

An alternative approach to estimate the benefits of investing in an urban rail network

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Abstract

Authorities around the world are looking for new approaches to justify the implementation of capital intensive transport infrastructure such as urban rail solutions. Traditionally, the benefits of an urban rail line include conventional user benefits such as savings in travel time, vehicle operating costs, accident costs and environmental costs, and more recently, wider economic benefits. An alternative approach which is occasionally used is to consider the appreciation of property prices along a rail corridor, and the intensification of land development surrounding a rail station.

Using the development of new rail lines in Singapore as a case study, this paper will first apply the hedonic regression method to obtain estimates of elasticity between property price and transport accessibility. Secondly, using historical land use masterplans, the paper will discuss how the density of land use adjacent to rail stations has intensified over the past 15 years, through a comparative analysis of the land use density with respect to the distance from a rail station. Finally, using the Circle Line as an example, the alternative approach, which utilizes the land value enhancement of existing properties and the land intensification due to proximity to the line, will be compared against the conventional user benefits.

1. Introduction

Authorities around the world usually adopt a project evaluation approach, using cost-benefit analysis, to facilitate decision-making regarding investment in transport projects. Economic evaluation requires estimation of the social benefits, such as travel time savings, travel time reliability savings, crowding reductions, vehicle operating cost savings, and accident cost savings. These benefits are also known as conventional benefits.

In light of increasing cost projections, there is interest in alternative, but complementary, ways of measuring the benefits of transport projects, particularly in the case of the infrastructure-heavy urban rail network known in Singapore as the Mass Rapid Transit (MRT). One approach being considered is to estimate land value enhancement, which represents a once-off uplift in the value of existing properties after the implementation of an MRT line. Concurrently, land intensification benefits, which represents the benefits of increasing land densities due to their proximity to MRT stations, can also be estimated and added on to land value enhancement.

In Section 2, we will present a brief literature review. In Section 3, we discuss the methodology for estimating the elasticity of property value enhancement with respect to transport accessibility, and the estimation of this benefit for an MRT line, the Circle Line. In Section 4, we look into how the density of land use adjacent to MRT stations has intensified over the past 15 years by using historical land use masterplans produced by the Singapore government. Section 5 presents a comparison of alternative benefits, which comprises of land value enhancement and land intensification, to conventional user benefits, using the Circle Line as a case study. Section 6 provides our conclusions.

2. Literature review

This section provides a brief literature review on the theory of land rent relationship, empirical evidence on the relationship between the public transport investment and land use, and the methodology to estimate the land enhancement benefits.

Alonso (1964) developed a bid-rent model in which consumers are willing to pay a higher price for properties nearer to a centre of activities. This leads to a rent gradient that increases with higher accessibility to the centre. Using accessibility as the distance or the cost of transportation to the destination, Alonso suggested that locations with better accessibility had a higher rental value, where rental value was the annualised capital value. New transport infrastructure including both highway and public transport (PT) projects increase accessibility. This therefore increases rental value, and hence, land values.

The impact of PT could be on land value as well as land development (Ferguson et al, 1988). On the subject of land value uplift, there have been numerous studies such as by Benjamin and Sirman (1996), Cervero (1997) and Nelson (1998), who proved a positive uplift of property values by its proximity to a railway station. In Singapore, Fesselmeyer, E., & Liu, H. (2016) showed that housing prices increase in areas that were already connected to the MRT as a result of the expansion of the network. Debrezion et al (2003) conducted a meta-analysis of the impact of railway stations on properties. Property prices were considered as a function of three main groups of variables: the structural characteristics, the accessibility and the environmental amenities. Most of the earlier studies considered the first two determinants.

While there are numerous detailed papers on the impact of PT accessibility on land value, studies on the impact of PT accessibility on land intensification are not often encountered in the literature, and when they are, these studies tend to be nested within a broader research agenda. For example, Debrezion (2003) mentioned briefly that the theory on land prices and settlement indicates that a higher accessibility of a location leads to a dense settlement. Litman (2017) showed that a multi-modal transport policy with transit would support higher density development. For example, when comparing the land utilisation in Netherlands and Southern California, he showed that the typical land consumption per capita (square feet) for a multi-modal policy is only 32% of that for an auto-oriented city. Le et al (2017) presented a methodology to estimate land enhancement and land intensification benefits using the North East Line in Singapore as a case study. This paper discusses a similar approach but uses the Circle Line as a case study.

3. Land enhancement benefits

3.1. Methodology

The basic premise in real estate price studies is that property price is affected by both its structural and locational characteristics. When a location becomes more attractive due to an

improvement in certain characteristics such as its accessibility, demand for property in that location increases, resulting in higher prices. However, it is also necessary to control for the different structural characteristics of properties such as the property-type and tenure-type whenever possible¹. If undertaken successfully, the accessibility impact of the transport infrastructure can be isolated and the estimated elasticity parameter can then be a benchmark value applied to proposed future changes to the network to obtain estimates of future property value enhancements.

A simple way to assess the impact on property prices of changes in accessibility is using a before and after case study. However, since there are limitations in obtaining the sales price data for the same property before and after the transport improvement, the before-and-after approach is not widely used in practice.

When comparing the values of many different properties across many different locational settings within a region, it is possible to statistically estimate a series of coefficients that represent the incremental effect on property value associated with each individual characteristic of a building and its setting. Economists often refer to these regression estimates of property values as “hedonic price models” because they represent the implied prices that people place on obtaining desirable and avoiding undesirable features in a property. Hedonic regression is a revealed preference method of estimating the value placed on the attributes of certain assets. In this case, we are looking at the relationship between residential property price data and the structural and location attributes of the property.

With structural and location attributes, the regression analysis takes the following form, as in Equation (1):

$$\text{Log}(P_i) = \gamma_0 + \sum_m \gamma_m S_{im} + \sum_n \gamma_n L_{in} + \varepsilon_i \quad (1)$$

where:

P = Price per square metre

i = identifier for property *i*

S = Structural attribute of property

L = Location attribute of property

m = number of structural attributes

n = number of location attributes

ε_i = error term

γ = coefficients

Among the location attributes considered for the hedonic analysis, special attention should be called to an Employment Accessibility (EA) factor, which is designed to represent the accessibility of a property to employment. Significant research into property price effects for public transport access utilise distance to the rail station as the location attribute of interest (see, for example, Mi et al. (2017) in the Singapore context). However, in most cases, the effects of proximity to an “average” station are estimated in this approach; stations-specific effects and their contribution to accessibility and connectivity of a network are ignored. For this reason, including the EA factor into the hedonic regression is preferred to a pure distance-to-station measure. The EA can be calculated for each property using transport model outputs and walking distance from property location to station. Each property sale in the database is assigned an EA depending on the sale date, and EA is calculated using Equation (2):

¹ Many residential properties in Singapore have lease tenures of 99 years and are generally less desirable than those of freehold properties.

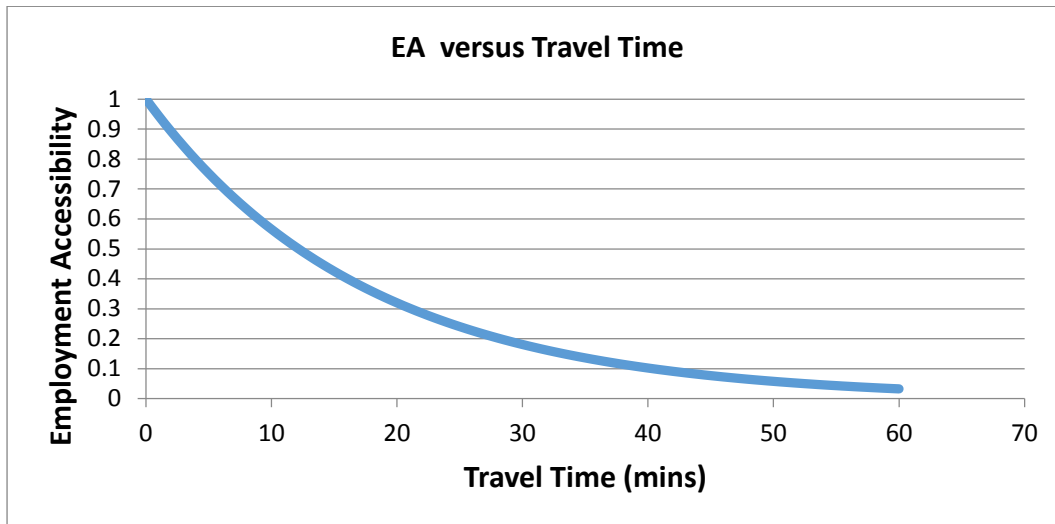
$$EA_i = \sum_j \frac{E_j}{E} e^{-\beta TT_{ij}} \quad (2)$$

where:

- $\frac{E_j}{E}$ is the share of employment at Transport Zone j of the total employment E in Singapore.
- TT_{ij} is the transport cost incurred in terms of public travel time when travelling from property i to transport zone j . Each building in Singapore is identified using a postcode that is unique to that building.
- β is the decay parameter determining how households discount the value of employment at location j on travel time. A decay parameter of 0.057 has been used based on research undertaken in the UK for a similar study assessing the property price impacts of the Jubilee line and Docklands light rail extension (Ahlfeldt, 2011).

The EA factor is a number between 0 and 1 representing the accessibility from one property postcode to all other zones weighted by employment share at destination. EA is essentially the inverse of an exponential function of travel time to employment. The shorter the travel time, the higher the EA. Figure 1 shows a relationship between EA and travel time.

Figure 1: Relationship between employment accessibility and travel time



Using the employment accessibility factor means that the result of the hedonic regression with log (prices) as the dependent variable will be a semi-elasticity factor (α) relating to a given change in employment accessibility by public transport to a percentage change in property prices. This can then be applied to future projects to estimate predicted net land value uplift. The regression equation therefore becomes:

$$\text{Log}(P_i) = \sum_m \gamma_m S_{im} + \sum_n \gamma_n L_{in} + \alpha \sum_j \frac{E_j}{E} e^{-\beta TT_{ij}} + \epsilon_i \quad (3)$$

Equation (3) was applied to property transaction databases with records from 1995 to 2014, with a discussion of results in the following Section 2.2. During this period, Singapore opened two MRT lines: the North East Line (NEL) in 2003 and the Circle Line (CCL) in stages between 2009 and 2012.

3.2. Regression Results of Private Residential Data

The hedonic regression was performed for two residential data sets: private residential data and Housing Development Board (HDB) data². For private residential data, the REALIS database from the Urban Redevelopment Authority (URA) was used. It contained 331,940 private residential transactions between January 1995 and December 2014. Almost all available variables in the database were included in the model. The main variables are described below.

Structural attributes include:

- a) Size of property (m²), with value ranging from 24m² to 98,773m² and an average of 128m²
- b) Number of floors, with a maximum of 69 floors and an average of 9 floors.
- c) Whether purchaser previously owned a HDB flat or not
- d) Freehold or not
- e) Property type in terms of apartments, condominiums or other. 69% of private properties were condominiums, 30% were apartments and the remainder were landed houses.
- f) Prices were normalised to December 2014 levels using the monthly Singapore Real Estate Exchange Property Index (SPI)³

Unfortunately, more detailed structural attributes of the property, such as the number of bedrooms and bathrooms, were not available in the dataset. Year dummies, with 19 (0,1) variables covering 20 years of data were also included to control for the impact of cyclical economic factors on property prices.

The following location attributes were calculated from the postcode identifier of each property.

- a) Distance to CBD was calculated using the geodesic distance (straight line distance) between the postcode of the property and the Singapore City Hall, which has been used as the centre of the city. 407 entries had incomplete postcode identifiers and were removed from the database.
- b) Distance to nearest MRT station, which had an average of 1,084m. This variable was only used to test alternative specifications to the EA factor. On average, there were about 58% of properties within 1000 metres of a MRT station and 42% outside this catchment.
- c) The EA factor was calculated for each postcode for the 3 transport scenarios (Pre-NEL, Post-NEL and Pre-CCL, Post CCL). For each property transaction, an EA was assigned depending on the postcode and date of sale.
- d) Postal district that each property was a member of. There are 28 such postal districts in Singapore.

After cleaning the data, a total of 319,102 transaction records remained. Using the LTA strategic transport model, public transport travel time was estimated for three transport

² HDB flats are public housing in Singapore. Over 80% of Singapore residents live in these.

³ <http://www.srx.com.sg/price-index>

scenarios during the 1995-2014 period: (i) Pre-NEL, (ii) Post-NEL and Pre-CCL, and (iii) Post CCL. The zone to zone travel time matrix was converted to a postcode to zone matrix by replacing walking time from a zone to a MRT station with walking time from a postcode to MRT station to improve travel time accuracy.

Employment data for 2008 was used for all locations and periods in the calculation of the EA weighting, so that the changes in employment distribution over time did not impact the EA.

The results for the regression analysis are shown in Annex A. Due to the large number of variables, the time and locational dummy variables have been omitted from the table. As can be observed from the t- statistics and p-values, all variables are significant, except the strata. Given the property data base has limited structural information about the properties, an adjusted R square of 0.71 represents a very good fit. The R square is also comparable to Ahlfeldt's (2011) UK study, where more structural data on properties such as number of bedrooms, number of bathrooms, the presence or lack of central heating, the presence or lack of a garage, parking space, and details of property types were available. In the private property regression model for Singapore, the estimated α coefficient for EA is 1.088 and statistically significant at the 5% level.

Property price impacts for the Circle Line were then estimated by using the following formula in Equation (4) derived from Equation (3):

$$\Delta P/P = (e^{\alpha * (EA_2 - EA_1)} - 1) \quad (4)$$

A simulation was calculated for all postcodes in Singapore to calculate EA before and after CCL. The percentage change in property price for all private properties can be estimated and is shown in Figure 2. Private property locations close to the new stations have estimated property price increases of 5 to 15%. As distance to station increases and the accessibility benefits of the MRT line reduces, so does the impact of accessibility on prices.

3.3. Regression Results of HDB Residential properties

Singapore HDB resale data was available for the period January 2000 to December 2014. The database contains the address, property number and a concordance table with the postcode of each address. Unfortunately, addresses were not in the same format and some data manipulation was required to match a significant number of the addresses in order to assign a postcode to each property. Of the 422,861 property transactions provided, 292,589 could be matched with a postcode and were used in the analysis. The average adjusted price per m² of HDB property was S\$ 4,710, which was much lower than that of private property at S\$15,292.

Structural variables used in the analysis were:

- a) Size of property (area in m²), with an average of 97m², smaller than that of private property
- b) Number of floors (or storey in integer), with an average of 7 floors
- c) Apartment Type (1 room, 2 rooms, 3 rooms, 4 rooms, 5 rooms, Executive)
- d) Age (integer), with an average of 19 years

Locational variables used were:

- a) Distance to centre of the city (metres) (based on the straight line distance to City Hall)
- b) Distance to MRT station. This variable is only used to test alternative specifications to EA. For HDB apartments, the average distance to MRT (914 m) was closer than the average distance for a private property (1083 m). Nearly two thirds (65.7%) of HDB properties compared to 58% of private properties were within 1 km of a MRT station
- c) Postal District
- d) EA was calculated using the same method as that for private residential property

The results for the regression analysis are shown in Annex B. Due to the large number of time and locational dummy variables, these were omitted from the table.

The α coefficient for EA in the HDB regression is 2.546. This is more than double the α coefficient of private residential property. This means that a HDB property owner in general would value MRT accessibility much more highly than a private property owner. This is reasonable since HDB property owners, with lower car ownership, are likely to rely more on MRT to provide accessibility than private property owners. This is illustrated in Figure 2 and Figure 3, which show that the percentage increase in HDB property prices is much higher than that in private property.

Figure 2: Estimated % increase in private property prices due to CCL

(Postcode data is available as points so areas close to stations with no colored markers are due to gaps between postcodes)

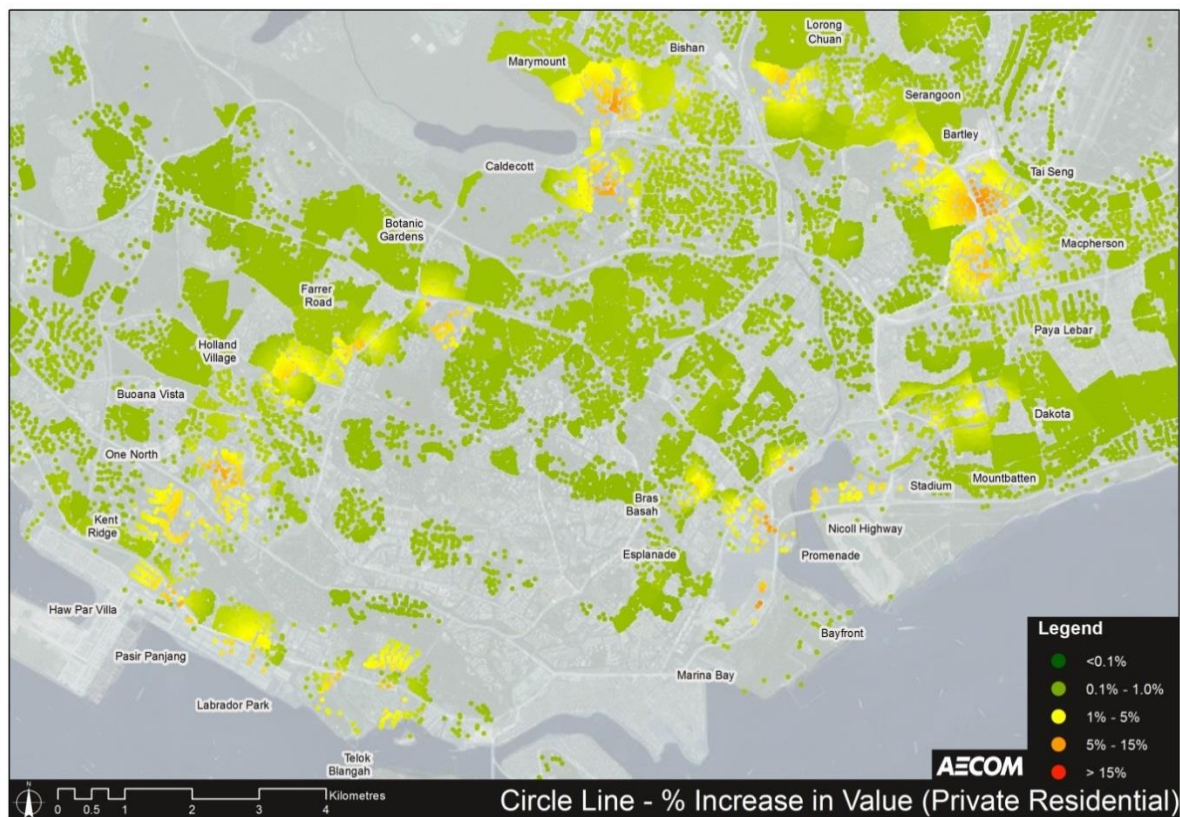
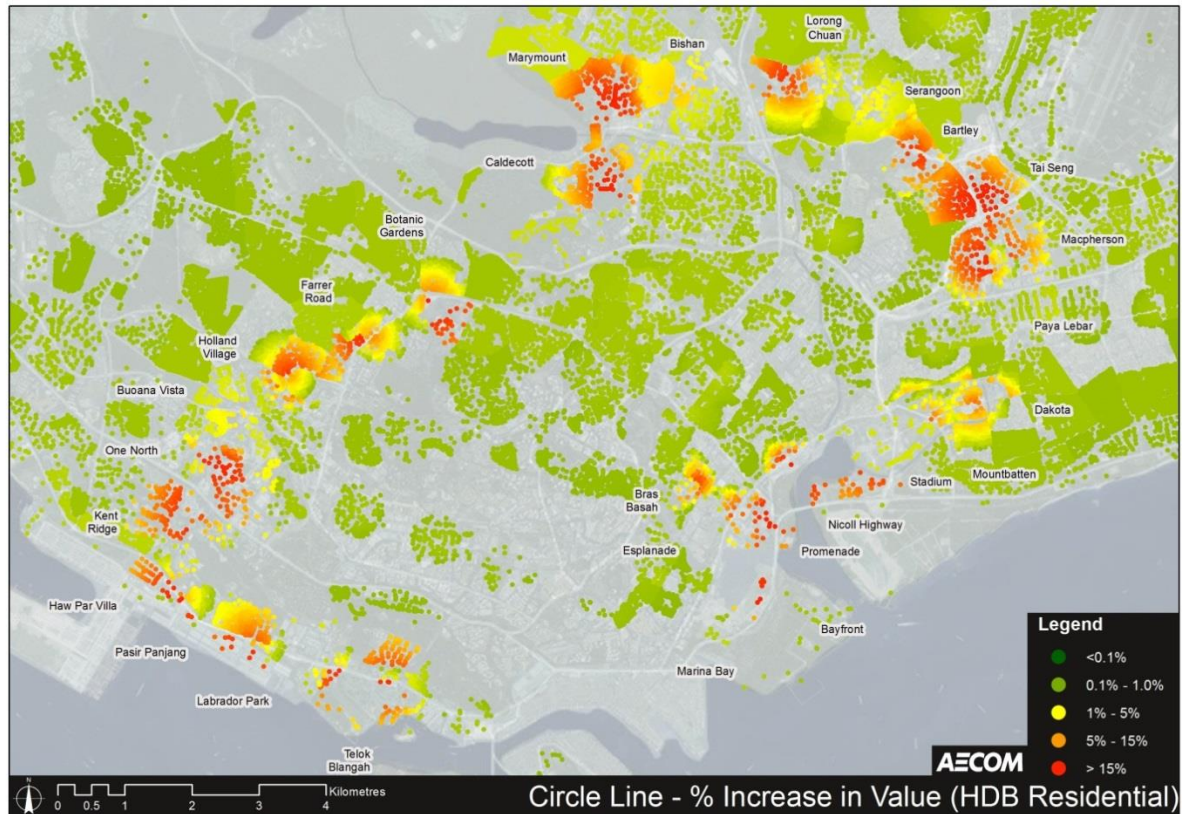


Figure 3: Estimated % increase in HDB property prices due to CCL



3.4. Comparison to other results

The impact of public transport on property prices is difficult to compare across studies due to the different nature of the transport networks and the different methodologies used. Some results are shown in Table 1. While not all are directly comparable, they give some indication of the impacts found in other cities. The table shows that the UK study results (Ahlfeldt, 2011) are in the middle of the Singapore private and HDB residential property results.

Table 1: Comparison of other published studies

Study	Result
Singapore NEL & CCL	1% and 2.5% increase in private and HDB property prices respectively for every 1% increase in EA
1999 Jubilee Line and DLR Extension. London (Ahlfeldt, 2011)	2% increase in property prices for every 1% increase in EA
Atlanta Rapid Transit System (Nelson, 1998)	\$1.05 per feet distance to the station. Premium on property value in low-income areas; \$0.96 per feet distance to the station.
Washington D.C Metro Stations (Benjamin and Sirmans, 1996)	Rent decreased by 2.4 to 2.6% for each one tenth mile distance from the metro station
Bay Area Rapid Transit, San Francisco (Cervero , 1997)	10- 15% increase in rent for rental units within 1/4 mile of BART
Dallas Area Rapid Transit (Weinstein and Clower, 1999)	5.97% Increase in property value for properties within ¼ mile of the station
Portland Light Rail (Dueker and Bianco, 1999)	Property value declines \$1593 for every 200 feet from the station

3.5. Estimation of Land Value Enhancement for CCL

By using the regression equation and applying to a property before and after the implementation of an MRT line, and given all the structural and location attributes of the property remain unchanged and the only change being the accessibility, the land value uplift for a property can be estimated by applying Equation (5):

$$\Delta P = P_2 - P_1 = (e^{\alpha * (EA_2 - EA_1)} - 1)P_1 \quad (5)$$

Where:

- ΔP the change in property price per square metre
- P_1 and P_2 the price per square metre of the property before and after the implementation of an MRT line
- EA_1 and EA_2 the employment accessibility of the property before and after implementation of an MRT line
- α the coefficient of EA

EA_1 and EA_2 were calculated for every postcode in Singapore based on public transport travel time before and after the implementation of a MRT line, weighted by employment. The estimated change of property price for one postcode is the product of $(P_2 - P_1)$ with the total gross floor area of residential property within the postcode. The impact of the MRT line on the whole of Singapore is the sum of all price changes of all postcodes in Singapore. Since the EA coefficient is different for private and HDB property, the calculation is also separate for private and HDB properties.

In the calculation of residential land value uplift, the following parameters were deriving from the property transaction databases and applied.

- a) Average dwelling floor area for HDB and private residential property: 97m² and 122m².
- b) Adjusted average property price per square metre for HDB and private residential property in 2014: \$4,710 and \$15,331.

Table 2 below shows a summary of EA coefficients for the impact of NEL and CCL separately by partitioning the data into two subsets: before and after 2005. The regression was then conducted separately. Interestingly, there appears to be a time dimension to the EA coefficient and the R² was improved when the full dataset was separated into two subsets, which is especially seen in the HDB data. For the purpose of estimating the property value uplift for CCL, the EA coefficients used for residential property were obtained from estimating the 2006-2014 dataset.

Table 2: Summary of EA coefficients for residential property

Residential property data source	Records	R ²	EA Coefficients
Private			
NEL (1994-2005)	118,585	0.61	1.093
CCL (2006-2014)	200,517	0.76	0.981
All years	319,102	0.71	1.088
HDB			
NEL (2000-2005)	142,535	0.61	2.138
CCL (2006-2014)	150,054	0.72	2.702
All years	292,589	0.54	2.546

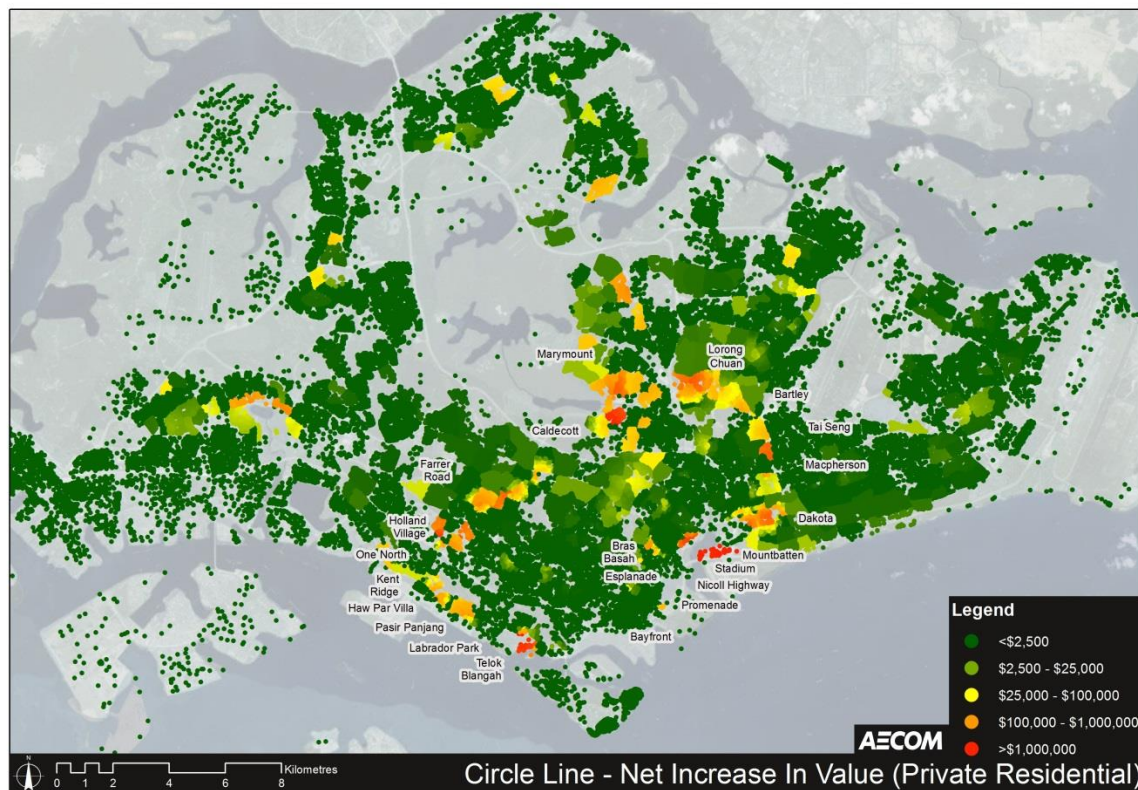
The total residential property value uplift for CCL is shown in Table 3.

Table 3: Total residential property value uplift for CCL (in \$Million)

Line (year)	Private property value uplift (\$M)	HDB property value uplift (\$M)	Residential property value uplift (\$M)
CCL (2014)	1,102	1,705	2,807

It can be seen that for the CCL the land value uplift for HDB property is about 1.5 times that for private property. This is expected because while there are more private properties than HDB along the CCL corridor, the percentage increase in HDB property prices is much higher than that of private property (due to much higher EA coefficient). Figure 4 shows the estimated price increase in private residential property. The colors represent the total increase in property value in each postcode.

Figure 4: Estimated increase in private property prices from CCL



The above figure indicates that the impact of the CCL on increasing property values is not restricted within the CCL corridor, but also extends to other properties surrounding existing MRT lines, although their level of increase is smaller. This is expected as the opening of a new line would result in an increase in accessibility in other properties located along the existing MRT lines due to the enhanced connectivity of the overall system, on top of the improved accessibility of properties within the CCL corridor.

4. Land Use Intensification

4.1. Introduction

Over the years in Singapore, property adjacent to MRT stations has been developed into areas of higher density than property further away from the station. This phenomenon has taken

place due to market forces facilitated by land use planning. It can be said that transport infrastructure enables the intensification of land use along the transport corridor. By way of background, land planning in Singapore is undertaken by another government agency called the Urban Redevelopment Authority (URA), which releases a development Master Plan every 5 years. The Master Plan represents the distribution of existing land use as well as the intention of future use for green field sites and areas to be rezoned. Hence, the Master Plan represents both market demand as well as the planning intention for the entire country.

The Master Plans prepared in 2003, 2008 and 2014 were analysed to determine the density of different land use types with respect to their distance to MRT station. The impact of the MRT on land use intensification can then be determined by comparing the density of different land use types between land within and outside the MRT catchment.

There are five planning regions in Singapore: Central, East, North, North-East and West. Each region provides a mix of residential, commercial, business and recreational areas and supports a population of over 1,000,000 people. The regions are divided into a total of 55 smaller planning areas which have a population of about 100,000 each, served by a town centre and several smaller commercial/shopping centres. There are 32 land use types defined in the Master Plan which are grouped into six main categories. Table 4 shows the allocation of land by these categories over the past 12 years.

Table 4: Total land (m²) by land use type and year

Land use	2003		2008		2014		Percentage change	
	m ²	%	m ²	%	m ²	%	2003-08	2008-14
Industrial	123,772,597	16%	129,635,250	17%	119,868,013	15%	5%	-8%
Education and health	21,225,848	3%	20,754,422	3%	21,260,885	3%	-2%	2%
Commercial	6,219,772	1%	6,646,128	1%	6,715,578	1%	7%	1%
Residential	152,450,017	20%	132,675,725	17%	138,010,926	18%	-13%	4%
Open space and park	118,151,745	15%	119,027,164	15%	122,783,698	16%	1%	3%
Transport, utilities, reserve and others	353,000,669	46%	367,882,040	47%	373,336,446	48%	4%	1%
Total land	774,820,647	100%	776,620,728	100%	781,975,546	100%	0%	1%

Overall, the largest allocation of land is for transport, utilities, reserve and others. This is then followed by residential, industrial, open space and park, education and health, and commercial. This pattern is fairly consistent over the three periods: 2003, 2008 and 2014.

4.2. Methodology for measurement of land use intensification

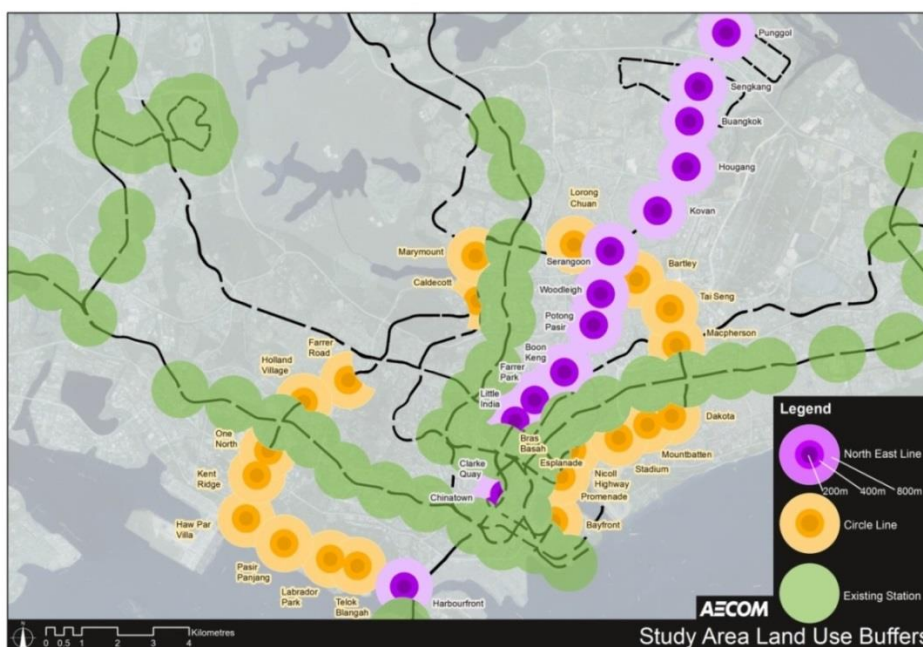
The measurement of land use intensification is conducted by analysing the Master Plans through several steps using GIS, as follows:

- Determine the average gross plot ratio (GPR) with respect to distance to the MRT station for four main land use types over the three Master Plan periods: industrial, education & health, commercial, and residential. The GPR refers to the ratio of the Gross Floor Area to site area (or surface area), and is considered as a measure of the density of development of the site.

- b) Determine the change in GPR by comparing the GPR for land within MRT catchments (radius <800m), with the GPR of land outside the catchment (radius >800m). 800m is considered to be a reasonable distance where people are willing to walk to a station, and hence, is adopted as a reasonable distance of influence of MRT.
- c) Create buffer zones around stations of CCL and future committed rail lines to form three sub-catchment areas: within 200m, between 200 and 400m, and between 400 and 800m. Each buffer is adjusted to not include the catchment of existing stations (see Figure 5).
- d) Calculate land parcel by land use type for each station buffer. A land parcel is included if its centre point is within the buffer area
- e) Calculate the land intensification benefit for a station as equal to the land parcel area (within a sub-catchment) multiplied by the net change in GPR (by sub-catchment) and multiplied by land value (\$/m²) for each land use type. The formula is expressed as below:

$$\text{Land intensification benefit (\$)} = \text{parcel area (m}^2\text{)} \times \text{GPR net change} \times \text{land value (\$/m}^2\text{)}$$

Figure 5: Land use buffers for NEL and CCL for land intensification calculation



4.2.1 Analysis of average plot ratios

The level of land intensification around MRT stations can be estimated by looking into the change of GPR for each main land use type with respect to its distance from the MRT station. Table 5 shows the average GPR over the three Master Plans for four land use types: industrial, education and health, commercial, and residential, and also categorises it by its region and distance to the MRT station. The average GFRs with respect to distance to the MRT station (<800m) were based on the base network (i.e. without NEL and CCL). The GPR with respect to distance to the MRT station (>800m) were also calculated for each region but excluded all existing and future station catchments.

Table 5: Average GPR by land use and by distance to MRT station

Region	Dist. to MRT	Average GPR			
		Industrial	Education & Health	Commercial	Residential
WHOLE ISLAND	<200m	1.86	4.20	4.11	2.98
	200m - 400m	1.80	-	3.44	2.40
	400m - 800m	1.91	3.33	3.39	2.21
	>800m	2.02	1.76	2.48	1.77
CENTRAL AREA	<200m	-	-	4.59	3.11
	200m - 400m	-	-	4.33	2.84
	400m - 800m	-	4.20	4.23	2.91
	>800m	2.35	2.75	2.59	2.19
WEST REGION	<200m	1.43	-	4.56	2.97
	200m - 400m	1.41	-	4.43	2.89
	400m - 800m	1.61	-	4.96	2.69
	>800m	1.84	1.78	1.65	1.86
EAST REGION	<200m	2.50	-	4.00	2.39
	200m - 400m	2.41	-	3.67	1.62
	400m - 800m	2.17	-	-	1.54
	>800m	2.11	1.72	1.70	1.84
NORTH REGION	<200m	-	-	3.70	2.88
	200m - 400m	-	-	3.50	2.82
	400m - 800m	2.39	3.00	3.50	2.75
	>800m	2.28	1.87	1.25	2.24
NORTH-EAST REGION	<200m	-	-	2.83	3.63
	200m - 400m	2.50	-	-	2.91
	400m - 800m	2.50	-	-	2.85
	>800m	2.03	1.40	1.59	1.72
CENTRAL REGION (exclude CA)	<200m	2.50	4.20	3.59	3.27
	200m - 400m	2.55	-	3.05	2.70
	400m - 800m	2.54	2.80	3.03	2.33
	>800m	2.18	2.15	2.64	1.70

Generally, it can be seen that the GPR for a land use is highest near to MRT stations and lower further away. For example, looking at the residential land use for the whole island, the GPR for land within 200m of MRT stations (2.98) is higher than that for land within 200-400m (2.40), which is, in turn, higher than land within 400-800m (2.21), and then higher than land within 800m (1.77). The pattern is similar for commercial land and other land uses. For industrial land, the GPR for developments within 800m are higher than those outside 800m for most regions, although the relative difference of GPR between <800m segments does vary. Therefore, it can be said that the presence of an MRT station will increase the GPR or the density of land use development. The benefits of land intensification of an MRT station are calculated as the net increase of GPR (i.e. the difference between the GPR of land (e.g. within 200m) and the GPR of land outside the MRT catchment (i.e. distance to MRT >800m)), multiplied by the size of the relevant land parcels (within a sub-catchment for each land use), and by an average unit value (\$/m²) for each land use type.

4.2.2 Average land price

In order to convert the land use intensification into monetary form, the average land values indexed to the last quarter of 2014 by land use type and by postal district derived from property sale transactions as presented in the previous chapter were used. Table 6 shows the average 2014 indexed land price by land use. Since there is no transaction price data for education and health, the unit land price of commercial was adopted for this land use.

Table 6: Average 2014 indexed land price (\$/m²) by land use

Residential - Private	Residential - HBD	Commercial	Industrial
15,217	5,233	21,918	6,249

4.2.3 Land parcels

The land intensification for CCL requires calculations of the land parcels by land use type and by sub-catchment (i.e. 200m, 400m and 800m). Table 7 shows the aggregation of all sub-catchments of land parcels by land use type and by station.

Table 7: Total land parcels (m²) within 800m catchment of CCL stations

Station	Postal District	Region	Residential	Commercial	Health/Edu	Industrial	Total
Caldecott	12	Central Region	199,187	-	57,342	-	256,529
Pasir Panjang	5	Central Region	182,939	-	20,576	127,714	331,228
Kent Ridge	5	Central Region	114,393	-	244,840	-	359,233
Haw Par Villa	5	Central Region	315,932	27,685	-	142,701	486,318
Labrador Park	3	Central Region	873,499	60,811	30,277	114,736	1,079,323
Bartley	12	Central Region	500,546	-	72,863	151,063	724,473
One North	5	Central Region	29,193	-	121,297	-	150,490
Dakota	14	Central Region	874,286	11,528	111,371	-	997,185
Bayfront	6	Central Region	32,498	-	-	-	32,498
Lorong Chuan	13	North-East Region	935,251	-	84,891	39,805	1,059,948
Marymount	20	Central Region	544,525	19,209	65,365	46,587	675,686
Farrer Road	10	Central Region	1,162,220	3,807	32,966	-	1,198,994
Holland Village	10	Central Region	793,938	-	-	-	793,938
Telok Blangah	3	Central Region	198,053	11,540	6,815	-	216,408
Tai Seng	12	Central Region	51,663	-	-	537,340	589,002
Mountbatten	14	Central Region	105,175	16,018	52,119	-	173,312
Stadium	15	Central Region	99,502	14,058	-	-	113,560
Nicoll Highway	15	Central Region	136,996	5,435	-	-	142,431
Esplanade	6	Central Region	-	35,672	-	-	35,672
Promenade	6	Central Region	-	25,021	-	-	25,021
Macpherson	14	Central Region	482,642	10,747	83,829	502,575	1,079,793
Total			7,632,438	241,532	984,552	1,662,521	10,521,043

4.3 Land intensification benefit calculations

The land intensification benefit in dollars for stations on the CCL are summarised by station and postal district as shown in Table 8.

Table 8: Total land use intensification value (\$mil) for CCL stations

Station	Postal District	Region	Residential	Commercial	Health/Ed	Industrial	Total
Caldecott	12	Central Region	1,105	-	480	-	1,585
Pasir Panjang	5	Central Region	1,149	-	-	267	1,416
Kent Ridge	5	Central Region	488	-	15,265	-	15,752
Haw Par Villa	5	Central Region	1,599	437	-	297	2,333
Labrador Park	3	Central Region	6,303	546	439	346	7,634
Bartley	12	Central Region	2,934	-	2,584	447	5,965
One North	5	Central Region	124	-	3,027	-	3,151
Dakota	14	Central Region	4,902	104	1,021	-	6,027
Bayfront	6	Central Region	199	-	-	-	199
Lorong Chuan	13	North-East Reg	7,497	-	-	141	7,638
Marymount	20	Central Region	2,840	152	-	98	3,090
Farrer Road	10	Central Region	8,407	39	504	-	8,951
Holland Village	10	Central Region	5,794	-	-	-	5,794
Telok Blangah	3	Central Region	1,217	101	-	-	1,318
Tai Seng	12	Central Region	230	-	-	1,613	1,843
Mountbatten	14	Central Region	434	288	739	-	1,461
Stadium	15	Central Region	491	88	-	-	580
Nicoll Highway	15	Central Region	676	34	-	-	711
Esplanade	6	Central Region	-	279	-	-	279
Promenade	6	Central Region	-	185	-	-	185
Macpherson	14	Central Region	2,876	91	545	1,110	4,622
Total			49,267	2,345	24,605	4,319	80,535

Overall, the table above indicates that the CCL could bring about a total land intensification benefit of \$80,535 million compared to the case without CCL. This land use intensification is regarded as an additional benefit to the initial property value uplift based on existing land use. Assuming that the land intensification happens gradually over 60 years and allowing a discount rate of 4%, the net present value of this intensification benefit (in 2014) is estimated at \$30,367 million.

5. Comparison of results between approaches

5.1. Conventional approach

The total benefits by the conventional approach for CCL were estimated using an official discount rate of 4% and project life of 60 years. They are summarized in **Table 9**.

Table 9: Total benefits for CCL by conventional approach

Components	2015 PV of benefits (\$ mil.)
Public transport time savings	25,505
Private vehicle highway time savings	2,074
Vehicle operating cost savings	950
Accident cost savings	254
Bus operating cost savings	132
Total present value of benefits	28,915

5.2. Alternative approach

Table 10 shows the present value of property value uplift and intensification benefits for the CCL. The land value and intensification benefits are calculated as real and excluded tax. The property value uplift was calculated for the base year of 2014, and represents a once-off property value enhancement of existing properties due to the improvement in accessibility resulting from the implementation of an MRT line. The land use intensification benefits represent the additional property development that can occur due to the proximity to a MRT station. It was assumed to spread over the span of 60 years, the life of a railway infrastructure, and was discounted back to the present year of 2014. Therefore, these two are mutually exclusive benefits that can be added together to represent the total benefits of building MRT lines without double counting.

Table 10: Present value of property value uplift and intensification benefits

Type of benefits	2014 PV of benefits (\$M)			
	Residential	Commercial	Industrial	Total
Land Uplift	2,807	5,159	2,044	10,010
Land Intensification	18,577	10,162	1,629	30,367
Total	21,384	15,321	3,673	40,377

However, when compared against the conventional benefits, the land value uplift was calculated on the improvement of accessibility, which in turn was based on the reduction of public transport travel time. It therefore represents the capitalization of travel time savings. Separately, the land use intensification benefits would be realized when the land is developed, and when there is demand driven by population growth. It therefore relates to the increase of travel time savings in the conventional benefits due to the growth of population. This suggests that the benefits estimated from the alternative approach should not be added to the conventional benefits to prevent the risk of possible double counting.

5.3. Comparison between two approaches

The benefits estimated by the alternative approach are about 40% higher than those calculated by the conventional method for the CCL. The difference is partly due to the conventional benefit totals not yet incorporating Wider Economic Benefits and travel time reliability benefits, and the selection of discount rate. Conventional benefits are estimated for each future year and then discounted to a present value using a public sector discount rate. Property market values which are the basis for the alternative approach are a capitalization of future benefits in property prices and hence, are equivalent to a present value. However, this present value does not necessarily reflect the same discount rate as used for the conventional benefits calculation. Rather, it will be the average of the discount rates (or rate of time preference) of all the individual property purchasers. Depending on how the public sector rate is derived and how recently it has been reviewed, these individual discount rates may be less than the public sector rate, particularly when global interest rates have been trending lower. For example, if the discount rate used to calculate the present value of conventional benefits was assumed to be 3% in real terms, instead of 4%, conventional benefits would be much closer to the benefits derived by the alternative approach.

6. Conclusion

The estimates of property value enhancement and land use intensification benefits provide an alternative measure of some of the benefits of the MRT projects and a different way of describing and demonstrating the validity of these benefits. These benefits are not additional to the conventional transport benefits and should not be simply included in conventional benefit/cost ratios. However, the alternative approach can be useful in cross-checking the validity of the conventional approach and may provide a scale of the benefits not yet captured if the discrepancy between the alternative and conventional approach is large.

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Appendix

A1 - Regression results for private residential properties

R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
			R Square Change	F Change	df1	df2	Sig. F Change
0.705	0.705	0.20346	0.705	12918.997	59	319042	0.000

Independent variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	9.309	.059		157.626	0.000					
Floor	.006	.000	.121	108.451	0.000	.261	.189	.104	.740	1.351
area_sqm	-2.583E-06	.000	-.003	-3.044	.002	.015	-.005	-.003	.994	1.006
Freehold	.150	.001	.200	160.033	0.000	.372	.273	.154	.589	1.697
EA	1.088	.019	.123	56.514	0.000	.496	.100	.054	.197	5.084
Hdbpur	-.018	.001	-.023	-22.033	.000	-.262	-.039	-.021	.844	1.185
Strata	.031	.059	.001	.534	.593	-.001	.001	.001	.999	1.001
Resale	-.252	.001	-.329	-314.766	0.000	-.255	-.487	-.303	.847	1.180
sub_sale	-.036	.001	-.029	-28.150	.000	.147	-.050	-.027	.859	1.164
dist_city	-3.255E-05	.000	-.387	-120.448	0.000	-.617	-.209	-.116	.089	11.179
t1995	-.018	.003	-.008	-5.402	.000	.011	-.010	-.005	.389	2.572
t1996	.000	.003	.000	.079	.937	.027	.000	.000	.308	3.242
t1997	.013	.003	.006	3.859	.000	.000	.007	.004	.428	2.334
t1998	.017	.003	.007	4.813	.000	-.018	.009	.005	.429	2.328
t1999	.004	.003	.002	1.216	.224	.003	.002	.001	.281	3.557
t2000	.023	.003	.010	6.723	.000	.012	.012	.006	.411	2.432
t2001	.002	.003	.001	.694	.488	-.028	.001	.001	.439	2.280
t2002	-.005	.003	-.003	-1.721	.085	-.015	-.003	-.002	.311	3.214
t2003	-.005	.003	-.002	-1.564	.118	.000	-.003	-.002	.446	2.243
t2004	-.004	.003	-.002	-1.154	.249	.021	-.002	-.001	.408	2.451
t2005	.004	.003	.002	1.246	.213	.067	.002	.001	.322	3.106
t2006	.030	.003	.019	9.916	.000	.095	.018	.010	.250	4.001
t2007	.046	.003	.037	16.302	.000	.098	.029	.016	.178	5.621
t2008	.008	.003	.004	2.308	.021	-.014	.004	.002	.372	2.685
t2009	-.016	.003	-.012	-5.565	.000	.005	-.010	-.005	.198	5.048
t2010	.013	.003	.010	4.598	.000	.010	.008	.004	.180	5.541
t2011	.003	.003	.003	1.195	.232	-.047	.002	.001	.209	4.790
t2012	-.018	.003	-.013	-6.088	.000	-.088	-.011	-.006	.197	5.084
t2013	-.032	.003	-.021	-10.860	.000	-.111	-.019	-.010	.246	4.072
distri1	.352	.005	.117	64.293	0.000	.203	.113	.062	.280	3.576

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Independent variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
distri2	.150	.006	.044	26.660	.000	.098	.047	.026	.343	2.913
distri3	.037	.005	.016	7.857	.000	.046	.014	.008	.235	4.246
distri4	.429	.005	.163	94.822	0.000	.134	.166	.091	.315	3.180
distri5	.114	.004	.065	29.470	.000	-.059	.052	.028	.191	5.232
distri6	.326	.031	.010	10.620	.000	.015	.019	.010	.974	1.027
distri7	.000	.006	.000	.038	.970	.026	.000	.000	.426	2.348
distri8	-.143	.005	-.052	-28.233	.000	.017	-.050	-.027	.278	3.602
distri9	.330	.005	.230	72.331	0.000	.389	.127	.070	.092	10.904
distri10	.392	.004	.293	97.127	0.000	.327	.169	.093	.102	9.839
distri11	.182	.004	.100	41.986	0.000	.157	.074	.040	.163	6.149
distri12	-.095	.004	-.049	-21.704	.000	-.014	-.038	-.021	.184	5.434
distri13	-.089	.005	-.025	-17.307	.000	-.016	-.031	-.017	.449	2.226
distri14	-.130	.004	-.072	-30.978	.000	-.086	-.055	-.030	.174	5.763
distri15	.091	.004	.074	23.492	.000	.025	.042	.023	.093	10.764
distri16	.145	.004	.091	38.091	0.000	-.088	.067	.037	.161	6.226
distri17	.088	.004	.036	20.358	.000	-.120	.036	.020	.288	3.466
distri18	.068	.004	.040	17.675	.000	-.200	.031	.017	.181	5.510
distri19	-.016	.004	-.012	-4.379	.000	-.193	-.008	-.004	.126	7.920
distri20	.013	.004	.006	3.091	.002	-.067	.005	.003	.260	3.849
distri21	.201	.004	.119	52.195	0.000	-.023	.092	.050	.179	5.586
distri22	.173	.004	.075	39.561	0.000	-.120	.070	.038	.256	3.910
distri23	.154	.004	.105	40.426	0.000	-.164	.071	.039	.136	7.349
distri25	.186	.005	.054	37.578	.000	-.124	.066	.036	.441	2.267
distri26	.071	.005	.020	14.682	.000	-.057	.026	.014	.480	2.083
distri27	.101	.004	.038	22.862	.000	-.142	.040	.022	.330	3.029
Apartment	.202	.004	.246	56.242	0.000	.096	.099	.054	.048	20.674
Condo	.282	.003	.348	80.678	0.000	-.043	.141	.078	.050	20.090
Quarter1	-.028	.001	-.030	-25.092	.000	-.022	-.044	-.024	.627	1.595
Quarter2	-.027	.001	-.032	-25.980	.000	-.004	-.046	-.025	.599	1.670
Quarter3	-.012	.001	-.014	-11.629	.000	.002	-.021	-.011	.612	1.634

A2 - Regression results for HDB properties

R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
			R Square Change	F Change	df1	df2	Sig. F Change
.540	.540	.11630414	.540	7008.430	49	292538	0.000

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	8.889	.005		1744.639	0.000					
area_sqm	-.002	.000	-.319	-71.495	0.000	.009	-.131	-.090	.079	12.665
Ep	2.546	.016	.406	162.630	0.000	.504	.288	.204	.252	3.973
disttocbd	-1.808E-05	.000	-.466	-96.161	0.000	-.504	-.175	-.121	.067	14.955
Age	-.007	.000	-.388	-182.300	0.000	.040	-.319	-.229	.347	2.884
Floor	.007	.000	.181	140.598	0.000	.261	.252	.176	.945	1.058
executive	.093	.001	.144	78.872	0.000	.066	.144	.099	.474	2.111
room1	-.439	.007	-.094	-66.223	0.000	-.020	-.122	-.083	.781	1.281
room2	-.210	.003	-.111	-63.505	0.000	.015	-.117	-.080	.514	1.946
room3	-.121	.002	-.328	-71.319	0.000	.010	-.131	-.089	.074	13.437
room4	-.076	.001	-.217	-81.615	0.000	-.101	-.149	-.102	.221	4.515
t2000	-.085	.001	-.142	-59.489	0.000	.018	-.109	-.075	.278	3.602
t2001	-.071	.001	-.122	-50.464	0.000	.037	-.093	-.063	.270	3.707
t2002	-.071	.001	-.120	-50.412	0.000	.017	-.093	-.063	.279	3.587
t2003	-.085	.001	-.127	-58.395	0.000	-.024	-.107	-.073	.331	3.024
t2004	-.073	.001	-.109	-50.717	0.000	-.010	-.093	-.064	.341	2.935
t2005	-.068	.001	-.101	-47.226	0.000	-.003	-.087	-.059	.343	2.918
t2006	-.072	.001	-.102	-49.485	0.000	-.014	-.091	-.062	.370	2.704
t2007	-.081	.001	-.113	-55.635	0.000	-.040	-.102	-.070	.379	2.637
t2008	-.059	.001	-.083	-40.838	0.000	-.013	-.075	-.051	.385	2.600
t2009	-.046	.001	-.068	-32.920	.000	-.003	-.061	-.041	.366	2.735
t2010	-.039	.001	-.062	-28.733	.000	-.014	-.053	-.036	.333	3.001
t2011	-.017	.001	-.022	-11.631	.000	.007	-.021	-.015	.436	2.291
t2012	-.002	.001	-.002	-1.190	.234	.020	-.002	-.001	.428	2.339
t2013	.000	.002	.000	.215	.830	.012	.000	.000	.517	1.933
distri1	-.145	.012	-.016	-12.353	.000	.031	-.023	-.015	.938	1.066
distri2	-.090	.019	-.006	-4.725	.000	.028	-.009	-.006	.976	1.024
distri3	.011	.003	.010	4.233	.000	.224	.008	.005	.278	3.597
distri4	-.005	.003	-.003	-1.594	.111	.061	-.003	-.002	.468	2.135
distri5	.104	.002	.122	65.276	0.000	.124	.120	.082	.450	2.224
distri7	-.137	.004	-.051	-30.720	.000	.109	-.057	-.039	.580	1.724
distri8	-.182	.004	-.083	-47.667	0.000	.084	-.088	-.060	.523	1.911
distri10	.169	.003	.096	60.906	0.000	.143	.112	.076	.639	1.565
distri11	.102	.020	.006	5.132	.000	.020	.009	.006	.985	1.015
distri12	-.119	.003	-.112	-45.632	0.000	.086	-.084	-.057	.259	3.863
distri13	-.083	.002	-.069	-33.761	.000	.006	-.062	-.042	.374	2.674
distri14	-.124	.002	-.116	-53.470	0.000	.069	-.098	-.067	.333	3.007
distri15	.188	.003	.125	72.528	0.000	.179	.133	.091	.527	1.898
distri16	-.081	.002	-.078	-42.748	0.000	-.019	-.079	-.054	.471	2.124
distri17	.128	.010	.015	12.235	.000	-.019	.023	.015	.990	1.010
distri18	.077	.001	.163	77.468	0.000	.115	.142	.097	.355	2.815
distri19	-.051	.001	-.090	-35.481	.000	.000	-.065	-.044	.245	4.086

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
distri20	.048	.002	.085	29.780	.000	.185	.055	.037	.192	5.213
distri21	.285	.005	.077	59.334	0.000	.066	.109	.074	.927	1.079
distri22	.030	.001	.055	31.419	.000	-.215	.058	.039	.513	1.951
distri23	.016	.001	.026	14.168	.000	-.140	.026	.018	.483	2.072
distri25	.019	.001	.035	18.495	.000	-.231	.034	.023	.438	2.281
Quater1	.004	.001	.011	7.003	.000	.004	.013	.009	.665	1.503
Quater2	.003	.001	.007	4.819	.000	.010	.009	.006	.661	1.512
Quater3	-.002	.001	-.005	-3.023	.003	-.007	-.006	-.004	.660	1.515