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運輸與物流管理學系

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探討輕軌系統不同通車階段對房地產價格的影響：以臺灣為例

Exploring property value uplift effects of Light Rail Systems in construction, delivery and operation stage: Evidence from Taiwan

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中文摘要

由於政府預算有限，如何為公共運輸基礎設施的興建營運提供資金，已成為一個緊迫的問題。溢價返還（value capture）被視為解決這種情況的另一種籌資方法。為了提出合適的溢價返還方案，應事先研究價值提升（value uplift）。以輕軌運輸（LRT）為例，過往研究集中在測量特定輕軌運輸系統的價值提升量。但是過往研究中彼此未有一致性的結論。因此，本研究首先採用後設分析（meta-analysis）的方法，系統地回顧了以往的文獻，以確定價值提升的關鍵因素。接著透過台灣的案例，將關鍵因素考慮在內以進行價值提升分析。因此，本研究的目的是探討涉及多個輕軌系統的價值提升效應。通過構建和解釋回歸模型來評估台灣 3 種輕軌系統的影響。結果可為決策者提供關於價值提升的全面理解。

為了比較不同模型設置的效果，本研究使用兩種模型（差異中之差異模型 difference-in-differences, DID 和多層次迴歸模型 multi-level regression, MLR）以及兩種研究區域識別方法（基於距離的方法 distance-based method, DBM 和傾向得分匹配 propensity score matching, PSM）。從 DID 模型和 MLR 模型的結果看出，來自 3 個 LRT 系統的影響在 1600m 的範圍內皆為正。價值提升的時間效應在不同階段有所不同。最高的價值提升率發生在輕軌運輸系統綜合規劃核可的前後。在運營階段，比較距輕軌車站 600m 以內和距 1600m 以上，發現存在最高的價值提升量：其中利用多層次迴歸模型並以 PSM 挑選的資料顯示輕軌的價值提升效果為 36.6%。

關鍵字：房價、價值提升、輕軌、差異中之差異模型、多層次迴歸模型、傾向得分匹配

ABSTRACT

How to fund public transport infrastructure has become a pressuring issue due to public funding shortfall. Value capture has been viewed as one of the alternative funding methods to release this situation. In order to propose a suitable value capture scheme, value uplift should be investigated in advance. Take light rail transit (LRT) as an example, there are rich previous studies have focused on measuring value uplift amount for a particular system. However, it is hard to find a firm conclusion from previous studies. Therefore, this study first adopts meta-analysis approach to systematically review previous literature to identify the key factors for value uplift. Then, take the key factors into account for the value uplift analysis with the case studies in Taiwan. Therefore, the purpose of this study is to explore the value uplift effect involving multiple LRT systems. Influences from 3 LRT systems in Taiwan are evaluated through constructing and explaining regression models. Results might provide comprehensive understandings on value uplift for policy makers.

In order to compare the effect from different model setting, this study uses two model (i.e., difference-in-differences model and multi-level regression model) and with two study area identification methods (distance-based method and propensity score matching). Model results from both difference-in-differences (DID) model and multi-level regression (MLR) model show that impact from 3 LRT systems are all positive within 1600m catchment area. Timing effect of value uplift varies in different stages. The highest rate of value uplift changes happens on the period from before to after the approval announcement of the LRT system plan. The strongest value uplift effect found in operation stage and within 400m distancing LRT stations, taking distancing further than 1600m as reference. The effect is 36.6% from results of MLR approach with PSM selected data.

Keywords: property price, value uplift, light rail, difference-in-differences, multi-level regression, propensity score matching

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Chapter 1 INTRODUCTION

1.1 Background description & motivation

The difference in property value stems from the accessibility to the central business district (CBD). This concept came from the bid rent theory proposed by Alonso (1960). Assuming there's a CBD existing on a homogeneous plain. Different land use purposes have its corresponding bid rent curve. The curve indicates the willingness to pay for the land use purpose on different locations. Different land use purposes bid with the willingness to pay, and the highest one win out, making land use different from regions. As the result, getting closer to the CBD areas, the willingness to pay rises.

Abovementioned relationship is also held for main transport infrastructure, especially in urban or CBD areas. Typical example can be found for metro station in Taipei, Taiwan. Properties have higher price and this might be due to better accessibility of transport infrastructure. Therefore, it is believed that newly built transport infrastructures, including roads, stations, terminals, airports, etc.; and newly announced transport services, such as the opening of new bus routes, could all bring property value uplift around the transport infrastructure (Shin et al., 2007; Martínez & Viegas, 2009).

The main reason for introducing more or improving transport infrastructure is to relief traffic congestion and improve environment sustainability. Not to mention that traffic congestion issues become worse and worse alone with population growth. Recently, the population of six municipalities in Taiwan (i.e., Taipei city, New Taipei city, Taoyuan city, Taichung city, Tainan city, and Kaohsiung city) continues to increase and counted almost 70% of total population in Taiwan. Take New Taipei City (the former Taipei County) as an example. In 2010, the population was 3.88 million. In 2020, the population grew to 4.02 million. The growth rate of population was 4% in last decade (Department of Household Registration, 2020). Along with the population growth, the pressure of current transport infrastructure increases. It is a challenge for policy makers to meet the growth demand to transport infrastructure. In order to promote sustainable transport, provide a better public transport infrastructure and service becomes essential to those cities.

The most straightforward way to meet this increasing need is to introduce more public transport infrastructures. Take Taiwan as an example, there are several major public transport infrastructures that are planned and delivered in recent years. Most of them are LRT system, including Kaohsiung Circular light rail starts operation since 2015; Danhai light rail starts operation since 2018; Ankeng light rail starts construction since 2016. However, those infrastructures come with very large amount of construction cost. Budget amounts of 6 coming metro lines ranges from NT$19billion to NT$145billion, including Kaohsiung Metropolitan line for NT$145billion, Green line (Taoyuan Metro) for NT$98billion, Blue line (Taichung Metro) for NT$84billion, Sanying line for NT$50billion, Green line (Tainan Metro) for NT$22billion and Blue line (Tainan Metro) for NT$19billion (Executive Yuan, 2017). How to fund new public transport infrastructure is a pressing issue for policy makers who are constantly searching for alternative funding for new development. Value capture has become one of the most popular ways to fund future transport infrastructure. However, before implement one of the value capture scheme, property value effects need to be investigated for target infrastructure. Besides, previous studies were tending to focus on one infrastructure in one location. It would be difficult to provide homogenous value uplift analysis thus to propose a homogenous value capture scheme. In Taiwan, 3 LRT systems are introduced and this provides a natural case study to investigate timing effects for the same public transport infrastructure in different locations.

Currently, the LRT system in Taiwan are in different stages. Kaohsiung Circular light rail starts to operate from 2015 and Danhai light rail is 2018. Those 2 LRT systems can be viewed as mature and newly opened system. As to Ankeng light rail just starts construction in 2016. Those 3 LRT systems are all in peri-urban areas with lower population density compared to Taipei CBD. These 3 LRT systems provide us a natural research setting to investigate timing effects of property uplift, including mature, newly opened and under construction, respectively.

Former studies indicate non-universal effects of value uplift (Ryan, 1999). Theoretically, increment of accessibility brings positive effect on property price. However, some observed property prices remained or even showed a negative effect. In order to precisely measure impacts from accessibility improvement of a certain public transport infrastructure, several studies control the variation with socio-economic attributes, property characteristics and amenity effects by including those characteristics as one of the variables in the model. In terms of public transport accessibility measurement, previous studies point out that the property price will increase to a certain extent, within a certain distance to the station (Knaap et al., 2001; Hess & Almeida, 2007; Duncan, 2011; Golub et al., 2012; Song et al., 2019). In terms of amenity effects, some studies further show the inconsistent effect of value uplift varying with the spatial differences, such as the location of stations (Ransom, 2018). Besides, there are obvious spatial differences of property prices. Several modelling approach is used to capture spatial differences, such as geographic weighted regression model, GWR (Mulley et al., 2018), MLR model (Pan, 2019; Yen et al., 2019) and DID model (Wagner et al., 2017; Cao & Lou, 2018; Pilgram & West, 2018; Yen et al., 2019). GWR modeling approach can consider spatial difference for cross sectional data but not panel data. MLR and DID model are both reported to be appropriated modelling approach for panel data and Yen et al. (2019) have further concluded that MLR might be a more proper approach.

This research would investigate timing effects for property uplift effects of LRT system differences with the case study in Taiwan. In order to better understanding different LRT systems. This research proposes using different model forms to understand property value uplift effect by MLR or DID model. The results would provide policy discussions on the planning and construction of future LRT systems.

1.2 Research purposes

To identify key variables influencing the value uplift effects from system literature review.

To investigate timing effects of value uplift effects of LRT.

To construct model for comparing the property value effect of LRT systems.

1.3 Research framework

Several steps shown in Figure 1.1 are involved in this research. The main purpose is to construct the model for examining the impact of LRT system on value uplift. The important measures are identification of research problem; identification of key variables; data collection; decision on methods of analysis and control area selection. After completing the model construction, following steps are explaining results from the model; discussion on results comparing to former studies; and conducting conclusions.

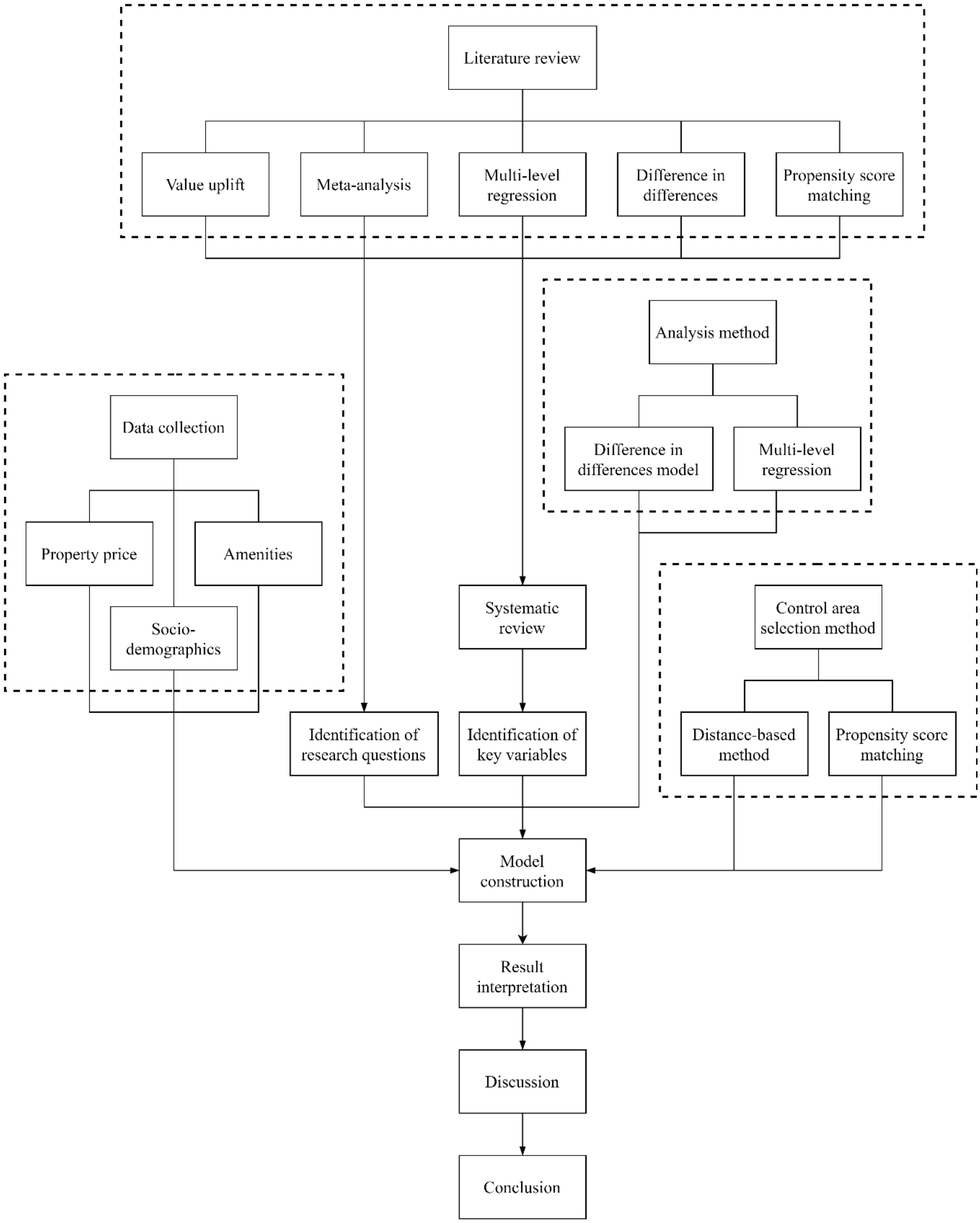

Figure 1.1 Flowchart of research framework

Chapter 2 LITERATURE REVIEW

2.1 Value uplift

Value uplift is a common phenomenon nowadays. Due to the increment of accessibility, property value increases after the construction or the operation of the transport infrastructure. This isn't the main reason for government to construct or to operate a new transport infrastructure. For example, the purpose of the construction of expressway might be the better connection between city center and industrial area. Meanwhile, it provides an easier way travelling to the city center for people who reside along the expressway. This might lead the land use changing from rural land to residential area. As a result, value uplift happens out of expectation.

Lands surrounding the transport infrastructure benefit from the increment of property value, without any efforts to the infrastructure, such as payment or investment. Since people without payment or investment still can benefit from the transport infrastructure, this situation is a free-rider problem. Policy interventions is needed for solve this kind of market failure.

Value capture is an answer for this free-rider problem. The basic concept is that, government should capture the amount of benefit from land owners, and then invest it back to the transport infrastructure. The way to put "value capture" this concept into practice is tax increment financing (TIF). TIF is an economic tool allowing government to capture the value uplift through tax. Several types of tax can be used for TIF, including land value tax, land value increment tax, house tax, deed tax, etc.

The effectiveness of TIF is widely studied and be confirmed by former studies. Anderson (1990) examined the relationship between property price and adoption of TIF. The result shows cities adopting TIF policy experience higher property price appreciation, compared to cities without adopting TIF.

Studies on value uplift are important, these results provide instructions for future policies. Value capture eliminates the inequality from value uplift. Government needs to take value capture measures appropriately. Thus, the understanding on value uplift induced by additional transport infrastructures or services is necessary.

2.2 Value uplift in public transport

Modes of transport infrastructure are diverse to its objective. Roads and highways are design for car users; sidewalks for pedestrians; tracks, railway stations and bus stops for commuters; airports and terminals for travelers. Pros and cons of modes are different. For example, Highways might provide better mobility to cars. The construction of airport needs the acquisition of rural lands. Different studies focus on the examination of value uplift induced by different modes of transport.

Early studies examine the value uplift caused by highways and expressways. Most studies show that property price increases due to the existence of the nearby highway or expressway. The extent of value uplift in these studies are up to more than 100% (Adkins, 1959; Bone & Wohl, 1959). Only few studies find out that the value uplift may not be positive. Property price might decrease within short distance to highway or expressway (Gamble et al., 1974).

Governments rise emphasis on public transport, due to the reality of population growth and urbanization. Recently, studies of value uplift focus on the field of public transport. These studies show inconsistent relationship between property price and accessibility. The differences might stem from the measure of accessibility or the selection of study area (Ryan, 1999).

Dewees (1976) first introduced hedonic price model (HPM) for examining the effect of stations on property price. The model result shows that the replacement of a streetcar line to a subway increases the rent. This effect disappeared when distancing to a station for over 1/3 miles.

Several studies focus on light-rail-induced value uplift in recent years. Around 1980s, several LRT systems constructed and started its operation in the US. San Diego Trolley opened in 1981; Buffalo Metro Rail in 1984; MAX Blue Line in 1986. These and the coming LRT systems become the suitable research objectives. These studies will be introduced in the next section.

2.3 Value uplift in LRT

Early studies use HPM to examine the effect of LRT station on property prices. These models take property price as dependent variable with consideration of impacts from both property characteristics, neighborhood characteristics and facilities. Corresponding results clearly point out that the positive value uplift strengthened by being closer to the station (Knaap et al., 2001; Hess & Almeida, 2007). The relationship between increment of property price and distance to the station might not be linear. Some studies try to examine the effect of LRT station with the logarithm of property price. Study results show the positive effect of LRT station when using the logarithm of property price as dependent variable. It means that if the property locates closer to LRT station, the percentage change of property price gets higher. Depending on the differences of LRT systems, the property price growth rates vary from 1% to 5% for every 250m closer to the LRT station (Duncan, 2011; Golub et al., 2012; Song et al., 2019).

There's a shortcoming for using HPM, overestimation or underestimation on the effect. It necessary for HPM to fully collect variables that might influence the property price. The lack of key variables will increase or decrease the effect of accessibility to station in proportion. Since there are several stages for LRT systems such as planning, construction or operation, etc. Single continuous temporal variable in HPM is not sufficient for controlling effects varying in different stages. One solution is the usage of different analysis method, DID. DID focus on the effect of "treatment" and time series. It provides better understanding on the time series impacts through interaction term. Cao & Lou (2018) evaluating value uplifts provided by Metro Green Line in Minneapolis. The study indicates that value uplift occurred after the announcement and before the commencement. Pilgram & West (2018) testify properties locate around another LRT system, METRO Blue Line. The result shows that properties within 0.5miles experience a significant 4% premium compared to the rest of south Minneapolis. Yen et al. (2018) divided the developing process of Gold Coast Light Rail into 4 stages, including commitment, construction and operation. The result indicates that property price starts to increase after the announcement of the plan and with the highest slope being found after the financial commitment made by government.

Following studies use other modelling method in order to better capture the effect of value uplift. DID can discover the differences of time series; GWR provides further information on differences of locations. Mulley et al. (2018) studied Inner West Light Rail with GWR and found that value uplift in an average of 0.5% of each 100m nearer to a station, and a reduction in uplift within 100m to a station. MLR is also used for examining value uplift considering differences of locations. The MLR separates the attributes into individual level and group level. The separation of group level from individual level allows model to reflect more realistic impacts from geographic differences. Results from studies using MLR indicate the opening of LRT giving significant positive effect on property price and the immediate proximity to station causing significant negative impact (Pan, 2013; Pan, 2019). The study conducted by Yen et al. (2019) examined the value uplift with Gold Coast light rail surroundings using both DID and MLR. Results not only confirm the increases in property price, but also state that the amount of uplift varies depending on the analysis method and the selection of catchment and control areas.

Studies focus on other LRT systems might get opposite results against mentioned above. Yan et al. (2012) discover the negative effect of Lynx Blue Line on the percentage change of property price. Study conducted by Wagner et al. (2017) indicates that properties within 1500 meters experienced a decline in sale price of nearly 8%.

The defects of taking many variables into account urge researchers using repeat sales model (RSM) to overcome. RSM uses transaction data of the same property, which means there's no any differences on property characteristics or neighborhood characteristics. Billings (2011) and Kim & Lahr (2014) found the positive effect of before & after the LRT system operation, with the usage of RSM. Chatman et al. (2012) using same tool examine the value uplift effect of River LINE. The result shows that the impact of River LINE on property price is neutral to slightly negative.

Station differences are discussed in few papers. Camins-Esakov & Vandegrift (2018) analyze the effect induced by an extended LRT station and find out no significant impact on property price appreciation. Ransom (2018) examined the effect of 7 different stations on Link light rail. The result shows positive effect for only one station, negative for two stations, and statistically insignificant for the other stations.

In summary, except few researches using RSM as analysis method, property characteristics and neighborhood characteristics are involved in most models. Other categories of variables, such as facilities or temporal variables, may also perform as important role. Varieties of arguments concluded by these papers rise the interests of understandings on value uplift. Systematic review is a practical tool for summing up results qualitatively. The method of systematic review used in this research is meta-analysis, with attributes and conclusions collected from the 19 papers. The result is provided in Chapter 3.

Table 2.1 Summary of literatures for meta-analysis

Authors	LRT	Year	Methods	Variables	Catchment	Findings
LRT system in US						
Knaap et al.	MAX Blue Line	2001	HPM	property char., neighborhood char., facilities, temporal var.	0~1/2mi, 0~1mi (1mi ≒ 1609m)	The value uplift is 9% higher within 1mile and 36% higher within 0.5mile, compared to properties locate outside the catchment.
Duncan	San Diego Trolley	2011	HPM	property char., neighborhood char., temporal var.	0~1mi (continuous)	The effect of value uplift for properties within 500m is 10% higher than property outside the catchment.
Golub et al.	Valley Metro Rail	2012	HPM	property char., facilities	0~2mi (continuous)	The value uplift for after the LRT operation is 25% higher than properties before the operation.
Ransom	Link light rail	2018	DID	property char., neighborhood char.	0~1/2mi	The effect of value uplift is positive for only one station, negative for two stations, and insignificant for others.
Hess & Almeida	Buffalo Metro Rail	2007	HPM	property char., neighborhood char., facilities	0~1/2mi (continuous)	1 foot decrease in distancing station provides $2.31 increment in property price.
Billings	Lynx Blue Line	2011	DID, RSM	property char., neighborhood char., facilities, temporal var.	0~1mi (continuous), 0~1/2mi, 0~1mi	The effect of value uplift for single-family properties within 1mile is 4% higher than properties locate outside the catchment area.

Table 2.1 (continued)

Authors	LRT	Year	Methods	Variables	Catchment	Findings
LRT system in US						
Yan et al.	Lynx Blue Line	2012	HPM	property char.	0~1mi (continuous)	The negative value uplift effect faded for closer to station, suggesting a trend of living closer to station.
Chatman et al.	River LINE	2012	RSM	property char., neighborhood char., temporal var.	0~1/4mi, 1/4~1/2mi, 1/2~1mi, 1~2mi, 2~3mi, 3~4mi, 4~5mi	The effect of value uplift is statistically insignificant to slightly negative.
Pan	METRORail (Houston)	2013	HPM, MLR	property char., neighborhood char., facilities	0~1/4mi, 1/4~1/2mi, 1/2~1mi, 1~2mi, 2~3mi	The opening of LRT provides positive effect. However, immediate proximity to station provides negative effect.
Pan	METRORail (Houston)	2019	HPM, MLR	property char., neighborhood char., facilities	0~1/4mi, 1/4~1/2mi, 1/2~1mi, 1~2mi, 2~3mi	The effect of value uplift is positive.
Kim & Lahr	Hudson-Bergen Light Rail	2014	RSM	neighborhood char., facilities	0~2.5mi (continuous)	The effect of value uplift is 18.4% higher in annual appreciation rate, compared to properties locate outside the catchment.
Camins-Esakov & Vandegrift	Hudson-Bergen Light Rail	2018	RSM	temporal var.	0~1mi (continuous)	1% decrease in distance provides 0.6~2.1% increment in annualized price change
Wagner et al.	Tide Light Rail	2017	DID	property char., neighborhood char., temporal var.	0~1500m (continuous), 0~800m, 800~1500m	The effect of value uplift for properties within 1500m is 8% lower than properties without the catchment area.

Table 2.1 (continued)

Authors	LRT	Year	Methods	Variables	Catchment	Findings
LRT system in US						
Pilgram & West	Metro Blue Line	2018	DID	neighborhood char., temporal var.	0~1/2mi	The value uplift within 0.5mile is 4% higher than properties without the catchment area.
Cao & Lou	Metro Green Line	2018	DID	property char., neighborhood char.	0~1/4mi	The funding announcement provides \$9.2/ft^2 increment in property price.
LRT system in Australia						
Mulley et al.	Inner West Light Rail	2018	GWR	property char., neighborhood char., facilities	0~800m (continuous), 0~100m	100m decrease in distance to station provides a 0.5% increment in property price. Reduction in value uplift occurred within 100m of a station.
Yen et al.	Gold Coast Light Rail	2018	DID	property char., neighborhood char., facilities	0~100m, 100~400m, 400~800m	The effect of value uplift varies from stage differences. Value uplift occurred after the announcement of LRT plan.
Yen et al.	Gold Coast Light Rail	2019	DID, MLR	property char., neighborhood char., facilities	0~100m, 100~400m, 400~800m	MLR is more suitable in analyzing value uplift, compared to DID.
LRT system in UK						
Song et al.	Dockland Light Railway	2019	HPM	property char., neighborhood char., facilities	0~1000m (continuous)	100m decrease in distance to station provides a 0.352% and 0.093% value uplift, for properties locate in eastern and northern branches of the DLR.

Chapter 3 SYSTEMATIC REVIEW

3.1 Systematic reviews on public transport

Debrezion et al. (2007) first applied meta-analysis on the synthetization of value uplift induced by railway stations. Several attributes considered in this model, including property types, modes, variable forms, temporal factors and inclusion of neighborhood characteristics. For every 250m located closer to a station, price of residential properties is 2.3% higher than commercial properties. Commuter railway stations give higher positive impact on the property value compared to LRT/heavy rail/Metro stations. The inclusion of other accessibility variables reduces the level of railway station impact.

Mohammad et al. (2013) conducted the meta-analysis model with the consideration of more study-related factors. System maturity, distance to station, price types, spatial factors, analysis methods, and inclusion of property characteristics are taking into account in the model. The result shows that several variables give significant variations on the estimation of effect. These variables include modes, system maturity, distance to station, spatial factors, accessibility to roads, and analysis methods.

Zhang & Yen (2020) introduced the meta-analysis on the review of studies related to value uplift of bus rapid transit. Model result shows that significant factors include system maturity, price types, distance to stations, analysis methods, and spatial factors. Differences on significant factors implies different value uplift impacts between bus rapid transit and rail rapid transit.

According to those former studies, five categories of variables are involved for the meta-analysis. The five categories are LRT system factors (S), research method factors (M), property characteristics (P), neighborhood characteristics (N) and facilities (F).

3.2 Meta-analysis adoption on LRT-related studies

Studies in Table 2.1 are focus on the same issue, the value uplift induced by the LRT system. It is suitable for adopting meta-analysis model with similar study objectives. For comparing study results meaningfully, the comparable unit among these studies is necessary to be defined. This research adopts the definition of the comparable unit in former studies, the value uplift effect on the change of property price (Debrezion et al., 2007; Mohammad et al., 2013; Zhang & Yen, 2020).

351 observations are obtained from studies listed in Table 2.1. Each observation owns its value uplift effect (Y_{ij}) and the corresponding attributes (shown in Table 3.2). Adoption of random effect model can better capture the system error within a study. The equation of random effect meta-analysis model is shown as follow,

$$Y_{ij} = \alpha_0 + \beta_1 S_{ij} + \beta_2 M_{ij} + \beta_3 P_{ij} + \beta_4 N_{ij} + \beta_5 F_{ij} + \mu_j + \varepsilon_{ij}$$

where *i* is the index of observations and *j* is the index of studies, referring observation *i* obtained from study j. Y_{ij} is the dependent variable. $S_{ij}, M_{ij}, P_{ij}, N_{ij}, F_{ij}$ are categories of variables describing in Table 3.2. $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are parameters measuring its impact on the dependent variable. μ_j is the study-specific residual and ε_{ij} is the error term.

The meta-analysis model (Model 1 listed in Table 3.3) in this research adopts 19 categorical variables and 6 continuous variables. This is not as same as former meta-analysis studies that only adopts categorical variables. Descriptive statistics of continuous variables, *C_ROW*, *C_location*, *C_corridor*, *C_frequency*, *C_maturity* and *C_distance*, are provided in Table 3.1.

Table 3.1 Descriptive statistics on continuous variables

	Mean	Min.	Median	Max.	Skewness	Kurtosis
C_ROW	0.582	0	0.690	1	-0.501	-1.412
C_location	0.692	0	0.800	1	-1.191	-0.082
C_corridor	0.289	0	0	1	0.836	-0.774
C_frequency	7.593	4	8	15	0.456	-0.619
C_maturity	-2.288	-20	0	21	-0.057	-0.572
C_distance	0.793	0	0.805	1.609	0.179	-1.282

Table 3.2 Variables used in meta-analysis model

Variables	Description	Sample size / sample mean
LRT system factors (S)		
C_ROW	The ratio of length with separated ROW to total length	0.582
C_location	The ratio of length in rural area to total length	0.692
C_corridor	The ratio of length rebuilding on former rail to total length	0.289
C_frequency	The number of service per hour in peak hours	7.593
Capacity		
D_ridership15	1 if the annual ridership is >15million (approximately 75% of average capacity)	187
	reference: the annual ridership is ≤15million	164
Research method factors (*M*)		
C_maturity	The number of years after the announcement of the LRT system	-2.288
C_distance	The distance of catchment area (kilometer as the unit), within the range of 1609m	0.793
Catchment distance		
D_1609m	1 if the distance of catchment is >1609m	76
	reference: the distance of catchment is <1609m	275
Price type		
D_sales	1 if the analysis is evaluated by sales price	321
	reference: the analysis is evaluated by assessed price	30
Analysis method		
D_HPM	1 if the method is hedonic price model	107
	reference: other method, including DID, MLR, etc.	244
Control selection		
D_DBM	1 if the control area decided by distance-based method (DBM)	285
	reference: the control area decided by propensity score matching (PSM)	66

Table 3.2 (continued)

Variables	Description	Sample size
Research method factors (*M*)		
Variable form		
D_semiLog	1 if the variable form is semi-log	291
D_doubleLog	1 if the variable form is double-log	30
	reference: the variable form is linear	30
Data dimensions		
D_longitudinal	1 if the data is longitudinal	268
	reference: the data is cross-sectional	83
Property characteristics (*P*)		
Area		
D_size	1 if the model considering the size of property	282
	reference: without considering the size of property	69
Interior		
D_bed/bath	1 if the model considering the number of bedroom or bathroom	231
	reference: without considering the number of bedroom or bathroom	120
Parking space		
D_parking	1 if the model considering the size or the number of parking space	118
	reference: without considering the size or the number of parking space	233
Neighborhood characteristics (*N*)		
Household income		
D_HHincome	1 if the model considering household income	148
	reference: without considering household income	203
Population indicators		
D_population	1 if the model considering population indicators	225
	reference: without considering population indicators	116

Table 3.2 (continued)

Variables	Description	Sample size
Facilities (*F*)		
Amenity		
D_amenity	1 if the model considering amenities including school, park, etc.	132
	reference: without considering amenity	219
Nature		
D_nature	1 if the model considering nature environment	133
	reference: without considering nature environment	218
Proximity		
D_disutility	1 if the model considering the disutility of nearby proximity	61
	reference: without considering the disutility of nearby proximity	290
Highway		
D_highway	1 if the model considering distance to highway	106
	reference: without considering distance to highway	245
Bus		
D_bus	1 if the model considering distance to bus stop	147
	reference: without considering distance to bus stop	204
Heavy rail		
D_rail	1 if the model considering distance to rail station	70
	reference: without considering distance to rail station	281

There are some expectations on sign of variable. Variables with expected positive sign include *C_ROW*, *C_location*, *D_ridership15*, *D_sales* and *D_HPM*. Variables with expected negative sign include *C_corridor*, *C_distance*, *D_1609m*, *D_DBM*, *D_amenity*, *D_highway* and *D_heavyrail*.

LRT systems with the separated right-of-way (ROW) provide higher speed, shorter travel time, fewer interruption from other modes, than LRT systems with street-running ROW. The expected sign of *C_ROW* is positive, which indicates the higher effect of value uplift induced by LRT system with the separated ROW, compared to LRT system with street-running ROW. Accessibility provided by other modes in rural area is lower than in urban area. LRT systems in rural area give more accessibility gains. The rural area experience higher effect of value uplift comparing with downtown area, leading the sign of *C_location* to be positive. The more annual ridership can be related to more increment on accessibility, making the possibility of positive sign on *D_ridership15*. Accessed price is the willingness to pay for buyers, meaning that this price is lower than sales price in average. Using HPM as modelling tool, it's commonly ignoring some key variables affecting the effect of value uplift. Overestimated results from studies adopting HPM, making the positive sign of *D_HPM*. The expected positive sign of *D_sales* means that models using accessed price, in comparison with using sales price, might underestimate the property price and its corresponding value uplift effect.

Passenger rail corridor, or freight rail corridor, provides negative effect on property price to the surrounding properties. This effect might take times to ease after LRT system rebuilding on these corridors. As a result, they are possible to be negative for signs of *C_corridor*. The expected sign of *C_distance* and *D_1609m* are negative, meaning that the reduction of value uplift effect rises while the distance from LRT station gets higher. The PSM is another method to generate control area, compared to the DBM. Due to the minor but not zero effect of value uplift experienced in control area decided by DBM, the effect of value uplift might be underestimated with the usage of DBM, causing negative sign of *D_DBM*. Ignoring the impact of amenities or other modes might overestimate the level of effect of value uplift induced by LRT system, making it possible of expected negative signs on *D_amenity*, *D_highway*, and *D_heavyrail.*

2 meta-analysis models are established for several considerations. All variables listed in Table 3.2 are included in model 1. Model 2 only involve some variables avoiding the impact of collinearity. Results of these models are provided in Table 3.3.

Table 3.3 Results of meta-analysis

	Model 1		Model 2	
	Estimate	P-value	Estimate	P-value
(Intercept)	15.862	0.002	-0.102	0.263
LRT system factors (*S*)				
C_ROW	-1.765	0.018		
C_location	-2.447	0.004	0.313	0.006
C_corridor	4.760	0.003	-0.212	0.051
C_frequency	-0.595	0.002		
D_ridership15	1.402	0.013		
Research method factors (*M*)				
C_maturity	0.010	0.000	0.009	0.000
C_distance	-0.031	0.113		
D_1609m	-0.071	0.018	-0.047	0.027
D_sales	-1.449	0.021	0.184	0.105
D_HPM	0.130	0.000	0.136	0.000
D_DBM	-0.136	0.000	-0.134	0.000
D_semiLog	-0.122	0.211		
D_doubleLog	-4.949	0.001		
D_longitudinal	-2.236	0.002		
Property characteristics (*P*)				
D_size	-3.977	0.003		
D_bed/bath	-1.820	0.001		
D_parking	-2.126	0.001		
Neighborhood characteristics (*N*)				
D_HHincome	-3.530	0.001		
D_population	-0.066	0.050		
Facilities (*F*)				
D_amenity	-0.273	0.000	-0.240	0.000
D_nature	-0.014	0.379		
D_disutility	1.233	0.000		
D_highway	3.883	0.001		
D_bus	-3.464	0.001		
D_heavyrail	-0.398	0.039		
Log likelihood	142.701		152.502	
ICC	0.387		0.620	
R^2	0.300		0.296	

Model 1 gives the whole picture about effect of each variable to the value uplift. Conflicts are observed between the expectations on variables and the result of model 1 in Table 3.3. Some variables with expected positive sign show negative parameter result in model 1, including *C_ROW*, *C_location* and *D_sales*. Some variables with expected negative sign also show positive parameter result in model 1, such as *C_corridor* and *D_highway*.

This problem might root in the inappropriate modeling formulation in model 1. Therefore, collinearity in model 1 should be examined. There are different methods for testing collinearity between categorical variables and continuous variables.

The method can be chi-square test for testing the independency between 2 categorical variables. The null hypothesis (H_0) is that 2 variables are independent to each other. The chosen significance level for this research is 0.001, which means if the p-value is smaller than it, I can reject the H_0 and accept the alternative hypothesis (H_1) The H_1 of the test is that 2 variables are correlated to each other. The method to examine collinearity between continuous variables is to calculate the value of Pearson's correlation coefficient (denoted by ρ). The value of ρ for determining collinearity is 0.7.

The result of chi-square test and value of ρ are shown in Table 3.5 and Table 3.4 respectively. Collinearity do exist between categorical variables and continuous variables.

Table 3.4 Value of ρ between continuous variables in model 1

	C_location	*C_corridor*	*C_frequency*	*C_maturity*	*C_distance*
C_ROW	-0.168	0.714	-0.534	-0.403	0.331
C_location		-0.068	0.152	0.135	-0.494
C_corridor			-0.539	-0.244	0.114
C_frequency				0.447	-0.031
C_maturity					-0.100

* The red color indicates the existence of collinearity between 2 variables.

Table 3.5 Chi-square test for categorical variables in model 1

	D_1609m	*D_sales*	*D_HPM*	*D_DBM*	Variable form	*D_longitudinal*	*D_size*	*D_bed/bath*	*D_parking*	*D_amenity*	*D_nature*	*D_disutility*	*D_highway*	*D_bus*	*D_rail*	*D_HHincome*	*D_population*
D_ridership15	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.002	0.000	0.000	0.102	0.005	0.000	0.000	0.000
D_1609m		0.005	0.926	0.000	0.000	0.000	0.006	0.002	0.000	0.275	0.000	0.354	0.662	0.080	0.591	0.000	0.018
D_sales			0.006	0.012	0.185	0.039	0.010	0.000	0.000	0.001	0.000	0.018	0.000	0.000	0.009	0.000	0.000
D_HPM				0.024	0.000	0.002	0.000	0.000	0.000	0.134	0.000	0.013	0.000	0.000	0.000	0.576	0.087
D_DBM					0.000	0.000	0.025	0.000	0.000	0.223	0.886	0.004	0.004	0.607	0.030	0.644	0.041
Variable form						0.000	0.001	0.003	0.042	0.001	0.000	0.003	0.001	0.000	0.016	0.000	0.000
D_longitudinal							0.000	0.000	0.000	0.000	0.000	0.000	0.225	0.000	0.000	0.703	0.030
D_size								0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D_bed/bath									0.000	0.000	0.000	0.000	0.757	0.000	0.000	0.165	0.299
D_parking										0.232	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D_amenity											1.000	0.000	0.025	0.346	0.000	0.000	0.000
D_nature												0.000	0.000	0.000	0.000	0.000	0.275
D_disutility													0.000	0.000	0.000	0.000	0.002
D_highway														0.000	0.852	0.000	0.000
D_bus															0.000	0.000	0.000
D_rail																0.015	0.000
D_HHincome																	0.000

* The red color indicates the existence of collinearity between 2 variables.

Model 2 adopts some certain variables for eliminating collinearity. The result of chi-square test for model 2 listed in Table 3.6, with only few variables remaining correlated to another variable. The result from model 2 can further interpret the level of effect on value uplift. The 8 variables in model 2 are *C_location*, *C_corridor*, *C_maturity*, *D_1609m*, *D_sales*, *D_HPM*, *D_DBM* and *D_amenity*.

Table 3.6 Chi-square test for categorical variables in model 2

	D_sales	*D_HPM*	*D_DBM*	*D_amenity*
D_1609m	0.005	0.926	0.000	0.275
D_sales		0.006	0.012	0.001
D_HPM			0.024	0.134
D_DBM				0.223

The parameter of *C_location* shows that 1% increment in the ration of length building on rural area gives roughly 0.3% increment on percentage change in value uplift amount. The location of LRT systems may influence the observed amount of value uplift. It fits the expectation that constructing LRT system in rural area provides higher accessibility gains. The adoption of *D_newroads* variable in case study models is also based on this result. The parameter of *C_corridor* shows that 1% increment in the ration of length building on former rail corridor gives roughly 0.2% reduction on ratio of value uplift amount. The parameter of *C_maturity* indicates that the surrounding properties on average experience 0.9% increment on value uplift effect for every 1 year pass after the announcement of LRT systems. For better understanding timing effect of LRT systems, 3 categorical variables (*D_announcement*, *D_construction* and *D_operation*) are involved for evaluation. The negative parameter of *D_1609m* indicates that the amount of value uplift within 1609m to LRT stations is significantly higher than distancing further 1609m. This distance is an important reference for determining the control and catchment areas for case study models. The positive coefficient on D_HPM indicates the overestimated value uplift effect evaluated by HPM. For preventing this overestimation problem, this study uses 2 approaches introduced in next chapter. The parameter of *D_DBM* indicates that the usage of PSM provides 30% premium on ratio of value uplift amount, comparing to the adoption of DBM. The parameter of *D_amenity* shows without adopting amenity into model overestimates the ratio of value uplift amount for about 24%. This result shows that amenities are necessary for value uplift model construction.

Some variables are closely related to the property price, making the endogeneity existing between key variables and the amount of value uplift. These key variables include property characteristics, neighborhood characteristics and facilities which is able to influence the accessibility. The insignificance might due to the endogeneity. Thus, the inclusion of these insignificant key variables is necessary for the case study model.

Variables adopted in model 2 are key variables affecting the effect of value uplift. These key variables are used for the construction of the model. Further information about the model construction is introduced in Chapter 4.

Chapter 4 METHODOLOGY

4.1 Analysis method

In order to capture changes of value uplifts in each stage, the proposed analysis method is DID model. The parameters of interaction terms in DID model indicate the amount of value uplift. Since results of meta-analysis model 2 show that regional difference is a key factor influencing the effect of value uplift, methods considering regional difference should be involved. The candidate solving this issue is MLR model. These methods are used in previous study for identifying the stage differences on the effect of value uplift (Yen et al., 2019). Introductions of each method are provided in the following.

4.1.1 Difference-in-differences model

DID model can investigate the timing effect of "treatment" on study objective. "Treatment" in this research refers to properties locating in catchment area comparing to those locating in control area.

This study adopts the nonlinear DID model developed by Athey & Imbens (2006). The formulation of a nonlinear DID model can be simplified as follow:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Tr_{it} + \beta_3 period_{it} + \sum \theta_t Tr_{it} \cdot period_{it} + \varepsilon_{it}$$

where *i* is the index of individuals and *t* is the index of times, referring individual *i* at certain time *t*. Y_{it} is the dependent variable. X_{it} are variables for controlling effects influencing dependent variable. Tr_{it} is the variable representing the treatment. $period_{it}$ is the variable reflecting different time periods. $\beta_0, \beta_1, \beta_2, \beta_3, \theta_t$ are parameters measuring the impact on dependent variable. ε_{it} is the error term.

4.1.2 Multi-level regression model

Comparing to multiple linear regression, MLR model takes random effect into account. There are 2 types of model capturing random effect, random-interception model and random-slope model. Random-interception model considers random effect from group level reflecting on interception. The formulation of random-interception model can be represented as follow:

$$Y_{ij} = \gamma_{00} + \gamma_{01}Z_{ij} + \gamma_{10}X_{ij} + \mu_j + \varepsilon_{ij}$$

where *i* is the index of individuals and *j* is the index of groups, referring individual *i* belongs to group j. Y_{ij} is the dependent variable. Z_{ij} are variables related to group-level characteristics. X_{ij} are variables related to individual characteristics. $\gamma_{00}, \gamma_{01}, \gamma_{10}$ are parameters measuring the impact on dependent variable. μ_j is the group-specific residual and ε_{ij} is the error term.

Assumptions include inexistence of interactions between variables and diversity on background value of value uplift effect from different areas make random-interception model suitable for solving problems in this research. Results of further examination on intraclass correlation coefficient (ICC) will be provided in Table 5.7 and Table 5.8.

4.2 Model formulation

The interaction terms between treatments and time periods in DID model should be defined properly. Supported by the result of meta-analysis model 2, treatments of DID model in this research are defined as several levels of catchment distance. These levels of distance are between 0 to 400 meters, 400 to 800 meters, and 800 to 1600 meters, taking distancing over 1600 meters as the reference. Time periods are defined as LRT system developing stages includes approval announcement of the plan, construction of the LRT system, and its operation, taking before the approval announcement as the reference.

LRT systems with multiple opening time on different stations are considered. For example, assuming there are 2 stations, station A starting operation in February, 2020 and station B starting operation in December, 2019. A transaction locates near station A with the trade time in January, 2020 is clustered as construction stage, another transaction locates near station B with the trade time in January, 2020 is clustered as operation stage.

Based on meta-analysis results, there are 2 categories of variables involved in case study models, LRT characteristics (*S*) and amenities (*A*). Insignificant variables categories, including property characteristics (*P*) and neighborhood characteristics (*N*), due to the endogeneity, are also involved for controlling internal and external impacts. Model formulation is shown below:

$$Y_i = \alpha + \tau \cdot Time_i + \sum \theta \cdot (Tr_i * Pr_i) + \beta \cdot S_i + \gamma \cdot P_i + \delta \cdot N_i + \mu \cdot A_i + \varepsilon_i$$

where *i* is the index of individuals. Y_{it} is the dependent variable, which is logarithm value of property price in this research. S_i, P_i, N_i, A_i are variables for controlling effects influencing dependent variable. Tr_i is the variable representing the treatment. Pr_i is the variable reflecting different time periods. $Time_i$ is the variable controls effects of inflation. $\alpha, \beta, \gamma, \delta, \mu$ are parameters measuring the impact on dependent variable. τ shows the amount of inflation on property price. θ are parameters of interaction terms, which indicates the value uplifts. ε_i is the error term.

4.3 Data acquisition

Data needed in this research include property transactions, its corresponding property attributes, LRT system characteristics, neighborhood demographics and facilities locations. These requirements on data can be satisfied by using open data provided by government agencies.

The open data of property transactions are provided by Department of Land Administration, Ministry of the Interior, Executive Yuan, Taiwan. The property transactions' data providing system opens access to transaction records since 2012. Data attributes are sufficient for the study, important information including sales price, transaction time, property address, zoning of corresponding location, property type, property size, numbers of bedrooms and bathrooms, the year completing construction, and serial number for tracing. The transaction time is used for determining stages, based on the comparison to phases of the closest LRT station. For example, transaction of property A locating in proximity to LRT station B happened at the time that station B is constructed. In this situation, the stage of this data is classified as construction period. Property transactions happened during January, 2012 to June, 2020 are collected as the data for modeling. Figure 4.1 to Figure 4.6 shows locations of property transactions near the 3 LRT systems.

The open data of demographics, including population density, dependency rate and education level are provided by Department of Statistics, Ministry of the Interior, Executive Yuan, Taiwan. The latest data are records in June, 2020 and are generated at the basic statistical area (BSA), which is the smallest area unit with number of people ranging from 150 to 450. The area unit is designed and published by the government. The shape and the location of each BSA is meaningful for demographic attributes.

The open data of district median personal income are provided by Fiscal Information Agency, Ministry of Finance, Executive Yuan, Taiwan. The latest data are income tax records in 2017.

The data of unemployment rate in town are generated through the survey of labor force from 2012 to 2019. The survey is conducted by Directorate General of Budget, Accounting and Statistics, Executive Yuan, Taiwan. Results of the survey are released by Survey Research Data Archive, Academia Sinica, Taiwan.

Geographic information of several facilities, shown in Figure 4.7, Figure 4.8, Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12, are provided by different authorities. Locations of schools and university are from Department of Statistics, Ministry of Education, Executive Yuan, Taiwan. Locations of hospitals are from Bureau of Labor Insurance, Ministry of Labor, Executive Yuan, Taiwan. Locations of tourist attractions are from Tourism Bureau, Ministry of Transportation and Communications, Executive Yuan, Taiwan.

4.4 Study area selection

Most of former studies (listed in Table 2.1) use DBM to decide the study area. However, some studies use PSM to determine the area suitable for being studied. Decision on method for study area selection do influence the effect of value uplift based on the result of meta-analysis model 2 provided in Chapter 3. This research adopts these 2 selection methods for defining study areas in 3 LRT systems.

The selection on study area with DBM is based the distance to LRT stations. Areas within defined distance to the nearest LRT station will be selected as study area. The defined distance in this study is 2000m, supported by significant variables on catchment distance (D_1609m) from previous meta-analysis model 2 listed in Table 3.3. Catchment areas are areas distancing nearest LRT station within 1600m. 1600m is also the catchment distance for several former studies (Billings, 2011; Camins-Esakov & Vandegrift, 2018; Duncan, 2011; Knaap et al., 2001; Wagner et al., 2017; Yan et al., 2012). The closer distances, 400m and 800m, are defined as different catchment levels, for evaluating stronger effects. Control areas are areas locating further to LRT stations, ranging from 1600m to 2000m. Result of descriptive statistic on study area with DBM selection is provided in Table 4.2.

The method of adopting PSM into study area selection is first proposed by Billings (2011), and further applicate by Yen, et al. (2019). A probit model is established for estimating the probability of the nearby area as LRT neighborhood. The area unit for the probit model is the BSA proposed by Department of Statistics, Ministry of the Interior, Executive Yuan, Taiwan. Model formulation of this probit model is listed in below:

$$Pr(Y = 1 \mid X) = \Phi(\beta \cdot X^T)$$

where Pr represents the probability, Φ represents the cumulative distribution function of the normal distribution. β is the parameter of corresponding independent variable, X.

The dependent variable, Y, is a dummy variable, indicating whether the BSA is catchment (which is defined as area within distancing 1600m to the nearest LRT station) or not. There are 2 categories of independent variable involved in this probit model. These independent variables include several neighborhood attributes and distances to amenities. The attributes' information is allocated in 2012. Year 2012 is the time before the approval announcement of 3 LRT systems. It's important for matching similar areas without involving the following LRT impacts on neighborhood attributes. Observations for the probit model are all BSAs distancing nearest LRT station within 5km.

Table 4.1 provides descriptions of attributes of BSAs. Descriptive statistic results on independent variables used in the probit model are listed in Table 4.2 and Table 4.3. Results of study area selection are showed in Figure 4.2, Figure 4.4, and Figure 4.6.

The selection of control areas will be based on the fitted value of each candidate BSA in the probit model. Each BSA locating proximity to any LRT station is matched up to 5 other BSAs with the similar fitted value (error within 0.05) in the probit model.

Table 4.1 Descriptions of attributes in data used for the PSM

	Description	Unit
Neighborhood characteristics		
C_postsecondary	the ratio of population with higher education in BSA	100%
C_dependency	the dependency ratio in BSA	100%
C_unemployment	The unemployment rate in BSA	100%
C_popdensity	the population density in BSA	people/km^2
C_medincome	the median personal annual income in BSA	1000 NT$
C_dist_CBD	the centroid of BSA distancing the CBD	km
Amenities		
C_dist_bus	the centroid of BSA distancing the bus stop	km
C_dist_MLbus	the centroid of BSA distancing the bus stop with main line buses arrived	km
C_dist_MRT	the centroid of BSA distancing the MRT station	km
C_dist_freeway	the centroid of BSA distancing the freeway interchange	km
C_dist_hospital	the centroid of BSA distancing the hospital	km
C_dist_park	the centroid of BSA distancing the park	km
C_dist_attraction	the centroid of BSA distancing the tourism attraction	km
C_dist_school	the centroid of BSA distancing the primary or secondary school	km
C_dist_university	the centroid of BSA distancing the public university	km

Table 4.2 Descriptive statistics on attributes of catchment areas

	DBM selection						PSM selection					
	Mean	Min	Median	Max	Skewness	Kurtosis	Mean	Min	Median	Max	Skewness	Kurtosis
Neighborhood characteristics												
C_postsecondary	0.665	0	0.701	1	-1.374	2.094	0.668	0	0.702	1	-1.381	2.203
C_dependency	0.317	0	0.313	10	23.172	1065.443	0.317	0	0.312	10	23.680	1079.382
C_unemployment	0.234	0.150	0.240		-1.796	2.750	0.235	0.150	0.240	0.270	-1.838	2.997
C_popdensity	3.700	0	1.553	29.523	1.807	6.787	3.734	0	3.121	29.523	1.836	6.937
C_medincome	626	437	567	995	1.192	2.068	626	437	609	995	1.213	2.124
C_dist_CBD	6.023	0.074	4.354	20.173	1.160	0.342	6.005	0.007	4.288	19.640	1.163	0.333
Amenities												
C_dist_bus	0.119	0.002	0.104	1.408	3.598	29.554	0.117	0.002	0.104	0.988	2.155	12.385
C_dist_MLbus	0.284	0.003	0.188	2.474	2.386	7.242	0.280	0.003	0.187	2.057	2.243	6.071
C_dist_MRT	1.108	0.015	0.797	5.966	1.788	3.346	1.104	0.015	0.796	5.106	1.783	3.306
C_dist_freeway	3.646	0.030	2.369	15.390	1.479	1.145	3.647	0.030	2.357	14.809	1.473	1.106
C_dist_hospital	2.249	0.026	1.847	8.610	1.033	0.687	2.251	0.026	1.851	8.052	1.025	0.633
C_dist_park	0.337	0.001	0.272	2.392	2.657	10.531	0.330	0.001	0.270	2.238	2.411	8.817
C_dist_attraction	0.581	0.007	0.519	2.517	0.717	0.100	0.577	0.008	0.515	2.157	0.691	-0.077
C_dist_school	0.432	0.006	0.369	2.032	1.613	3.283	0.427	0.006	0.367	1.922	1.603	3.283
C_dist_university	3.369	0.091	3.078	9.794	0.851	0.315	3.366	0.091	3.070	9.240	0.837	0.265

Table 4.3 Descriptive statistics on attributes of control areas

	DBM selection						PSM selection					
	Mean	Min	Median	Max	Skewness	Kurtosis	Mean	Min	Median	Max	Skewness	Kurtosis
Neighborhood characteristics												
C_postsecondary	0.696	0	0.737	1	-1.715	3.463	0.686	0	0.731	1	-1.665	2.926
C_dependency	0.321	0	0.318	1.333	0.990	8.614	0.311	0	0.309	3	3.277	46.690
C_unemployment	0.221	0.150	0.240	0.270	-0.983	-0.487	0.226	0.150	0.235	0.270	-1.529	1.356
C_popdensity	4.136	0	3.531	25.218	1.389	3.308	4.488	0	3.853	44.917	2.402	13.888
C_medincome	664	457	625	1275	0.708	2.316	640	0	631	1275	-1.228	10.768
C_dist_CBD	5.520	0.477	5.074	20.437	1.462	3.160	5.769	0.404	5.248	23.283	1.426	3.735
Amenities												
C_dist_bus	0.124	0.007	0.107	1.025	2.968	18.370	0.122	0.002	0.099	1.609	5.630	48.133
C_dist_MLbus	0.273	0.010	0.211	2.465	3.890	22.082	0.257	0.002	0.177	5.812	6.897	70.282
C_dist_MRT	0.931	0.002	0.640	5.447	1.854	4.656	1.000	0.002	0.681	9.295	2.060	7.349
C_dist_freeway	2.712	0.053	2.423	15.719	2.440	8.184	2.382	0.030	2.169	19.575	3.366	19.239
C_dist_hospital	1.677	0.050	1.280	8.854	1.749	4.159	1.744	0.042	1.471	12.357	2.120	7.936
C_dist_park	0.338	0.003	0.259	2.700	3.597	15.763	0.330	0.002	0.241	4.460	4.040	22.622
C_dist_attraction	0.649	0.011	0.572	2.819	0.765	0.515	0.725	0.010	0.532	5.834	2.046	5.672
C_dist_school	0.459	0.008	0.391	2.347	1.367	3.020	0.456	0.008	0.388	3.397	3.250	18.014
C_dist_university	2.944	0.557	2.900	10.042	1.130	2.740	3.066	0.126	3.026	13.433	1.038	3.356

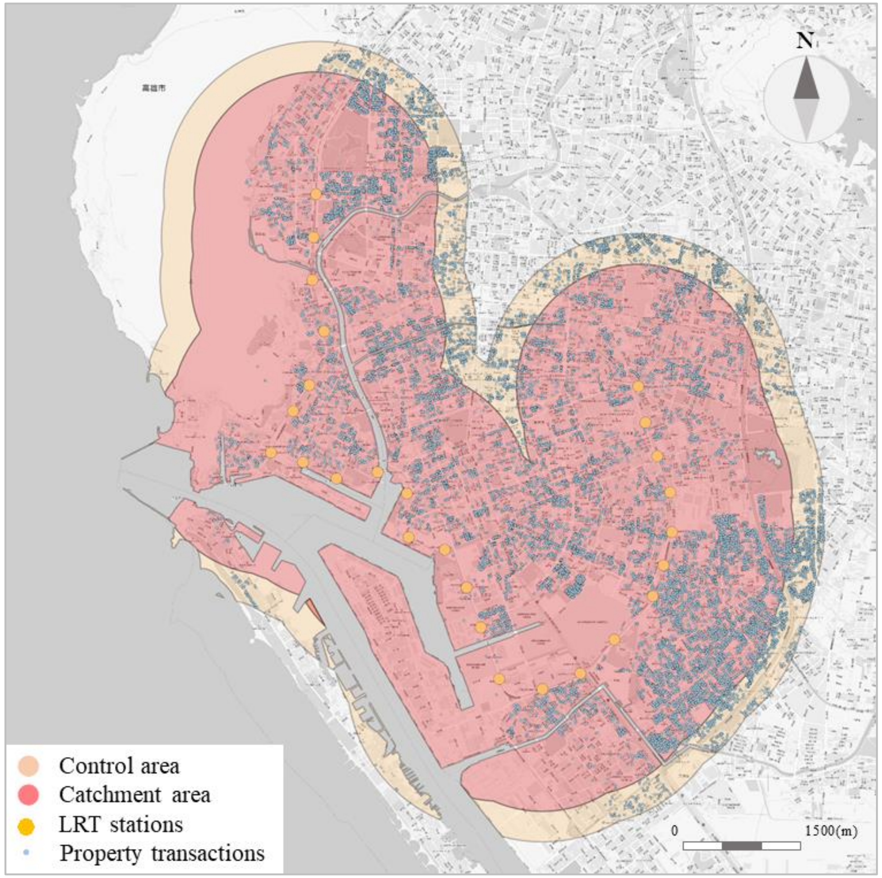

Figure 4.1 Study area with DBM selection in Kaohsiung Circular light rail

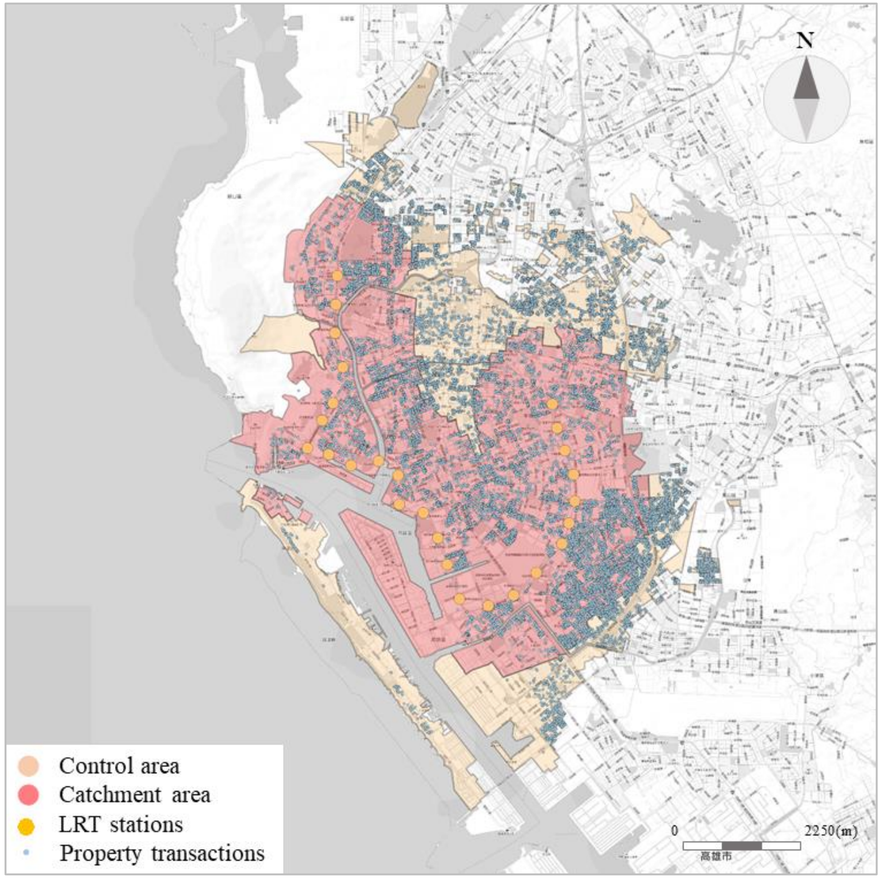

Figure 4.2 Study area with PSM selection in Kaohsiung Circular light rail

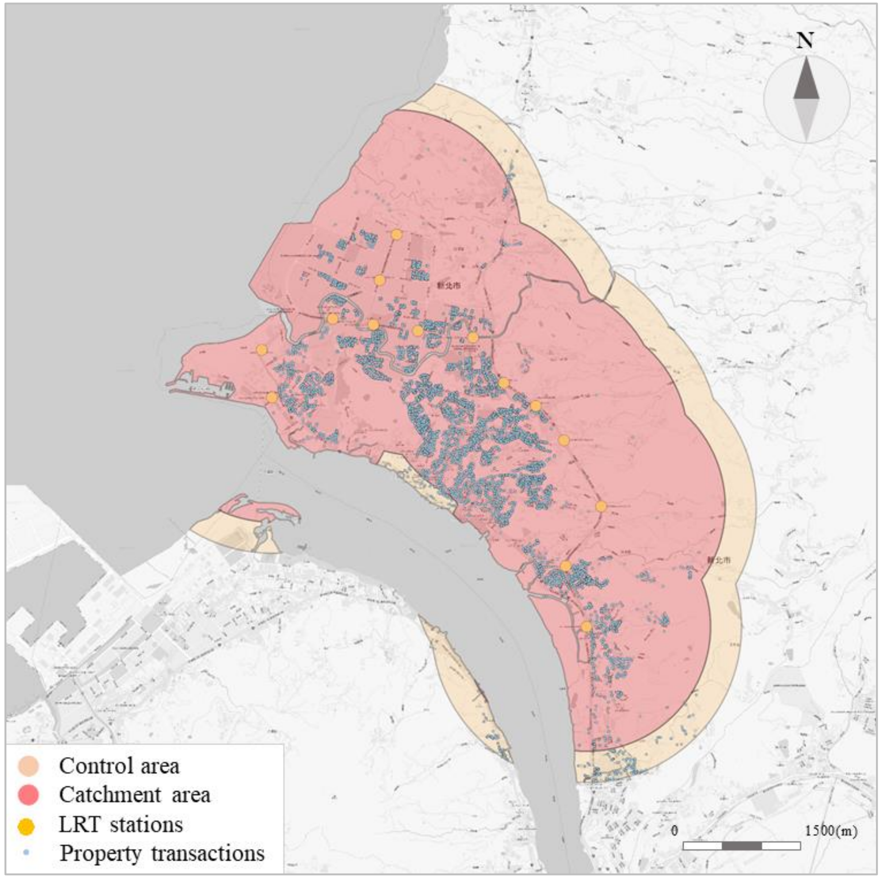

Figure 4.3 Study area with DBM selection in Danhai light rail

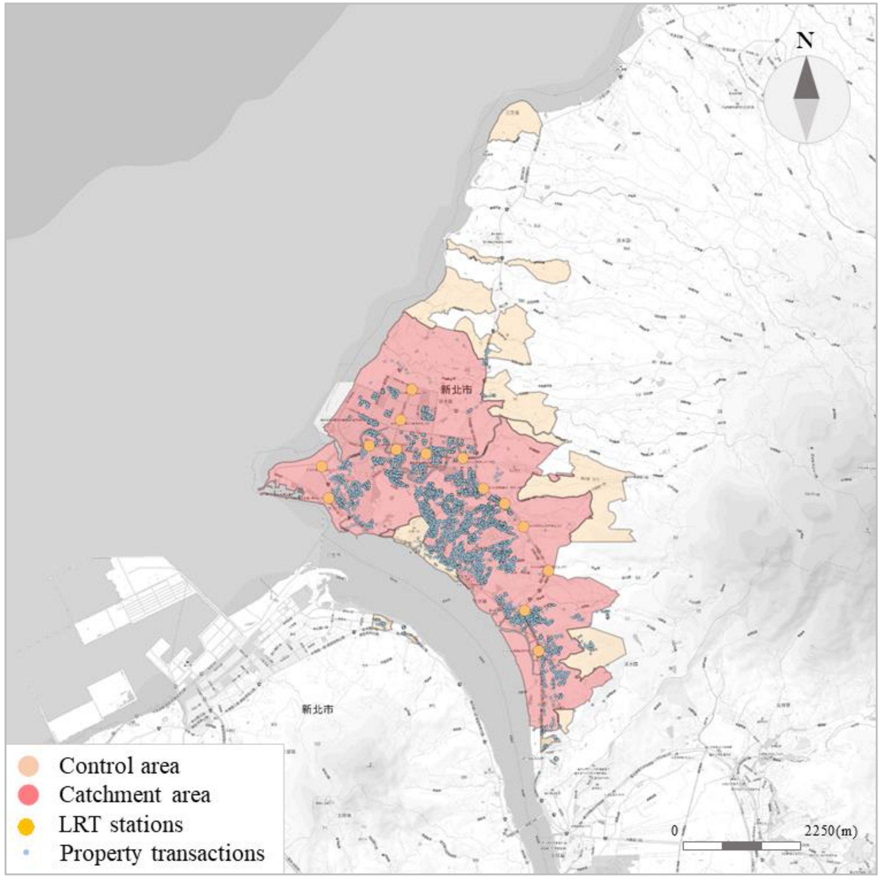

Figure 4.4 Study area with PSM selection in Danhai light rail

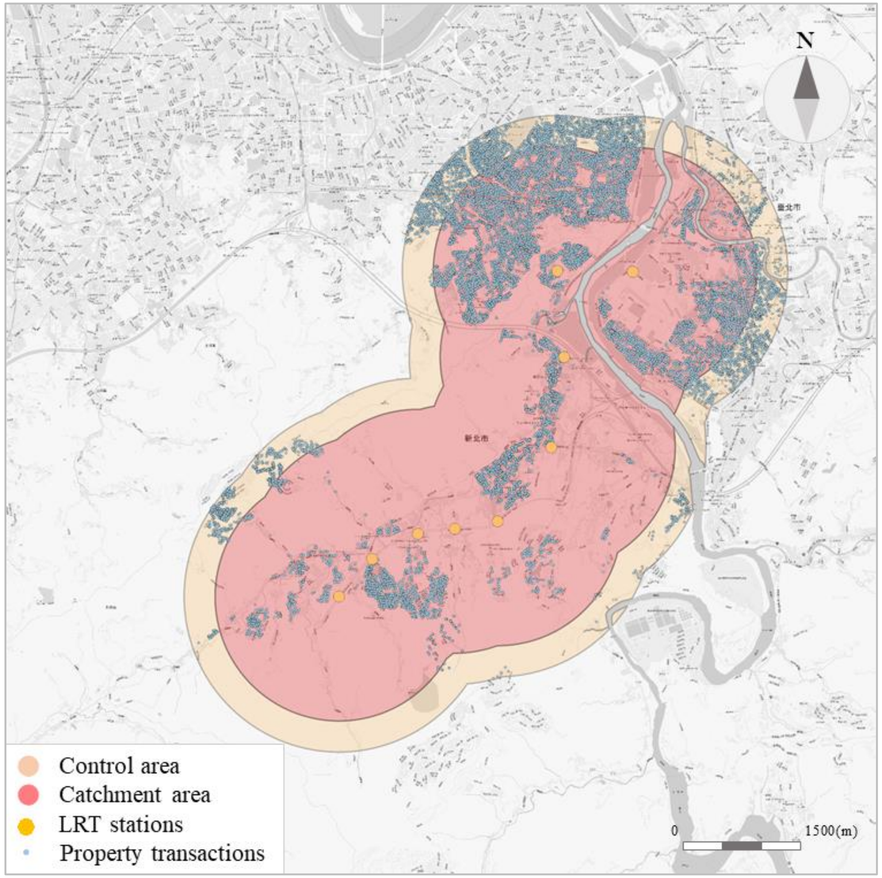

Figure 4.5 Study area with DBM selection in Ankeng light rail

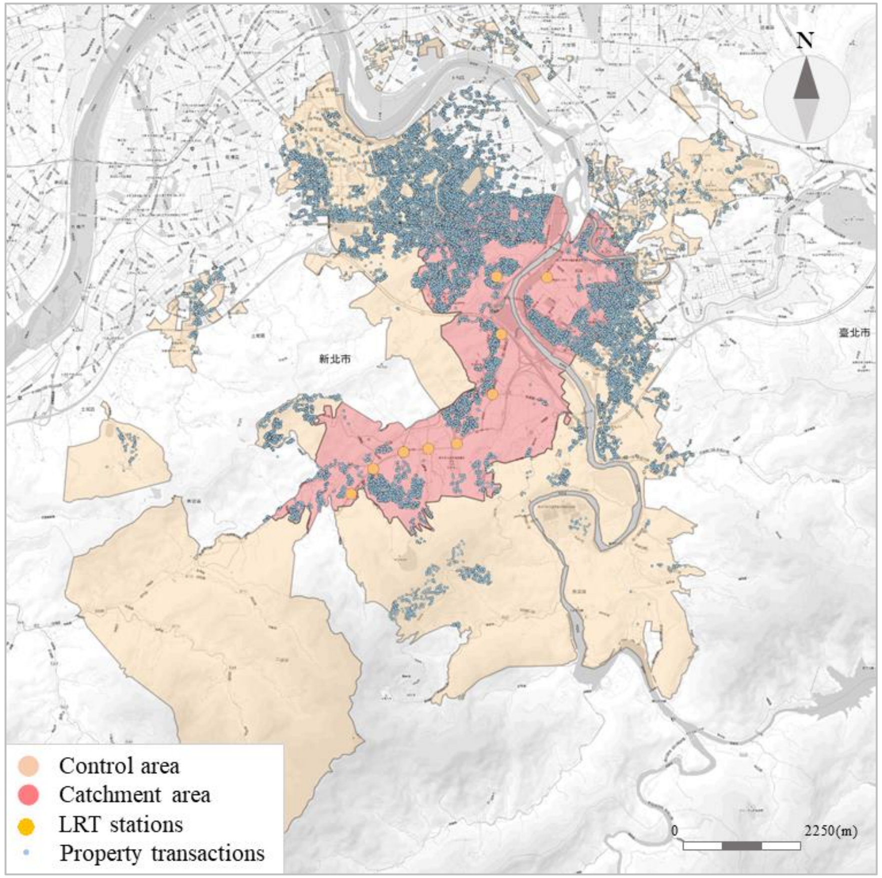

Figure 4.6 Study area with PSM selection in Ankeng light rail

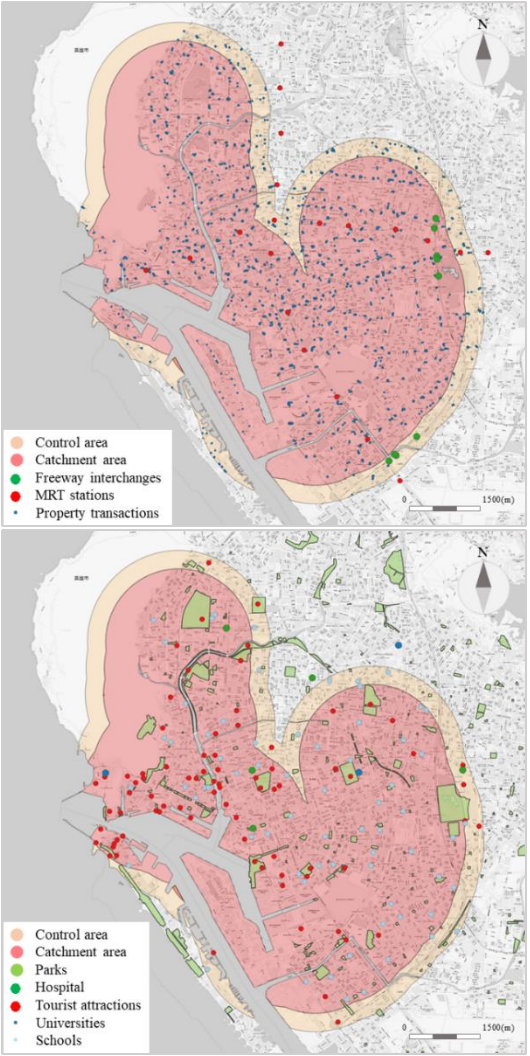

Figure 4.7 Facilities on study areas with DBM selection in Kaohsiung Circular light rail

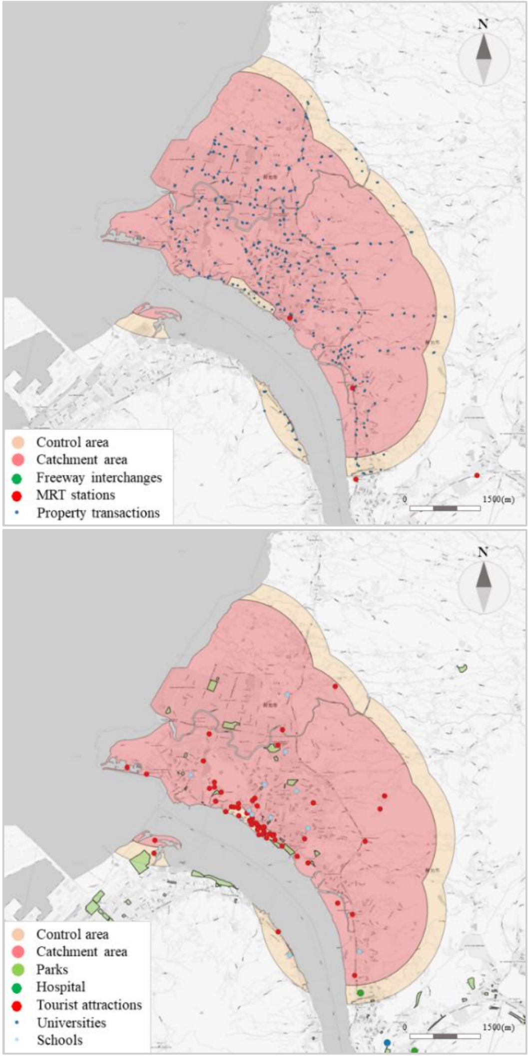

Figure 4.8 Facilities on study areas with DBM selection in Danhai light rail

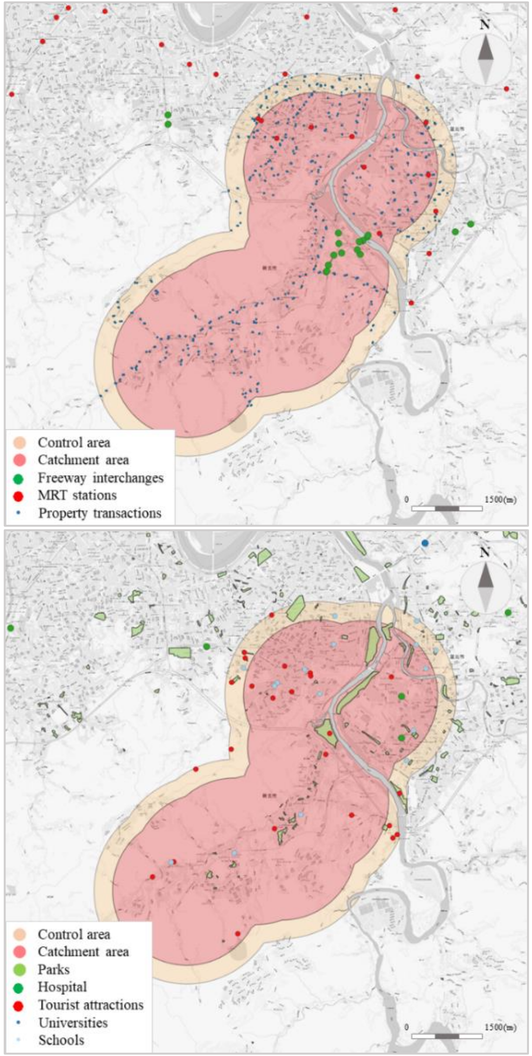

Figure 4.9 Facilities on study areas with DBM selection in Ankeng light rail

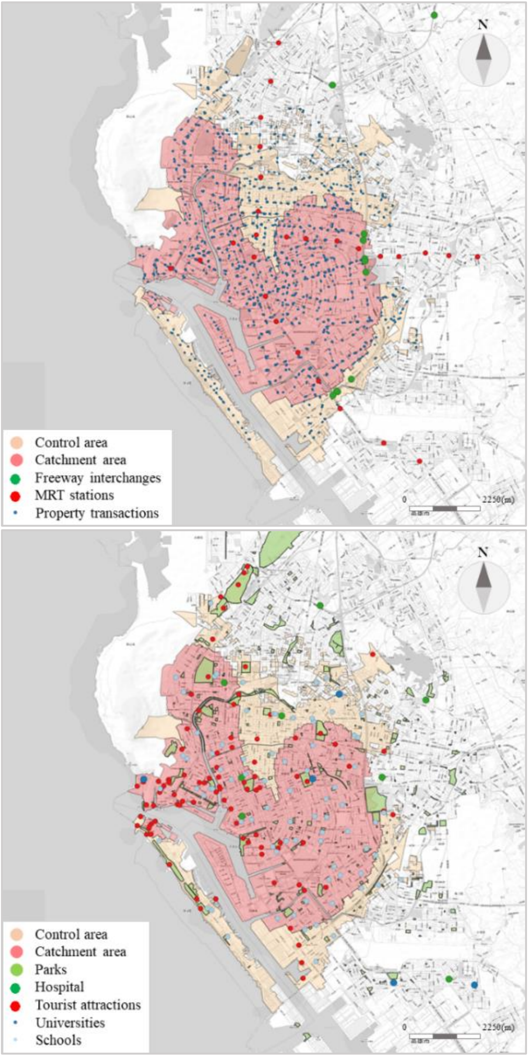

Figure 4.10 Facilities on study areas with PSM selection in Kaohsiung Circular light rail

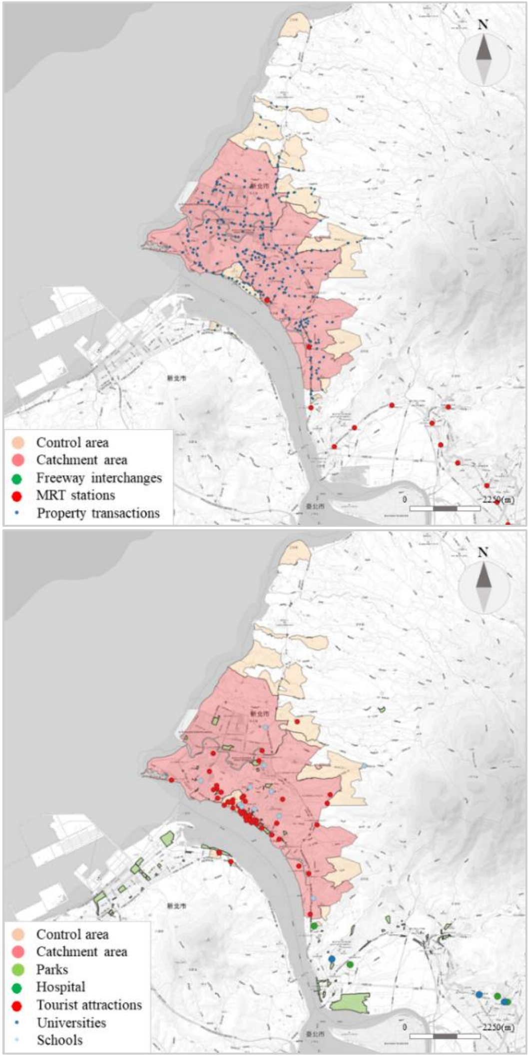

Figure 4.11 Facilities on study areas with PSM selection in Danhai light rail

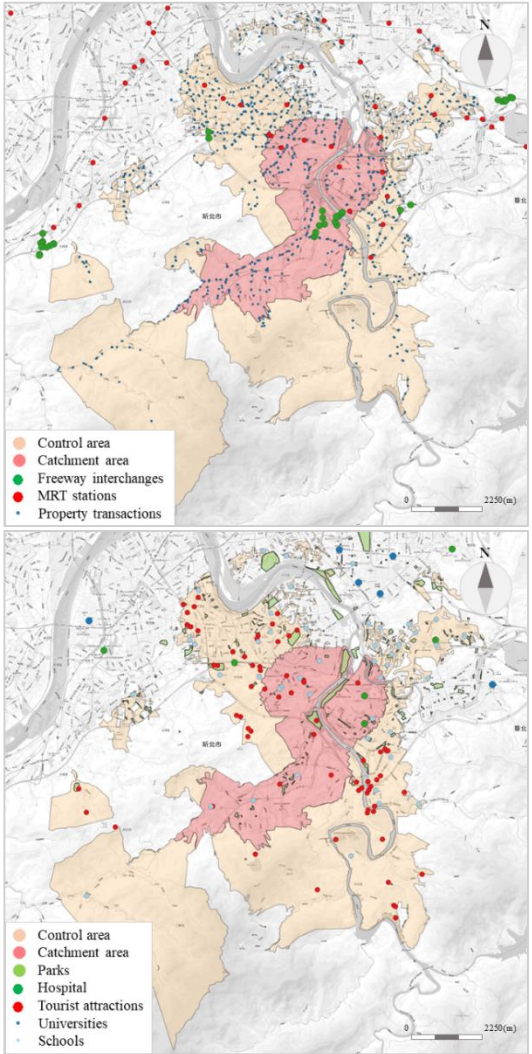

Figure 4.12 Facilities on study areas with PSM selection in Ankeng light rail

Chapter 5 CASE STUDY & MODEL RESULT

5.1 LRT systems in Taiwan

There are at least 10 LRT systems been discussed in Taiwan. 7 systems are in discussion or planning: Shezi light rail, Shenkeng light rail, Wu-Tai light rail, Hsinchu Circular light rail, Taoyuan metro brown line, Taoyuan metro orange line, and Kaohsiung metro purple line; 1 system in construction: Ankeng light rail; and 2 systems in operation: Kaohsiung Circular light rail, and Danhai light rail. This study takes 3 systems in construction or operation as case study, investigates interactions between distancing LRT stations, LRT system stages, and property prices.

The idea of constructing mass rapid transit in Kaohsiung city is discussed since 1979. The prototype of Kaohsiung Circular light rail is the former freight rail, Kaohsiung Port Line. Its delivery service was suspended in 2011 for the following light rail construction. The commencement of Kaohsiung Circular light rail is in June, 2013. Operation was started in October, 2015. Route length in operation (in February, 2021) is 12.8 km. 23 stations are in operation. 3 stations are in construction and expected operation in end of the year 2021.

The first proposal of Danhai light rail was released in November, 1992. The LRT system is coordinated with the development of urban plan. About half of the route locates inside the area of the urban plan. The LRT system is approved by Executive Yuan in February, 2013. Local government started the construction in November, 2014, the operation began in December, 2018. 14 stations are in operation (in February, 2021), with length 9.6 km.

The discussion of mass rapid transit in Ankeng area is first proposed in 1992, with the plan of MRT extension. This extension plan was overruled by the authority. The later on plan with light rail system is approved by Executive Yuan in June, 2015, and starting construction in April, 2016. The predicted time providing service is in 2022.

5.2 Data of property transactions

Property transactions are obtained from the property transactions' data providing system. The time series of the data is from January, 2012 to December, 2020. Figure 5.1 shows the time of LRT systems starting different stages. The period of data collection covers time points of different stages.

The property price of each observation is adjusted by consumer price index (CPI). Observations with extreme value or unexpected transaction time are removed. There are 5 defined rules for determining observation with extreme value:

(1) property price over NT$100,000,000;

(2) property price below NT$ 1,000,000;

(3) floor area of the property over 400 m^2;

(4) number of rooms over 10;

(5) number of bathrooms over 10;

(6) number of berths over 10.

Models in this research only consider properties with residential usage. The key factors influencing property price for residential usage and business usage are different.

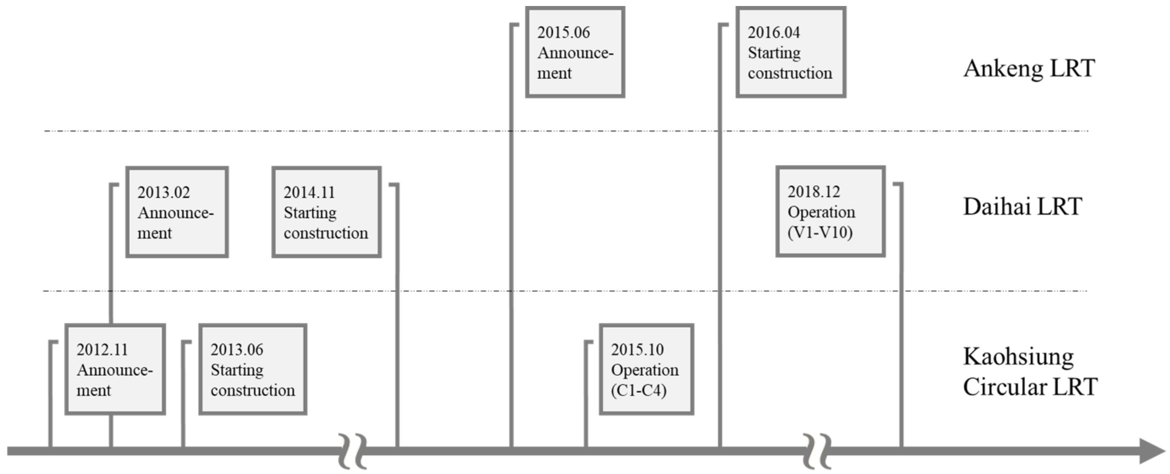

Figure 5.1 Starting time of stages in LRT systems

5.3 Descriptive Analysis

Records mentioned above are used for the value uplift model construction. Total numbers of records are 90,453 in the study area with DBM selection and 115,186 in the study area with PSM selection. Numbers of records on categorical variables and the corresponding explanations are provided in Table 5.1. The explanations of continuous attributes are provided in Table 5.2 and the results of descriptive analysis on continuous variables are listed in Table 5.3.

Numbers of observations in proximity to these 3 LRT systems are different. There are 37,819 observations locating in study area of Kaohsiung Circular light rail selected by DBM and 46,141 observations locating in study area selected by PSM; There are 30,494 observations locating in study area of Danhai light rail selected by DBM and 30,327 observations locating in study area selected by PSM; There are 22,140 observations locating in study area of Ankeng light rail selected by DBM and 38,718 observations locating in study area selected by PSM.

Since observations with extreme value are eliminated, the minimum or maximum value of each attribute is reasonable. Lengths of all properties distancing to nearest amenities are roughly or less than 10 kilometers. The value of unemployment rate is derived through the results of labor force survey. However, these values are higher than expected. This situation may due to the inappropriate definition on calculating unemployment rate through survey results. The center points of CBDs are defined on Taipei Main Station for Danhai light rail and Ankeng light rail and Shinkuchan business area for Kaohsiung Circular light rail. *C_floor_apartment* is for observations with apartment type and *C_floor_house* is for house.

Table 5.1 Descriptions of categorical attributes in modeling data

	Description	Sample size	
		DBM	PSM
Time variables			
D_tax2016	1 if the transaction time is after the amendment of transaction tax in 2016	43,788	55,617
	reference: the transaction time is before the amendment of transaction tax in 2016	46,665	59,569
LRT effects			
D_400m	1 if the property locates within 400m to the nearest LRT station	23,272	23,272
D_800m	1 if the property locates between 400~800m to the nearest LRT station	22,303	22,303
D_1600m	1 if the property locates between 800~1600m to the nearest LRT station	30,532	30,532
	reference: the property locates in control areas(over 1600m for DBM)	14,346	39,079
D_announcement	1 if the transaction time is after the approval announcement and before the construction	25,901	31,457
D_construction	1 if the transaction time is after the construction and before the operation	37,455	48,038
D_operation	1 if the transaction time is after the operation	10,922	11,413
	reference: the transaction time is before the approval announcement	16,175	24,278
LRT characteristics			
D_elevated	1 if the LRT station is elevated	37,991	53,692
	reference: the LRT station is on the ground	52,462	61,494
D_newroads	1 if the LRT station locates in the newly-developed area	23,146	27,158
	reference: the LRT station locates in the well-organized area	67,307	88,028

Table 5.1 (continued)

	Description	Sample size	
		DBM	PSM
LRT characteristics			
D_MRT_high	1 if the LRT station provides transferring to high capacity MRT line	2,293	1,945
D_MRT_medium	1 if the LRT station provides transferring to medium capacity MRT line	5,560	8,586
	reference: the LRT station doesn't provide transferring availability	82,600	104,655
Property characteristics			
D_house	1 if the type of the property is house	3,319	4,277
	reference: the type of the property is unit in apartment	87,134	110,909
D_management	1 if there is existing management organization for the property	75,076	94,149
	reference: there is no management organization for the property	15,377	21,037
Neighborhood characteristics			
D_business	1 if the property locates in the area of business usage	17,478	22,113
D_residential	1 if the property locates in the area of residential usage	64,113	81,159
	reference: the property locates in the area with other usage (industry, agriculture, etc.)	8,862	11,914
D_urbanplan	1 if the property locates within the urban plan area	88,412	112,773
	reference: the property locates outside the urban plan area	2,041	2,413

Table 5.2 Descriptions of continuous attributes in modeling data

	Description	Unit
Dependent variable		
C_ln_price_CPI	the natural log value of property price with CPI adjustment	ln(NT$)
Time variables		
C_time	difference on the transaction time with the time of first transaction	month
LRT effects		
C_dist_LRT	the distance to the nearest LRT station	km
LRT characteristics		
C_capacity	the maximum car capacity of the LRT system for single direction	1,000 people
C_MRT_capacity	the maximum daily capacity of the transferred MRT system for single direction	100,000 people
Property characteristics		
C_area_building	the floor area of the property	m^2
C_room	the number of the living room inside the property	-
C_bath	the number of the bathroom inside the property	-
C_berth	the number of the berth attached to the property	-
C_floor_apartment	the level number of the property in the apartment	level
C_floor_house	the total level number of the house	level
C_age	the age of the property	year

Table 5.2 (continued)

	Description	Unit
Neighborhood characteristics		
C_postsecondary	the value of ratio with higher education population in area where the property locates	100%
C_dependency	the value of dependency ratio in area where the property locates	100%
C_unemployment	The value of unemployment rate in area where the property locates	100%
C_ln_popdensity	the natural log value of population density in area where the property locates	ln(people / km^2)
C_ln_medincome	the natural log value of median personal annual income where the property locates	ln(1,000 NT$)
C_dist_CBD	the distance to the CBD	km
Amenities		
C_dist_bus	the distance to the nearest bus stop	km
C_dist_MLbus	the distance to the nearest bus stop with main line buses arrived	km
C_dist_MRT	the distance to the nearest MRT station	km
C_dist_freeway	the distance to the nearest freeway interchange	km
C_dist_hospital	the distance to the nearest hospital	km
C_dist_park	the distance to the nearest park	km
C_dist_attraction	the distance to the nearest tourist attraction	km
C_dist_school	the distance to the nearest primary or secondary school	km
C_dist_university	the distance to the nearest public university	km

Table 5.3 Descriptive statistics on continuous attributes of transaction records

	data with DBM selection						data with PSM selection					
	Mean	Min.	Median	Max.	Skewness	kurtosis	Mean	Min.	Median	Max.	Skewness	kurtosis
Dependent variable												
C_ln_price_CPI	15.944	13.816	15.961	18.390	-0.275	0.465	15.991	13.816	15.998	18.420	-0.205	0.333
Time variables												
C_time	50.475	1	47	107	0.258	-1.248	50.432	1	47	107	0.266	-1.247
LRT effects												
C_dist_LRT	0.903	0.013	0.791	2.000	0.374	-1.177	1.315	0.013	1.118	4.998	1.154	1.185
LRT characteristics												
C_capacity	1.885	1.000	2.650	2.650	-0.123	-1.962	1.930	1.000	2.650	2.650	-0.238	-1.925
C_MRT_capacity	1.183	0.000	1.010	2.208	0.132	-1.260	0.929	0.000	1.010	2.208	0.432	-1.221
Property characteristics												
C_area_building	140.598	3.140	130.130	399.770	1.015	1.111	139.240	3.140	127.975	399.770	1.029	1.118
C_room	2.651	0	3	9	-0.062	1.113	2.653	0	3	9	-0.103	1.080
C_bath	1.690	0	2	9	1.575	8.441	1.685	0	2	9	1.471	7.707
C_berth	1.208	0	0	9	0.882	-0.071	1.144	0	0	9	1.006	0.232
C_floor_apartment	8.507	-5	7	41	1.117	1.416	8.462	-5	7	41	1.086	1.236
C_floor_house	3.070	1	3	23	2.709	28.207	3.105	1	3	15	1.516	9.899
C_age	11.471	0	7	64	1.024	0.182	12.057	0	8	64	0.924	-0.031

Table 5.3 (continued)

	data with DBM selection						data with PSM selection					
	Mean	Min.	Median	Max.	Skewness	kurtosis	Mean	Min.	Median	Max.	Skewness	kurtosis
Neighborhood characteristics												
C_postsecondary	0.603	0.000	0.620	1.000	-0.418	1.028	0.597	0.000	0.608	1.000	-0.369	0.954
C_dependency	0.327	0.000	0.325	9.385	7.200	342.923	0.325	0.000	0.323	9.385	6.036	281.127
C_unemployment	0.230	0.148	0.228	0.315	0.577	1.798	0.230	0.148	0.228	0.315	0.450	1.787
C_ln_popdensity	0.724	-7.842	0.998	3.824	-1.383	3.083	0.822	-7.842	1.124	3.857	-1.400	3.118
C_ln_medincome	6.527	6.080	6.512	7.151	0.559	0.036	6.489	0.000	6.509	7.151	-12.060	158.831
C_dist_CBD	8.752	0.104	6.583	19.750	0.390	-1.415	8.157	0.104	6.035	20.617	0.646	-1.014
Amenities												
C_dist_bus	0.106	0.000	0.095	1.105	2.285	16.011	0.108	0.000	0.094	1.816	6.315	80.106
C_dist_MLbus	0.303	0.000	0.208	2.417	2.061	5.590	0.292	0.000	0.193	3.545	3.148	17.058
C_dist_MRT	1.365	0.002	1.174	5.173	0.959	0.399	1.278	0.001	1.008	6.151	1.083	0.737
C_dist_hospital	5.654	0.042	3.852	15.027	0.576	-1.327	4.837	0.024	2.886	16.482	0.917	-0.779
C_dist_park	2.792	0.010	2.059	8.192	0.634	-0.921	2.546	0.000	1.891	9.355	0.886	-0.435
C_dist_attraction	0.404	0.007	0.331	2.482	2.276	7.258	0.384	0.007	0.305	2.359	2.425	8.121
C_dist_school	0.541	0.004	0.490	2.133	0.950	0.881	0.551	0.002	0.480	3.723	2.078	9.097
C_dist_university	0.543	0.000	0.443	2.096	1.283	1.201	0.523	0.000	0.426	3.238	1.658	3.785

5.3 Model results interpretation

There are some expectations on coefficients of independent variables with positive or negative sign. These expectations listed in Table 5.4 are based on the discovers of former studies, or the existing facts of socio-demographic condition in Taiwan.

Table 5.4 Several expectations on the sign of variables

Time variables				
C_time	*D_tax2016*			
+	-			
LRT characteristics				
C_capacity	*D_elevated*	*D_newroads*	*D_MRT_high*	*D_MRT_medium*
+	+	+	+	+
Property characteristics				
C_area_building	*C_room*	*C_bath*	*C_berth*	*C_floor_apartment*
+	+	+	+	+
C_age	*D_house*			
-	+			
Neighborhood characteristics				
C_postsecondary	*C_unemployment*	*C_ln_popdensity*	*C_ln_medincome*	*C_dist_CBD*
+	-	-	+	-
D_business	*D_residential*	*D_urbanplan*		
+	+	+		
Amenities				
C_dist_bus	*C_dist_MLbus*	*C_dist_MRT*	*C_dist_freeway*	*C_dist_hospital*
-	-	-	-	-
C_park	*C_attration*			
-	-			

The phenomenon of investing real estate indicates that the changes on property price over times are higher than on price of other estate. The relative higher rate of price change results more investments on property market and escalating property price. In order to prevent damaging the basic need of residence. The government released a bill in 2016 for additional taxation on specific real estate transactions. The result of this action is the slower growth on property market and property prices, referring to the expected negative sign on *D_tax2016*.

Characteristics of the property are key factors influencing the corresponding price, including size, space arrangement, age, etc. Preferences, such as low-price seeking, impacts the price of different kinds of real estates. It is expected that properties with huge floor area, more living rooms, more bathrooms, more parking lots, higher level, or less years of age, are more expensive. The single house is more expensive than the property in the apartment.

5.3.1 Models for single LRT system

Models for single LRT system can better understanding the impacts from different LRT systems. These models only consist of 3 categories of variables, property characteristics (*P*), neighborhood characteristics (*N*) and amenities (*A*). The analysis approach of these models is MLR (Results with different approaches are listed in Appendix). The data for modelling is selected by PSM with both un-standardized coefficients and standardized coefficients. The method for generating data with standardized coefficients is introduced in later part. Results of the 3 models with un-standardized coefficients are listed in Table 5.5. Signs of most variables are the same in these models. Some variables with inconsistent effect may due to influences of characteristics of systems or stations. The standardized coefficients models listed in Table 5.6 are constructed for comparing effects across different models. Value uplift effects are shown in Figure 5.2, Figure 5.3 and Figure 5.4.

Similar trends are found across the 3 LRT systems. The value uplift effects increase through stages. The price decay is discovered in control area. The amount of effect in Danhai light rail is the highest. The possible reason is the capacity differences on the transferred MRT systems. The variable for controlling this impact, *C_MRT_capacity*, is involved in the homogeneous case study models.

Table 5.5 Single LRT system models results (MLR + PSM) with un-standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	12.515	0.000	6.954	0.000	15.077	0.000
Time variables						
C_time	0.004	0.000	0.001	0.000	0.004	0.000
D_tax2016	-0.035	0.000	-0.071	0.000	-0.062	0.000
LRT effects						
C_dist_LRT	0.027	0.000	-0.007	0.507	0.000	0.873
D_400m	-0.036	0.087	-0.101	0.005	-0.180	0.000
D_800m	-0.010	0.598	-0.167	0.000	-0.086	0.000
D_1600m	0.009	0.511	-0.061	0.079	-0.034	0.000
D_announcement	0.089	0.000	0.154	0.000	-0.007	0.285
D_construction	0.059	0.000	0.038	0.300	-0.065	0.000
D_operation	0.025	0.071	0.025	0.557	-	
D_400m:D_announcement	0.094	0.000	-0.039	0.300	0.000	0.990
D_400m:D_construction	0.077	0.000	0.147	0.000	0.026	0.018
D_400m:D_operation	0.127	0.000	0.156	0.000	-	
D_800m:D_announcement	0.048	0.014	-0.018	0.642	0.051	0.000
D_800m:D_construction	0.100	0.000	0.136	0.000	0.001	0.918
D_800m:D_operation	0.080	0.000	0.169	0.000	-	
D_1600m:D_announcement	0.018	0.187	0.009	0.824	0.003	0.746
D_1600m:D_construction	0.029	0.041	0.094	0.012	0.007	0.201
D_1600m:D_operation	0.091	0.000	0.077	0.078	-	
Property characteristics						
C_area_building	0.006	0.000	0.007	0.000	0.006	0.000
C_room	0.102	0.000	0.079	0.000	0.079	0.000
C_bath	-0.020	0.000	-0.005	0.046	-0.019	0.000
C_berth	0.004	0.003	-0.018	0.000	-0.017	0.000
C_floor_apartment	0.002	0.000	0.005	0.000	0.000	0.896
C_floor_house	-0.305	0.000	-0.294	0.000	-0.160	0.000
C_age	-0.025	0.000	-0.015	0.000	-0.012	0.000
D_house	1.572	0.000	1.036	0.000	0.705	0.000
D_management	-0.011	0.009	-0.062	0.000	-0.060	0.000

Table 5.5 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.028	0.004	0.000	0.983	0.010	0.250
C_dependency	-0.038	0.000	0.037	0.000	0.083	0.000
C_unemployment	0.739	0.000	-0.247	0.404	1.064	0.000
C_ln_popdensity	-0.006	0.000	-0.010	0.000	0.008	0.000
C_ln_medincome	0.316	0.000	0.510	0.000	0.002	0.275
C_dist_CBD	-0.029	0.000	0.559	0.000	0.010	0.000
D_business	0.004	0.521	0.070	0.000	0.074	0.000
D_residential	0.029	0.000	-0.037	0.000	0.072	0.000
D_urbanplan	-		0.022	0.249	0.190	0.000
Amenities	-0.263	0.000	0.041	0.067	0.275	0.000
C_dist_bus	0.135	0.000	-0.172	0.000	-0.088	0.000
C_dist_MLbus	-0.033	0.000	0.060	0.000	-0.130	0.000
C_dist_MRT	-0.016	0.000	-0.134	0.000	0.082	0.000
C_dist_freeway	-0.028	0.000	-0.090	0.264	-0.030	0.000
C_dist_hospital	0.013	0.107	0.073	0.000	-0.203	0.000
C_dist_park	-0.014	0.011	0.059	0.000	0.039	0.000
C_dist_attraction	0.004	0.627	-0.054	0.000	0.013	0.012
C_dist_school	-0.005	0.052	-0.447	0.000	-0.004	0.209
C_dist_university	-0.263	0.000	0.041	0.067	0.275	0.000
Log likelihood	-1564		4801		3664	
ICC	0.181		0.088		0.397	
R^2	0.870		0.864		0.867	

Table 5.6 Single LRT system models results (MLR + PSM) with standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	-1.024	0.000	-4.131	0.000	0.777	0.000
Time variables						
C_time	0.153	0.000	0.054	0.000	0.148	0.000
D_tax2016	-0.049	0.000	-0.099	0.000	-0.087	0.000
LRT effects						
C_dist_LRT	0.038	0.000	-0.010	0.507	0.001	0.873
D_400m	-0.051	0.087	-0.142	0.005	-0.253	0.000
D_800m	-0.014	0.598	-0.234	0.000	-0.121	0.000
D_1600m	0.013	0.511	-0.086	0.079	-0.047	0.000
D_announcement	0.125	0.000	0.216	0.000	-0.010	0.285
D_construction	0.082	0.000	0.053	0.300	-0.091	0.000
D_operation	0.036	0.071	0.035	0.557	-	
D_400m:D_announcement	0.132	0.000	-0.054	0.300	0.000	0.990
D_400m:D_construction	0.109	0.000	0.206	0.000	0.036	0.018
D_400m:D_operation	0.178	0.000	0.218	0.000	-	
D_800m:D_announcement	0.067	0.014	-0.025	0.642	0.071	0.000
D_800m:D_construction	0.141	0.000	0.191	0.000	0.001	0.918
D_800m:D_operation	0.112	0.000	0.237	0.000	-	
D_1600m:D_announcement	0.026	0.187	0.012	0.824	0.005	0.746
D_1600m:D_construction	0.040	0.041	0.132	0.012	0.010	0.201
D_1600m:D_operation	0.128	0.000	0.107	0.078	-	
Property characteristics						
C_area_building	0.591	0.000	0.651	0.000	0.630	0.000
C_room	0.155	0.000	0.120	0.000	0.119	0.000
C_bath	-0.022	0.000	-0.006	0.046	-0.021	0.000
C_berth	0.007	0.003	-0.037	0.000	-0.036	0.000
C_floor_apartment	0.018	0.000	0.045	0.000	0.000	0.896
C_floor_house	-0.270	0.000	-0.260	0.000	-0.142	0.000
C_age	-0.430	0.000	-0.263	0.000	-0.204	0.000
D_house	2.204	0.000	1.452	0.000	0.988	0.000
D_management	-0.015	0.009	-0.086	0.000	-0.084	0.000

Table 5.6 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.007	0.004	0.000	0.983	0.002	0.250
C_dependency	-0.008	0.000	0.008	0.000	0.017	0.000
C_unemployment	0.030	0.000	-0.010	0.404	0.043	0.000
C_ln_popdensity	-0.012	0.000	-0.019	0.000	0.014	0.000
C_ln_medincome	0.215	0.000	0.347	0.000	0.001	0.275
C_dist_CBD	-0.229	0.000	4.409	0.000	0.081	0.000
D_business	0.005	0.521	0.098	0.000	0.104	0.000
D_residential	0.041	0.000	-0.051	0.000	0.101	0.000
D_urbanplan	-		0.031	0.249	0.266	0.000
Amenities	-0.032	0.000	0.005	0.067	0.033	0.000
C_dist_bus	0.057	0.000	-0.073	0.000	-0.037	0.000
C_dist_MLbus	-0.046	0.000	0.085	0.000	-0.183	0.000
C_dist_MRT	-0.097	0.000	-0.819	0.000	0.499	0.000
C_dist_freeway	-0.076	0.000	-0.243	0.264	-0.080	0.000
C_dist_hospital	0.006	0.107	0.032	0.000	-0.089	0.000
C_dist_park	-0.007	0.011	0.030	0.000	0.020	0.000
C_dist_attraction	0.002	0.627	-0.026	0.000	0.006	0.012
C_dist_school	-0.015	0.052	-1.264	0.000	-0.010	0.209
C_dist_university	0.007	0.004	0.000	0.983	0.002	0.250
Log likelihood	-17127		-5422		-9394	
ICC	0.181		0.088		0.397	
R^2	0.870		0.864		0.867	

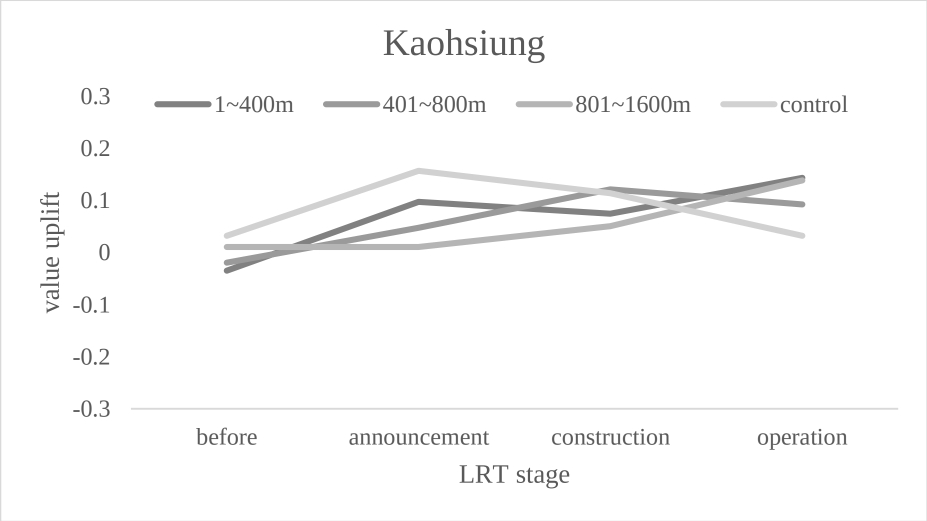

Figure 5.2 Value uplift effects from Kaohsiung Circular light rail in different stages

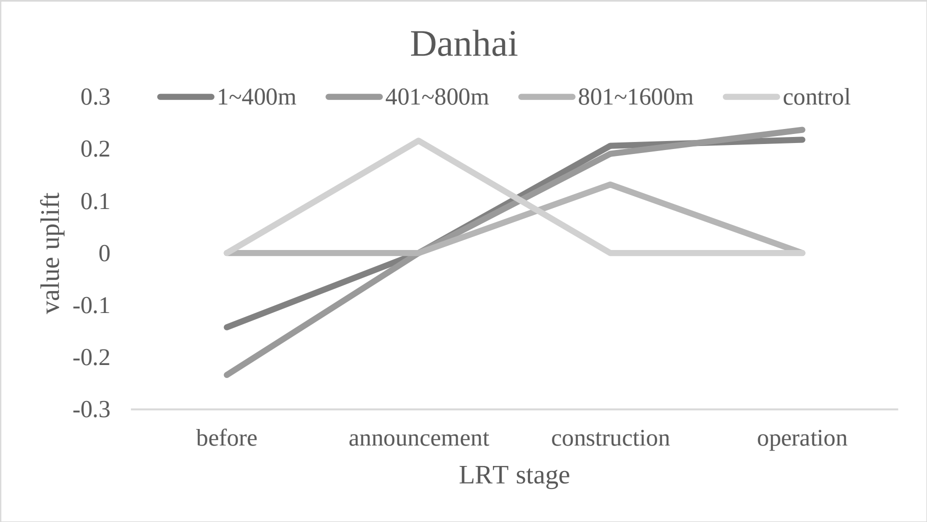

Figure 5.3 Value uplift effects from Danhai light rail in different stages

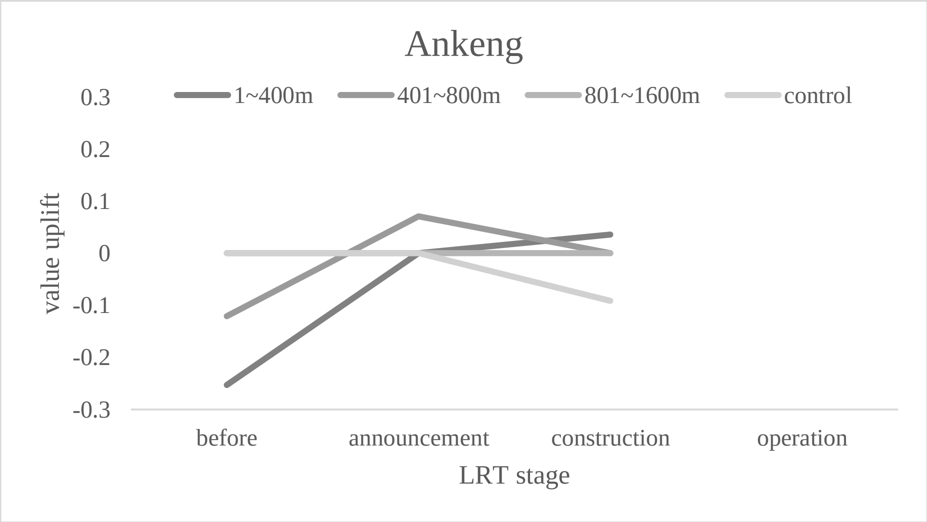

Figure 5.4 Value uplift effects from Ankeng light rail in different stages

5.3.2 Homogeneous model for the 3 LRT systems

Result from meta-analysis model 2 in Chapter 3 indicates that LRT system characteristics do influence the level of value uplift. There are some differences between 3 LRT systems or even between stations in the same LRT system. These differences include types of vehicle, service frequencies, station forms (elevated station), station locations, and availabilities on transferring to MRT systems. Impacts on types of vehicle and its corresponding service frequencies can be expressed by influences of capacities. It is expected that systems with higher capacity provide better accessibility gains, resulting in higher value uplifts on neighborhoods. LRT stations locate in newly-planning areas can provide better accessibility gains, comparing to those stations locate in well-organized areas. Similar to the inference on capacity, the influences on MRT systems differ from high/medium capacity. LRT stations with availability on transferring to high capacity MRT systems give higher premium than those transferring to medium capacity MRT systems.

Any transportation facility and its corresponding service can improve the accessibility in surrounding area. With the positive impact on accessibility, the expected signs of the following variables, *C_dist_bus*, *C_dist_MLbus*, *C_dist_MRT*, *C_dist_freeway*, are negative. The negative parameter indicates the reducing effect on increasing distance. In other words, the closer distance experiences more improvements on accessibility. Hospitals can provide health care services to surrounding areas. Parks are sites for leisure activities, including jogging or picnic. These amenities also give motivations for people living closer to them.

Table 5.7 shows the estimated parameter of each variable and its corresponding p-value. Since the dependent variable, property price with CPI adjustment, is expressed in natural log form. The explanation of the parameter value is the corresponding ratio change in property price with each unit change in independent variable.

The model fitness, represented as R^2 value, are 0.857 for DID model with DBM, 0.850 for MLR model with DBM, 0.860 for DID model with PSM, and 0.845 for MLR model with PSM. These values indicate that most modeling data can be correctly predicted by both the 4 models. This also refers that the following explanations of parameter values are reliable for certain extent.

Table 5.7 Model results with un-standardized variables

	DID with DBM		MLR with DBM		DID with PSM		MLR with PSM	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	13.645	0.000	14.079	0.000	14.783	0.000	15.416	0.000
Time variables								
C_time	0.004	0.000	0.003	0.000	0.005	0.000	0.004	0.000
D_tax2016	-0.083	0.000	-0.065	0.000	-0.077	0.000	-0.071	0.000
LRT effects								
C_dist_LRT	-0.031	0.000	0.008	0.139	-0.005	0.003	-0.016	0.000
D_400m	-0.215	0.000	-0.153	0.000	-0.236	0.000	-0.213	0.000
D_800m	-0.109	0.000	-0.085	0.000	-0.118	0.000	-0.100	0.000
D_1600m	-0.033	0.000	-0.011	0.082	-0.042	0.000	-0.027	0.000
D_announcement	-0.128	0.000	-0.030	0.000	-0.117	0.000	-0.022	0.000
D_construction	-0.128	0.000	-0.061	0.000	-0.140	0.000	-0.054	0.000
D_operation	-0.188	0.000	-0.075	0.000	-0.274	0.000	-0.092	0.000
D_400m:D_announcement	0.235	0.000	0.122	0.000	0.239	0.000	0.103	0.000
D_400m:D_construction	0.185	0.000	0.141	0.000	0.178	0.000	0.118	0.000
D_400m:D_operation	0.235	0.000	0.151	0.000	0.259	0.000	0.137	0.000
D_800m:D_announcement	0.139	0.000	0.077	0.000	0.143	0.000	0.071	0.000
D_800m:D_construction	0.156	0.000	0.117	0.000	0.168	0.000	0.110	0.000
D_800m:D_operation	0.220	0.000	0.141	0.000	0.265	0.000	0.149	0.000
D_1600m:D_announcement	0.103	0.000	0.044	0.000	0.109	0.000	0.052	0.000
D_1600m:D_construction	0.091	0.000	0.065	0.000	0.076	0.000	0.058	0.000
D_1600m:D_operation	0.149	0.000	0.087	0.000	0.180	0.000	0.103	0.000

Table 5.7 (continued)

	DID with DBM		MLR with DBM		DID with PSM		MLR with PSM	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
LRT characteristics								
C_capacity	0.125	0.000	-0.062	0.000	0.238	0.000	-0.062	0.000
C_MRT_capacity	-0.797	0.000	-0.911	0.000	-0.664	0.000	-0.507	0.000
D_400m:C_MRT_capacity	0.019	0.000	0.028	0.000	0.031	0.000	0.051	0.000
D_elevated	0.078	0.000	-0.010	0.013	0.085	0.000	0.005	0.236
D_newroads	0.073	0.000	0.072	0.000	0.027	0.000	0.090	0.000
D_MRT_high	0.396	0.000	0.119	0.000	0.423	0.000	0.188	0.000
D_MRT_medium	-0.011	0.071	0.084	0.000	0.028	0.000	0.000	0.944
Property characteristics								
C_area_building	0.006	0.000	0.006	0.000	0.006	0.000	0.006	0.000
C_room	0.096	0.000	0.098	0.000	0.095	0.000	0.097	0.000
C_bath	-0.026	0.000	-0.027	0.000	-0.026	0.000	-0.026	0.000
C_berth	-0.007	0.000	-0.008	0.000	-0.003	0.000	-0.006	0.000
C_floor_apartment	0.003	0.000	0.002	0.000	0.002	0.000	0.002	0.000
C_floor_house	-0.197	0.000	-0.206	0.000	-0.209	0.000	-0.226	0.000
C_age	-0.018	0.000	-0.018	0.000	-0.017	0.000	-0.017	0.000
D_house	0.956	0.000	1.009	0.000	0.992	0.000	1.073	0.000
D_management	-0.110	0.000	-0.097	0.000	-0.105	0.000	-0.083	0.000
Neighborhood characteristics								
C_postsecondary	0.021	0.001	-0.004	0.535	0.116	0.000	0.047	0.000
C_dependency	0.036	0.000	0.048	0.000	0.042	0.000	0.057	0.000
C_unemployment	-0.215	0.000	1.028	0.000	0.099	0.012	1.227	0.000

Table 5.7 (continued)

	DID with DBM		MLR with DBM		DID with PSM		MLR with PSM	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics								
C_ln_popdensity	-0.004	0.000	-0.005	0.000	-0.006	0.000	-0.003	0.000
C_ln_medincome	0.276	0.000	0.337	0.000	0.013	0.000	0.009	0.000
C_dist_CBD	0.090	0.000	-0.016	0.000	0.044	0.000	0.004	0.021
D_business	0.075	0.000	0.038	0.000	0.087	0.000	0.057	0.000
D_residential	0.069	0.000	0.037	0.000	0.080	0.000	0.060	0.000
D_urbanplan	0.319	0.000	0.212	0.000	0.344	0.000	0.253	0.000
Amenities								
C_dist_bus	-0.029	0.034	0.026	0.048	-0.021	0.051	0.062	0.000
C_dist_MLbus	-0.092	0.000	-0.076	0.000	-0.075	0.000	-0.058	0.000
C_dist_MRT	-0.116	0.000	-0.016	0.000	-0.112	0.000	-0.064	0.000
C_dist_freeway	0.051	0.000	-0.011	0.000	0.055	0.000	0.012	0.000
C_dist_hospital	-0.010	0.000	-0.029	0.000	-0.002	0.119	-0.032	0.000
C_dist_park	-0.120	0.000	-0.094	0.000	-0.131	0.000	-0.080	0.000
C_dist_attraction	0.035	0.000	-0.006	0.118	0.026	0.000	0.011	0.000
C_dist_school	0.106	0.000	-0.016	0.000	0.123	0.000	0.012	0.000
C_dist_university	-0.084	0.000	-0.025	0.000	-0.031	0.000	-0.031	0.000
Log likelihood	-		-1130.616		-		-2955.569	
ICC	-		0.920		-		0.844	
R^2	0.857		0.850		0.860		0.845	

Most parameters from model results listed in Table 5.7 match the expected sign. Only few parameters show adverse result against expectations. The expected sign on *C_bath* and *C_berth* are positive and the result is negative. The negative value may indicate that people prefer less and appropriate amount of bathrooms and parking spaces. The expected sign on *C_unemployment* is negative and the result is positive. This may due to inappropriate evaluation on unemployment rate from survey results. The expected sign on *C_dist_attraction* is negative and the result is positive. The possible reason for this result may be noises or other disutilities from these tourist attractions.

The estimated parameters of *C_time* in 4 models are ranging from 0.003 to 0.005, referring additional one month on transaction time will bring 0.3% to 0.5% premium on property price in average. This positive value further indicates that the inflation on property is higher than inflation represented by the CPI index. The effect of new taxation in 2016 is negative, supporting the expectation on the impact of this policy.

There are some positive values of parameters of systematic factors, including *D_elevated*, *D_new_roads*, *D_MRT_high* and *D_MRT_medium*. This result shows that an LRT station with elevated design, locating in newly-developed area, or providing transferring to MRT stations, can bring positive effect on property prices. The negative parameter of *C_MRT_capacity* and the positive parameter of *D_400m:C_MRT_capacity* indicates that the transferring accessibility provided by high capacity MRT system gives premium on properties locates within 400m catchment.

Positive parameters on *C_area_building*, *C_room*, *C_floor_apartment* and *D_house* coincide previous mentioned preference on house purchasing. Comparing to apartments, the average price of single houses is more expensive for 92.6% to 107.4%.The negative parameter of *C_floor_house* indicates that house owners prefer lower number of levels with bigger floor area in each level. The negative value on *D_management* shows preference on properties without management organization for reasons of saving money.

Significant parameters of neighborhood characteristics show existing impacts from regional differences. The price of properties locating areas with higher education level, more elderlies and kids, higher unemployment rate, lower population density and higher average income, are more expensive. Comparing to industry areas, properties inside residential areas or business areas experience higher value uplift. Distances from CBD reflect accessibilities in some extent.

Other types of accessibility, including main line buses and MRT stations, also increase the value of nearby properties. The negative effect from freeway interchanges might due to the noise of heavy traffic. The negative signs on *C_dist_park* are as expected. Direct proximity to schools, such as elementary school or junior high school, provides negative effect on property prices. This situation may due to the noise from bell ring of every class in schools.

For better understanding and comparing on value uplift effect in different models, the construction of models with standardized coefficients is needed. Bring (1994) mentioned one reason of using standardized coefficients been criticized is that the question of relative importance of different variables is very difficult to answer. In this study, the usage of same model formulation avoids the criticisms of standardized coefficients results. The definitions of standardized values for dependent variable and continuous independent variables are:

$$x_i^* = \frac{x_i - \bar{x_i}}{s_i}, i = 1 \dots k$$
$$y^* = \frac{y - \bar{y}}{s_y}$$

where i denoted for different continuous variables, s_i, s_y denoted for corresponding standard deviations of independent variables and dependent variable. Values of dummy variables remain the binary form. Table 5.8 shows the results on models with standardized coefficients.

Table 5.8 Model results with standardized variables

	DID with DBM		MLR with DBM		DID with PSM		MLR with PSM	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	-0.371	0.000	-1.045	0.004	-0.398	0.000	-0.551	0.006
Time variables								
C_time	0.159	0.000	0.136	0.000	0.191	0.000	0.155	0.000
D_tax2016	-0.121	0.000	-0.095	0.000	-0.107	0.000	-0.099	0.000
LRT effects								
C_dist_LRT	-0.025	0.000	0.006	0.139	-0.007	0.003	-0.022	0.000
D_400m	-0.258	0.000	-0.146	0.000	-0.255	0.000	-0.175	0.000
D_800m	-0.159	0.000	-0.124	0.000	-0.165	0.000	-0.140	0.000
D_1600m	-0.048	0.000	-0.016	0.082	-0.058	0.000	-0.037	0.000
D_announcement	-0.187	0.000	-0.044	0.000	-0.164	0.000	-0.030	0.000
D_construction	-0.187	0.000	-0.089	0.000	-0.196	0.000	-0.076	0.000
D_operation	-0.274	0.000	-0.109	0.000	-0.385	0.000	-0.129	0.000
D_400m:D_announcement	0.342	0.000	0.178	0.000	0.334	0.000	0.145	0.000
D_400m:D_construction	0.270	0.000	0.205	0.000	0.249	0.000	0.165	0.000
D_400m:D_operation	0.342	0.000	0.219	0.000	0.362	0.000	0.192	0.000
D_800m:D_announcement	0.202	0.000	0.112	0.000	0.201	0.000	0.100	0.000
D_800m:D_construction	0.227	0.000	0.171	0.000	0.236	0.000	0.154	0.000
D_800m:D_operation	0.320	0.000	0.206	0.000	0.372	0.000	0.208	0.000
D_1600m:D_announcement	0.150	0.000	0.064	0.000	0.152	0.000	0.072	0.000
D_1600m:D_construction	0.133	0.000	0.095	0.000	0.106	0.000	0.081	0.000
D_1600m:D_operation	0.217	0.000	0.126	0.000	0.252	0.000	0.144	0.000

Table 5.8 (continued)

	DID with DBM		MLR with DBM		DID with PSM		MLR with PSM	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
LRT characteristics								
C_capacity	0.147	0.000	-0.072	0.000	0.269	0.000	-0.070	0.000
C_MRT_capacity	-1.078	0.000	-1.233	0.000	-0.823	0.000	-0.628	0.000
D_400m:C_MRT_capacity	0.026	0.000	0.037	0.000	0.039	0.000	0.063	0.000
D_elevated	0.114	0.000	-0.014	0.013	0.119	0.000	0.007	0.236
D_newroads	0.106	0.000	0.104	0.000	0.039	0.000	0.126	0.000
D_MRT_high	0.576	0.000	0.173	0.000	0.592	0.000	0.264	0.000
D_MRT_medium	-0.016	0.071	0.122	0.000	0.039	0.000	-0.001	0.944
Property characteristics								
C_area_building	0.643	0.000	0.649	0.000	0.620	0.000	0.623	0.000
C_room	0.150	0.000	0.153	0.000	0.144	0.000	0.147	0.000
C_bath	-0.030	0.000	-0.030	0.000	-0.028	0.000	-0.028	0.000
C_berth	-0.016	0.000	-0.017	0.000	-0.006	0.000	-0.014	0.000
C_floor_apartment	0.022	0.000	0.020	0.000	0.019	0.000	0.015	0.000
C_floor_house	-0.179	0.000	-0.187	0.000	-0.185	0.000	-0.200	0.000
C_age	-0.314	0.000	-0.321	0.000	-0.295	0.000	-0.299	0.000
D_house	1.390	0.000	1.467	0.000	1.390	0.000	1.504	0.000
D_management	-0.160	0.000	-0.141	0.000	-0.147	0.000	-0.117	0.000
Neighborhood characteristics								
C_postsecondary	0.005	0.001	-0.001	0.535	0.028	0.000	0.011	0.000
C_dependency	0.008	0.000	0.010	0.000	0.009	0.000	0.012	0.000
C_unemployment	-0.009	0.000	0.044	0.000	0.004	0.012	0.049	0.000

Table 5.8 (continued)

	DID with DBM		MLR with DBM		DID with PSM		MLR with PSM	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics								
C_ln_popdensity	-0.008	0.000	-0.009	0.000	-0.011	0.000	-0.006	0.000
C_ln_medincome	0.060	0.000	0.074	0.000	0.009	0.000	0.006	0.000
C_dist_CBD	0.803	0.000	-0.139	0.000	0.344	0.000	0.031	0.021
D_business	0.109	0.000	0.056	0.000	0.121	0.000	0.080	0.000
D_residential	0.100	0.000	0.054	0.000	0.111	0.000	0.084	0.000
D_urbanplan	0.465	0.000	0.308	0.000	0.482	0.000	0.355	0.000
Amenities								
C_dist_bus	-0.003	0.034	0.003	0.048	-0.003	0.051	0.008	0.000
C_dist_MLbus	-0.038	0.000	-0.031	0.000	-0.032	0.000	-0.025	0.000
C_dist_MRT	-0.173	0.000	-0.023	0.000	-0.158	0.000	-0.090	0.000
C_dist_freeway	0.337	0.000	-0.072	0.000	0.339	0.000	0.073	0.000
C_dist_hospital	-0.029	0.000	-0.085	0.000	-0.005	0.119	-0.085	0.000
C_dist_park	-0.055	0.000	-0.043	0.000	-0.057	0.000	-0.035	0.000
C_dist_attraction	0.015	0.000	-0.003	0.118	0.013	0.000	0.006	0.000
C_dist_school	0.055	0.000	-0.008	0.000	0.061	0.000	0.006	0.000
C_dist_university	-0.257	0.000	-0.075	0.000	-0.086	0.000	-0.087	0.000
Log likelihood	-		-34994.332		-		-41830.105	
ICC	-		0.920		-		0.844	
R^2	0.857		0.850		0.860		0.845	

Table 5.8 provide comparable parameter value over different models. Signs of these parameters are as same as listed in Table 5.7. No further interpretation is needed. The only interest from results of these standardized coefficient models is the value uplift effect. Effects from LRT systems should be explained under different distances to LRT stations and different stages of LRT system. The parameter values of *D_400m*, *D_800m* and *D_1600m* indicate the value uplift before the approval announcement on corresponding catchments. The parameter values of *D_announcement*, *D_construction* and *D_operation* indicate the value uplift of control areas on corresponding time periods.

The value uplift effects of LRT within 400m on operation stage are 68.7% from results of DID approach with DBM selected data and 76.1% with PSM selected data. These values are stronger than 32.8% from results of MLR approach with DBM selected data and 36.6% from results of MLR approach with PSM selection. The stronger value uplifts from DID approach might indicate the inappropriate model formulation. MLR approach considers controls the variance in group level, which is geographic differences in this research, making the results becoming more accurate.

Figure 5.5 shows the value uplift effects evaluated by MLR approach, using data with PSM selection. It is found that the highest rate of value uplift effect change happened between the before and after the approval announcement. The closer to the LRT station, the higher value uplift the property experiences.

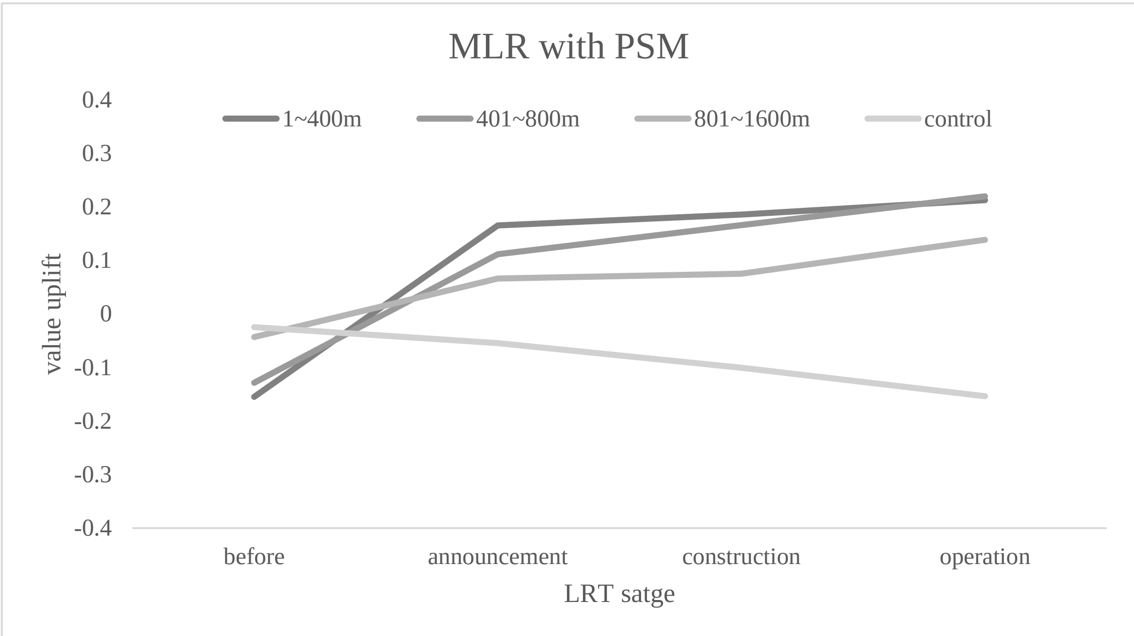

Figure 5.5 Value uplift effects from LRT in different stages

Chapter 6 CONCLUSION & DISCUSSION

6.1 Conclusions from meta-analysis

Different from reviews made by Debrezion et al. (2007), Mohammad et al. (2013), and Zhang & Yen (2020), this study first adopts meta-analysis as modeling approach for systematic review on LRT-related value uplift researches. Meta-analysis models consider impacts from LRT system factors, research methods used in the study, and property/neighborhood characteristics involved in the model. Results show that differences in some attributes, including LRT system factors, amenities location, study area identification, and modeling methods, do influence the investigated value uplift effect in certain extent.

Based on above result, it is necessary involving LRT system characteristics into the model for investigating value uplift effect. This pioneering model formulation is different from those in former studies, and make the investigating effect more accurate. According to conclusion conducted by Yen et al. (2019), models with different analysis methods or catchment selection approaches can bring distinctive values of value uplift. Similar view can be expressed from meta-analysis result in this research.

6.2 Conclusions from case study

This research evaluates value uplift effect with different approaches, including 2 study area selection methods (DBM selection and PSM selection) and 2 different modeling approaches (DID model and MLR model). There are six categories of variables, time variables, LRT characteristics, property characteristics, neighborhood characteristics, and amenities, involved for the model investigating value uplift.

The overall results are as expected, value uplift increases through stages and closer distances. Most parameters of variables in models are significant. Signs of property characteristics and neighborhood characteristics are also as predicted. The highest rate of effect change happened at the time of approval announcement. The strongest value uplift found within 500m to LRT stations. The price decay of properties locating in control areas is observed from models results. This phenomenon is also found in research conducted by Cao & Lou (2018). The possible reason may be the living preference on closer distance to facilities providing accessibility, causing distraction on properties locating in control areas.

One important purpose of this study is the detail considerations and discussions on results of different methods. For DID approach, the lack of consideration on regional differences causes harmful impacts on evaluating timing effect, making the result of overestimation. This overestimated parameter result is also found in study conducted by Billings (2011) that the coefficient from DID result is higher than from RSM result. The result from MLR model, taking group level variance into accounts, has a better fitness than the result from DID model. The spatial difference in study area with PSM selection is lower than in study area with DBM selection. This may due to the probit model generation considering neighborhood characteristics and amenities locations.

In conclusion, this research investigates the influences between study area selections, modeling methods, and corresponding value uplift results. For the given transaction data in Taiwan, results suggest that MLR model provide better fitness, and less differences between catchment and control areas find in study area with PSM selection.

6.3 Discussions

This study answers the question whether it is possible constructing single model with considering multiple LRT systems. The limitation of this study is the similar backgrounds on these LRT systems as case study. Further research on examination of different cases needs to overcome the issue of comparability on LRT systems in regions with totally different backgrounds.

This research only focus on 3 stages including approval announcement, construction, and operation. Value uplifts from early stages such as feasibility announcement or conceptual proposal are not in consideration. Further research can take other LRT systems in discussion or planning as case study, investigating effects on these early stages.

Statement of data resources usage

All data used in this study are obtained from 3 data providing platforms, Government Open Data Platform (GODP), Socio-Economical Geographic Information System (SEGIS), and Survey Research Data Archive (SRDA).

The open data available on GODP is opening access to the public under the Open Government Data License, any user can make use of it when complying to the condition and obligation of its terms.

The data on SEGIS and SRDA provide registered members applying needed data. The application of these data can not violate privacy of any individual. Some certain data can only be used for academic purposes.

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Appendix

Table 0.1 Single LRT system models results (DID + DBM) with un-standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	12.560	0.000	3.699	0.000	12.428	0.000
Time variables						
C_time	0.004	0.000	0.001	0.000	0.003	0.000
D_tax2016	-0.036	0.000	-0.076	0.000	-0.041	0.002
LRT effects						
C_dist_LRT	-0.049	0.000	-0.020	0.079	0.079	0.000
D_400m	-0.153	0.000	0.056	0.070	-0.047	0.004
D_800m	-0.108	0.000	-0.007	0.825	-0.001	0.921
D_1600m	-0.057	0.001	0.101	0.000	0.030	0.000
D_announcement	0.058	0.000	0.166	0.000	-0.026	0.022
D_construction	0.027	0.080	0.143	0.000	-0.115	0.000
D_operation	-0.030	0.136	0.095	0.008	-	
D_400m:D_announcement	0.140	0.000	-0.054	0.062	0.009	0.708
D_400m:D_construction	0.122	0.000	0.040	0.152	0.040	0.001
D_400m:D_operation	0.175	0.000	0.081	0.019	-	
D_800m:D_announcement	0.091	0.000	-0.032	0.284	0.065	0.000
D_800m:D_construction	0.141	0.000	0.030	0.301	0.033	0.000
D_800m:D_operation	0.130	0.000	0.095	0.007	-	
D_1600m:D_announcement	0.059	0.001	-0.006	0.851	0.008	0.567
D_1600m:D_construction	0.071	0.000	-0.014	0.644	0.033	0.000
D_1600m:D_operation	0.149	0.000	0.002	0.950	-	
Property characteristics						
C_area_building	0.006	0.000	0.007	0.000	0.006	0.000
C_room	0.099	0.000	0.078	0.000	0.089	0.000
C_bath	-0.028	0.000	-0.004	0.086	-0.032	0.000
C_berth	0.003	0.014	-0.019	0.000	-0.019	0.000
C_floor_apartment	0.003	0.000	0.005	0.000	-0.001	0.001
C_floor_house	-0.254	0.000	-0.248	0.000	-0.163	0.000
C_age	-0.024	0.000	-0.015	0.000	-0.012	0.000
D_house	1.411	0.000	0.879	0.000	0.706	0.000
D_management	-0.016	0.001	-0.061	0.000	-0.088	0.000

Table 0.1 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.042	0.000	-0.004	0.654	0.030	0.011
C_dependency	0.020	0.065	0.038	0.000	0.085	0.000
C_unemployment	0.527	0.000	-0.373	0.206	1.014	0.000
C_ln_popdensity	-0.003	0.094	-0.010	0.000	0.006	0.000
C_ln_medincome	0.322	0.000	0.494	0.000	0.407	0.000
C_dist_CBD	-0.007	0.012	0.905	0.000	0.023	0.000
D_business	0.006	0.328	0.080	0.000	0.037	0.000
D_residential	0.033	0.000	-0.038	0.000	0.062	0.000
D_urbanplan	-		-0.008	0.682	0.176	0.000
Amenities						
C_dist_bus	-0.227	0.000	0.034	0.129	0.143	0.000
C_dist_MLbus	0.117	0.000	-0.172	0.000	-0.105	0.000
C_dist_MRT	-0.044	0.000	0.054	0.000	-0.061	0.000
C_dist_freeway	-0.002	0.271	-0.092	0.000	0.049	0.000
C_dist_hospital	-0.026	0.000	0.409	0.000	-0.031	0.000
C_dist_park	0.040	0.000	0.057	0.000	-0.221	0.000
C_dist_attraction	0.027	0.000	0.045	0.000	0.029	0.000
C_dist_school	-0.011	0.192	-0.046	0.000	0.006	0.401
C_dist_university	0.004	0.173	-1.322	0.000	-0.045	0.000
R^2	0.892		0.862		0.861	

Table 0.2 Single LRT system models results (DID + DBM) with standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	-0.546	0.000	-7.538	0.000	0.860	0.000
Time variables						
C_time	0.151	0.000	0.058	0.000	0.147	0.000
D_tax2016	-0.052	0.000	-0.111	0.000	-0.059	0.002
LRT effects						
C_dist_LRT	-0.040	0.000	-0.016	0.079	0.065	0.000
D_400m	-0.223	0.000	0.081	0.070	-0.068	0.004
D_800m	-0.157	0.000	-0.010	0.825	-0.002	0.921
D_1600m	-0.083	0.001	0.147	0.000	0.043	0.000
D_announcement	0.085	0.000	0.241	0.000	-0.038	0.022
D_construction	0.040	0.080	0.207	0.000	-0.167	0.000
D_operation	-0.043	0.136	0.138	0.008	-	
D_400m:D_announcement	0.204	0.000	-0.078	0.062	0.012	0.708
D_400m:D_construction	0.177	0.000	0.058	0.152	0.058	0.001
D_400m:D_operation	0.255	0.000	0.118	0.019	-	
D_800m:D_announcement	0.133	0.000	-0.046	0.284	0.094	0.000
D_800m:D_construction	0.206	0.000	0.043	0.301	0.047	0.000
D_800m:D_operation	0.189	0.000	0.138	0.007	-	
D_1600m:D_announcement	0.086	0.001	-0.008	0.851	0.012	0.567
D_1600m:D_construction	0.104	0.000	-0.020	0.644	0.048	0.000
D_1600m:D_operation	0.216	0.000	0.003	0.950	-	
Property characteristics						
C_area_building	0.624	0.000	0.686	0.000	0.665	0.000
C_room	0.155	0.000	0.122	0.000	0.140	0.000
C_bath	-0.032	0.000	-0.005	0.086	-0.036	0.000
C_berth	0.007	0.014	-0.041	0.000	-0.041	0.000
C_floor_apartment	0.022	0.000	0.046	0.000	-0.009	0.001
C_floor_house	-0.232	0.000	-0.225	0.000	-0.148	0.000
C_age	-0.436	0.000	-0.266	0.000	-0.213	0.000
D_house	2.052	0.000	1.279	0.000	1.026	0.000
D_management	-0.023	0.001	-0.089	0.000	-0.128	0.000

Table 0.2 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.011	0.000	-0.001	0.654	0.007	0.011
C_dependency	0.004	0.065	0.008	0.000	0.018	0.000
C_unemployment	0.022	0.000	-0.016	0.206	0.043	0.000
C_ln_popdensity	-0.005	0.094	-0.019	0.000	0.011	0.000
C_ln_medincome	0.070	0.000	0.108	0.000	0.089	0.000
C_dist_CBD	-0.060	0.012	8.029	0.000	0.200	0.000
D_business	0.009	0.328	0.117	0.000	0.054	0.000
D_residential	0.048	0.000	-0.056	0.000	0.090	0.000
D_urbanplan	-		-0.012	0.682	0.256	0.000
Amenities						
C_dist_bus	-0.022	0.000	0.003	0.129	0.014	0.000
C_dist_MLbus	0.048	0.000	-0.071	0.000	-0.043	0.000
C_dist_MRT	-0.065	0.000	0.080	0.000	-0.092	0.000
C_dist_freeway	-0.014	0.271	-0.612	0.000	0.328	0.000
C_dist_hospital	-0.076	0.000	1.213	0.000	-0.093	0.000
C_dist_park	0.019	0.000	0.026	0.000	-0.102	0.000
C_dist_attraction	0.012	0.000	0.020	0.000	0.013	0.000
C_dist_school	-0.006	0.192	-0.024	0.000	0.003	0.401
C_dist_university	0.011	0.173	-4.028	0.000	-0.137	0.000
R^2	0.892		0.862		0.861	

Table 0.3 Single LRT system models results (MLR + DBM) with un-standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	12.578	0.000	4.992	0.000	11.894	0.000
Time variables						
C_time	0.003	0.000	0.001	0.000	0.004	0.000
D_tax2016	-0.038	0.000	-0.070	0.000	-0.039	0.003
LRT effects						
C_dist_LRT	-0.034	0.000	-0.011	0.335	0.056	0.000
D_400m	-0.162	0.000	0.024	0.438	-0.034	0.040
D_800m	-0.113	0.000	-0.043	0.152	-0.005	0.685
D_1600m	-0.057	0.001	0.063	0.030	0.025	0.002
D_announcement	0.058	0.000	0.173	0.000	-0.032	0.005
D_construction	0.029	0.064	0.164	0.000	-0.120	0.000
D_operation	-0.036	0.068	0.135	0.000	-	
D_400m:D_announcement	0.138	0.000	-0.059	0.039	0.003	0.890
D_400m:D_construction	0.124	0.000	0.022	0.435	0.032	0.009
D_400m:D_operation	0.203	0.000	0.048	0.173	-	
D_800m:D_announcement	0.091	0.000	-0.036	0.216	0.064	0.000
D_800m:D_construction	0.147	0.000	0.013	0.655	0.034	0.000
D_800m:D_operation	0.159	0.000	0.062	0.081	-	
D_1600m:D_announcement	0.059	0.001	-0.010	0.740	0.011	0.445
D_1600m:D_construction	0.073	0.000	-0.030	0.319	0.034	0.000
D_1600m:D_operation	0.162	0.000	-0.031	0.404	-	
Property characteristics						
C_area_building	0.006	0.000	0.007	0.000	0.006	0.000
C_room	0.101	0.000	0.078	0.000	0.089	0.000
C_bath	-0.029	0.000	-0.005	0.074	-0.031	0.000
C_berth	0.003	0.017	-0.018	0.000	-0.019	0.000
C_floor_apartment	0.003	0.000	0.005	0.000	-0.001	0.000
C_floor_house	-0.257	0.000	-0.255	0.000	-0.163	0.000
C_age	-0.025	0.000	-0.015	0.000	-0.012	0.000
D_house	1.424	0.000	0.902	0.000	0.704	0.000
D_management	-0.011	0.016	-0.061	0.000	-0.085	0.000

Table 0.3 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.038	0.000	0.001	0.885	0.039	0.001
C_dependency	0.011	0.307	0.036	0.000	0.075	0.000
C_unemployment	0.785	0.000	-0.112	0.704	1.330	0.000
C_ln_popdensity	-0.004	0.009	-0.010	0.000	0.005	0.003
C_ln_medincome	0.306	0.000	0.508	0.000	0.451	0.000
C_dist_CBD	-0.009	0.047	0.758	0.000	0.061	0.000
D_business	0.002	0.735	0.079	0.000	0.052	0.000
D_residential	0.029	0.000	-0.034	0.000	0.062	0.000
D_urbanplan	-		0.026	0.191	0.173	0.000
Amenities						
C_dist_bus	-0.224	0.000	0.042	0.065	0.159	0.000
C_dist_MLbus	0.104	0.000	-0.176	0.000	-0.125	0.000
C_dist_MRT	-0.032	0.000	0.055	0.000	-0.062	0.000
C_dist_freeway	0.004	0.154	-0.122	0.000	0.060	0.000
C_dist_hospital	-0.023	0.000	0.301	0.000	-0.065	0.000
C_dist_park	0.033	0.000	0.064	0.000	-0.216	0.000
C_dist_attraction	0.008	0.243	0.057	0.000	0.016	0.028
C_dist_school	-0.008	0.365	-0.050	0.000	0.019	0.012
C_dist_university	-0.008	0.013	-1.042	0.000	-0.049	0.000
Log likelihood	-1275		4777		1899	
ICC	0.162		0.500		0.125	
R^2	0.876		0.863		0.861	

Table 0.4 Single LRT system models results (MLR + DBM) with standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	-0.612	0.000	-6.232	0.000	0.985	0.000
Time variables						
C_time	0.149	0.000	0.056	0.000	0.153	0.000
D_tax2016	-0.055	0.000	-0.102	0.000	-0.056	0.003
LRT effects						
C_dist_LRT	-0.027	0.000	-0.009	0.335	0.045	0.000
D_400m	-0.235	0.000	0.035	0.438	-0.050	0.040
D_800m	-0.164	0.000	-0.063	0.152	-0.007	0.685
D_1600m	-0.082	0.001	0.091	0.030	0.036	0.002
D_announcement	0.084	0.000	0.251	0.000	-0.047	0.005
D_construction	0.042	0.064	0.239	0.000	-0.174	0.000
D_operation	-0.053	0.068	0.197	0.000	-	
D_400m:D_announcement	0.200	0.000	-0.086	0.039	0.005	0.890
D_400m:D_construction	0.180	0.000	0.032	0.435	0.046	0.009
D_400m:D_operation	0.295	0.000	0.069	0.173	-	
D_800m:D_announcement	0.132	0.000	-0.053	0.216	0.094	0.000
D_800m:D_construction	0.214	0.000	0.019	0.655	0.049	0.000
D_800m:D_operation	0.231	0.000	0.091	0.081	-	
D_1600m:D_announcement	0.086	0.001	-0.015	0.740	0.015	0.445
D_1600m:D_construction	0.106	0.000	-0.043	0.319	0.049	0.000
D_1600m:D_operation	0.236	0.000	-0.045	0.404	-	
Property characteristics						
C_area_building	0.621	0.000	0.685	0.000	0.664	0.000
C_room	0.157	0.000	0.123	0.000	0.140	0.000
C_bath	-0.034	0.000	-0.005	0.074	-0.035	0.000
C_berth	0.007	0.017	-0.040	0.000	-0.041	0.000
C_floor_apartment	0.023	0.000	0.046	0.000	-0.009	0.000
C_floor_house	-0.234	0.000	-0.232	0.000	-0.149	0.000
C_age	-0.439	0.000	-0.267	0.000	-0.213	0.000
D_house	2.071	0.000	1.311	0.000	1.023	0.000
D_management	-0.016	0.016	-0.088	0.000	-0.123	0.000

Table 0.4 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.010	0.000	0.000	0.885	0.010	0.001
C_dependency	0.002	0.307	0.008	0.000	0.016	0.000
C_unemployment	0.033	0.000	-0.005	0.704	0.056	0.000
C_ln_popdensity	-0.008	0.009	-0.019	0.000	0.009	0.003
C_ln_medincome	0.067	0.000	0.111	0.000	0.099	0.000
C_dist_CBD	-0.075	0.047	6.726	0.000	0.539	0.000
D_business	0.003	0.735	0.115	0.000	0.075	0.000
D_residential	0.042	0.000	-0.049	0.000	0.090	0.000
D_urbanplan	-		0.038	0.191	0.251	0.000
Amenities						
C_dist_bus	-0.022	0.000	0.004	0.065	0.016	0.000
C_dist_MLbus	0.043	0.000	-0.072	0.000	-0.052	0.000
C_dist_MRT	-0.048	0.000	0.082	0.000	-0.092	0.000
C_dist_freeway	0.029	0.154	-0.809	0.000	0.396	0.000
C_dist_hospital	-0.068	0.000	0.891	0.000	-0.192	0.000
C_dist_park	0.015	0.000	0.029	0.000	-0.099	0.000
C_dist_attraction	0.004	0.243	0.025	0.000	0.007	0.028
C_dist_school	-0.004	0.365	-0.026	0.000	0.010	0.012
C_dist_university	-0.024	0.013	-3.177	0.000	-0.150	0.000
Log likelihood	-15425		-6629		-6378	
ICC	0.162		0.500		0.125	
R^2	0.876		0.863		0.861	

Table 0.5 Single LRT system models results (DID + PSM) with un-standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	12.222	0.000	6.454	0.000	14.999	0.000
Time variables						
C_time	0.004	0.000	0.001	0.000	0.004	0.000
D_tax2016	-0.035	0.000	-0.072	0.000	-0.064	0.000
LRT effects						
C_dist_LRT	0.002	0.647	-0.018	0.085	-0.027	0.000
D_400m	-0.028	0.182	-0.095	0.008	-0.213	0.000
D_800m	-0.006	0.750	-0.158	0.000	-0.136	0.000
D_1600m	0.012	0.366	-0.048	0.163	-0.064	0.000
D_announcement	0.091	0.000	0.152	0.000	-0.002	0.755
D_construction	0.050	0.000	0.043	0.247	-0.064	0.000
D_operation	0.015	0.270	0.033	0.440	-	
D_400m:D_announcement	0.101	0.000	-0.038	0.315	-0.009	0.676
D_400m:D_construction	0.082	0.000	0.142	0.000	0.012	0.275
D_400m:D_operation	0.106	0.000	0.147	0.000	-	
D_800m:D_announcement	0.050	0.011	-0.016	0.665	0.048	0.001
D_800m:D_construction	0.100	0.000	0.131	0.000	-0.002	0.758
D_800m:D_operation	0.062	0.004	0.159	0.000	-	
D_1600m:D_announcement	0.015	0.268	0.009	0.808	-0.001	0.938
D_1600m:D_construction	0.031	0.026	0.089	0.019	0.003	0.636
D_1600m:D_operation	0.091	0.000	0.067	0.122	-	
Property characteristics						
C_area_building	0.006	0.000	0.007	0.000	0.006	0.000
C_room	0.102	0.000	0.079	0.000	0.079	0.000
C_bath	-0.020	0.000	-0.005	0.044	-0.019	0.000
C_berth	0.004	0.002	-0.018	0.000	-0.016	0.000
C_floor_apartment	0.002	0.000	0.005	0.000	0.000	0.530
C_floor_house	-0.299	0.000	-0.295	0.000	-0.163	0.000
C_age	-0.025	0.000	-0.015	0.000	-0.012	0.000
D_house	1.540	0.000	1.032	0.000	0.702	0.000
D_management	-0.015	0.000	-0.061	0.000	-0.060	0.000

Table 0.5 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.038	0.000	0.000	0.997	0.085	0.000
C_dependency	-0.025	0.006	0.038	0.000	0.118	0.000
C_unemployment	0.594	0.000	-0.323	0.273	1.526	0.000
C_ln_popdensity	-0.004	0.001	-0.010	0.000	0.004	0.001
C_ln_medincome	0.358	0.000	0.502	0.000	0.004	0.011
C_dist_CBD	-0.004	0.075	0.619	0.000	0.004	0.000
D_business	0.009	0.122	0.070	0.000	0.084	0.000
D_residential	0.036	0.000	-0.037	0.000	0.067	0.000
D_urbanplan	-		0.012	0.507	0.182	0.000
Amenities						
C_dist_bus	-0.279	0.000	0.038	0.091	0.282	0.000
C_dist_MLbus	0.164	0.000	-0.171	0.000	-0.069	0.000
C_dist_MRT	-0.058	0.000	0.061	0.000	-0.120	0.000
C_dist_freeway	-0.008	0.000	-0.126	0.000	0.060	0.000
C_dist_hospital	-0.036	0.000	-0.041	0.607	-0.002	0.499
C_dist_park	0.033	0.000	0.074	0.000	-0.195	0.000
C_dist_attraction	0.013	0.009	0.060	0.000	0.054	0.000
C_dist_school	-0.014	0.070	-0.056	0.000	-0.018	0.000
C_dist_university	0.006	0.011	-0.565	0.000	-0.017	0.000
R^2	0.888		0.865		0.864	

Table 0.6 Single LRT system models results (DID + PSM) with standardized variables

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
(Intercept)	-0.750	0.000	-4.611	0.000	0.806	0.000
Time variables						
C_time	0.158	0.000	0.054	0.000	0.158	0.000
D_tax2016	-0.049	0.000	-0.101	0.000	-0.090	0.000
LRT effects						
C_dist_LRT	0.002	0.647	-0.025	0.085	-0.038	0.000
D_400m	-0.040	0.182	-0.133	0.008	-0.298	0.000
D_800m	-0.009	0.750	-0.222	0.000	-0.190	0.000
D_1600m	0.017	0.366	-0.068	0.163	-0.089	0.000
D_announcement	0.127	0.000	0.214	0.000	-0.003	0.755
D_construction	0.070	0.000	0.060	0.247	-0.090	0.000
D_operation	0.022	0.270	0.047	0.440	-	
D_400m:D_announcement	0.142	0.000	-0.053	0.315	-0.012	0.676
D_400m:D_construction	0.115	0.000	0.199	0.000	0.017	0.275
D_400m:D_operation	0.149	0.000	0.205	0.000	-	
D_800m:D_announcement	0.070	0.011	-0.023	0.665	0.067	0.001
D_800m:D_construction	0.141	0.000	0.184	0.000	-0.003	0.758
D_800m:D_operation	0.087	0.004	0.224	0.000	-	
D_1600m:D_announcement	0.022	0.268	0.013	0.808	-0.001	0.938
D_1600m:D_construction	0.044	0.026	0.124	0.019	0.004	0.636
D_1600m:D_operation	0.127	0.000	0.094	0.122	-	
Property characteristics						
C_area_building	0.594	0.000	0.651	0.000	0.636	0.000
C_room	0.154	0.000	0.120	0.000	0.120	0.000
C_bath	-0.022	0.000	-0.006	0.044	-0.020	0.000
C_berth	0.008	0.002	-0.037	0.000	-0.034	0.000
C_floor_apartment	0.017	0.000	0.044	0.000	0.001	0.530
C_floor_house	-0.265	0.000	-0.261	0.000	-0.144	0.000
C_age	-0.426	0.000	-0.262	0.000	-0.200	0.000
D_house	2.158	0.000	1.447	0.000	0.984	0.000
D_management	-0.022	0.000	-0.086	0.000	-0.083	0.000

Table 0.6 (continued)

	Kaohsiung		Danhai		Ankeng	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Neighborhood characteristics						
C_postsecondary	0.009	0.000	0.000	0.997	0.020	0.000
C_dependency	-0.005	0.006	0.008	0.000	0.024	0.000
C_unemployment	0.024	0.000	-0.013	0.273	0.061	0.000
C_ln_popdensity	-0.008	0.001	-0.019	0.000	0.007	0.001
C_ln_medincome	0.243	0.000	0.341	0.000	0.003	0.011
C_dist_CBD	-0.035	0.075	4.885	0.000	0.035	0.000
D_business	0.013	0.122	0.099	0.000	0.118	0.000
D_residential	0.051	0.000	-0.052	0.000	0.094	0.000
D_urbanplan	-		0.017	0.507	0.255	0.000
Amenities						
C_dist_bus	-0.034	0.000	0.005	0.091	0.034	0.000
C_dist_MLbus	0.070	0.000	-0.073	0.000	-0.029	0.000
C_dist_MRT	-0.082	0.000	0.086	0.000	-0.169	0.000
C_dist_freeway	-0.048	0.000	-0.771	0.000	0.366	0.000
C_dist_hospital	-0.096	0.000	-0.109	0.607	-0.005	0.499
C_dist_park	0.014	0.000	0.032	0.000	-0.086	0.000
C_dist_attraction	0.007	0.009	0.030	0.000	0.027	0.000
C_dist_school	-0.007	0.070	-0.027	0.000	-0.009	0.000
C_dist_university	0.016	0.011	-1.595	0.000	-0.049	0.000
R^2	0.888		0.865		0.864	