not yet been identified.

Property type is another important impact factor. Many researchers have indicated that the impact of rail transit systems on different types of residential properties will vary. A study by Zhong and Li (2016) compared between multi-family properties and single-family properties. The results of that study revealed that where the impact on multi-family properties is broadly positive, the impact on single-family properties is precisely the opposite. Hawkins and Habib (2018) drew different conclusions again from their study of Toronto, Ontario where the impact of a rail transit system on house values is found to be positive, but for the value of a condominium the impact is negative. At the same time, Mulley and Tsai (2017) found that the impact of a new rail station on the value of an apartment is less significant than the impact of the same station on house values. This differentiation may be accounted for by the fact that multi-floor buildings are less influenced by noise and pollutions, and apartments can therefore often be built much closer to rail stations and other infrastructure. Li et al. (2017) found that the property values are positively related to potentially shorter metro headways (being the time between trains). Other influential factors identified in previous studies include: whether the rail line is entirely new or just an extension (Camins-Esakov and Vandegrift, 2018; Lee et al., 2018); the level of crime rate near stations (Bowes and Ihlanfeldt, 2001); market circumstances (Wang et al., 2015); size or development level of the relevant city (Pan et al., 2014), Hensher et al. (2012); and broader development patterns and urban configuration (Hawkins and Habib, 2018).

2.4. Rail transit projects and property price fluctuations in Australia

Related case studies that focus on Australia are limited. Mulley and Tsai (2017) have investigated the impacts of the Bus Rapid Transit system in Sydney, New South Wales, and have demonstrated a strong connection between the improvement of accessibility of bus systems and premiums to adjacent residential property values. That study also included a quantitative analysis of houses and apartments located near transit stations and found a positive radius of influence for houses between 100 m and 400 m, and apartments between 800 m and 1200 m of a transit station. Similar research and findings have also been reported by Mulley et al. (2016) specific to the Brisbane Bus Rapid Transit system in Queensland, Australia. An empirical study by Mulley et al. (2018) of the Sydney Inner West Light Rail system found that the value of TOD-impacted housing is increased. Specifically, the value lift on average is halved for every additional 100 m distance further away from the station the property is located beyond the first 100 m. Housing located too close to, and within 100 m of, a station are negatively impacted.

Overall, these studies highlight the fact that the impact of the transportation infrastructures on the adjacent residential property values varies across different locations and situations. Studies also demonstrate that the impacts cannot be associated with any single, primary or consistent factor in isolation. To improve the comparison across situations and factors, this study investigates TOD-impacted property values along the corridor of the Sydney Northwest Metro Line (SNML). SNML is the largest public transport project in Australia, and the first metro transit project of its kind in New South Wales. There have been no previously published studies using this project as a case study to investigate TOD-impacted property values. The case is particularly meaningful because the transit stations include redevelopment of existing stations and entirely new stations. This will allow a comparison of the TOD impact across different conditions and influences along the same transportation facility.

3. Methodology

3.1. A case of Sydney Northwest Metro Line

The focus of this case study is the Sydney Metro Northwest Line (SMNL). SMNL is a significant phase of the broader Sydney Metro program, currently the highest value public transport project in Australia with an eventual total length of 66 km including 33 stations (Sydney Metro, 2018). SMNL will provide a rapid transit link to the north-western suburbs of Sydney, New South Wales. It will connect Tallawong to Chatswood via 13 stations and an interchange to existing rail networks at Epping and Chatswood, as shown in Fig. 1. SMNL, and Sydney Metro more broadly, offers a new generation of quick, safe and reliable train services which are high-frequency and use driverless trains. The construction stage of the SMNL commenced in 2013 and was planned to be operational in 2019. This stage comprises 8 new metro stations and 5 upgraded stations. This study investigates the 8 new stations and their surrounding suburbs.

The analytical data for the case study has been collected from several sources, primarily: (i) CoreLogic, the largest provider of property information and analytics in Australia, using the RP Data database; (ii) Google Maps, a web mapping service to locate each of the stations and distances to specific properties and other facilities; and (iii) the Australian Government, Australian Bureau of Statistics context information on community profiles, extracted from the 2016 Census data.

3.2. Hedonic price model

This study adopts a quantitative method to guide the research. The hedonic price model (HPM) is used to analyse the collated data on residential properties in target areas. The data variables are then analysed to determine the influence of each variable on the property values of interest. Specifically, each property is treated as a member a heterogeneous commodity, in which the price determinants can be divided into three broad types of attributes: structural attributes, location attributes, and neighbourhood attributes. These three attributes work together to establish the value of a property, and ultimately are capitalized into house prices. Structural attributes are the factors that have the greatest impact on property prices. When buying properties, purchasers usually pay more attention to the structural attributes of the house – the number of bedrooms, bathrooms, parking, etc. Properties in otherwise indistinguishable settings will tend to have different values depending on their

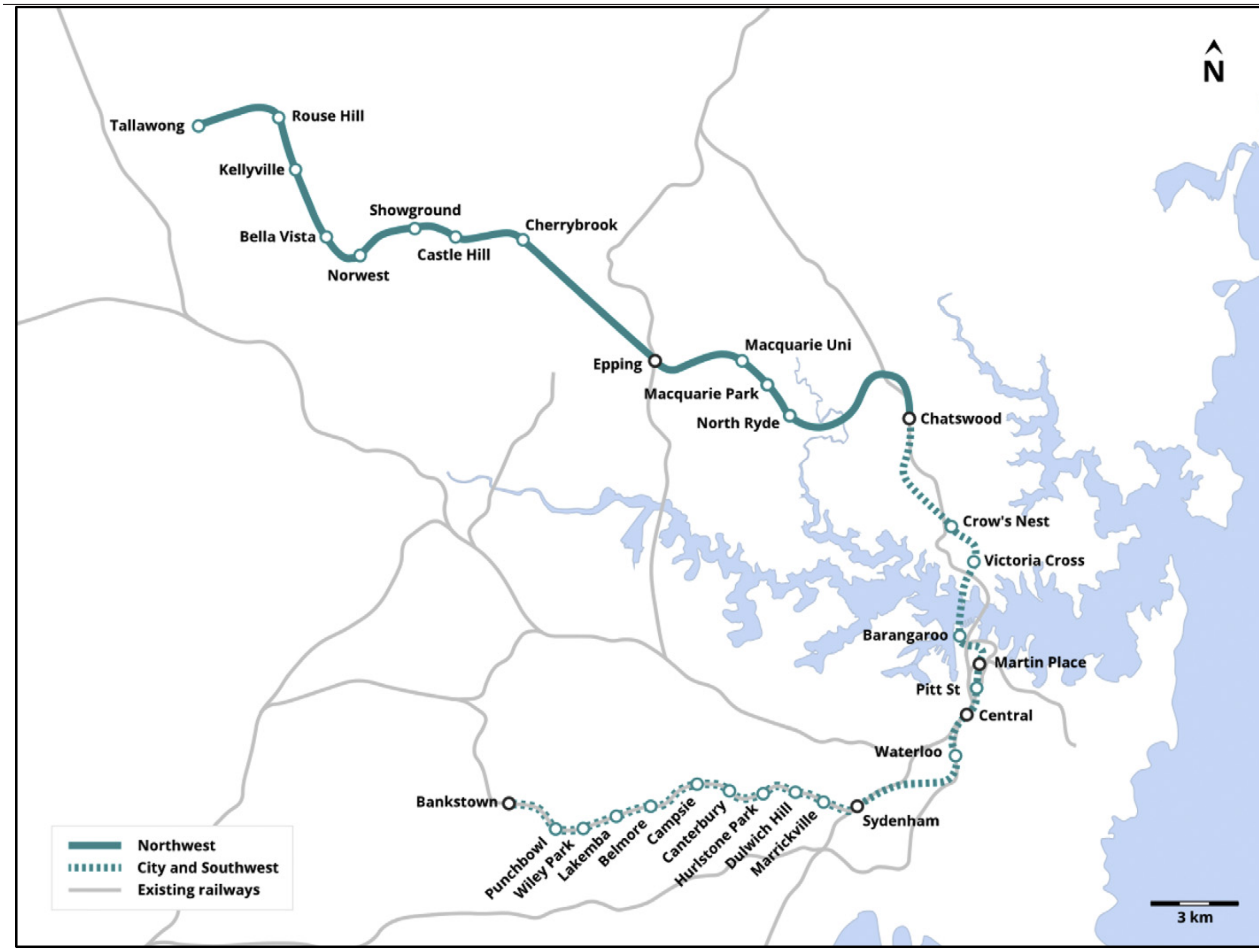

Fig. 1. Sydney Metro Northwest line.
(Source: https://upload.wikimedia.org/wikipedia/commons/thumb/2/2c/Map_of_Sydney_Metro.svg/1365px-Map_of_Sydney_Metro.svg.png)

structural attributes, which makes these the underlying determinants of property value. Location attributes are also an important factor in determining property prices, and most especially in large cities. The time taken to commute, distance from key schools, distance from shopping centres, and similar, all exert a premium effect on the value of properties. Neighbourhood attributes are similarly significant in determining property prices. These attributes refer more directly to the local amenities, such as quality of the various utilities services, noise and pollution, and access to transportation facilities.

The HPM method was first proposed by Rosen (1974) and has matured greatly as a method of valuing individual attributes in the >30 years since then. HPM is now a common method used to study changes in the value of real property (Dai et al., 2016). The basic concept of HPM is that each property value is determined by the utility provided to the owner by the various structural, location, and neighbourhood attributes of that property. HPM maintains that the combined influence of all property attributes will determine the value of the property. Vice versa, the value of a property can be decomposed to establish the influence of each attribute on the value of a property in generic terms. When the HPM is applied across a large sample of known property values and their known associated attributes, the influence of each attribute on overall value can be aggregated. When like properties are compared the value should be the same. Any differences in value between otherwise like properties, where the only difference is proximity to a transport interchange (or any other variable of interest) can be presumed to reflect the influence of that factor on property values.

The capacity to analyse the impact of individual attributes in this way has made the HPM a common and favoured research instrument for the investigation of individual property attributes. For example, the effects on property values of property attributes such as age, size and type (Ko and Cao, 2013; Agostini and Palmucci, 2008), parking (Efthymiou and Antoniou, 2013; Debrezion et al., 2011), urban greening (Wei et al., 2015), and ocean views (Efthymiou and Antoniou, 2013) have all been analysed using an HPM.

To apply the HPM in specific cases, fundamental attributes (building area, distance from a regional centre, and so on) are calculated first. Where the different attributes of a property are represented by Z, then a pricing model $P = f(z)$. By calculating the derivative of each characteristic attribute or variable, the influence range that each factor exerts on property value can be established. In general, HPM represents the functional relationship between property values and each characteristic variable. However, there is no clear form of HPM. The function is mostly often instigated from experience, and then continuously revised until the final function form performs well in predicting value variations in the sample data.

There are three main forms an HPM can take, wherein P represents the housing price, Z_i represents the housing characteristic variable i, a_i

represents the coefficient to be estimated, a_0 is the constant, and ε is the error term.

1. Linear model. The relationship between property values and each characteristic variable is linear, and each regression coefficient represents the average value uplift of property values caused by unit changes in the characteristic variable (Liao and Wang, 2012).

$$P = a_0 + \sum a_i Z_i + \varepsilon \quad (i = 1, 2, 3, \ldots, n) \tag{1}$$

2. Log-linear model (elastic model). The property values and each characteristic variable all take logarithmic form, and each regression coefficient represents the elasticity of the characteristic variable. That is, the percentage change in the value of a property caused by the percentage change of the characteristic variable (Wang and Yu 2012).

$$\log P = a_0 + \sum a_i \log Z_i + \varepsilon \quad (i = 1, 2, 3, \ldots, n) \tag{2}$$

3. The semi-log linear model (growth model). Each characteristic variable adopts the linear form and the property values adopt logarithmic form. The regression coefficient represents the ratio of the characteristic values to the total property value, that is, the percentage change of the property value caused by the unit change of the characteristic variable (Wang and Yu 2012).

$$\log P = a_0 + \sum a_i Z_i + \varepsilon \quad (i = 1, 2, 3, \ldots, n) \tag{3}$$

Following the identification of relevant attributes/variables and data collation of a sample dataset, the regression method in SPSS statistical software is used for analysis. Data on each property is substituted into the three forms of model progressively and iteratively until the model with the best regression effect can be determined. According to the statistical significance of multiple regression, the closer the coefficient is to 1, the better the fitting effect of the model, and thus the most effective HPM can be identified (Wang and Yu 2012).

4. Results and discussion

4.1. Statistical interpretation of the HPM model

Given the number of variables available and the number of property valuations possible, the HPM utilised 264 valid property data sets (138 in group1, and 126 in group 2). The descriptive statistics of the variables are shown in Tables 1 and 2.

The regression method in SPSS statistical software is used for analysis. The data was compiled into each of the three basic HPM formula presented above. Using a trial and error approach, and comparing results across the three models, the Log-linear model (elastic model) is shown to deliver the best regression results.

According to the determined HPM, the regression coefficients of the data obtained for the construction stage are provided in Table 3. The R of regression is 0.904, and the adjusted R^2 is 0.798, which means that almost 80% of the total variation of the residential property price is explained by the selected variables. Table 4 shows the model summary for the data derived from the announcement stage. The R is 0.872 and the adjusted R^2 is 0.733, which means approximately 75% of the total variation of the residential property price is explained by the selected variables. According to the statistical significance of the multiple regression, the closer the R^2 is to a value of 1, the better the goodness-of-fit of the model, which suggests a good explanatory power of the established model.

Table 1
Descriptive statistics of the property transaction data. (construction stage 2013–2019).

Variable	N	Mean	Min.	Max.	S.D.
Price ($)	138	1,303,488.96	528,000	3,045,000	447,914.628
Bedrooms	138	4.04	3	5	0.603
Baths	138	2.33	1	6	0.698
Parking	138	2.163	1	4	0.5024
Land area (m^2)	138	683.54	171	3753	357.526
Floor	138	1.54	1	2	0.501
Age (year)	138	21.16	1	78	12.148
DTM(m)	138	650.79	123	1860	249.418
DTSC(m)	138	1314.07	242	3190	750.251
DTSYD (minute)	138	34.47	27	51	3.986
DTPT (minute)	138	21.09	16	29	2.727
DTBUS (minute)	138	4.53	1	12	2.634
Unemployment rate (%)	138	4.919	4.4	6.1	0.5933
Household income ($)	138	2451.75	2219	2942	186.921

4.2. Results

Table 5 shows the result of the HPM for data relating to the 2013–2019 construction stage. The results indicate whether and how the various independent variables influence the property value. The p-value represents the significance of the selected attributes. 1% ($p < 0.01$) means extremely significant, 5% ($p < 0.05$) means relatively significant, 10% ($p < 0.1$) means significant, and higher values ($p > 0.1$) means no significance. According to the characteristic variable regression coefficient, 9 of 13 variables are statistically significant at 1% and 5% levels, and also carry the expected signs.

In terms of property attributes, the number of bedrooms, bathrooms and parking spaces are positively linked to the property price, and all significant at the 5% level. This indicates that the property prices will rise with an increase in the number of those attributes. This finding is consistent with the majority of previous research. Results also reveal that residential property prices are positively correlated with the land area, which is also in line with expectations. The coefficient of the property age was found to be negatively linked to the property price, and highly significant at 1% level. This confirms that in general, the older the house, the lower the price. Furthermore, the results show that there is no significant relationship between the housing price and the number of storeys.

Table 2
Descriptive statistics of the property transaction data. (Announcement stage 2008–2012).

Variable	N	Mean	Min.	Max.	S.D.
Price ($)	126	709,426.98	286,000	1,715,000	233,006.408
Bedrooms	126	4.05	3	6	0.591
Baths	126	2.36	1	4	0.572
Parking	126	2.20	1	6	0.716
Land area (m^2)	126	744.60	220	5007	474.945
Floor	126	1.51	1	2	0.502
Age(year)	126	14.49	0	69	10.065
DTM(m)	126	635.77	116	1320	254.257
DTSC(m)	126	1287.33	292	3220	793.497
DTSYD (minute)	126	34.67	27	53	4.907
DTPT (minute)	126	20.31	17	25	1.970
DTBUS (minute)	126	4.69	1	12	2.744
Unemployment rate (%)	126	4.928	4.4	6.1	0.6444
Household income ($)	126	2469.51	2219	2942	184.048

Table 3
Model summary (construction stage 2013–2019).

Model	R	R^2	Adjusted R^2	Std. error
1	0.904	0.817	0.798	0.071

In terms of the neighbourhood attributes, results indicate that the median weekly household income is positively correlated with the residential property price, with a high significance ($p < 0.01$). This is consistent with the findings of Mulley et al. (2018) and (Mulley and Tsai, 2016) from their study of the Sydney Light Rail and Bus rapid transit system. The unemployment rate is found not to be significant in the case of this study. This may be due to the consistency in the unemployment rate across the study areas.

The key focus of this analysis is the impact of distance to/from the nearest metro station on property value. The findings of the study are statistically significant with a p-value lower than 0.01. Distance has a strong correlation with residential property price, and the correlation is negative. Specifically, holding all other variables constant, residential prices are found to rise on average at 0.037% for every 1% reduction in the distance to the nearest metro station. This finding demonstrates that the construction of the SMNL project has brought positive benefits to the neighbouring residential property prices. Similar findings have been common in the literature. Jayantha et al. (2015) found that before the operation stage, adjacent residential property benefitted from new rapid transport facilities in Hong Kong. Mcmillen and Mcdonald (2004) noted an average increase in equivalent property values in Chicago. Agostini and Palmucci (2008) found that in the construction stage, the property value increased in Santiago. However, in other cases, Yan et al. (2012) found that in Charlotte, the effects of the rail line construction impacted negatively on the value of single-family properties.

In terms of other accessibility attributes, the distance to the nearest shopping centre and the distance to the Sydney Central Business District (CBD) both show a high level of statistical significance. Notably, the results show a negative trend in property prices as the distance to the shopping centre is reduced. This may be because the environment around the shopping centre is complex, which may have a hidden negative impact on the value of private homes. Consistent with the research results of Shen et al. (2017) for Seattle, Wang et al. (2015) for Cardiff, and Salon et al. (2014) for Guangzhou, the walking distance to the nearest bus station is positively correlated with the residential property price. However, the distance to the Parramatta CBD (a satellite to Sydney CBD) is found to be not significant.

Table 6 shows the result of the HDM applying the data from 2008 to 2011 which indicate the relationship between selected independent variables and residential property prices at the announcement stage. Similar to the findings of the construction stage, the number of bedrooms, bathrooms, the plot size of the land, the age of the property, the distance to the metro station, the distance to the shopping centre, the distance to the Sydney CBD, and the median weekly household income, all have significant relationship with the residential property prices. Differently, however, the p-value of the distance to the metro station is 0.05, which is much higher than that found for the construction stage (0.001). This difference indicates that the distance from the metro station has less impact on the property price in the announcement stage than in the construction stage. By contrast, the distance to the metro station is positively linked to the metro station, which means the closer to the metro station, the relatively lower the property prices become. This result may be due to the length of time generally required to plan and construct a major rail line after the initial announcement, during which time there is often increased uncertainty and the prospect of long-term construction noise and pollution. The uncertain political environment at the time of the announcement (immediately prior to a national general election) might also have contributed to the uncertainty. Where there is uncertainty there is greater risk, potential property buyers will have less confidence in the project, and will generally discount the future possibilities in valuing a property. Notably, Gatzlaff and Smith (1993) also found only weak evidence that the announcement of a major rail transit project has a positive benefit to the value of POD-impacted property.

Table 4
Model summary (announcement stage 2008–2011).

Model	R	R^2	Adjusted R^2	Std. error
1	0.872	0.761	0.733	0.071

Table 5
Estimated results of the hedonic price model (construction stage 2013–2019).

Independent variable	Coefficient	t-Statistic	p-Value
Constant		3.433	0.000
Bedrooms	**0.114**	**2.156**	**0.033**
Baths	**0.104**	**1.987**	**0.049**
Parking	**0.107**	**2.121**	**0.036**
Land area	**0.434**	**6.311**	**0.000**
Floor	0.039	0.798	0.426
Age	**−0.261**	**−4.359**	**0.000**
DTM	**−0.153**	**−3.388**	**0.001**
DTSC	**0.322**	**4.408**	**0.000**
DTSYD	**−0.201**	**−2.775**	**0.006**
DTPT	0.043	0.836	0.405
DTBUS	**−0.081**	**−1.833**	**0.069**
Unemployment rate	−0.068	−1.449	0.150
Household income	**0.118**	**2.040**	**0.044**

Table 6 also shows several variables with rather different results from those at the construction stage. For example, at the announcement stage the number of parking spaces is insignificant when at the construction stage it is strongly significant. This may be accounted for by the sharp increase in motor vehicle ownership over that period. The proportion of households owning more than three cars increased significantly between the 2011 and 2016 Census findings. This would place a premium on properties with more than two parking spaces. Also, the distance to the Parramatta CBD is found to be significant at the announcement stage when it is insignificant at the construction stage. In 2008–2011, the development of the north west of Sydney was not matured and residents at that time would have been more heavily reliant on access to the commercial and social facilities of the adjacent Parramatta CBD. Over time, areas such as Rouse Hill and Castle Hill have established their own commercial town centres, so the significance of the Parramatta CBD to local residents has gradually declined.

5. Conclusions

The development and improvement of transportation facilities, especially large rail transit systems, will promote regional social and economic activity growth. This finding has been confirmed in multiple studies across multiple jurisdictions. Such projects can also shape the pattern of urban development. However, large-scale projects usually require significant

Table 6
Estimated results of the hedonic price model (announcement stage 2008–2012).

Independent variable	Coefficient	t-Statistic	p-Value
Constant		5.831	0.000
Bedrooms	**0.174**	**2.945**	**0.004**
Baths	**0.157**	**2.347**	**0.021**
Parking	0.039	0.704	0.483
Land area	**0.284**	**3.958**	**0.000**
Floor	0.080	1.373	0.173
Age	**−0.268**	**−3.942**	**0.000**
DTM	**0.106**	**2.015**	**0.046**
DTSC	**0.309**	**3.355**	**0.001**
DTSYD	**−0.182**	**−1.827**	**0.070**
DTPT	**−0.198**	**−2.969**	**0.004**
DTBUS	**0.100**	**1.700**	**0.092**
Unemployment rate	−0.098	−1.448	0.151
Household income	**0.119**	**1.785**	**0.077**

funding and investment. Securing the investment for such major projects is a growing challenge for public authorities across the globe. An understanding of the economic benefits created by such projects is critical before those who benefit most from the investment can be required to contribute to that investment. This study uses HPM to quantitatively analyse the impact of the SNML on the residential property values in selected TOD-impacted areas, and most specifically, the value-added effect of the distance between the property and the nearest metro station on the price of housing. The Log-linear model (elastic model) has been shown to perform best in representing the relationships in that case.

According to the results, the following specific conclusions can be drawn. The residential property price is influenced by many factors, and the impact of rail transit on property prices will vary at different stages of the project. The SMNL has had significant impact on the residential property price of TOD-impacted properties both at the announcement stage and the construction stage. In the announcement stage, the impacts are generally negative, which means that the closer to the proposed metro station, the lower the residential property prices become. At the construction stage, the impact is almost entirely reversed. It is shown that residential prices rose an average of 0.037% for every 1% reduction in the distance to the nearest metro station at the construction stage.

The impact of different attributes on the price of housing is not consistent. The impact can be affected by the economy, policy, social, environmental, and other changes. For example, in this study, the influence of parking space on housing prices gradually increased over time, as the significance of the Parramatta CBD waned. This had a substantial influence on the relative impact of the SMNL project on house prices. The study demonstrates the need to consider time and environmental changes when predicting the impact of a major transportation development on property values.

Given the duration and context dynamics of a major transportation project construction stage, further study is warranted to investigate the impacts at different phases of the construction (such as early, middle and later phases).

Overall, the findings of the study provide valuable insights to public administrators, urban planners and other investment stakeholders to achieve more equitable and broader contribution to the monumental cost that large transport infrastructure projects impose on the public purse. More explicitly, the study demonstrates the financial benefit of the SMNL to TOD-impacted properties and provides a measure of that benefit. Based on such findings, and the potential to use the same methodology to analyse proposed projects in the future, the study supports the call for property investors who gain from public expenditure on transport projects to contribute a portion of that benefit towards the cost of the project.

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