ผลกระทบของเสียงจากท่าอากาศยานต่อมูลค่าอสังหาริมทรัพย์: กรณีศึกษา
ท่าอากาศยานสุวรรณภูมิ

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

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AIRPORT NOISE IMPACT ON PROPERTY VALUES: CASE OF SUVARNABHUMI AIRPORT

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Civil Engineering
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ไม่แตกต่างจากท่าอากาศยานทั่วโลก ท่าอากาศยานสุวรรณภูมิก็ต้องเผชิญกับการร้องเรียนเกี่ยวกับเสียงรบกวนจากอากาศยานอย่างต่อเนื่อง ซึ่งเสียงจากท่าอากาศยานนี้ส่งผลกระทบต่อคุณภาพชีวิตของประชาชนที่พักอาศัยหรือทำงานในบริเวณใกล้เคียง และส่งผลต่อมูลค่าของอสังหาริมทรัพย์ที่ตั้งอยู่ในบริเวณดังกล่าวด้วย โดยตั้งแต่เมื่อท่าอากาศยานสุวรรณภูมิเปิดให้บริการในปี พ.ศ. 2549 ได้ส่งผลให้เกิดการร้องเรียนและการเรียกร้องค่าชดเชยโดยเจ้าของอสังหาริมทรัพย์บริเวณรอบท่าอากาศยานเป็นจำนวนมาก ดังนั้นวิทยานิพนธ์ฉบับนี้จึงมีจุดประสงค์เพื่อศึกษาถึงปัญหานี้ โดยการประเมินมูลค่าของอสังหาริมทรัพย์ที่ได้รับผลกระทบจากเสียงของท่าอากาศยานและการพัฒนาแบบจำลองความถดถอยฮีโดนิคของมูลค่าอสังหาริมทรัพย์โดยใช้ข้อมูลอาคารที่พักอาศัยที่สร้างขึ้นใหม่ ระหว่างปี พ.ศ. 2545 ถึง พ.ศ. 2551 จำนวน 37,539 ตัวอย่าง เพื่อทดสอบสมมุติฐานเกี่ยวกับผลกระทบในแง่ต่างๆ ของท่าอากาศยาน ในแบบจำลองจึงประกอบด้วยตัวแปรที่สะท้อนทั้งผลเชิงลบเนื่องจากเสียงรบกวนจากท่าอากาศยาน และผลเชิงบวกจากความสะดวกในการเข้าถึงระบบขนส่งที่เพิ่มขึ้น จากผลการศึกษา พบว่าไม่มีผลกระทบของเสียงจากท่าอากาศยานต่อมูลค่าอสังหาริมทรัพย์ในช่วงก่อนการเปิดให้บริการของท่าอากาศยาน แต่ผลกระทบเริ่มแสดงให้เห็นอย่างชัดเจนหลังปี พ.ศ. 2549 ซึ่งผลการวิเคราะห์แสดงให้เห็นว่าบ้านพักอาศัยที่ตั้งอยู่ในเขตระดับเสียง NEF 35 ถึง 40 มีมูลค่าลดลงเฉลี่ยร้อยละ 25.9 ส่วนบ้านพักอาศัยที่ตั้งอยู่ในเขตระดับเสียง NEF 30 ถึง 35 มีมูลค่าลดลงร้อยละ 9.53 โดยผลดังกล่าวเมื่อแสดงในหน่วยของ Noise Depreciation Index (NDI) จะคิดเป็นมูลค่าลดลงร้อยละ 3.27 ต่อเดซิเบล ซึ่งเป็นค่าที่ค่อนข้างสูงเมื่อเปรียบเทียบกับค่า NDI ของงานวิจัยที่ผ่านมาทั้งในทวีปยุโรปและอเมริกาเหนือ

ภาควิชา...........วิศวกรรมโยธา...	ลายมือชื่อนิสิต..
สาขาวิชา.........วิศวกรรมโยธา...	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก....................
ปีการศึกษา...... 2552............	

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Not unlike other airports around the world, Suvarnabhumi International Airport is also faced with complaints of noise generated by aircrafts approaching and taking off from the airport. The airport noise affects quality of lives of people who live and work in nearby areas as well as prices of properties in the areas. Since the airport operation began in 2006, property owners in the airport vicinities have protested and demanded for monetary compensation for their deteriorated quality of lives. The objective of this study is to examine the problem by assessing the discount in housing prices due to the impact of Suvarnabhumi Airport noise. A series of hedonic regression models of property values are developed and estimated based on a data set of 37,539 new house sale records transacted between 2002 and 2008. To test the hypotheses about the impact of the airport, the hedonic models contain two features that could quantify the magnitude of noise effects and the beneficial effects of transportation access improvements. The results confirm that there was no impact of airport noise on property prices before the opening of airport, but the impact became negative and significant after 2006. Specifically, there is on average a 25.9 percent discount in price of new properties located between NEF 35 and 40 contour lines and 9.53 percent discount for property located between NEF 30 and 35 contour lines. These estimates can be translated to a noise depreciation index (NDI) of 3.27 percent per dB, which is in the high range compared to NDI estimates in the previous studies of Europe and North America.

Department: ......Civil Engineering... Student's Signature ....

Field of Study: ...Civil Engineering... Advisor's Signature ....

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LIST OF ABBREVIATIONS

ANEF	:	Australia Noise Exposure Forecast
ANN	:	Artificial Neural Networks
AoT	:	Airport of Thailand
AREA	:	Agency for Real Estate Affairs Co., Ltd.
ARL	:	Airport Rail Link
BMA	:	Bangkok Metropolitan Administration
BOI	:	Thailand Board of Investment
BTS	:	Bangkok Mass Transit System
CDB	:	Central Business District
CNEL	:	Community Noise Exposure Level
CNR	:	Composite Noise Rating System
CVM	:	Contingent Valuation Method
DNL or L_{dn}	:	Day Night Average Sound Level
EEAT	:	Environmental Engineering Association of Thailand
EIA	:	Environmental Impact Assessments
ESS	:	Explained Sum of Squares
FAA	:	Federal Aviation Administration
GIS	:	Geographic Information System
JBIC	:	Japanese Bank for International Cooperation
KMITL	:	King Mongkut Institute of Technology, Latkrabang
Ku	:	Kosten Units
LA_{eq}	:	A-weighting of Equivalent Noise Level
LEQ or L_{eq}	:	Equivalent Noise Level
Lmax	:	Maximum Sound Level
NDI	:	Noise Depreciation Index
NEF	:	Noise Exposure Forecast
NNI	:	Noise and Number Index
OLS	:	Ordinary Least Squares
PCD	:	Pollution Control Department
PCD-ISC	:	Pollution Control Department-Information Service Center
PCL	:	Public Company Limited
RSS	:	Residual Sum of Squares
SAT	:	Suvarnabhumi Airport of Thailand
SEL	:	Sound Exposure Level
TSS	:	Total Sum of Squares

CHAPTER I
INTRODUCTION

1.1 Introduction

Like any airports around the world, Bangkok's Suvarnabhumi International Airport, Thailand, not only provides many benefits such as increase in service-related to employment, reduction in transportation costs for business and the general public, etc., but also serious environmental impacts, such as vibration, air quality degradation, traffic congestion, flooding, and noise from aviation activities. To examine and propose measure to mitigate these impacts, Environmental Impact Assessments (EIA) was carried out before, during, and after the airport construction. At the same time, 13 noise monitoring stations were also implemented in order to measure the noise exposure level around the airport. Figure 1.1 illustrates the noise monitoring location and the original noise contour maps drawn by EIA in 2006. In addition, there have also been many operational problems occurred from the beginning such as poor lighting and air conditioning in the passenger terminal, lack of connecting transportation from this airport to other part of the city, and flawed runway construction. Several of these problems have been gradually resolved. However, the most concerned issue is the airport noise impact which degrades the quality of lives of people living in the surrounding areas. In the airport development phase, the issue of airport noise was addressed in the EIA report so that the severity of noise exposure was evaluated, the affected groups were identified, and mitigative measures were proposed. Based on the EIA report prepared during the feasibility study period, there were more than 3,000 houses, 46 schools and universities, and 76 religious centers that would be affected by loud noise (PCD-ISC). Subsequently, the noise impact encompass 70 square kilometer around the airport in which the high impact zone has Noise Exposure Forecast (NEF) over 40 while moderate zone NEF values between 35 and 40 (EEAT, 2006).

Since Suvarnabhumi Airport began operations in September 2006, complaints about airport noise from residents in the surrounding areas and property owners' demand for monetary compensation have been a major point of contention. For example, in 2006, King Mongkut Institute of Technology, Latkrabang, a major public university, located about 3.5 km north of the airport and suffered noise with NEF between 30 and 35, sued the Airport of Thailand PCL (AoT) for 214 million Baht for expenditures of soundproofing their 22 buildings (PCD-ISC). Later that year, AoT agreed to compensate 71 residents affected by noise higher than 70 decibels the amount of 300 million Baht for their suffering from noise caused by planes landing and taking off at the airport (PCD-ISC). Homeowners 32 communities were unhappy with AoT's tardy responses and in 2007 threatened to releasing balloons to hinder air traffic if the AoT did not resolve the problem of noise pollution (Bangkok Post). After several rounds of negotiations, in March 2009, the government was convinced by AoT to approve the budget of 7.14 billion Baht in order to compensate the affected parties over the period of 10 years (The Nation). More recently, the Thai government approves AoT's budget in the amount of 11,233 million Baht for compensating owners of properties affect by noise over the period of 2009-2010 (Logisticnews, 2009).

Currently, the compensation scheme for Suvarnabhumi airport is set for the properties owners who are affected by severe and moderate noise level. In the severe noise of NEF 40 or above, the owners of properties will have a choice of selling the properties to AoT at the price assessed by independent professional real estate agents. The assessed values would include the value of land, building, and other expenditures such as relocation expenses. Moreover, this assessed value would also reflect the psychological effect, due to the home relocation as demonstrated by AoT. For moderate noise level of NEF from 30 to 40, AoT initially only help in covering expenditure for soundproofing, but recently agreed to purchase the properties, using similar assessment procedures as mentioned above. In term of compensation policy, there are still many people unhappy with the current financial compensation scheme while some affected parties are not eligible for compensation. However, how much the amount of such compensation is computed remains unclear.

1.2 Problem Statement

In this study, we want to examine the impact of airport noise on prices of house located in the vicinity of Suvarnabhumi airport. We believe that the airport noise would have a negative effect on the sale prices of the residential properties. This study will focus on the new sales of residential properties which transacted between 2002 and 2008. And those target properties are single-family detached, duplex, and townhouse. In addition, the time factors also influences on the residential property values. It might have different effect of the airport noise impact on housing price transacted before and after the airport operation initiated. Obviously, there is no noise effect occurred before 2006 and hence it became into matter only after the airport opening year. Moreover, the areas surrounded are considered as well. The beneficial effects of the distance from each residential property to the nearest transportation facilities such as distance to the nearest expressway ramp and BTS stations on property prices are also addressed.

1.3 Objective

The objective of this study is to examine how much discount in housing price due to the impact of aircraft noise coming from Bangkok's Suvarnabhumi Airport, so that appropriate amount of compensation for decline in property value could be estimated. In addition, the residential property values according to their characteristics before and after the airport operations began would be reviewed along with the analysis of beneficial effects of transportation access improvements to the airport.

1.4 Scope of the Study

The scope of the present study would be limited to prices of residential properties (single-family detached, duplex, and townhouse) located within the vicinity of Suvarnabhumi International Airport. These prices are new sales from 2002 to 2008. In addition, the area of study is defined from the airport by the following:

- To the north, until Sowinthawong Road
- To the south, until Theparak Road
- To the east, until Luang Prang-Lat krabang Road
- And to the west, until Kanchanaphisek wongwaen Tawan-Ok Road.

1.5 Expected Benefits

This study is expected to provide the following benefits.

- Reveal the reduction in housing price after the initiation of the airport operation due to the airport noise
- Noise Depreciation Index in the case of Suvarnabhumi airport
- The estimated model could be helpful for AoT in formulating compensation scheme for those residents affected by the airport noise
- Information gathered and obtained from the study will be useful for planning of future development and expansion of the airport.

1.6 Report Organization

The report of this study is organized by five chapters.

Chapter 1 gives the introduction, overview of the airport noise problems, research objective, and expected benefits.

Chapter 2 gives the overview of Suvarnabhumi airport, the review of airport noise basic and the airport noise metrics, variables utilization and functional forms, and basic concepts about the econometric issues occurred and addressed in previous hedonic price studies.

Chapter 3 describes the methodology of hedonic price modeling for this study; data and descriptive statistics, model specification, and diagnostics.

Chapter 4 describes the hedonic model analysis in which several tests are performed including test for group of dummy variables and heteroscedasticity. In addition, the best model is finally selected following by the estimate results and discussion.

For the last section of this study, Chapter 5 provides the conclusion of the study, recommendation, and further study.

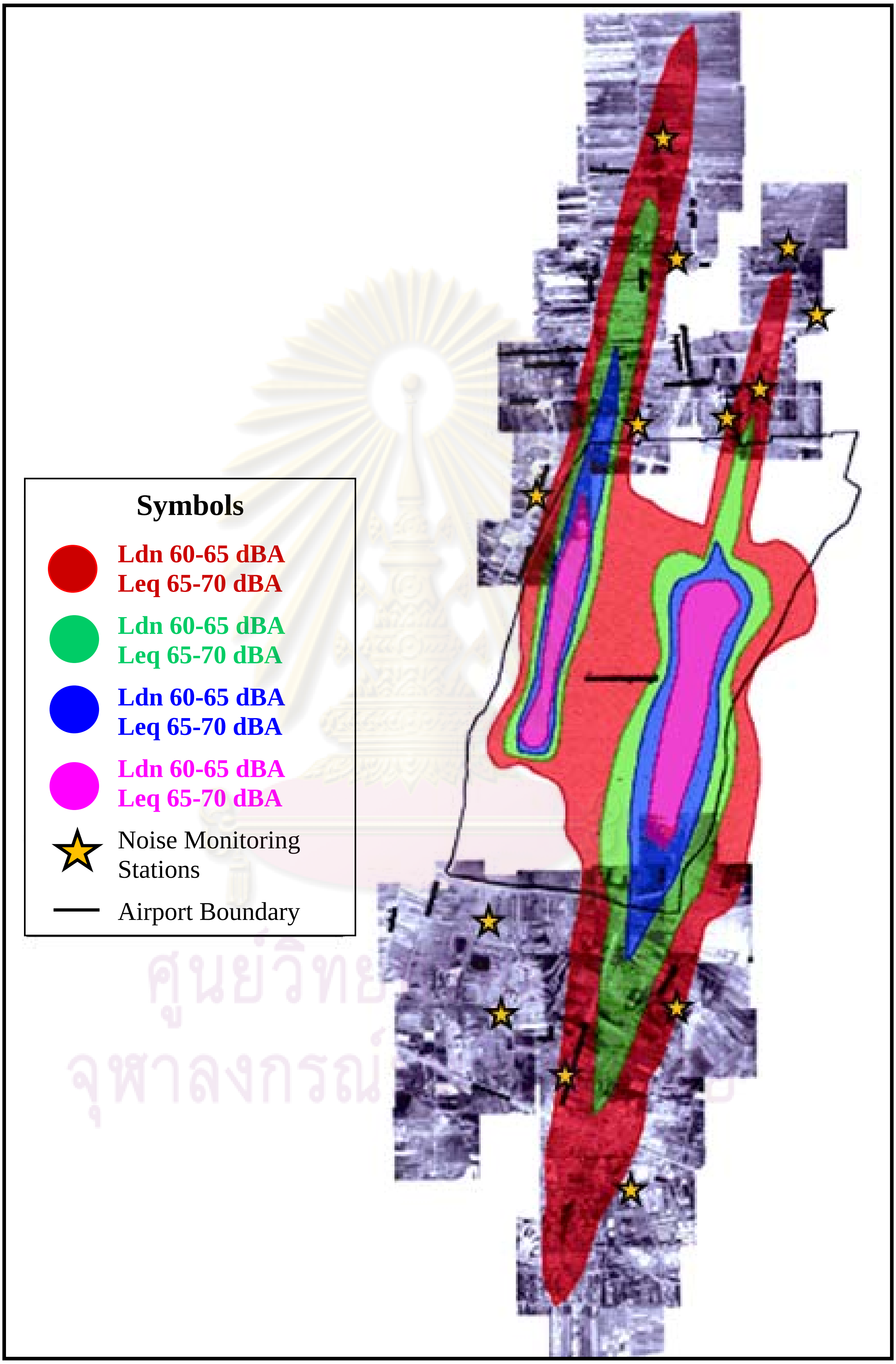


Figure 1.1 The original noise contour map (Source: EIA, 2006)

CHAPTER II
LITERATURE REVIEW

2.1 Sovarnabhumi International Airport

2.1.1 General

The location of Suvarnabhumi International Airport is in Bang Phli District of Samut Prakan Province, Thailand. It was placed on the land with the area of 32 square kilometer, about 25 kilometers to the east of Bangkok. It was initially designed to serve the rapid expansion of air traffic volume at the old Bangkok's International Airport, known as Don Mueang Airport, and also to make separation from the city and the military airfield. After an investment of 155 billion Baht, which 30 percent of the budget came from the AoT while another 70 percent came from the Japanese Bank for International Cooperation (JBIC), the civil work on the airport construction began on 19 January 2002. It took about five years in establishing all the airport constructions. Thus, the full operations date has now been established on 28 September 2006. (Wikipedia, BOI)

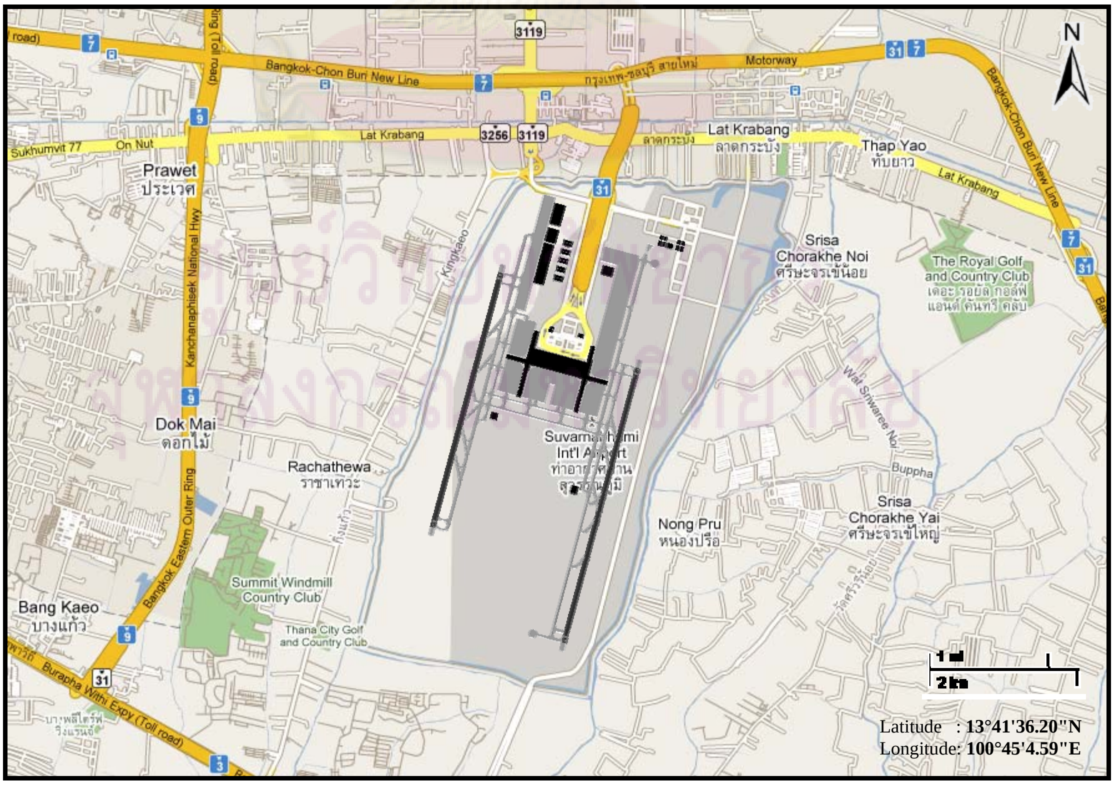


Figure 2.1 Suvarnabhumi International Airport location (Source: Google Maps)

2.1.2 Airport Facilities

Regarding the airport facilities, Suvarnabhumi Airport provides many conveniences such as 130 passport control checkpoints for arrivals and 72 for departures, 26 customs control checkpoints for arrivals and eight for departures, 22 baggage conveyor belts, 360 check-in counters (108 Domestic and 252 International), 107 moving walkways, 102 elevators, 83 escalators, two five-storey car park buildings with a capacity of 5,000 cars, and the passenger terminal building, covering the area of 182,000 square meter (terminal itself and the concourses), has seven stories with two underground floors decorating with blend of modern steel and glass framework. Furthermore, the control tower of 132.2 meters high, two parallel taxi-ways, and 120 aircraft parking bays (51 with contact gates, five capable of accommodating A380, and 69 remote gates) together have ability to accommodate simultaneous departures and arrivals up to 76 flights per hour and 45 million passengers and three million tons of cargo per year. Moreover, the main airport access routes are Motorway (No. 7), Bangkok Chonburi Expressway (No. 9), and Airport Rail Link which is expected to run its full operation in December 2009. (Wikipedia, BOI)

2.1.3 Airport Runway Operations and Utilizations

Currently, Suvarnabhumi airport has two parallel runways with 60 meters wide, 4,000 meters and 3700 meters long, and 2.2 kilometers separation (Wikipedia). Figure 2.2a provides the schematic illustration of the airport. Basically, the western runway operation of Suvarnabhumi airport was initially set up to 98% for landing aircrafts while the eastern runway is almost entirely used for the aircraft take-offs rather than landings (PCD-ISC). Since the majority of people who live close to the western runway faced high noise pollution, the Pollution Control and Aviation department, in 2006, proposed a plan to use the eastern runway more for landings in order to relieve noise pollution from western part of the airport. The proposed plan would decrease the use of landings at western runway to 85% while all of the remaining flights landing on the eastern runway. Moreover, this proposed change in operational runways was done based on research conducted by a committee to solve the problem of noise pollution. The report found that the noise level measured in noise exposure forecast (NEF) would be reduced for western runway from 44.5-33.1 to 41.8-30.1. For eastern runway, the noise level would be increased from 10.8-11.1 to 32.4-38.7. According to the Airport of Thailand Public Company Limited (AoT), in 2007, the operational runway has been set to 80:20 for both eastern and western runways. However, the runway management could change regularly to accommodate certain seasonal factors, such as wind direction and congestion of air traffic. Therefore, the nearby areas would face with varied noise impacts.

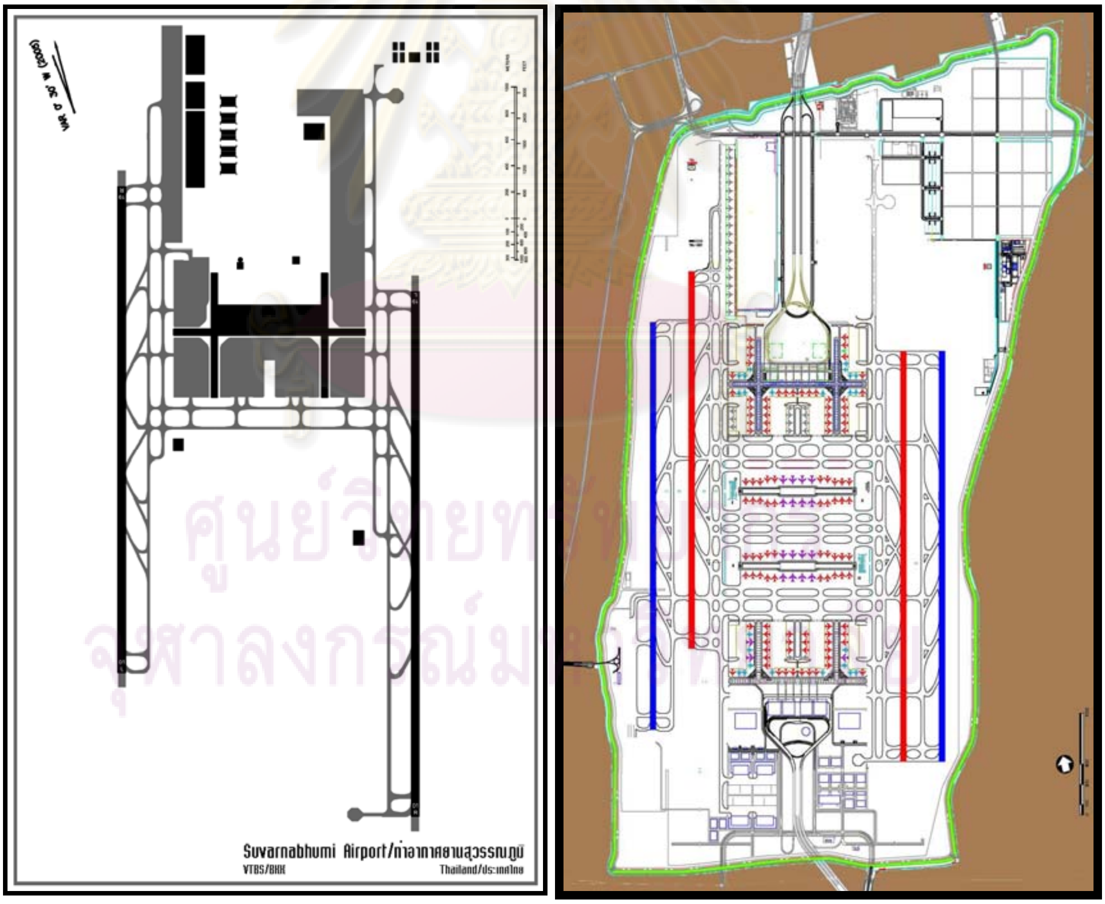
2.1.4 Land Use and Control

To avert the airport from becoming bounded by residential area and other business activities, a better management is needed (Wanisubut, Director of the Office of the Suvarnabhumi Airport Development Committee). Under the plan, water catchment basins were designed for the area to the north and south of the airport while to the west, from King Kaew Road to the outer ring road, is suitable for the industrial development (SAT). In order to maintain the arranged and sustainable development, land use planning around the airport should be set up. The projected land use was expected to 41 percent for residential, 10 percent for commercial and service (include health center and education), eight percent for industrial, 27 percent for agriculture, and 14 percent for green area and flood preservation use (EEAT, 2006).

A proper land use regulation and control for Suvarnabhumi’s surrounding area development is importantly needed to limit the number of population exposed to the airport noise. Since the report about the impact of noise exposure, the parties affected by severe noise, and propose of mitigative measures are examined by the EIA, the restrictions of new development on the land use in the vicinity of the airport were already reported in the EIA’s report as well. However, both responsible authorities, the AoT and the government’s enterprise which own and operate Suvarnabhumi airport, have no control over land use regulation. In fact, the land controlling power was fallen under the jurisdiction of local governments, the Bangkok Metropolitan Administration (BMA), and the neighboring province of Samutprakarn. With the idea of getting benefit from the new airport as well as the absent of precise land use regulation and controls from responsible authorities, many new investments on land development sprang up near the airport site during the construction period and even after.

2.1.5 Airport Expansion

In long-term planning, Suvarnabhumi Airport will be expected to have four runways, two satellite buildings and one more low-cost terminal capable to handle more than 130 million passengers and 6.4 million tons of cargo per year, and parking capacity over 15,600 cars. The planed project is expected to begin in three to five years after the succession of the first main terminal. In this second phase of airport expansion, the four runways are capable to handle 112 flights per hour and expected to run its full operation between 2017 and 2020. Figure 2.2b illustrates the layout of geometric structure of the expanded airport (Wikipedia).



a) Phase I b) Phase II

Figure 2.2 The schematic illustration of Suvarnabhumi and its expansion

(Source: Wikipedia and AoT, 2009)

2.2 Noise Basic

2.2.1 Background

In daily activities, people cannot escape from aircraft noise while the level of disturbing depends on their living area and some other factors such as time of the day, length of time, predictability, control, emotional variables, and physical surroundings. However, it is not easy to determine whether the noise is too noisy due to the different perception in noise of different individuals. Noise is a sound that is loud, unpleasant, unexpected, or undesired (Noise Quest, 2009). Sound is usually expressed in decibels

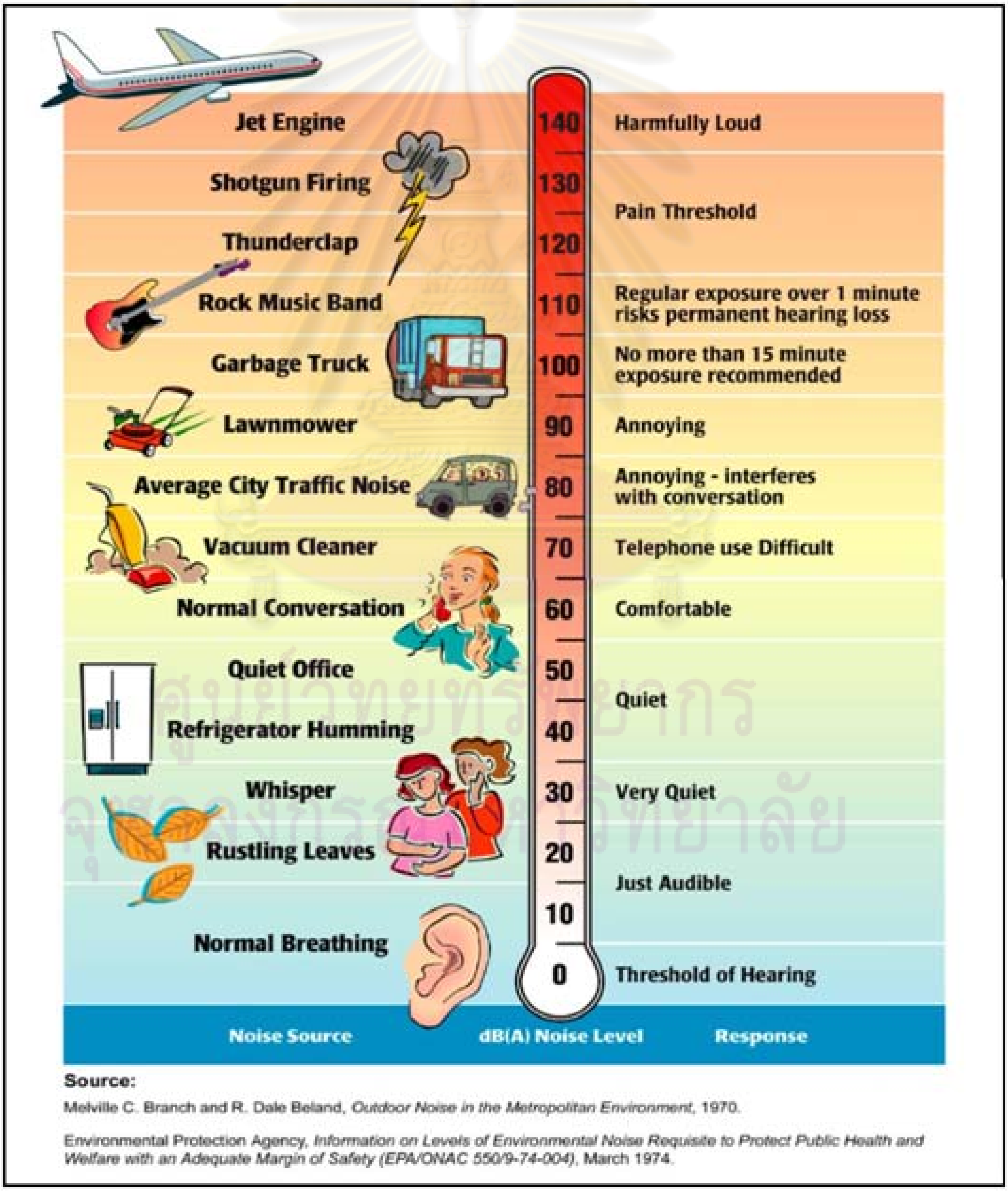


Figure 2.3 Comparative sound levels (Source: City of Glendora, 2008)

(dB) on a logarithmic scale to measure the sound intensity over the standard threshold of hearing. Figure 2.3 provides the comparative levels of common sound. Each 10 dB increases meaning that a doubling of the absolute loudness. Thus, 80 dB is about twice as loud as 70 dB, and four times as loud as 60 dB. Additionally, the sound that you are hearing is not an exact representation of the pressure waves that reach your ear because of the none-linear response of the human ear.

The standard unit of sound frequency is cycles per second (cps) or hertz (Hz). The normal human ear can detect sounds ranging from about 20 Hz to about 15,000 Hz while the most sensitive ranging between 1,000 to 4,000 Hz. The most common weightings are A-weighting (dBA) and C-weighting (dBC). A-weighted sound accounts for frequency dependence by adjusting the very high and very low frequency, as can be seen in Figure 2.4. In written documents, the measurements are simply expressed as dB instead of dBA. C-weighted sound is generally used to describe impulsive sound since it is nearly flat throughout the audible frequency range, hardly deemphasizing the low frequency.

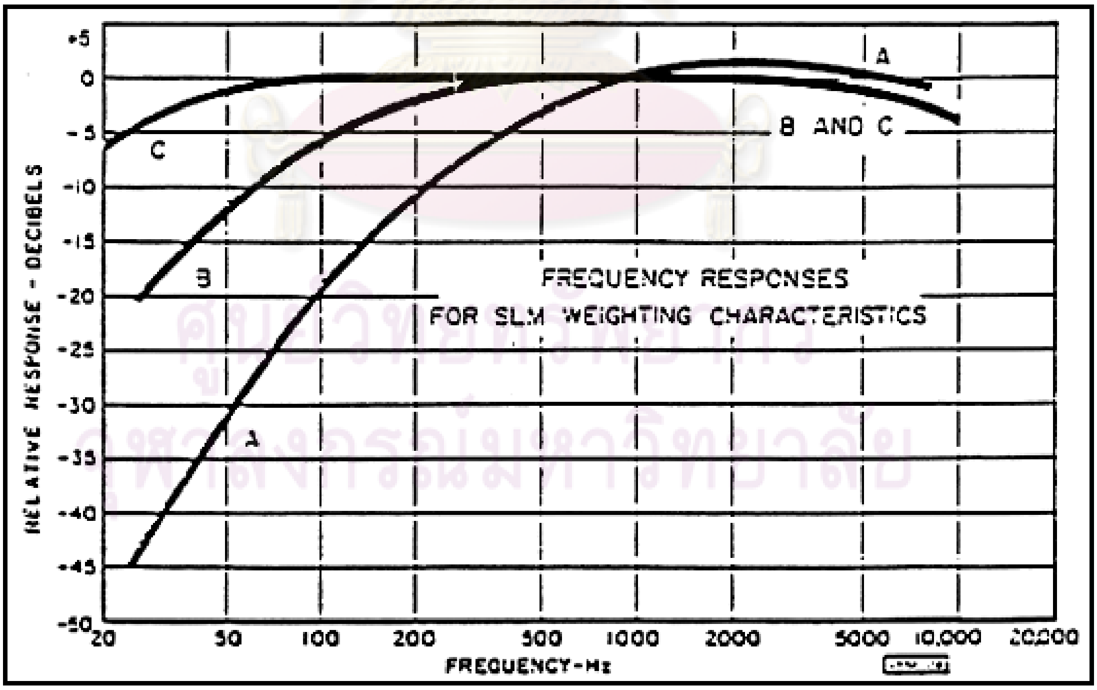


Figure 2.4 Frequency Response Characteristics of A & C Weighting Networks

(Source: Noise Quest, 2009)

2.2.2 Airport Noise and Noise Metrics

The definition of airport noise is provided by Noise Quest that "Airport noise is defined as sound produced by any aircraft or its components, during various phases of a flight, on the ground while parked such as auxiliary power units, while taxiing, on run-up from propeller and jet exhaust, during take-off, underneath and lateral to departure and arrival paths, over-flying while en route or during landing."

The level of noise generating from any aircraft movement varies during the time of the day (at the same level of airport noise might be louder at night because the background noise level is lower than during the daytime), in different seasons (more noise during summer months), in different location, and based on the type of movements such as approach, overflight, surface movement, and departure. As pointed out by Noise Quest, there are many ways to measure the effect of noise on the environment. For example, three noise metrics are used by the U.S. Federal Aviation Agency, namely 1) a measurement of the highest sound level occurring during and individual aircraft overflight (single event), 2) maximum level of single event plus its duration, and 3) the cumulative noise levels from multiple flights.

Single noise events can be described with Maximum Sound Level (L_{max}) or Sound Exposure Level (SEL). L_{max} is used to measure noise at its highest level during one noise event while SEL represent the total sound energy occurring during a flight event. Alternatively, Cumulated noise measurements combine all of the noise events and duration into one rating. In terms of the unit of measurement, there are several airport noise measurements units that have been used in different countries, as shown in Table 2.1.

Table 2.1 Some common metrics for airport noise

Noise Metric	Country
Community Noise Exposure Level (CNEL)	California
Composite Noise Rating System (CNR)	Canada
Day Night Average Sound Level (DNL or L_{dn})	North America
Equivalent Noise Level (LEQ or L_{eq})	United Kingdom
Kosten Units (Ku)	Netherland
Noise and Number Index (NNI)	United Kingdom
Noise Exposure Forecast (NEF)	North America, California, Canada, Thailand

Here are the definitions of some popular noise measurements that have been used in several airports in the world:

1) *Equivalent Noise Level* (LEQ or L_{eq}): essentially the average sound level as measured by the A-weighted decibel scale over a period of time.

2) *Day-Night Average Sound Level* (DNL or L_{dn}): the accumulated noise level over 24 hours with a penalty of 10 dB given to operations taking place at night between 10pm and 7am. DNL is similar to LEQ and it is used by federal agencies including the FAA. The development of DNL measurements associated with *Noise and Land use guideline* including the compatibility of certain aviation noise levels. The acceptable levels are 65DNL for residential areas and schools, 70DNL if sound insulated, and 75DNL for commercially developed areas. Noise levels and DNL can be represented by the noise contour maps which can also help to show which area is exposed to high noise level and even determine which areas are considered for zoning ordinances and airport overlay zones. In Federal Aviation Regulations (FARs), noise exposure maps show the noise level with five dB increments (65, 70, 75 DNL). In addition, noise exposure maps are used either to determine the compatible land uses for different noise levels or propose noise-mitigating measures in an associated noise compatibility program.

3) *Community Noise Exposure Level* (CNEL): this metric is used to help predict the response of the community to noise exposure and mostly in California with even higher penalty to night flight operations.

4) *Kosten Units* (Ku): Dutch noise descriptor which was named after a government commission chaired by Professor Kosten derived a formula based on the noise in decibels, the frequency of flights, and a correcting factor for day and night traffic (Van Praag and Baarsma (2005))

5) *Noise and Number Index* (NNI): most common noise descriptor in the United Kingdom. Given N the number of noisy events and PNdB the average peak noisiness in dB between 7:00 am and 7:00 pm during an average summer's

day, therefore, the *NNI* can be computed by: $\mathrm{NNI} = \mathrm{PNdB} + 15\log \mathrm{N} - 80$ (Pennington *et al*. (1990)).

6) *Composite Noise Rating System* (CNR): a graphically produced measure which is used to produce aircraft noise annoyance on the house based on the number of flights, the time of day, and the perceived loudness of noise (Miseszkowski and Saper (1978)).

7) *Noise Exposure Forecast* (NEF): noise descriptor method developed by the U.S. Federal Aviation Administration (FAA) to predict the degree of community annoyance from aircraft noise (and airports) on the basis of various acoustical and operational data. This descriptor was later developed to be Australia Noise Exposure Forecast (ANEF) based on NEF system for Australia' noise metric (Greaves and Collins (2007)). Regarding to the level of annoyance, Nelson (1980) mentioned that with NEF between 15 and 20 is suitable for residential area with little annoyance; NEF ranges from 25 to 40 for some to much annoyance; and considerable annoyance for NEF higher than 40. To determine the NEF, McMillen (2004) reported that NEF aggregates the noise produced by individual flights over a day into a single statistic. The central component of NEF is EPNL(i,j), which is the *Effective Perceived Noise Level* produced by flight *i* using flight path *j*. Additional penalties are then built into the formula for the number of daytime (N_d) (from 7:00 am to 10:00 pm) and nighttime (N_n) flights, . So the formula of NEF for an individual flight is:

$$\mathrm{NEF}(i, j) = \mathrm{EPNL}(i, j) + 10[\log N_d + 16.67 N_n] - 88$$

which is aggregated into a single index using the formula:

$$\mathrm{NEF} = 10\log \sum_i \sum_j \exp\left(\frac{\mathrm{NEF}(i, j)}{10}\right)$$

2.2.3 Suvarnabhumi Noise Contour Map

As shown in Figure 1.1, the first original noise contour maps of Suvarnabhumi airport were drawn by the environment impact assessment (EIA) in 2006. Pollution Control Department (PCD) is the responsible agency in measuring the aircraft noise at this airport. In addition, the noise data collecting from the 13 noise monitoring stations (five stations in the south and eight stations in the north of the airport) have been used to compute the L_{eq} and L_{dn}. These two cumulated noise measurement were measured in the basic unit as dB and then it was converted to A-weighted scale (dBA). Thus, there were four different noise contour levels 60, 65, 70, and 75 dBA for L_{dn} (or 65, 70, 75, and 80 dBA for L_{eq}) which were basically depicted on a combination of several pieces of land maps. According to the noise contour maps, landings and take-offs at the western runway seemed to be used only at the north direction. The most severe zone which encompassed by noise level higher than L_{dn} 75 dBA or L_{eq} 80 dBA are only located inside the airport boundary. It can be explained that there is no known property affected by these severe noise.

However, a new version of the airport noise contour maps established by the AoT and approved by the Thai Government in 2007 is provided in Figure 2.5. The new airport noise measurement of Suvarnabhumi has been utilized as the official airport noise metrics instead of L_{dn} and L_{eq} to define the areas affected by aircraft noise. That is noise exposure forecast (NEF) which anticipated representing the long-term average noise exposure in communities around the airports. Similar to the original version, there are also four different noise contour levels such as NEF 30, NEF35, NEF 40, and NEF 45 illustrated on the new version of Suvarnabhumi airport noise contour maps. As shown in the figure, the NEF 30 noise contour line is sketched about 10 kilometers from the airport boundary to the north and the south. As can be seen, a majority of residential property affected by the noise level between NEF 30 and NEF 35 are in all directions except at the east where there is few houses located near the airport. Besides, the noise contour seemed to be drawn symmetrically, due to the similar operation of both runways. In this study, therefore, we will use the new version of noise contour maps shown in Figure 2.5. The noise contour maps will be then redrawn in the ArcGIS software combining with the ESRI GIS Map of Bangkok (ESRI Data & Maps) to generate the main control variables such as noise dummy variables, distances from each sold property to the airport entrance and to the nearest transportation facilities.

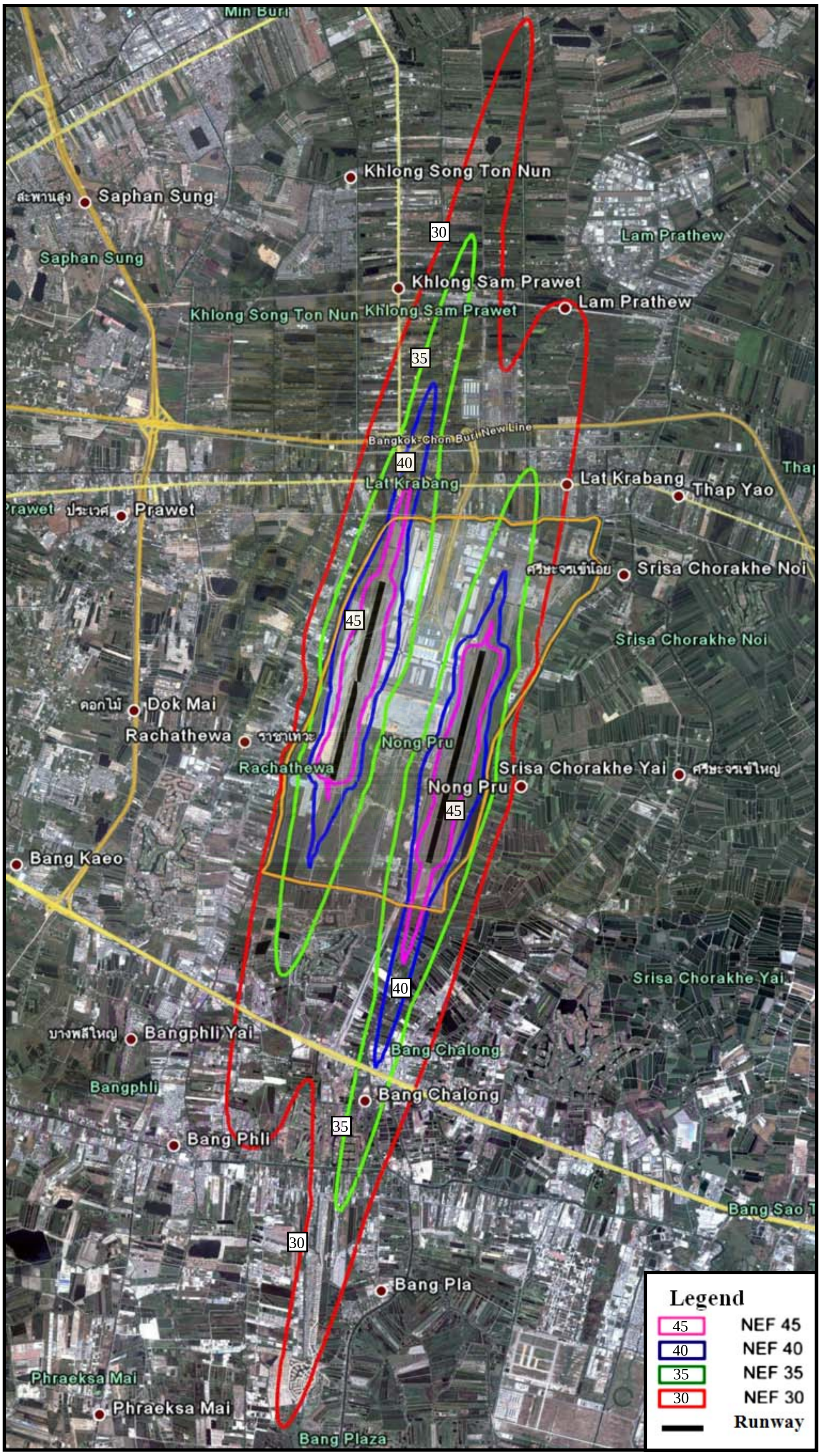


Figure 2.5 Suvarnabhumi airport noise contour map (Source: AoT, 2007)

2.3 Hedonic Price Model

In hedonic house price studies, researchers attempt to find the relationship between house price on the one hand and their multidimensional characteristics on the other. Rosen (1974) firstly demonstrated how the regression technique can be used to estimate the implicit price of the different attributes of heterogeneous goods with the belief that goods are valued for their utility-bearing attributes or characteristics (Selim, 2009). In addition, this technique has been employed to estimate the consequences of various amenities and disamenities on residential property values (Nelson, 2004). Although there were many similar hedonic price studies, the differences depend on the researchers' objective, variables used in analysis, as well as the data that are available.

2.3.1 Dependent and Explanatory Variables

Based on the previous studies, most researchers on hedonic modeling of property value have utilized the property prices, which can be sale or transaction price, as dependent variable while explanatory variables such as structural (description of the property's characteristics), neighborhood (quality of the neighborhood), accessibility (access to various type of transportation, economic, and social facilities), and environmental characteristics (Can, 1992). The structural characteristics often include floor area, lot size, number of floor and fireplace, number of bed- and bathroom, garage, swimming pool, etc. Neighborhood characteristics such as crime, school quality, green space, etc. are often included to control for disparity in quality of public services in different local authority. Accessibility characteristics often include the distance to the airport entrance, expressway, shopping center, bus or rail transit station, etc. And environmental characteristics mostly include the air pollution and noise level.

2.3.2 Functional Form

An important aspect to be considered before estimating the chosen model is the functional form of hedonic equation (Can, 1992). Two major approaches concern the linear or linear in parameter (semi-log, double log). According to the literature review on housing price and airport noise, various functional forms have been used to model the hedonic relationships. But, four of which have been most frequently utilized, namely linear, semi-log, log-linear, and box-cox transformation. On the basis of statistical performance and diagnostics of estimated models, the researcher should choose the functional form because it cannot be predetermined. The application of different functional forms provides different interpretations of the findings. For example, if we regress the housing price on aircraft noise (measured in decibel) and given noise estimated coefficient β, in the linear specification the coefficient β reflects the price discount due to an increase of one dB in noise. In the semi-log specification, the coefficient can be interpreted as the discount in percentage point, due to an increase of one dB in noise (see Mieszkowski and Saper (1978), Pennington *et al.* (1990), Espey and Lopez (2000), and Pope (2008)).

2.3.3 Econometric Issues in Hedonic Modeling

In the previous literature, three important econometric issues in hedonic modeling have been identified and addressed. These issues are multicollinearity, heterogeneity, and spatial autocorrelation.

a. Multicollinearity: The problem of multicollinearity occurs when there is correlation between explanatory variables and it does not cause the regression coefficients to be biased but unsatisfactorily large variances (Dougherty, 2002). In short, it leads to imprecise estimate of coefficient. As mentioned by Nelson [3] the problem of multicollinearity can be solved by dividing the block property into group according to the distance and use dummy variable to represent the block in a particular circular distance ring. In the same way, Can (1992) also created a composite neighborhood quality index as a substitute of neighborhood characteristic measurements. Furthermore, the problem of large variances can be dealt with by various techniques, such as including additional variables, increasing the number of observations, and dropping certain correlated variables. In this study, the problem of multicollinearity might occur when we include the explanatory variables such as noise level and airport proximity. In this case, the airport noise impact makes the property values go down while the airport proximity may raise the price. If these two variables are high correlated and included in the hedonic model, it might yield the insignificant coefficient. However, this problem may not be serious because correlation may be weak due to the shape of airport runway and noise contour are stretched.

b. Heterogeneity: In the previous studies, Praag and Baarsma (2005) suggested heterogeneity that results from the psychological characteristics of affected persons which are not observable. Dwellers in the vicinity of the airport may vary in noise sensitivity due to the aircraft noise and this would yield the imprecise estimation. Pope (2008) also argued about the heterogeneity that the property buyers with lack of information about the noise will cause downward biased estimate of airport noise effects on residential property prices. One possible solution in controlling market heterogeneity has been proposed in Theebe (2004) by generating sub-sample and dummy variables utilization.

c. Spatial Autocorrelation: This is defined as a correlation of a variable with its self through a space. Three possible explanations about this problem are: 1) there is a simple spatial correlation relationship: whatever is causing an observation in one location also causes similar observations in nearby locations, 2) spatial causality: something at a given location directly influences the characteristics of nearby locations, and 3) a spatial interaction: the movement of people, goods or information creates apparent relationships between locations (Wikipedia). In addition, spatial dependency guides to spatial autocorrelation problem like temporal autocorrelation, this violates standard statistical techniques that assume independence among observations. However, when the cross-sectional data is used to estimate the econometric model, spatial effects should be considered for two reasons: the first is related to the underlying process based on theoretical or conceptual consideration; the second reason is associated with misspecification resulting from omitted variables, mistaken functional specification, and measurement errors (Can, 1992). The author argued that the presence of spatial effects – spatial dependence and spatial heterogeneity – will violate the standard error assumptions under normality of the linear regression model (Regarding the test for these spatial effects, see Can (1992)). Additionally, it would not be sufficient to analyze and model the geographically referenced data by using traditional methods due to spatial effects. Anselin (1993) proposed spatial econometric approach to incorporate location information of each observation as an important attribute in the hedonic model.

2.4 Hedonic Price Studies of Airport Noise

2.4.1 Previous Findings

With regards to the airport noise impact on property values, several researchers conducted the studies, using hedonic approach, in developed countries such as Canada and the United State (e.g. in Nelson (2004)), the United Kingdom (e.g. in Pennington et al. (1990)), and some western European countries. But, no such a study could be found in developing countries. Most of the authors found the effects of airport noise to be significant and negative. This noise effect is generally expressed as noise depreciation index (NDI), the percentage discount on residential properties due to a decibel increase in noise exposure. McMillen (2004) summarized the previous studies which indicate that NDI is in the range from 0.64 to 2.4 percent. In addition, similar survey conducted by Praag and Baarsma (2005) in four different countries such as Australia, Canada, the U.K., and the U.S. shows that the NDI estimated by hedonic approach ranged from 0.15 to 3.57 percent for the studies in which NNI was used and ranged from 0.22-2.3 percent for the studies in which NEF was used. McMillen (2004) argued that the variation might result from the model specification, estimation technique, and noise measurement used in the research.

Among recent studies, McMillen (2004) conducted a study on the effects Chicago O'Hare Airport's expansion in which the impact of airport noise surrounding property values would be examined. The Illinois Department of Revenue provided the property characteristics such as transacted price data in 1997, building area, land area, age of the house, and number of bedrooms. So the total sample of 4,012 single-family homes in the Cook County and within two miles of the 1997 noise contour was employed in the standard hedonic regression analysis. In addition, the City of Chicago Department of Aviation has provided the noise contour maps for 1997 and 2000. In fact, the maps has only three contour lines showing only one noise level of 65 dB, measured as annual average sound level (L_{dn}), in different year 1997, 2000, and for projection of long-range contour. Thus, the noise dummy variable was defined equal to 1 if the property situated in the 65dB of 1997 noise contour line and 0, otherwise. Moreover, the addresses of each building were coded into the Geographic Information program to generate the distances from each property to the airport entrances and other transportation facilities. These distance variables would show its selves significant in the model as it signifies the benefit effect from being closer. On the other hand, log-linear was selected as the functional form in the hedonic regression analysis. After the data analysis, the result shows that about 70 percent of the data can be described by the model while most of the coefficient estimates are highly significant with the expected signs. The result indicates that, for properties situated in the 65 dB noise contour zone of Chicago O'Hare airport, the noise discount is 9.2 percent. This noise discount could be interpreted as NDI which equals to 0.81 percent, meaning that property would reduce the price by 0.81 percent for one additional dB. He also reported that this estimated result is higher than those found in recent studies, which focus on smaller airports. Nevertheless, he maintained that O'Hare airport can be expanded without significant reduction in surrounding property prices due to the new aircrafts produce much less noisy. In contrast, those nearby properties might be sold in higher price as a result from the growth in business and employment activities.

Similar study conducted by Pope (2008) to estimate the impact of airport noise disclosure on housing prices near Raleigh-Durham International airport (RDU) in North Carolina. Later, the disclosure laws, took place on April 1, 1997, in housing market provide an opportunity to better understand the impact that symmetric information acquisition between buyers and sellers may have on housing price. By seeing this, he examined the policy which enforced the sellers to inform buyer about the airport noise level. Under the hedonic model, semi-log was chosen in constructing a best price regression function based on a total of 16,900 observations of single family housing transactions from 1992 to 2000 in Wake County, North Carolina. The sale prices and property characteristics were provided by the Wake Country Revenue Department. The observations included were only those transacted houses that were in noise zones requiring disclosure, or transacted houses within a one mile buffer around this area of disclosure. Besides, a GIS shape file was also available from RDU. Using AreView GIS software based on the GIS shape file provided, location characteristics such as distance to the nearest transportation facilities and business centers were generated. Distances from each property to the airport terminal variable were measured in linear distance. Another important variable is noise levels. The noise contour maps drawn in 1996 were provided by the RUD authority. There are four noise contour lines for different noise levels, namely 55, 60, 65, and 70 dB of L_{dn} and hence two noise dummy variable were defined for those property located inside the noise level of L_{dn} 55-60 dB, and 60-65 dB. With regard to the methodology of this study, the author utilized a fixed-effects model in time and in space. So that, the yearly dummy variables were created for the years 1992-2000 and separated by the month of April (the month that noise disclosure took place). Yet, two additional dummy variables were also created to capture the effects of those property affected by airport noise and transacted after the noise disclosure took place. Hence, there were 46 explanatory variables included in the model. As result, he found that the policy increase the noise discount for properties located in the 65 dB contour zone from 7.8 percent without disclosure to 11.7 percent. This can be explained that because of the problem of asymmetric information before the disclosure was enforced. In order to possibly sell the property at a high price, real estate agents who know about the airport noise level during noisy period might show the property only in the quieter time.

2.4.2 Meta-analysis Technique

Since the study on the airport noise impact on property value has been become a hot topic in the last few decades, these empirical results provide enough data for some researcher to conduct a meta-analysis of hedonic price studies. Nelson (2004) analyzed on 33 estimates of noise discount from 20 hedonic value studies for 23 airports in Canada and the United State. Various factors such as country, model specification, size of sample, and mean property value have been considered in the study. He found that the effects of country and model specification are statistically significant. In addition, for properties located at noise exposure level of 75 dB or less, the noise discount found to be about 0.5 to 0.6 percent per dB in the U.S. while about 0.8 to 0.9 percent per decibel in Canada.

Another recent meta-regression of hedonic price studies has been conducted by Wadud (2009). In his study, more empirical results from 65 studies from eight countries were included in the analysis. Wadud claimed that, according to his survey on previous studies, the noise discount ranges from no statistically significant to 2.3 percent per dB. As he noted about the different NDI estimates in previous studies, several factors have been identified and incorporated in the study. Those factors are functional specification, spatial autocorrelation, regional differences, noise measurement, and other statistical modeling issues. He also mentioned about the correction of the present of the airport access control. He found that the NDI estimate is between 0.73 and 0.75 without airport access control and between 0.81 and 0.85 with airport access control. Besides, he also found significant effect of average property price in the sample and thus the NDI estimate at the mean sample property price ranges from 0.58 to 0.64 percent per dB for different specification.

2.4.3 Recent Development in Hedonic Price Method

In the literature, the development of hedonic price method in determining the noise discount is the application of spatial econometric technique. Theebe (2004) conducted a study to estimate the non-linear impact of the traffic noise (road, rail, and air traffic) on property prices in the Amsterdam areas, Netherland, using spatial auto-correlation techniques. He addressed three innovative issues of hedonic regressions. Firstly, the author incorporated the spatial regression technique in which an observation in time series analysis depends on observations nearby in time whereas an observation in cross-sectional analysis may depend on observations located nearby in space. Second, the heterogeneity and biased in housing market may result in the potential estimation error terms. And third, a set of noise dummy variables were included in the model instead of a noise index. As in the empirical experiments, the author constructed hedonic regression model using 16,000 individual properties transacted between 1997 and 1999 and provided by Dutch Association of Brokers. Noise levels, expressed as the cumulative energy level index (LAeq), for small areas of 100 square meters were obtained from the National Institute of Public Health and the Environment. This noise index which generated by road, rail, and air traffic for 1999, was ranged into 10 categories of five dB each. In addition to controlling for positive effects from getting benefit of being close to the transportation facilities, distances to the nearest highway onramp and to the nearest train station were generated using many detailed maps with X- and Y-coordinates (the maximum deviation is 12.5m). After that, the data could be analyzed based on log-log specification. Finally, Theebe found a significant impact of traffic noise on housing prices with the estimated price per reduction of NDI ranges from 0.3 to 0.5 percent.

Cohen and Coughlin (2008) provided an example that spatial econometric techniques can prove useful in estimating a housing price model when the sales price of specific house is similar to that of a nearby house for reasons not fully incorporated into model. The authors believed that the exclusion of this spatial consideration will cause biased estimates of parameters and their statistical significances as well as errors in interpreting standard regression diagnostic test. In their study, spatial hedonic regression was estimated using generalize method of moments (GMM) approach for house price near Atlanta airport. Those spatial effects are spatial lagging of the dependent variable (i.e. spatial autoregressive), spatial lagging of the error term (i.e. spatial auto-correlation, and a combination of both (called general spatial model). As the proof, the authors constructed several modes, namely ordinary least squares (OLS), spatial error model, spatial autoregressive model, general spatial model, etc. to examine the airport noise impact on 508 single-family house transacted in 2003. The sale prices and housing characteristics were acquired from the First American Real Estate Service. On the other hand, the noise contour maps in 2003 provided by the City of Atlanta Department of Aviation was used with ArcView software to generate the other control variables such as noise dummies and distance from the houses to the airport. The noise contour lines were marked in the yearly day-night sound level (DNL). In the analysis, he used log-linear functional form for the spatial hedonic modeling approach. Therefore, they found strong evidence of spatial autocorrelation and the results indicated that the noise discount is not significant for houses located outside noise contour of 70 dB while significant noise discount of 20.8 percent of those properties lied in between the 70 to 75 dB noise contour line. Of course, the magnitude of noise discount estimated by OLS is somewhat higher than those implied by spatial regression.

Furthermore, Salvi (2008) also applied the spatial econometric techniques with which the author believed that various kind of spatial dependence (i.e. spatial autocorrelation and variable misspecification) could be dealt. The study aimed to measure the impact of airport noise on the prices of 3,737 single-family homes transacted between 1995 and 2005 in the areas around Zurich airport. The sale prices of the properties were provided be a original mortgage originator. Besides, the noise data (LAeq) was computed from the aircraft noise models provided by the Swiss Federal Laboratories for Material Testing and Research. The noise variable were divided into three categories, namely L_{eq} 16h (measured over 16 daytime hours), L_{eq} peak (the highest 1-hour L_{eq} during daytime, 6 am-10 pm), and L_{eq} evening (average noise level between 9 pm-11 pm. In addition, the travel time from each property to the central business district (CBD) and distance to the nearest power line and rail station were also included in the hedonic function. In the spatial estimation, the author developed two different models, namely spatial autoregressive error (SAR) and ordinary least squares (OLS). As results, there is an evidence of spatial autocorrelation and this leads the author to conclude that there are very small differences between the NDI resulting from OLS estimates and those produced by spatial estimation. The final NDI found and selected is 0.97 percent per dB which is in the range of earlier literature.

2.4.4 Summary of Previous Studies

Table 2.2 summarizes the findings of previous studies related to airport noise impact on property values between 1978 and 2008. As can be seen, a majority of studies have been conducted to determine the noise discount of property values in the vicinity airports in the U.S. and a few studies in Canada and the U.K. The treatment of aircraft noise measurements and quantitative methods for data analysis may result in different estimation results. In all of the studies reported in the table, the hedonic approach was employed, with an exception of Collins and Evans (1994) who used an artificial neural network approach. Additionally, hedonic approach has been developed to spatial hedonic model for better estimating the impact of airport noise on property values. These spatial models can be found in Theebe (2004) , Cohen and Coughlin (2008), and Salvi (2008), who has addressed spatial autocorrelation and spatial dependence, which could bias ordinary least squares (OLS) estimates, by using spatial regression technique.

The sample sizes in the studies reviewed in Table 2.2 range from 96 to 160,000 (O'Byrne *et al.* (1985) and Pope (2008)). In addition, many studies use individual property type (or single-family house) for the analysis. Meanwhile, property value proxies used in these previous studies are all transaction prices, with the exception of Praag and Baarsma (2005), who analyzed the results use asking price. Semi-logarithmic model were used in a majority of studies, the results of which can be used directly to estimate the property discount in percentage point due to airport noise effect.

The results of studies shown in Table 2.2 indicate significant airport noise discounts, except for Pennington *et al.* (1990), in which the authors found that positive but insignificant NDI. The lack of this statistical significance can be probably the consequence of neighborhood and other uncontrolled characteristics of the properties. Uyeno *et al.*(1993) estimate NDI of three types property using hedonic regression analysis based log-linear specification. The authors found significant effect of airport noise on property values: 0.65%, 0.90%, and 1.66% per dB for detached houses, condominiums, and vacant land sales, respectively. In the previous hedonic price studies, as shown in Table 2.2, the survey on NDI is in the range from insignificant impact to the 1.3 percent. The noise discount estimated using ANN approach for the Manchester areas was relatively high compared to others studies using hedonic method. Moreover, the results from spatial hedonic studies conducted by Theebe (2004), Salvi (2008), and Chen and Coughlin (2008) suggested the NDI in the range from 0.3 to 0.97 percent. Meanwhile, Nelson (2004) conducted a meta-anaylysis and found that the results of his study are consistent in the range of that in his previous works conducted in 1980. While the most recent meta-analysis study conducted by Wadud (2009) found that the NDI is in range of 0.81-0.85 percent and it still fall into the range of NDI found by Nelson (1980). On the other hand, the *t*-statistic of NDI are mostly significant at 99 percent level while only few are significant at 95 percent level. With regards to the utilization of NEF in residential property valuation, the studies suggested NDI in the range of 0.4% to 1.3% (Nelson (1980) and Levesque (1994)) while the coefficients of determination, R^2, in the studies range from 0.64 to 0.92.

Table 2.2 Summary of literature on noise impact on property values

Authors (Published year)	Airport(Country) Area	Data type, Sample size (study period)	Method	Airport Noise Metric (year)	Functional form	NDI (|t|)	R^2
Miseszkowski and Saper (1978)*	Toronto(U.S), Mississauga	Indiv. prop., 509 (1969-1973)	Hedonic	NEF (1971)	Semi-log	0.87% (4.10)	0.90
	Etobicoke	611 (1969-1973)	Hedonic	CNR (1975-76) and NEF (1971)		0.95% (5.08)	0.92
Nelson (1979)*	Six airports (U.S)	Census blocks, 845 (1970)	Hedonic	NEF (1972)	Log-linear	0.50% (2.75)	0.84
Nelson (1980)*	13 airport (U.S)	Previous studies, 13 (1967-1976)	Hedonic	NDSI (1967-76)	(Average)	0.4-1.1%	-
O'Byrne, Nelson, and Seneca (1985)*	Atlanta (U.S), Georgia	Indiv. Prop., 96 (1979-1980)	Hedonic	LDN (1980)	Semi-log	0.67% (2.233)	0.71
		Census blocks, 248 (1970)	Hedonic	NEF (1972)	Log-linear	0.64% (3.2)	0.74
Pennington et al. (1990)	Manchester (England)	House Mortgage, 3472 (1985-1986)	Hedonic	NNI (1985)	Semi-log	Statistically insignificant	0.80
Uyeno et al. (1993)*	Vancouver (Canada), Richmond,	Detached house, 645 (1987-1988)	Hedonic	NEF (1987)	Log-linear	0.65% (3.969)	0.64
		Condos, 909 (1987-1988)	Hedonic			0.90% (2.789)	0.79
		Vacant land sales, 319 (1987-88)	Hedonic			1.66 (2.919)	0.42
Collins and Evans (1994)	Manchester (England), Manchester	House mortgage, 3472 (1985-1986)	ANN	NNI (1985)	Noise discount: 8.02-9.54%		-
Levesque (1994)*	Winnipeg (Canada), Manitoba	Indiv. Prop., 1,635 (1985-1986)	Hedonic	NEF (average) No. Events > 75	-	1.3% (3.801)	0.80

Espey and Lopez (2000)	Reno-Tahoe (U.S), Nevada	Indiv. Prop, 1417 (1991-1995)	Hedonic	L_{dn} (1993)	Semi-log	0.28% (1.8)	0.85
Nelson (2004) (include *)	23 airports in Canada& U.S	Previous studies, 31 (1970-1994)	Meta-analysis	NDI	-	U.S:0.5-0.6% Canada:0.8-0.9%	-
McMillen (2004)	Chicago O'Hare (U.S), Chicago	Indiv. Prop., 4012 (1997)	Hedonic	L_{dn} (1997)	Log-linear	0.81% (9.57)	0.68
Theebe (2004)	Amsterdam (U.S), Netherland	Indiv. and multi. Prop., 160,000 (1997-1999)	Spatial Hedonic	LAeq (100x100m) (road,rail, and air traffic noise1999)	Log-log	0.3-0.5%	-
Praag and Baarsma (2005)	Amsterdam (U.S), Netherland	Asking price, 1,400 (1998)	Hedonic	Ku (1967)	Ordered logit or probit	9% to deactivate Ku from 20 to35	-
Pope (2008)	Raleigh-Durham (U.S), Carolina	Indiv. Prop., 16,900 (1992-2000)	Hedonic	L_{dn} (1996)	Semi-log	Noise discount 2.9% (2.071)	0.89
Salvi (2008)	Zurich (Switzerland), Zurich area	Indiv. Prop. 3,737(1995-2005)	Spatial Hedonic	L_{eq} (2005)	Log-linear	0.97 % (9.7)	-
Cohen and Coughlin (2008)	Atlanta's Hartsfield-Jacson (U.S)	Indiv. Prop., 508 (2003)	Spatial Hedonic	DNL (2003)	Log-linear	0.69% (2.8)	0.52
Wadud (2009)	8 Countries	Previous studies 65 (1970-2007)	Meta-analysis	NDI	-	0.81-0.85%	

Note: NDI = Noise Depreciation Index; ANN = Artificial Neural Networks;
LAeq = Equivalent Sound Pressure Level (A- Weighted) (Detail about A-Weighted, see Noise Quest (2009))

CHAPTER III
METHODOLOGY

3.1 Research Framework

To accomplish the objectives of this thesis, the research framework is designed and arranged as shown in Figure 3.1. First of all, the background information of Suvarnabhumi airport was reviewed along with the environmental problems occurred before, during, and after the opening of the airport. Among those problems, the impact from aircraft noise on quality of life and valuations of properties in surrounding neighborhood has been of most critical concerns. Both the government and responsible authorities have tried either to buy the property affected by severe noise or to compensate those affected by moderate noise. Then, the reviews of basic knowledge about the airport noise and approaches for examining the compensation strategies are also studied. In addition, the most widely used-approach for examining the relationship between the airport noise and property values, namely the hedonic regression approach is reviewed.

Secondly, the primary source of data for this study is identified. After exploring various data sources, cross-sectional data was purchased from the Agency for Real Estate Affairs (AREA). This data set consists of sale prices and characteristics of the properties located in the vicinity of the airport, but not the key control variables, such as noise level and beneficial access for each property. Therefore, noise contour lines from AoT and property address were obtained and locations coded into the ArcGIS® software in order to generate the key control variables. These data were also analyzed using STATA statistical software for descriptive statistics and further analysis.

Following the well-developed statistical modeling techniques for hedonic analysis, the best desired-model was selected from the standard hedonic price regression model using various functional forms. After testing and selecting significant explanatory variables, econometric issues such as multicollinearity and heteroscedasticity were also examined and corrected. Finally, the estimation results were described and discussed.

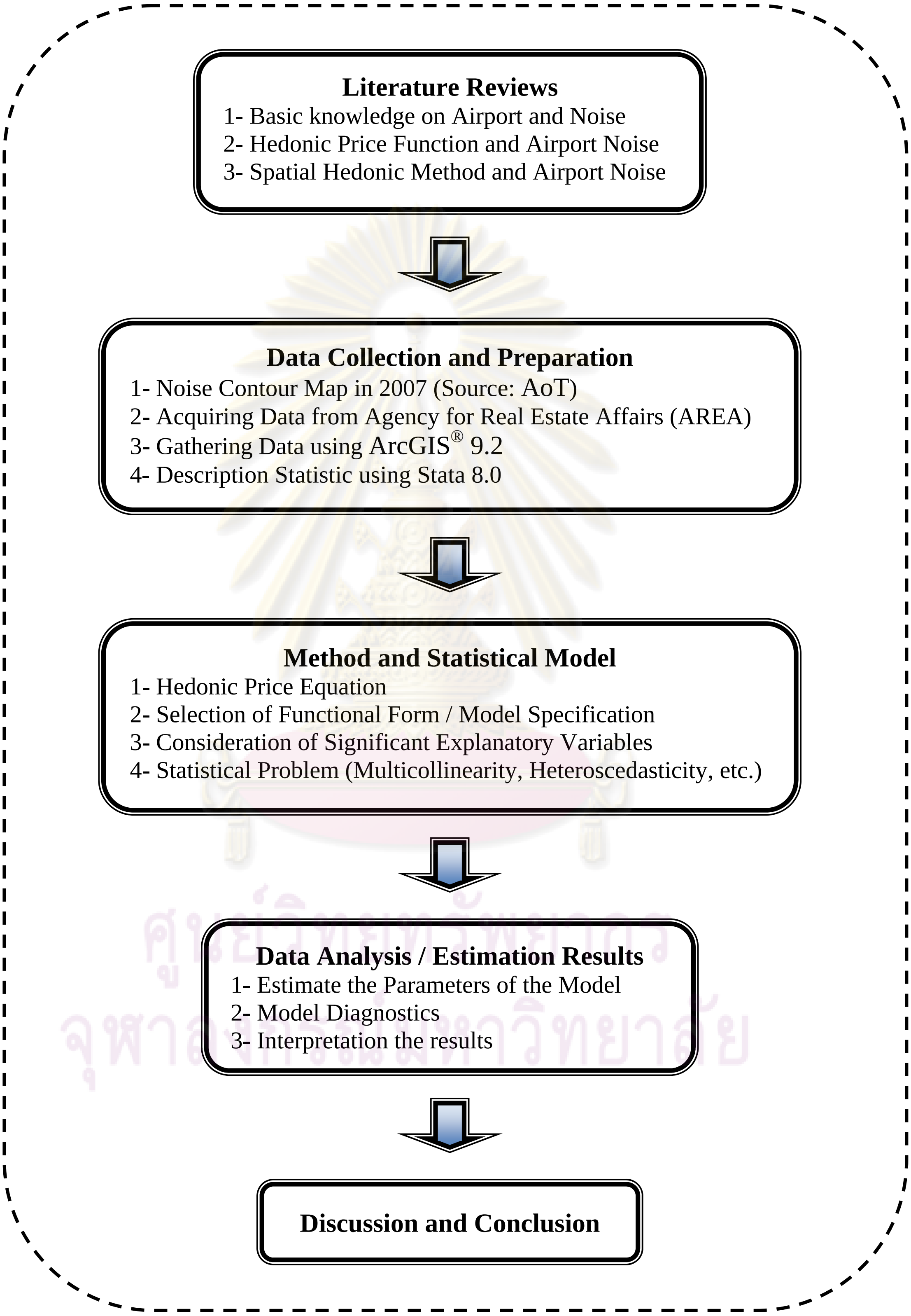


Figure 3.1 Research framework

3.2 Hypothesis

3.2.1 Noise Impact

After the opening of Suvarnabhumi in September 2006, noise impact occurred and has stalled the rise of property price in the surrounding areas (Bangkok Post News, 2007). Information was not available to homebuyers about the airport noise impact in 2003 and 2004, the year when prices began to rise in the nearby area. Some buyers followed the trend, buying property at very high prices. Based on AREA's survey, property prices rose only four to five percent in 2002, but more than 10 percent in 2004 and 2005 and some areas climbed by 50 percent or more due to the high demand. Currently, the property prices have become stable while some housing projects have experienced significant drop in sales. Because of this pattern of sale prices, our hypothesis is that experienced noise impact on property prices was not anticipated before the airport operation initiated but the impact became significant afterwards. Under the hypothesis, the coefficients of noise variables in the hedonic model of property prices should not be significant in all years except those after the opening of the airport. These coefficients should be negative and significant after the airport opening, and can be interpreted such that the higher the noise level is perceived the lower price the property could sell. In fact, there might also be noise impact on property values during the year prior to the airport construction completed because people living around the airport would begin to realize that the airport would begin operation soon. Therefore, people, especially buyers, would keep in mind that they would have the problem of aircraft noise as soon as the airport operations begin. This hypothesis will also be tested.

3.2.2 Airport Accessibility Effects

The accessibility effect is another important control variable for in this study and represents beneficial economic effect that results from being located in close proximity to the airport. We measure this effect by the distance from property to airport entrance based on road networks. Due to the elongated shape of the airport runway, this distance is not necessarily correlated with the airport noise. Yet, it was clear that since Suvarnabhumi airport started its construction, people, especially real estate project owners and developers, believed that the areas nearby the airport would soon be developed and even become a new commercial area. We hypothesize that the effects of access, as proxied by the distance to the airport entrance will be constant over years leading up to as well as after the airport opening. Under this hypothesis, we believe the coefficient estimate of the distance variable would be negative and significant. The further the distance from the airport entrance, the less the property values will be, all else being held equal.

3.2.3 Distance to Other Transportation Facilities

Similar to the airport accessibility, closer distance to other transportation facilities that are available in the neighborhood should be translated to the positive effect from easy access to economic activities, such as those agglomerated in the central business district. This positive effect occurred even before the announcement of the new airport construction because people who live near those transportation facilities already gain benefit of easy access to economic activities. Thus, we hypothesize that the effect of these control variables will be constant over the years. Under the hypothesis, the estimated coefficients are expected to be negative in the hedonic regression. We also believe that both magnitude and significance BTS access will be higher than that of expressway ramp access, according to the belief that people prefer their house closer to a BTS station rather than an expressway ramp. This is so because of the relatively limited availability of rail transit system compared to expressway.

3.3 Sources of Data

There are three sources of data that are acquired in order to examine the impact of the airport noise impact on property values. These include property sale prices and its characteristics, noise variables, and location characteristics. In this section, we will discuss each source of data in turn.

3.3.1 Data of Property Sale Prices

There is a total of 44,923 house sales records originally purchased from Agency for Real Estate Affairs Co., Ltd. (AREA). The property types in these cross-sectional data include commercial, condominium, single-family detached, duplex, and townhouse. The data set consists of transactions of all new properties in the airport vicinities that occurred between 2002 and 2008. Given the scope of the study, we focus only on three residential property types, namely single-family detached, duplex, and townhouse dwelling units that are located in the eastern suburban neighborhoods of Bangkok. After data cleaning and preparation, we obtained 37,539 property sale records. Since the project owners generally constructed similar houses with almost identical characteristics, these properties mostly sold in the same or similar price. Therefore, the total number of unique observations available for the analysis is 384.

Table 3.1 describes the number of properties sold and number of unique observations sold in each year. As can be seen, a majority of the properties that were sold in 2004, in the total of 8,204 sales, were single-family detached type. In addition, project owners, seemingly responding to the market trend, tend to build the individual unit rather than other property types. It is also shown in the table that the number of sales of duplex unit type was somewhat smaller than others. Surprisingly, the trend of sales seemed to have peaked in 2004 and started to decrease gradually in the following years. The reason behind this might be due to the noise pollution became noted by the potential buyers. In addition to pricing information, other variables in this data set include street address, sale prices, year of sale, floor are, lot size, number of stories, type of the property, etc.

Table 3.1 Number of properties sold in each year

Prop. type & Year	**Duplex (DPX)**		**Single-family detached (SFD)**		**Townhouse (TH)**		**Total**	
	No. of unique	No. of prop.	No. of unique	No. of prop.	No. of unique	No. of prop.	Total of unique	Total of prop.
2002	1	20	7	677	7	751	15	1,448
2003	3	147	31	3,227	10	860	44	4,234
2004	7	267	53	5,259	23	2,678	83	8,204
2005	2	34	46	3,102	22	2,532	70	5,668
2006	5	421	30	3,012	23	2,684	58	6,117
2007	18	2,025	15	1,370	26	3,292	59	6,687
2008	10	592	24	2,449	21	2,140	55	5,181
Total	46	3,506	206	19,096	132	14,937	384	37,539

3.3.2 Noise Contour Map

AoT provided noise contour map for area surrounding Suvarnabhumi airport. The noise contour map was prepared in 2007 by AoT using NEF as noise measurement unit. The map shows four level of noise contour lines with five increments of magnitude, NEF 30, 35, 40, and 45. The contours were drawn on aerial photographs, on which the affected communities were marked out. We use ArcGIS software to geocode the noise contour maps and property locations obtained from AREA. Figure 3.2 illustrates the GIS noise contour maps and the area of study.

Table 3.2 describes the number of properties located in different noise contour zones and were transacted during the period study between 2002 and 2008. According to the Geographic Information System (GIS) analysis, there are 1,611 dwelling units located in the noise contour zone with NEF from 30 to 40 and 968 dwelling units fall into the buffer zone of 500 meters extended from the noise contour line NEF 30. Based on the data set, there are no dwelling units sold between 2002 and 2008 located inside the NEF 40 and 45 contour lines. In addition, the number of properties was also divided for those transactions occurred before and after the opening of airport. As can be seen, there were 243 and 484 properties sold after 2006 and located in the noise contour line between NEF 35-40 and NEF 30-35, respectively. In addition, 363 properties located in the 500-meter buffer zone were transacted after the airport operation began.

Table 3.2 Number of the properties transacted during the period of study

Categorized properties located	No. of Transactions
between NEF 40 and 45	-
between NEF 35 and 40	311
between NEF 30 and 35	1,300
in the 500m buffer zone and outside of NEF 30 contour line	968
	Total = **2579**
between NEF 35 and 40 and sold after 2006	243
between NEF 30 and 35 and sold after 2006	484
in the 500 m buffer, outside NEF 30 and sold after 2006	363
	Total = **1090**

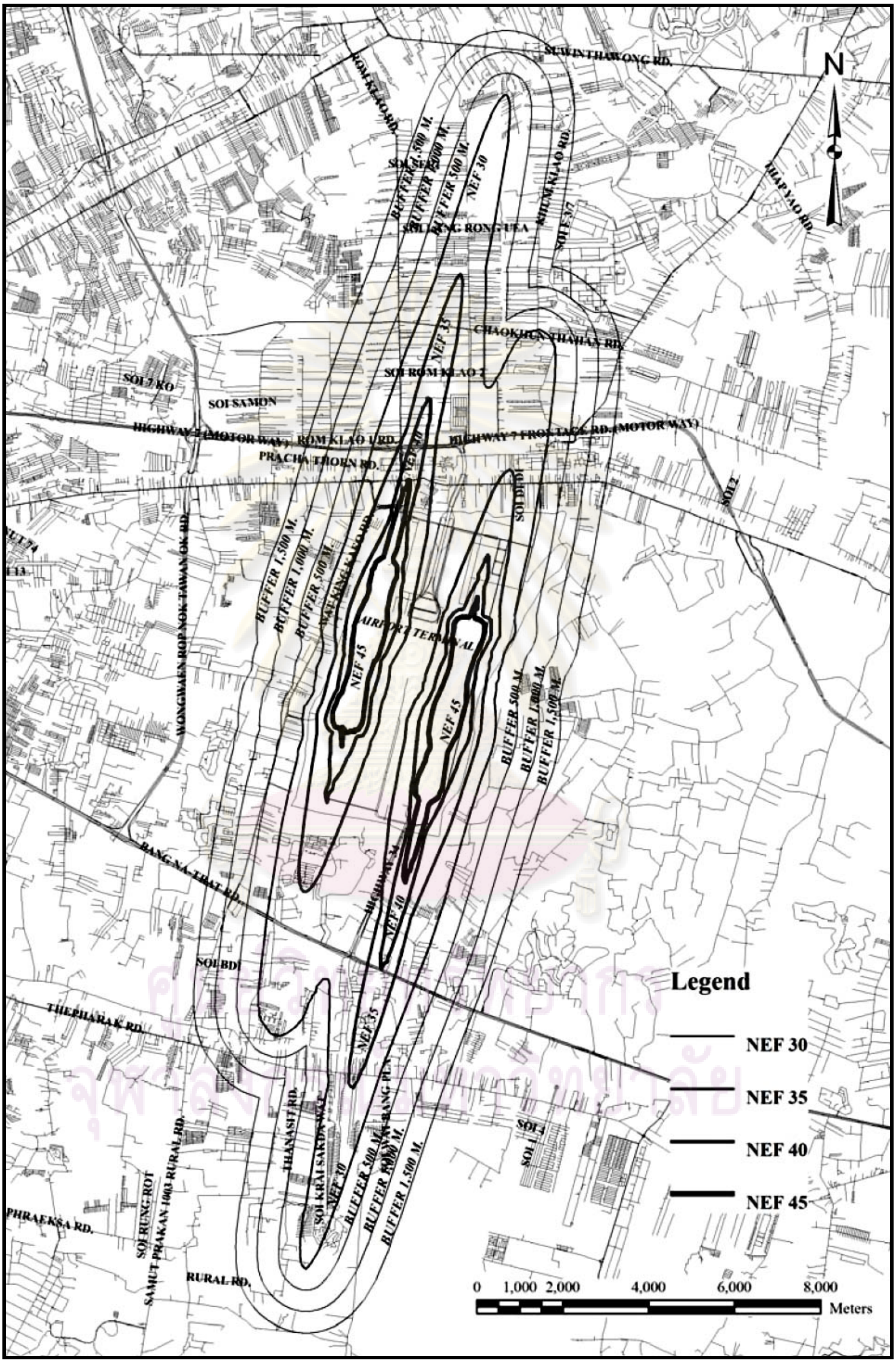


Figure 3.2 Suvarnabhumi airport noise contour map

(Sources: ESRI Bangkok GIS and AoT)

3.3.3 Location Characteristics

Based on GIS map of Bangkok, ArcGIS spatial analysis was used to generate location characteristics of properties. The locations of each property were coded into GIS, so that the distance can be measured as network distance along the road network. Therefore, we obtained the transportation access characteristics of each property such as distance to rail transit station (Bangkok Mass Transit System (known as BTS) and Airport Rail Link), expressway ramps, as well as the airport entrance (the main entrance of the passenger terminal).

3.4 Model Specification

3.4.1 General Model Structure

Selim (2009) maintained that there are numerous methods existing to estimate the market price. These methods have been categorized into two groups: “traditional” and “advanced” by Pagourtzi *et al.* (2003). “Traditional”, which depends on some form of assessment or a range of observations, refers to comparable method, investment/ income method, profit method, development/residual method, contractor’s method/ cost method, multiple regression method, and stepwise regression method. On the other hand, “advance” which refers to the method that attempts to analyze the market includes artificial neural networks (ANN), hedonic pricing method, spatial analysis methods, fuzzy logic and autoregressive integrated moving average. Among these methods, hedonic technique is mostly applied as multiple regression procedures on large data sets in order to analyze the property valuation and housing market (Selim, 2009)). Can (1992) has also discussed that hedonic technique has been a vital tool in econometric studies of urban housing markets. In this thesis, we follow the tradition and specify the standard hedonic price function as:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (1)$$

where $\mathbf{y}$ represents vector of observed property price,

$\mathbf{X}$ represents vector of property characteristics,

$\boldsymbol{\beta}$ represents vector of the unknown parameters, and

$\boldsymbol{\varepsilon}$ represents the vector of random error terms

3.4.2 OLS Estimation

In hedonic price study, the goal is to estimate the parameter β and this can be done using Ordinary Least Square estimation. Equation (1), in section 3.4.1, refers to the basic Multiple Linear Regression. By supposing that there is *k*-variable regression function and *n* observations, this equation can be written as:

$$Y_i = \hat{\alpha} + X_{2i}\hat{\beta}_2 + X_{3i}\hat{\beta}_3 + \ldots + X_{ki}\hat{\beta}_k + \hat{\varepsilon}_i \tag{2}$$

which can be written in matrix form as:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{21} & X_{31} & & X_{k1} \\ 1 & X_{22} & X_{32} & & X_{k2} \\ & & & & \\ 1 & X_{2n} & X_{3n} & & X_{kn} \end{bmatrix} \begin{bmatrix} \hat{\beta}_1 \\ \hat{\beta}_2 \\ \\ \hat{\beta}_k \end{bmatrix} + \begin{bmatrix} \hat{\varepsilon}_1 \\ \hat{\varepsilon}_2 \\ \\ \hat{\varepsilon}_n \end{bmatrix}$$

$$\underset{(n\times 1)}{\mathbf{y}} = \underset{(n\times k)}{\mathbf{X}} \; \underset{(k\times 1)}{\hat{\boldsymbol{\beta}}} + \underset{(n\times 1)}{\hat{\boldsymbol{\varepsilon}}} \tag{3}$$

where $\hat{\beta}$ is a *k*-element column vector of the OLS estimators of the regression coefficients and where $\hat{\varepsilon}$ is an $n\times 1$ column vector of *n* residuals. Note that $\hat{\beta}_1 = \hat{\alpha}$.

3.4.2.1 Assumptions

Before the parameter estimations, assumptions underlying the classical linear regression model are reviewed as follow:

1. The expected value of the disturbance vector, **ε:** E(**ε**) = **0**; where **ε** and **0** are $n\times 1$ column vectors, and **0** is a null vector.
2. The expected value of the product of disturbance vector and its transpose one equal to the its own variance, E(**εε'**) = σ^2 **I**; where **I** and $n\times n$ identity matrix.
3. The matrix of explanatory variables is nonstochastic, that is, it consists of a set of fixed numbers. As we know that our regression is conditional regression analysis, conditional upon the fixed values of the explanatory variables.

4. There is no exact linear relationship among the explanatory variables or we say that there is no multicollinearity.
5. The $\boldsymbol{\varepsilon}$ vector has a multivariate normal distribution, i.e. $\boldsymbol{\varepsilon} \sim N(\mathbf{0}, \sigma^2\mathbf{I})$

3.4.2.2 Parameters Estimation

In order to estimate the parameters $\hat{\beta}$, the residual sum of square (RSS) or $\sum \hat{\varepsilon}_i^2$ must be minimized.

Since we have $$\sum \hat{\varepsilon}_i^2 = \hat{\boldsymbol{\varepsilon}}'\hat{\boldsymbol{\varepsilon}} = \mathbf{y'y} - 2\hat{\boldsymbol{\beta}}'\mathbf{X'y} + \hat{\boldsymbol{\beta}}'\mathbf{X'X}\hat{\boldsymbol{\beta}} \tag{4}$$

Note that: $\hat{\boldsymbol{\varepsilon}}'$ is a transpose matrix of $\hat{\boldsymbol{\varepsilon}}$; $\mathbf{y}'$ is a transpose matrix of $\mathbf{y}$; and so on.

To minimize $\sum \hat{\varepsilon}_i^2$, we differentiate the equation (4) partially with respect to $\beta_1, \beta_2, ..., \beta_k$ and setting the resulting expressions to zero. After the process, we get the estimated parameter $\hat{\beta}$:

$$\underset{(k\times 1)}{\hat{\boldsymbol{\beta}}} = \underset{(k\times k)}{(\mathbf{X'X})^{-1}} \; \underset{(k\times n)}{\mathbf{X}'} \; \underset{(n\times 1)}{\mathbf{y}} \tag{5}$$

where $(\mathbf{X'X})^{-1}$ is the inverse matrix of $(\mathbf{X'X})$

and $\mathbf{X}'$ is the transpose matrix of $\mathbf{X}$

3.4.2.3 Variance-Covariance Matrix of $\hat{\boldsymbol{\beta}}$

Regarding the statistical inference, variance and covariance of the estimated parameters would be also needed. The variance-covariance of $\hat{\boldsymbol{\beta}}$, by definition, can be written as:

$$\text{var}(\hat{\boldsymbol{\beta}}) = E\{[\hat{\boldsymbol{\beta}} - E(\hat{\boldsymbol{\beta}})][\hat{\boldsymbol{\beta}} - E(\hat{\boldsymbol{\beta}})]'\} \tag{6}$$

$$\text{var}(\hat{\boldsymbol{\beta}}) = \sigma^2 (\mathbf{X'X})^{-1} \tag{7}$$

where σ^2 is the homoscedastic variance of ε_i. An unbiased estimator of σ^2 can be computed in the following formula:

$$\hat{\sigma}^2 = \frac{\sum \hat{\varepsilon}_i^2}{n-k} = \frac{\hat{\boldsymbol{\varepsilon}}'\hat{\boldsymbol{\varepsilon}}}{n-k} \tag{8}$$

Based on theory, the term $\hat{\boldsymbol{\varepsilon}}'\hat{\boldsymbol{\varepsilon}}$ can be computed from the estimated residuals (RSS). The total sum of square is written as $\text{TSS} = \text{RSS} + \text{ESS}$. RSS refers to Residual Sum of Square in which the source of variation is due to residuals, ESS refers to Explained Sum of Square in which the source of variation is due to the regression (that is, due to X_2, X_3,…, X_k), and TSS refers to the Total Sum of Square.

We have $$\sum \hat{\varepsilon}_i^2 = \sum y_i^2 - \hat{\beta}_2 \sum y_i x_{2i} - \ldots - \hat{\beta}_k \sum y_i x_{ki} \tag{9}$$

then $$\text{TSS}: \ \sum y_i^2 = \sum (Y_i - \bar{Y})^2 = \sum Y_i^2 - n\bar{Y}^2 = \mathbf{y'y} - n\bar{Y}^2 \tag{10}$$

$$\text{ESS}: \ \hat{\beta}_2 \sum y_i x_{2i} + \ldots + \hat{\beta}_k \sum y_i x_{ki} = \hat{\boldsymbol{\beta}}'\mathbf{X'y} - n\bar{Y}^2 \tag{11}$$

where the term $n\bar{Y}^2$ is the correction for mean.

we get $$\text{RSS} = \text{TSS} - \text{ESS} = \mathbf{y'y} - \hat{\boldsymbol{\beta}}'\mathbf{X'y} \tag{12}$$

Therefore $$\text{var}(\hat{\boldsymbol{\beta}}) = \sigma^2 (\mathbf{X'X})^{-1} = \frac{1}{n-k}(\mathbf{y'y} - \hat{\boldsymbol{\beta}}'\mathbf{Xy})(\mathbf{X'X})^{-1} \tag{13}$$

3.4.2.4 The Coefficient of Determination R^2

The coefficient R^2 is also known as the goodness-of-fit. The value of R^2 tells us how well the data can be described by the hedonic model. R^2 value is in a range of 0 to 1. The higher the R^2 is, the better the model will be. This value can be obtained from the ratio of ESS and TSS. That is $R^2 = \frac{\text{ESS}}{\text{TSS}}$. Based on equation (10) and (11), this expression can be written as:

$$R^2 = \frac{\text{ESS}}{\text{TSS}} = \frac{\hat{\boldsymbol{\beta}}'\mathbf{X'y} - n\bar{Y}^2}{\mathbf{y'y} - n\bar{Y}^2} \tag{14}$$

3.4.2.5 Individual Regression Coefficients Test: *t*-test

We will perform *t*-test in order to know whether an explanatory variable has significant effect on sale prices or not. Actually, the distribution of error terms ε should be normal with zero mean and constant variance σ^2, $\boldsymbol{\varepsilon} \sim N(\mathbf{0}, \sigma^2\mathbf{I})$; where $\boldsymbol{\varepsilon}$

and **0** are $(n\times 1)$ column vectors and **I** is an $(n\times n)$ identity matrix. In addition, the OLS estimators $\hat{\beta}_i$ are also normally distributed with a mean equaling to the corresponding of true $\boldsymbol{\beta}$ and the variance equal to σ^2 multiplied by the diagonal element of the inverse matrix $(\mathbf{X'X})^{-1}$. That is $\hat{\boldsymbol{\beta}} \sim N[\boldsymbol{\beta}, \sigma^2(\mathbf{X'X})^{-1}]$. In fact, the value of σ^2 is practically unknown and can be estimated by $\hat{\sigma}^2$. As it usually shift to *t*-distribution, the *t*-test with $(n-k)$ degrees of freedom can be formulated as:

$$t = \frac{Estimator - Parameter}{Estimated\ standart\ error\ of\ estimator} = \frac{\hat{\beta}_i - \beta_i}{\text{se }(\hat{\beta}_i)} \qquad (15)$$

where $\hat{\beta}_i$ is any element of matrix $\hat{\boldsymbol{\beta}}$

β_i is true value of observation *i*

And se($\hat{\beta}_i$) is the standard error of any element of matrix $\hat{\boldsymbol{\beta}}$

In our regression model, if we want to test whether one of the estimated coefficients is statistically significant or equal to zero. The hypothesis that we can test is that the null hypothesis H_0: $\hat{\beta}_i = 0$ and the alternative hypothesis H_1: $\hat{\beta}_i \neq 0$. To test this hypothesis, we use the result from the equation (15) and compare it with the value of $t_{critical}$ which generally equal to 1.96 for 95% confident interval. If the computed *t* has value higher than 1.96, then we fail to reject the null hypothesis. Therefore, we conclude that the alternative hypothesis is true.

3.4.2.6 Overall Regression Coefficients Test: F-test

We perform this test when we have more than one variable, suppose *k*-variable with *n* observations. Under the null hypothesis, we set all slope coefficients equal to zero (H_0: $\beta_2 = \beta_3 = ... = \beta_k = 0$) and the alternative one that not all slope coefficients are simultaneously zero. We have $TSS = RSS + ESS$ with the associated degree of freedom $(n-1)$, $(n-k)$, and $(k-1)$, respectively. Therefore, the value of *F*-test, based on ANOVA technique, can be written as:

$$F(k-1, n-k) = \frac{(\hat{\boldsymbol{\beta}}'\mathbf{X}'\mathbf{y} - n\bar{Y}^2)/(k-1)}{(\mathbf{y}'\mathbf{y} - \hat{\boldsymbol{\beta}}'\mathbf{X}'\mathbf{y})/(n-k)} > F_{critical}(k-1, n-k)$$

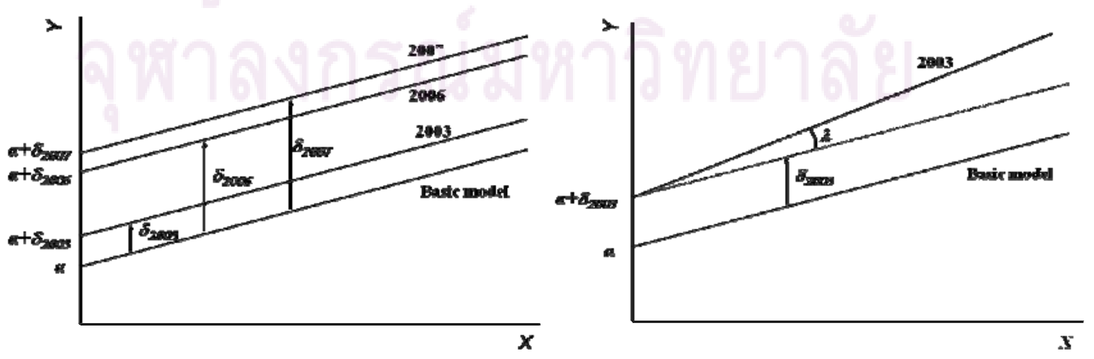
$$F(k-1, n-k) = \frac{ESS/(k-1)}{RSS/(n-k)} > F_{critical}(k-1, n-k) \qquad (16)$$

$$F(k-1, n-k) = \frac{R^2/(k-1)}{(1-R^2)/(n-k)} > F_{critical}(k-1, n-k)$$

3.4.3 Dummy Variables

3.4.3.1 Intercept and Slope Dummy Variables

In empirical analysis, there are four variable scales: ratio scale, interval scale, ordinal scale, and nominal scale (Gujarati and Porter, 2009). Nominal scale variables include indicator variables, categorical variables, qualitative variables, or dummy variables. Basically, dummy variables are usually used to indicate the presence or absence of a quality or an attribute such as gender, marital status, religion, nationality, geographical region, year, interval of noise level, etc. These dummies mostly have value of 1 for the presence of the quality or attribute and zero for its absence. Moreover, there are two types of dummy variable: intercept and slope dummy variable. For example of these dummy types is illustrated in Figure 3.3. The figure presents the different acts of year (Y_i) dummy variables. In Figure 3.3a, we allow the intercept of our model to be different in each year. In the basic model the intercept equals to α and ($\alpha + \delta_{2006}$) for property transacted in 2006. As illustrated in Figure 3.3b, both intercept and slope are allowed to be different in each year. For example, the slope coefficient of variable X in the basic model is β_2 and it will be $\beta_2+\lambda$ in 2003.



a) Intecept dummy variable b) Slope dummy variable

Figure 3.3 Intercept and slope dummy variables
(Source: Adapted from Dougherty (2002))

3.4.3.2 Dummy Variable Tests

There exist several statistical tests for testing the significance of each dummy's coefficient and the overall coefficients. These include *t*-test, *F*-test, and Chow test. We can perform *t*-test to test for each individual's significance of dummy coefficient whereas *F*-test is performed to test for joint explanatory power of dummy variables as a group. For year dummies, for example, the null hypothesis is stated that H_0: $\delta_{2003}=\delta_{2004}=\ldots=\delta_{2008}= 0$ and the at least one of δ is different from zero for the alternative hypothesis (Dougherty, 2002). The *F*-test can be performed based on the reduction in RSS when dummy variables are included in the regression model. If the reduction in RSS is statistically significant, inclusion of dummy variables is warranted. The statistic for the test can be written as follows:

$$F[(df_{res} - df_{unres}), df_{unres}] = \frac{(RSS_{res} - RSS_{unres})/(df_{res} - df_{unres})}{RSS_{unres}/df_{unres}} \qquad (17)$$

where RSS_{res} is residual sum of square of restricted model or model without dummy variables included.

RSS_{unres} is residual sum of square of unrestricted model or model that include dummy variables.

df_{res} is the degree of freedom of the restricted model

df_{unres} is the degree of freedom of the unrestricted model. Note that $df_{unres}<df_{res}$.

3.4.4 Model Development

In attempt to obtain the best possible model, we have tried different combinations of explanatory variables. Thus, several model structures were developed and estimated. Several test statistics such as *t*-test, *F*-test, and Chow test were also used to test and exclude some insignificant variables. The semi-log functional form is technically chosen for some practical reasons. For example, it allows the interpretation of coefficient as an approximate percentage change in price, due to a marginal increase in explanatory variables, and it also allows us to compare our outcomes with those of previous studies. Therefore, our preferred model can be written as:

$$\ln Price_i = \alpha + \mathbf{X}_i\beta + \mathbf{S}_i\gamma + \mathbf{T}_i\delta + \mathbf{N}_i\pi + \varepsilon_i \quad (18)$$

where lnPrice is the natural log of property sale price (in million Baht),

$\mathbf{X}_i$ is a vector of structural variables,

$\mathbf{S}_i$ is a vector of location variables,

$\mathbf{T}_i$ is a vector of temporal dummy variables,

$\mathbf{N}_i$ is a vector of noise dummy variables,

α, β, γ, δ, and π are parameters to be estimated, and

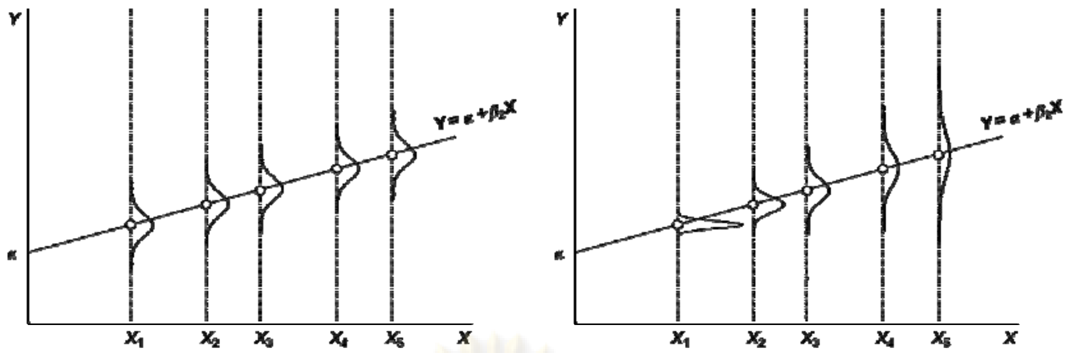
ε_i is the error term.

The definitions of these variables are presented in Table 4.2.

3.5 Model Diagnostics

3.5.1 Heteroscedasticity

The problem of heteroscedasticity often occurs when cross-sectional data are used for the analysis (Gujarati and Porter, 2009). Statistically, heteroscedasticity exists when the variance of distribution of disturbance term is not the same for each observation (Dougherty, 2002). Figure 3.4 illustrates the different between a) homoscedasticity and b) heteroscedasticity. In this study, for example, the larger houses might have larger variance of disturbance term than those of smaller houses. This problem leads to two main consequences: one is that the standard errors of the regression coefficients are estimated wrongly and the *t* tests are invalid. While another consequence is that the OLS estimation technique becomes inefficient. In other words, heteroscedasticity does not affect the unbiasedness and consistency properties of OLS estimators, but OLS estimates are no longer efficient. Heteroscedasticity causes OLS standard errors to be biased in finite samples, thereby leading to incorrect statistical inferences. However it can be demonstrated that they are nevertheless consistent, provided that their variances are distributed independently of the regressors (Dougherty, 2002).



a) Homoscedasticity b) Heteroscedasticity

Figure 3.4 Homoscedasticity and Heteroscedasticity illustration
(Source: Adapted from Dougherty (2002))

3.5.1.1 Detection of heteroscedasticity

Informal and formal methods are used to reveal the heteroscedasticity of in the data set (Gujarati and Porter (2009)). Informal method refers to the graphical method which is done by plotting the OLS residuals $\hat{\varepsilon}_i^2$ against $\hat{Y}_i$ or X_i. If the variances of the disturbance term have a linear relationship with $\hat{Y}_i$ or X_i, thus there is a problem of heteroscedasticity. Different from informal method, there are several tests in formal one. Those tests are: Park Test, Glejser Test, Spearman's Rank Correlation Test, Goldfeld-Quandt Test, Breusch-Pagan-Godfrey Test, Koenker-Bassett Test, and White's General Heteroscedasticity Test. We will not describe the detail of all tests, but particularly we provide an example of White's General Heteroscedasticity Test's procedure which does not rely on normality assumption and is easy to implement. To perform this test, we need to follow the four steps below (Gujarati and Porter (2009)):

For example, we have three-variable regression model:

$$\ln \mathrm{Price}_i = \alpha + X_{2i}\beta_2 + X_{3i}\beta_3 + \varepsilon_i \qquad (19)$$

Step 1. Given the data, we obtain the residuals $\hat{\varepsilon}_i$ from equation (19)

Step 2. Then, the following auxiliary regression is run. Here, we regress the square residuals from equation (19) on the original regressors, their squared values (even higher powers of regression can also be used), and the cross products of the regressors. It may or may not have the constant term, but it is included in this example. Thus, we can compute the value of R^2 from equation (20).

$$\hat{\varepsilon}_i^2 = \psi_1 + X_{2i}\psi_2 + X_{3i}\psi_3 + X_{2i}^2\psi_4 + X_{3i}^2\psi_5 + X_{2i}X_{3i}\psi_6 + \nu_i \qquad (20)$$

Step 3. In the null hypothesis, we state that there is constant variance of disturbance terms. According to this, the product of sample size n and R^2 from equation (20) asymptotically follows the chi-square distribution with $(k-1)$ degree of freedom. It can be written as: $n \times R^2 \sim \chi^2_{df}$ (21)

Step 4. We compare the $n \times R^2 \sim \chi^2_{df}$ computed value to the critical chi-square value at the chosen level of significance. Therefore, we conclude that there is no heteroscedasticity if it does not exceed the critical value. Alternatively, there is heteroscedasticity if it exceeds the critical value and thus corrections are needed.

3.5.1.2 Correction for Heteroscedasticity

In order to remedy the problem of heteroscedasticity, two approaches can be used: when σ_i^2 is known and σ_i^2 is unknown. Methods such as Generalize least Squares (GLS) is used when σ_i^2 is known and White's Heteroscedasticity-Consistent Variances and Standard Errors (known as White's Robust Standard Errors) is used when σ_i^2 is unknow. However, since the value of σ_i^2 is rarely known we will focus only on the technique of White's Robust Standard Errors. In White's Robust Standard Errors, the squared residual for each observation i is used instead of σ_i^2. For k-variable regression model as shown in equation (2), the variance of any partial regression coefficient, say $\hat{\beta}_j$, is obtained by the equation (22) below:

Recall the equation (2):

$$Y_i = \hat{\alpha}_1 + X_{2i}\hat{\beta}_2 + X_{3i}\hat{\beta}_3 + \ldots + X_{ki}\hat{\beta}_k + \hat{\varepsilon}_i$$

The formula to compute the variance of $\hat{\beta}_j$ is written:

$$\text{var}(\hat{\beta}_j) = \frac{\sum \hat{w}_{ji}^2 \hat{\varepsilon}_i^2}{(\sum \hat{w}_{ji}^2)^2} \tag{22}$$

where $\hat{w}_j$ are the residuals obtained from the (auxiliary) regression of the regressor X_j on the remaining regressors in equation (2), and $\hat{\varepsilon}_i$ are the residuals obtained from the equation (2).

However, it consumes much time in following the above procedure. As a new development of statistical package, statistical software such as STATA and LIMDEP are now available for White's heteroscedasticity-robust standard errors. Hence, the correction for such a problem can be done easily. In this thesis, the STATA package will be used if the problem of heteroscedasticity is detected.

CHAPTER IV
HEDONIC REGRESSION ANALYSIS AND RESULTS

4.1 Definition of Variables and Descriptive Statistics

Details about descriptive statistics as well as the definition of variables are provided in Table 4.2. As can be seen, the variables are divided into five different categories: price, structural, location, temporal, and noise level. The discussion and details about the variables used in the hedonic model will be described in the following sections.

4.1.1 Sale Price Characteristics

Sale price, which is the dependent variable in this table, as shown in Table 4.2 was adjusted using Consumer Price Index (CPI) to control for the house price inflation in different years. As can be noted, these adjusted prices provide little difference in average comparing to the original sale price, i.e. the mean of adjusted price is about 13,600 Baht higher than that of actual sale prices. The inflation index of housing price in different year is shown in Table 4.1, and these prices are computed based on the 2007 housing price. It should be noted that the property that could sell for the highest price of 65.46 million Baht is single-family detached house with two stories, floor area of 750 square meters, and lot size of 530 square wa. The lowest sale price about 0.4 million Baht was found in townhouse with one floor, floor area of 96 square meters, and lot size of 17 square wa.

Table 4.1 Consumer Price Index based on house price in 2007

Year	2002	2003	2004	2005	2006	2007	2008
CPI (%)	101.2	99.9	99.3	99.6	99.8	100	100.4

Source: Bureau of Trade and Economic Indices Ministry of Commerce Thailand

Table 4.2 Descriptive statistics and definition of variables (n=384 of unique of obs.)

Category	Definition	Var. Name	Mean	S.D.	Min.	Max.
Price	Sale Price (in million Baht)	Price	4.8436	6.1018	0.4394	65.4582
	Log of sale price	ln(Price)	1.1933	0.8260	-0.8222	4.1814
Structural	Floor area (in square meter)	fa	174.47	97.1232	18	750
	Lot size (in square wa)	lotsize	55.52	44.6487	16	530
	Number of stories	stories	2.17	0.4899	1	4
	Single-family detached unit dummy	SFD	0.5365	0.4993	0	1
	Duplex dummy	DPX	0.1198	0.3251	0	1
	Developer dummy for Land & House PCL/ Quality House PCL	LH	0.0729	0.2603	0	1
	Developer dummy for Preuksa Real Estate	PS	0.0469	0.2116	0	1
	Developer dummy for Noble Home PCL	NO	0.0130	0.1135	0	1
	Developer dummy for Sansiri PCL/Plus property	SA	0.0156	0.1242	0	1
Location	Network distance to airport entrance (in km)	ap_dist	15.63	5.37	2.80	30.73
	Network distance to nearest transit station (in km)	bts	20.11	9.52	2.23	47.99
	Network distance to nearest expressway ramp (in km)	exp	11.79	7.71	1.09	36.55
Temporal	Sale in 2003 dummy	Y03	0.1146	0.3189	0	1
	Sale in 2004 dummy	Y04	0.2161	0.4121	0	1
	Sale in 2005 dummy	Y05	0.1823	0.3866	0	1
	Sale in 2006 dummy	Y06	0.1510	0.3585	0	1
	Sale in 2007 dummy	Y07	0.1536	0.3611	0	1
	Sale in 2008 dummy	Y08	0.1432	0.3508	0	1
Environment	In NEF 35-40 zone dummy	NEF35	0.0130	0.1135	0	1
	In NEF 30-35 zone dummy	NEF30	0.0156	0.1242	0	1
	In buffer zone 500 meter outside NEF 30 dummy	buf5	0.0338	0.1811	0	1
	In NEF 35-40 zone and sold after 2006 dummy	N35af	0.0052	0.0721	0	1
	In NEF 30-35 zone and sold after 2006 dummy	N30af	0.0104	0.1017	0	1
	In buffer zone 500 meter outside NEF 30 and sold after 2006 dummy	buf5af	0.0182	0.1339	0	1

Table 4.3 shows the number of property sold based on different categories of sale price during the period of study. The sales prices were categorized into six intervals with five million Baht increments. As can be seen, most of the properties could sell for less than five million Baht while the majority of these sales are single-family detached unit type. The highest sale price that a duplex could sell is 15 million Baht; whereas the maximum that the townhouse type could sell is 10 million Baht. In other words, the townhouse type is cheaper on average than others while single-family detached house one could sell for higher price on average. In addition, there is no duplex sold in the range of price between five and 10 million Baht. The data table also shows that there are single-family detached houses in all prices categories.

Table 4.3 Property sale prices and property types

Sale Prices (million Baht)	Type of property			Total
	SFD	DPX	TH	
≤ 5	11,377	3,480	14,663	29,520
5 to 10	6,343	0	274	6,617
10 to 15	754	26	0	780
15 to 20	318	0	0	318
20 to 25	220	0	0	220
> 25	84	0	0	84
Total	19,096	3,506	14,937	37,539

The scatter diagram in Figure 4.1, Figure 4.2, and Figure 4.3 shows the plot between sale prices and the distances to transportation facilities. The observations seem to be close to each other in the range of sale prices below 10 million Baht and spread along the axis. This shows that the sale prices are stable over a wide range of distance from the transportation facilities. In Figure 4.1, the properties which could sell for the price higher than 10 million Baht are only those located from approximately 10 to 22 km from the airport entrance.

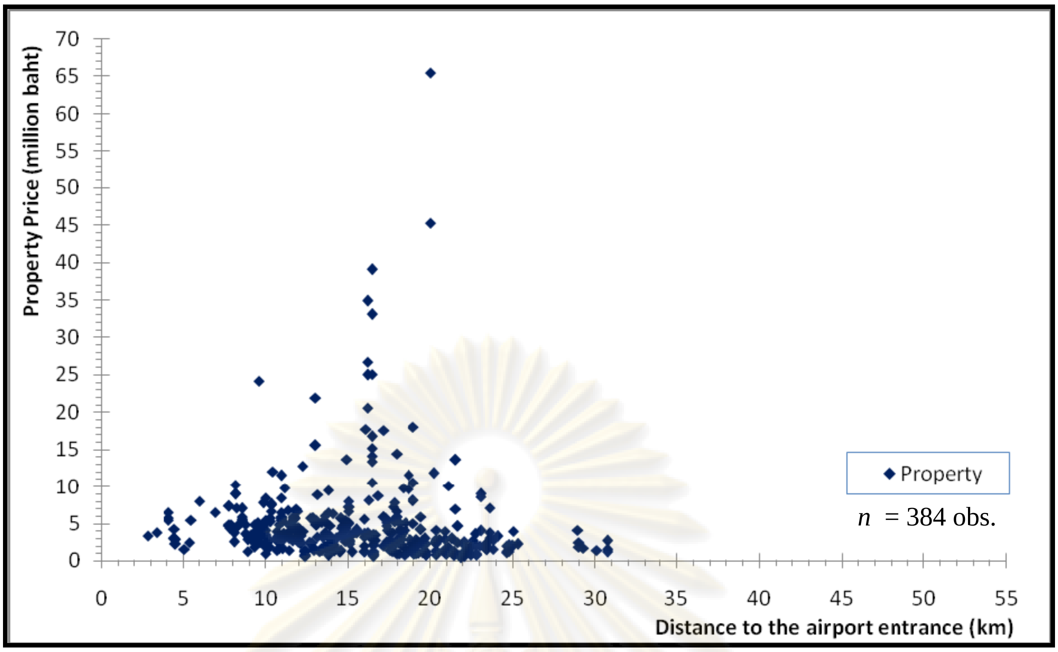


Figure 4.1 Property prices and distances to the airport entrance

The distribution of property sale prices with respect to the distance to the nearest BTS stations is shown in Figure 4.2. As can be seen, only the properties located less than 15 km from the nearest BTS stations could sell for price more than 15 million Baht. It is also can be explained by the figure that closer the locations of properties to the BTS stations, the higher the price the properties could sell. On the other hand, there is only few properties located less than five km from the BTS stations.

Similar to Figure 4.2, Figure 4.3 shows that most of the properties situated near to the expressway ramps. The properties that could sell higher than 10 million Baht are those located between four to 15 km from the expressway ramps. Particularly, there is only a dozen of properties that could sell for higher than 20 million Baht with the distance less than 10 km from the expressway ramps. Yet, there is no property located further than 37 km.

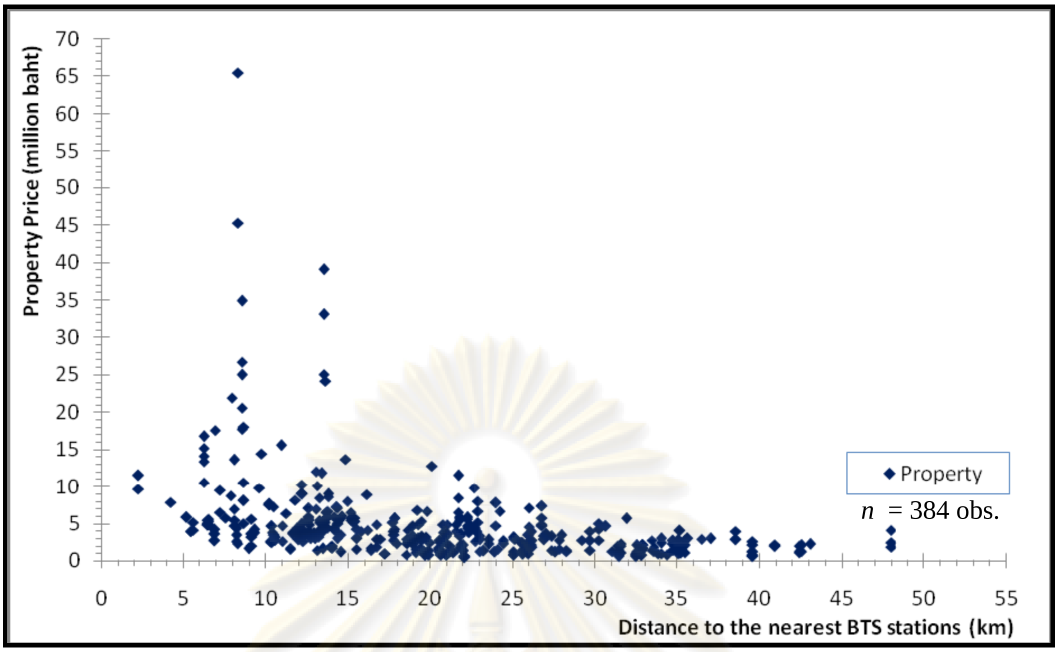


Figure 4.2 Property prices and distance to the nearest BTS stations

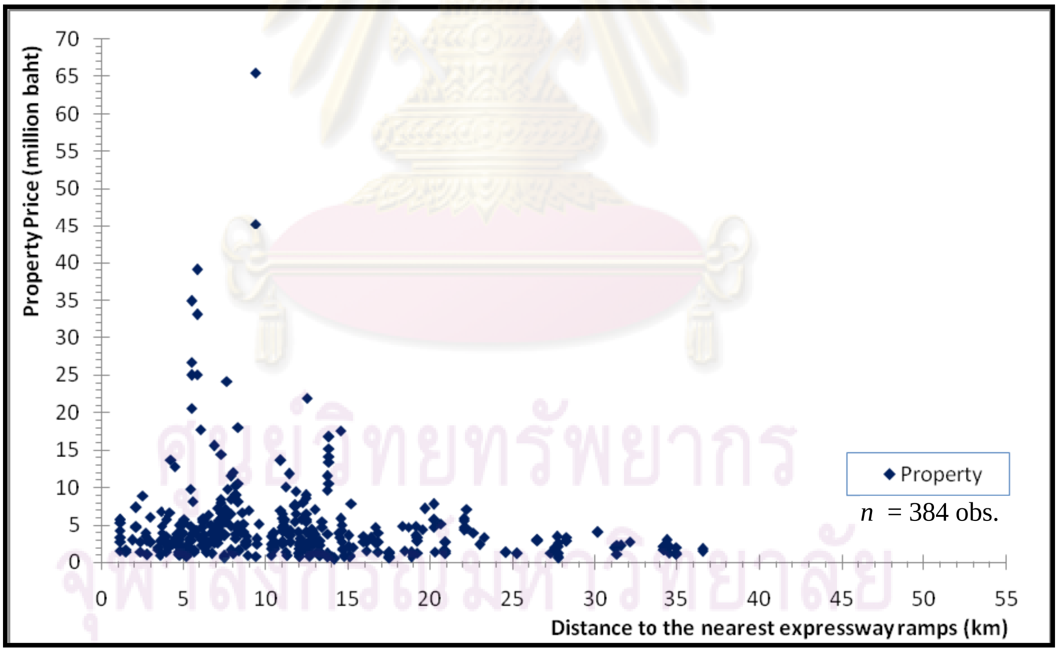


Figure 4.3 Property prices and distance to the nearest expressway ramps

4.1.2 Structural Characteristics

Structural variables consist of three quantitative variables, namely floor area in square meter, lot size in square wa, and number of floors. We are expecting the coefficients of these variables to be positive. If we cross-tabulate between the type of property and the number of stories, as shown in Table 4.4, we can see that the highest floor has four stories. Most of the properties constructed and sold have two stories while properties with three stories were less popular. Moreover, most of the three or more story-properties sold were of townhouse type. Most properties of duplex and single-family detached unit type have two stories. There is no duplex with three stories and single-family detached type with 3.5 stories that were sold during the period of study.

Table 4.4 Distribution of property types with different number of stories

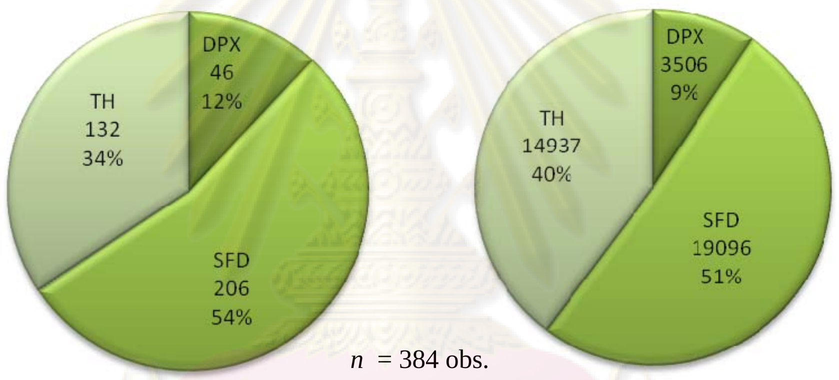
Property type	Number of Stories 1	2	3	3.5	4	Total
Duplex	36	3,444	0	12	14	3,506
Single-family detached	426	18,456	185	0	29	19,096
Townhouse	366	9,867	4,194	282	228	14,937
Total	828	31,767	4379	294	271	37,539

The names of project developer are also provided in the data set. To control for the price premium attached to reputable developers, we generated brand variables for properties whose developers are major companies that are listed in the Stock Exchange of Thailand (SET). By doing so, the dummy variable can capture the effect of branding on price. LH dummy in Table 4.2 equals to 1 if the project developer is Land & House PCL or Quality House PCL and 0, otherwise. SA dummy equals to 1 if the project developer is Sansiri PCL or Plus property or Plus property partner or Plus property venture and 0, otherwise. Land & House and Sansiri command substantial price premium over smaller developers. List of project owners and their project transacted during the period of study is shown in Table 4.5. As can be seen, Land & House PCL project appears to have the highest number of project sales. It was up to 23 of unique observations which equal to 4,587 property sales. Preuksa Real Estate PCL had also a high number of project sales after Land & House PCL. Preuksa Real Estate PCL sold more than 3,000 properties during the study period. Most of the developers appear to have up to 10 unique property types in total while there were 99 developers with the highest number of three property types.

Table 4.5 Project owners and number of projects sold

No.	Project developer or Owner	Property type DPX	SFD	TH	Total
1	Ananda Development	4	12	1	17
2	Ananda Development On	2	5	0	7
3	Asian Property Develo	1	1	7	9
4	Bhumivivat	0	2	4	6
5	Denchai Karnkaeha & L	0	2	3	5
6	Dynamic Property	0	0	4	4
7	East Bangkok Assets	0	3	2	5
8	FM Intergroup	0	0	4	4
9	Gold Residence Park	1	1	2	4
10	K.C. Property PCL	1	4	0	5
11	K.K. Asset	1	4	0	5
12	Kallapapreuk Group	1	2	3	6
13	Lalin Property PCL	1	11	4	16
14	Land & House PCL	1	20	2	23
15	MK Real Estate Develo	3	4	0	7
16	N Gate Development	0	4	0	4
17	NOBLE Development PLC	0	5	0	5
18	Nakorntong Real Estat	0	0	4	4
19	OGC Real Estate	0	1	3	4
20	Peace & Living	1	0	3	4
21	Petchboonma	0	4	0	4
22	Plus Property Partner	0	0	4	4
23	Preuksa Real Estate PCL	5	3	10	18
24	Prinsiri PCL	1	5	2	8
25	Quality Houses PCL	0	5	0	5
26	Supalai PCL	0	4	2	6
27	Ta Pra Kaehakarn (199	1	0	4	5
28	Tarasiri	2	2	0	4
29	Turakijanant (Chomcho	2	3	1	6
30	United Homes	0	4	0	4
31	Unnamed	0	5	4	9
32	V.A. Land	0	4	0	4
33	Other 99 owners	The total of projects that could sell not higher than 3			
	Total	**46**	**206**	**132**	**384**

The graphs shown in Figure 4.4 demonstrate the distribution of property type with respect to the number of unique observations and number of properties sold. According to Figure 4.4a, 54 percent or 206 of unique observations is single-family detached, 34 percent is townhouse type, and 12 percent is duplex type. With regard to the number of properties sold during the period of study, as seen in Figure 4.4b, project developers sold up to 19,096 single-family type units, representing 51 percent the largest share of all property types. In all, there are 37,539 properties and 384 unique observations sold and used in our data analysis. As for hedonic modeling expectation, the coefficient of the property type such as the single-family detached unit and duplex dummy are also expected to be positive since people seem to prefer those to townhouse, which is the baseline type in this study.



a) Number of unique observations b) Number of properties sold

Figure 4.4 Distribution of property types

4.1.3 Location Characteristics

Location characteristics consisting of three transportation access variables are also utilized for hedonic modeling. These transportation access characteristics, which were, as discuss earlier, measured as network distance, include distance to airport entrance, distance to the nearest expressway ramp, and distance to the nearest transit stations (BTS). The properties, on average, are located about 15 kilometers from the airport entrance, 11 kilometers from the expressway ramp, and 20 kilometers from the BTS station. The coefficients of these variables are expected to be negative due to the benefits of convenient transportation access amenities. The variable represented the distance to airport entrance will capture economic, employment, and other service-related benefits. These positive effects are reflected by negative coefficient in hedonic price function, i.e. the further the house located from the airport entrance the cheaper price the house can be sold. However, the distance to the airport entrance might be correlated with the airport noise level. Therefore, it is extremely important that both distance to the airport entrance and noise are included in the hedonic model to possibly account for the negative effect of confounding variables which are correlated with both dependent and independent variables.

The distances from each unique observation to the airport entrance and to the nearest expressway ramps are presented in Figure 4.5. The figure shows that the furthest distance from the property to the airport entrance is 30 km and to the nearest expressway ramp is 36 km. In addition, most of the properties located on average from eight to 20 km from the airport entrance, and the majority are within 15 km of an expressway ramp. It should be noted that the two distances do not seem to be correlated, and thus the problem of multicollinearity is not of concern.

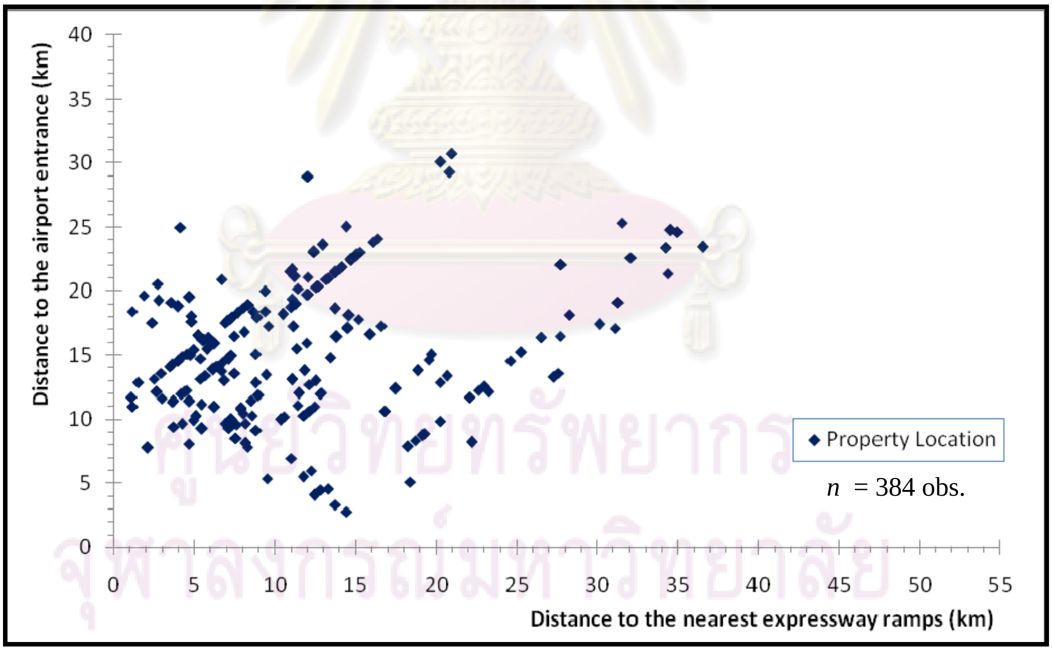


Figure 4.5 Distances to the airport entrance and expressway ramps

Similarly, Figure 4.6 shows the distances from each unique observation to the nearest BTS stations and the airport entrance. The distribution seems to be more scattered than that in Figure 4.5. As illustrated, most of the properties are located further from the nearest BTS stations than they are from the nearest expressway ramps. The longest distance from the property to the nearest BTS stations is approximately 50 km and about 28 km to the airport entrance. The distances from each unique observation to the nearest expressway ramps and BTS are stations also presented in Figure 4.7.

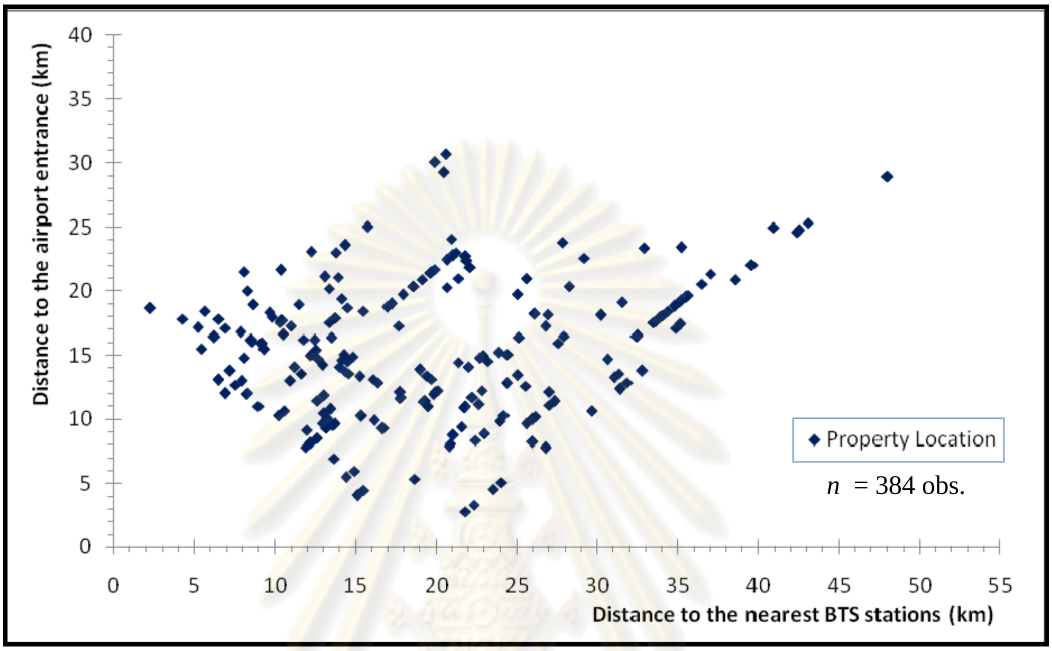


Figure 4.6 Distances to the airport entrance and BTS stations

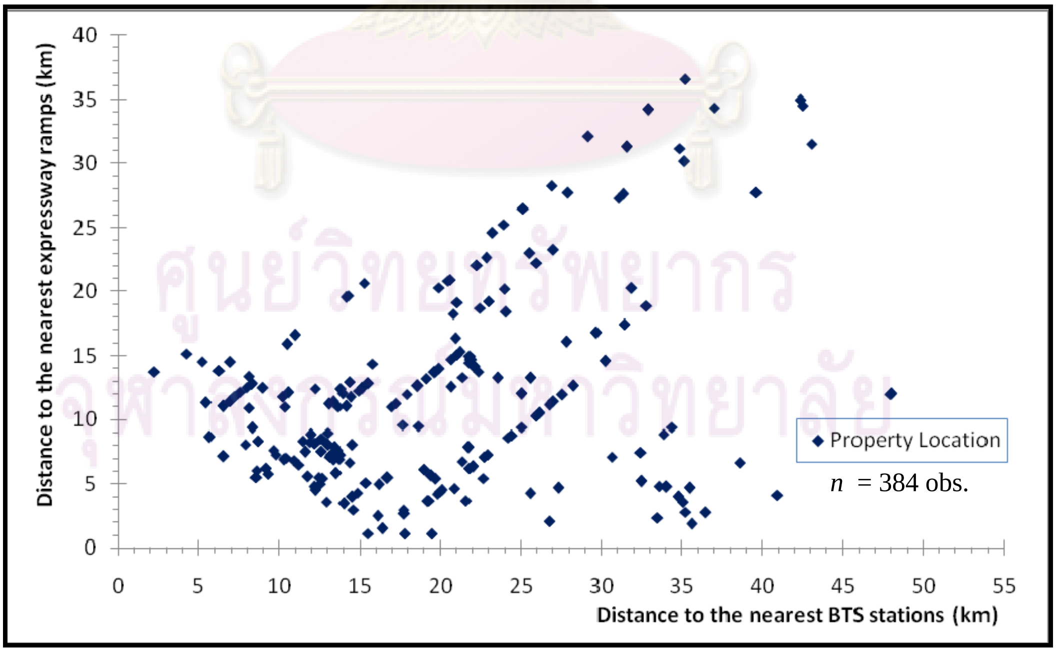


Figure 4.7 Distances to expressway ramps and BTS stations

4.1.4 Temporal Variables

The estimation strategy utilizes a fixed-effects model in time and space. In order to control for different year of properties sold, yearly dummy variables, therefore, were created for each year between 2003 and 2008 with 2002 as base year. For instance, Y05 in Table 4.2 is a dummy variable equal to 1 if the property was sold in year 2005. The years are divided as before and after 2006 to facilitate analyzing the airport noise impact on property values which happened only after 2006, the airport opening year.

The percentage of sales for each property types over years is illustrated in Figure 4.8. Each column shows different percentile of property types that were sold. The highest column represents the single-family type which accounted for up to 14 percent of all sales in 2004. Among the property types, single-family units sold more than others in each year, except in 2002 and 2007 where townhouse type sold about 0.2 and five percent higher, respectively.

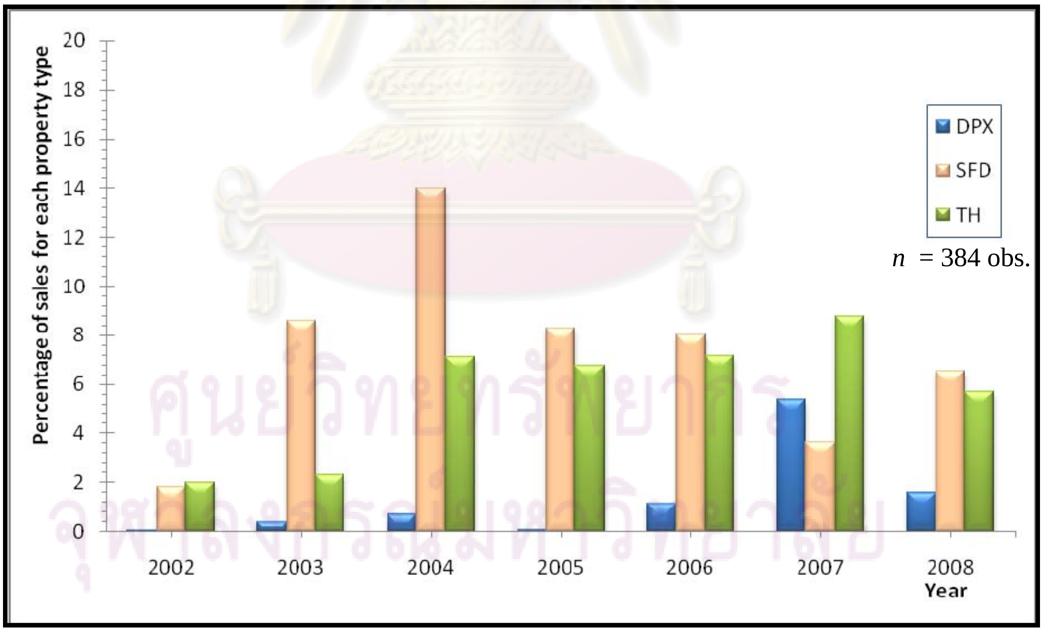


Figure 4.8 Distribution of sales of each property types over years

Figure 4.9 shows the distribution of transacted prices from 2002 to 2008. The sale prices were categorized into six intervals. In all years, the majority of sale prices are those properties which were valued at most five million Baht. Most of these prices (17.6 percent) were transacted in 2007. For properties sold for more than 25 million

Baht, there is about 0.22 percent in total which sold only two years: about 0.16 percent in 2004 and about 0.06 percent in 2006.

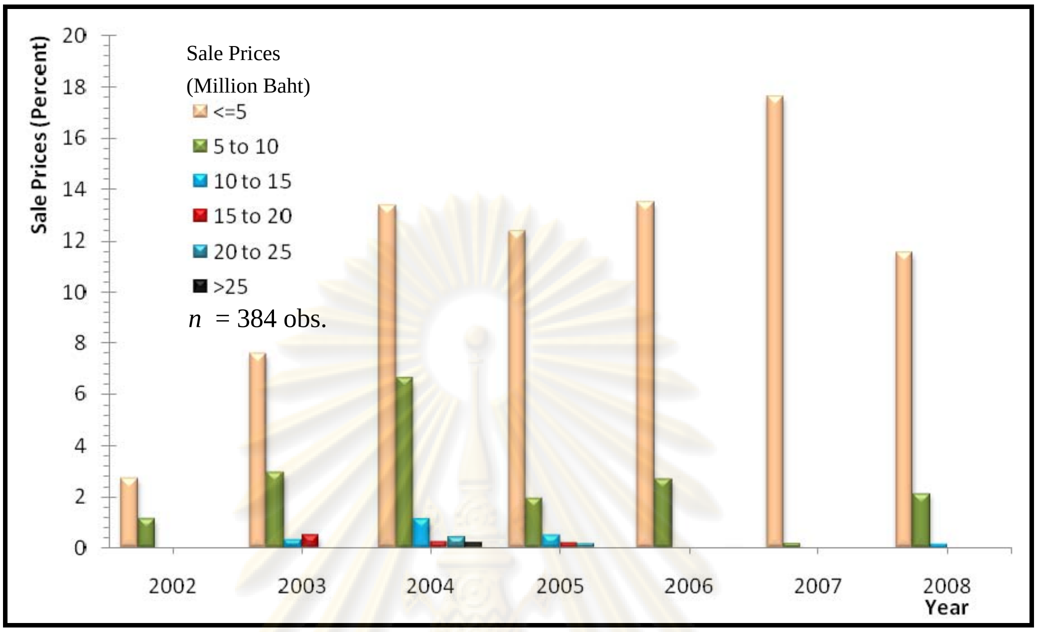


Figure 4.9 Distribution of transacted prices over years

4.1.5 Noise Level

Central to this study, the variables that capture airport noise impact were defined as dummy variables based on the noise contour maps as approved by the Thai cabinet in 2007 and publicly distributed by the AoT (as illustrated in Figure 3.2). The noise dummies, NEF30 and NEF35 were created according to the levels of NEF shown in the noise contour map. For instance, we created a dummy variable NEF30 taking value of 1 for a house situated in noise contour level between NEF 30 and NEF 35 and 0, otherwise. Since we know that noise impact only occurred after the airport began in 2006 and because of the data available includes both property sold before and after this year, hence N30af and N35af, dummy variables, were also created to control for the effect of airport noise only after airport operation began. These dummies are similar to those of noise, and the suffix *–af* was marked if the property was sold after the airport operation began. For example, N35af valued 1 if the property is located in the noise contour between NEF 35-40 and was sold after the airport operation began. Moreover, dummy variable buf5 and buf5aft which represent the buffer zone 500 meters extended from the NEF 30 contour line were additionally created to control for the effect of those properties located just outside the noise contour line NEF 30. And again, for example, buf5 takes value of 1 if the property is located in buffer zone, not further than 500 meters outside NEF30 contour line. Similar to buf5, buf5af equals to 1 if property is situated in 500 meters buffer zone and was sold after the airport operation began. Table 4.6 describes the distribution of sold properties in different conditional locations. As can be seen, there is no townhouse unit type sold and located between noise contour line of NEF 35-40. While 925 single-family detached units were sold and located between noise contour line NEF 30-35. There are 34,960 properties were sold from 2002 to 2008 and located outside the buffer zone. We can also see that the majority of property sold was single-family detached units.

Table 4.6 Distribution of properties in different conditional locations

Property type	Between NEF30-35	Between NEF35-40	In buffer zone 500m	Outside buffer zone	Total
Single-family detached	925	151	299	17,721	19,096
Duplex	186	160	2	3,158	3,506
Townhouse	189	0	667	14,081	14,937
Total	1,300	311	968	34,960	37,539

4.1.6 Correlation among Variables

One of the classical linear regression model’s assumptions is that there is no correlation among the regressors included in the regression model. If it has, the problem of multicollinearity may exist in our model (Gujarati and Porter (2009)).With concern about the multicollinearity, the correlation factors among the explanatory variables used in the hedonic model are shown in Table 4.7. As can be seen, there are only two pair variables which provide the positive correlation factors higher than 0.5, i.e. 0.622 for a pair-wise of lot size and floor area and 0.554 for a pair-wise of lot size and single-family detached type. Whereas, the highest negative correlation factor of −0.475 occurs in pair-wise of floor area and distance to nearest BTS station. These correlation factors might not be significant for our estimated model since a serious problem of multicollinearity occurs only when the correlation factor is higher than 0.8 (Gujarati and Porter (2009)).

Table 4.7 Correlation among explanatory variables

	fa	lotsize	stories	ap_dist	bts	exp	SFD	DPX	LH	PS	NO	SA	Y036	Y04	Y05	Y06	Y07	Y08	NEF30	NEF35	buf5
fa	1.000																				
lotsize	**0.622**	1.000																			
stories	0.269	-0.154	1.000																		
ap_dist	-0.164	-0.048	-0.061	1.000																	
bts	-0.475	-0.130	-0.436	0.296	1.000																
exp	-0.256	0.030	-0.174	0.319	0.364	1.000															
SFD	0.397	**0.554**	-0.316	-0.183	-0.037	0.027	1.000														
DPX	-0.178	-0.118	-0.086	0.036	0.177	-0.005	-0.397	1.000													
LH	0.087	0.255	-0.076	0.001	0.044	-0.080	0.200	-0.073	1.000												
PS	-0.169	-0.120	-0.076	0.007	0.125	0.077	-0.165	0.108	-0.062	1.000											
NO	0.168	0.138	-0.039	0.017	-0.168	0.030	0.107	-0.042	-0.032	-0.026	1.000										
SA	0.030	-0.063	0.214	-0.013	-0.144	-0.049	-0.093	-0.047	-0.035	-0.028	-0.015	1.000									
Y03	0.051	0.062	-0.023	-0.015	-0.061	-0.084	0.121	-0.057	0.025	-0.080	-0.041	0.021	1.000								
Y04	0.224	0.166	-0.057	0.010	-0.074	-0.027	0.108	-0.057	0.096	-0.117	0.219	-0.066	-0.189	1.000							
Y05	0.049	-0.007	0.059	0.013	0.039	-0.020	0.114	-0.133	-0.081	-0.073	-0.054	0.049	-0.170	-0.248	1.000						
Y06	0.047	-0.045	0.108	-0.200	-0.174	-0.104	-0.016	-0.044	-0.062	-0.025	-0.048	0.064	-0.152	-0.222	-0.199	1.000					
Y07	-0.172	-0.209	-0.021	0.047	0.104	-0.010	-0.241	0.243	-0.064	0.247	-0.049	0.005	-0.153	-0.224	-0.201	-0.180	1.000				
Y08	-0.219	0.019	-0.042	0.109	0.154	0.271	-0.082	0.078	0.000	0.085	-0.047	-0.052	-0.147	-0.215	-0.193	-0.173	-0.174	1.000			
NEF30	0.003	0.031	0.000	-0.122	0.001	-0.100	-0.009	0.083	0.045	-0.028	-0.015	0.153	-0.045	0.036	-0.060	-0.053	0.121	0.008	1.000		
NEF35	0.068	0.007	-0.039	-0.166	0.052	-0.129	0.061	0.028	-0.032	-0.026	-0.013	-0.015	-0.041	0.107	-0.054	0.080	-0.049	-0.047	-0.015	1.000	
buf5	-0.016	-0.049	-0.005	-0.197	0.031	-0.100	0.001	-0.025	0.058	0.027	-0.022	-0.024	-0.067	-0.028	0.061	0.162	-0.080	-0.035	-0.024	-0.022	1.000

4.2 OLS Estimation of Base Model

Table 4.8 shows the basic OLS estimation results of the semi-log hedonic model of the property prices described in Chapter 3. The estimation was carried out by STATA Statistical Software. As can be seen, we obtained a very high value of R^2. This can be interpreted that about 92 percent of the house price valuations can be described by the model. According to *t*-statistics, all of the coefficients of property characteristics are statistically significant at the one-percent level. In addition, all the coefficients of both temporal and location variables are also statistically significant at the 5-percent level, except the distance from the property to the nearest expressway ramp. Most of the variables included in the model show its expected sign as discussed a priori in Chapter 3. However, our key variables, the coefficient of noise dummies are not significant even at the 10-percent level. Based on the insignificant *t*-statistic, this evidence seemed to indicate that there is no noise impact on the sale prices of properties either before or after the airport operation began. However, we believe that the significance of noise variables might be affected by some unexpected econometric issues. Therefore, the results from the table are put on hold and we will find the ways to improve it and explore ways to correct for those problems. Thus, several tests such as overall coefficients test, Chow test for group of dummies, and White test for heteroscedasticity will be performed. In order to improve our hedonic model, corrections for the econometric issues would be needed while some of variables might be omitted from the model. After selecting the best model, we will discuss and conclude the results from the analysis of our best model.

Table 4.8 OLS estimation results of the hedonic model of property prices: Base Model

				Number of obs =	384
	SS	df	MS	F(24, 359) =	182.44
Model	241.52449	24	10.063520	Prob > F =	0.0000
Residual	19.802992	359	0.0551615	R-squared =	0.9242
Total	261.32748	383	0.6823172	Adj R-squared =	0.9192
Dependent variable = ln (Sale Price)				Root MSE =	0.23486

	Coef.	Std. Err.	t	P > | t |	[95% confident interval]	
Structural variables						
fa	0.003912	0.000215	18.20	0.0000	0.003490	0.004335
lotsize	0.002477	0.000432	5.74	0.0000	0.001628	0.003326
stories	0.280335	0.033273	8.43	0.0000	0.214900	0.345770
SFD	0.721265	0.036738	19.63	0.0000	0.649016	0.793514
DPX	0.468448	0.043601	10.74	0.0000	0.382702	0.554194
LH	0.212605	0.050751	4.19	0.0000	0.112799	0.312411
PS	-0.199686	0.060339	-3.31	0.0010	-0.318349	-0.081023
NO	0.276056	0.102070	2.70	0.0070	0.075325	0.476786
SA	0.330974	0.111929	2.96	0.0030	0.110854	0.551093
Location variables						
ap_dist	-9.87E-03	2.63E-03	-3.75	0.0000	-1.50E-02	-4.69E-03
bts	-1.79E-02	1.74E-03	-10.26	0.0000	-2.13E-02	-1.45E-02
exp	-2.73E-03	1.88E-03	-1.45	0.1470	-6.43E-03	9.65E-04
Temporal variables						
Y03	0.125115	0.071510	1.75	0.0810	-0.015516	0.265745
Y04	0.134926	0.067621	2.00	0.0470	0.001943	0.267909
Y05	0.170481	0.069142	2.47	0.0140	0.034508	0.306455
Y06	0.222363	0.070851	3.14	0.0020	0.083028	0.361697
Y07	0.147109	0.070557	2.08	0.0380	0.008352	0.285865
Y08	0.296435	0.070932	4.18	0.0000	0.156941	0.435929
Environmental variables						
NEF35	-0.053620	0.143360	-0.37	0.7090	-0.335550	0.228310
NEF30	0.041905	0.171163	0.24	0.8070	-0.294704	0.378513
buf5	-0.035014	0.101450	-0.35	0.7300	-0.234524	0.164496
N35af	-0.207770	0.220605	-0.94	0.3470	-0.641609	0.226070
N30af	-0.139532	0.211536	-0.66	0.5100	-0.555538	0.276474
buf5af	-0.008867	0.138633	-0.06	0.9490	-0.281502	0.263768
_cons	-0.315558	0.114404	-2.76	0.0060	-0.540543	-0.090573

4.3 Overall Coefficients Test

We will test whether all of the estimated coefficients from Table 4.8 are equal to zero or not. The *F*-test was used in this case. So the hypothesis is set up as follow:

H_0 : All slope coefficients are simultaneously zero

H_1: Some slope coefficients are zero

From equation (16), we have:

$$F(k-1, n-k) = \frac{R^2/(k-1)}{(1-R^2)/(n-k)} \square F_{critical}(k-1, n-k)$$

From the table, we obtain:

Number of observations	n = 384
Number of variables	k = 25
Coeffient of determination	R^2 = 0.9242

Thus, the value of F-test can be computed

$$F(24, 359) = \frac{0.9242/(25-1)}{(1-0.9242)/(384-25)} = 182.44$$

In addition, the value of $F_{critical}$ with 24 and 359 degree of freedom at 5-percent level is $F_{critical,95\%}(24,359) = 1.5477$. We can see that the value of computed *F*-test is 182.44 higher than the criticle value. Therefore, we conclude that the null hypothesis is rejected at 5-percent level that all the slope coefficients estimated are not simultaneously zero.

4.4 Year Dummy Variables

To test whether year dummy variables should be included in the hedonic model, we consider statistical performance of restricted and unrestricted models. In the restricted model, the year dummies are excluded. This means that there is no effects of time on property sale prices even the properties were sold in different year. In unrestricted one, we include the temporal variables in the regression model and the effects of time on the sale prices are allowed to be different in each year. In addition, this unrestricted model was already run and the estimated results are shown in Table

4.8. Thus, we run OLS regression only for the restricted model using the same number variables which are present in Table 4.8, but excluding the six temporal variables (Y_{03}, Y_{04},…, and Y_{08}). The estimated results from the restricted model are presented in Table 4.9.

Table 4.9 OLS estimation results without year dummies

	SS	df	MS		
				Number of obs =	384
				F(18, 365) =	228.72
Model	240.04543	18	13.335857	Prob > F =	0.0000
Residual	**21.282051**	365	0.0583070	R-squared =	0.9186
Total	261.32748	383	0.6823172	Adj R-squared =	0.9145
Dependent variable = ln (Sale Price)				Root MSE =	0.24147

Note: see Table A.1 in Appendix for full estimation results

However, we can set up our hypothesis as follow:

H_0 : $\delta_{2003}=\delta_{2004}=\ldots=\delta_{2008}= 0$

H_1: At least one of the δ's is different from zero

From equation (17), we have

$$F[(df_{res} - df_{unres}), df_{unres}] = \frac{(RSS_{res} - RSS_{unres})/(df_{res} - df_{unres})}{RSS_{unres}/df_{unres}}$$

Where $df_{unres} = 359$ (from Table 4.8)

$df_{res} = 365$ (from Table 4.9)

$RSS_{unres} = 19.802992$ (from Table 4.8)

and $RSS_{res} = 21.282051$ (from Table 4.9)

$$F(6,359] = \frac{(21.282051 - 19.802992)/(365 - 359)}{19.802992/359} = 4.468872$$

We also have $F_{critical,95\%}(6,359) = 2.123852$

The values of $F_{critical,95\%}$ is smaller than that computed from the model. The null hypothesis is rejected at 5-percent level. Therefore, we will use the regression model which provides different effects of sale years on property prices.

4.5 Brand Name/Developer Dummy Variables

To test for appropriateness of the dummy variables for brand name of developers, similar procedure to those used from the temporal variables was used. Since we have already tested and chosen the four developer names which have significant effects on the housing prices, we run another model without including those four developer variables as a restricted model. Table 4.10 provides the estimated results of this model. Again, we are interested in observing whether there is a significant reduction in RSS of the two models, with and without developer variables.

Table 4.10 OLS estimation results without developer dummies

	SS	df	MS		
				Number of obs =	384
				F(20, 363) =	196.04
Model	239.1827	20	11.959134	Prob > F =	0.0000
Residual	**22.14479**	363	0.0610049	R-squared =	0.9153
Total	261.3275	383	0.6823172	Adj R-squared =	0.9106
Dependent variable = ln (Sale Price)				Root MSE =	0.24699

Note: see Table A.2 in Appendix for full estimation results

The hypotheses to be tested are stated as follow:

H_0: All coefficients of developer dummies are zero

H_1: At least one of them is different from zero

From equation (17), we have

$$F[(df_{res} - df_{unres}), df_{unres}] = \frac{(RSS_{res} - RSS_{unres})/(df_{res} - df_{unres})}{RSS_{unres}/df_{unres}}$$

Where $df_{unres} = 359$ (from Table 4.8)

$df_{res} = 363$ (from Table 4.10)

$RSS_{unres} = 19.802992$ (from Table 4.8)

and $RSS_{res} = 22.144795$ (from Table 4.10)

$$F(4, 359] = \frac{(22.144795 - 19.802992)/(363 - 359)}{19.802992/359} = 10.613387$$

We also have $F_{critical,95\%}(4, 359) = 2.396812$

We can see that the computed F-value from Chow test is higher than that of $F_{critical,95\%}$. So we reject the null hypothesis at 5-percent level. The brand names of developers have significant effects on the sale prices of the residential properties. Hence, we include these variables in the model.

4.6 Chow Test for Market Segmentation

Since we do not know the exact nature of how the airport noise effects housing market, we might wish to consider whether distinction can be made between three types of the properties, namely single-family detached, duplex, and townhouse. In other words, we should investigate whether we should apply one restricted regression model for all of the different types of properties or whether we should estimate one separately for each of them using dummy variables. The restricted regression model refers to the regression in which the effect of property types on sale prices are supposed to be the same. The unrestricted one is already provided in Table 4.8. Thus we run another regression model excluding property type variables. Table 4.11 provides the OLS estimation results for restricted model.

Table 4.11 OLS estimation results without property types

				Number of obs=	384
	SS	df	MS	F(22, 361)=	86.87
Model	219.8072	22	9.9912344	Prob > F=	0.0000
Residual	**41.52033**	361	0.1150147	R-squared=	0.8411
Total	261.3275	383	0.6823172	Adj R-squared=	0.8314
Dependent variable = ln (Sale Price)				Root MSE =	0.33914

Note: see Table A.3 in Appendix for full estimation results

We are interested in observing whether there is a significant reduction in the total residual sum of square (RSS) when we allow different effects of property types on sale prices. To accomplish this, we use Chow test to test the following hypotheses:

H_0 : Identical effects of property types on sale prices

H_1: Different effect of property types on sale prices

Recall equation (17), the Chow test can be written:

$$F[(df_{res} - df_{unres}), df_{unres}] = \frac{(RSS_{res} - RSS_{unres})/(df_{res} - df_{unres})}{RSS_{unres}/df_{unres}}$$

Where $df_{unres} = 359$ (from Table 4.8)

$df_{res} = 361$ (from Table 4.11)

$RSS_{unres} = 19.802992$ (from Table 4.8)

and $RSS_{res} = 41.52033$ (from Table 4.11)

$$F(2,359) = \frac{(41.52033 - 19.802992)/(361 - 359)}{19.802992/359} = 196.8522$$

We also have $F_{critical,95\%}(2,359) = 3.0209$

As results, we get a computed F-values of F (2,359) = 196.85 higher than the critical value of $F_{critical,95\%}(2,359) = 3.0209$. We come to the conclusion that there is significant different effect of property types on sale prices. Therefore, we include these types of property to our base model are preferred.

4.7 Environmental Dummy Variables

In this section, we will test the significance of three environmental dummies, namely NEF35, NEF30, and buf5. Since the effect of noise just shown itself only after the airport operation initiated, we believe that the noise problem would have no effect on the property sale price before the opening of the airport. Hence, we keep other three dummies as our main control variables for the decline in property prices. So the test procedure is the same for year and developer dummy variables. We run another regression model with all the independent variables shown in Table 4.8 except NEF35, NEF30, and buf5. The estimation results of this regression are shown in Table 4.12

Table 4.12 OLS estimation without NEF35, NEF30, and buf5

	SS	df	MS		
				Number of obs =	384
				F(21, 362) =	210.04
Model	241.5068	21	11.500321	Prob > F =	0.0000
Residual	19.82073	362	0.0547534	R-squared =	0.9242
Total	261.3275	383	0.6823172	Adj R-squared =	0.9198
Dependent variable = ln (Sale Price)				Root MSE =	0.2340

Note: see Table A.4 in Appendix for full estimation results

Again, the hypothesis is stated that

H_0 : NEF35's, NEF30's, and buf5's coefficients are zero

H_1: At least one of them is different from zero

From the equation (17), we have

$$F[(df_{res} - df_{unres}), df_{unres}] = \frac{(RSS_{res} - RSS_{unres})/(df_{res} - df_{unres})}{RSS_{unres}/df_{unres}}$$

Where df_{unres} = 359 (from Table 4.8)

df_{res} = 362 (from Table 4.12)

RSS_{unres} = 19.802992 (from Table 4.8)

and RSS_{res} = 19.82073 (from Table 4.12)

$$F(3,359) = \frac{(19.82073 - 19.802992)/(362 - 359)}{19.802992/359} = 0.107188$$

We also have $F_{critical,95\%}(3,359) = 2.629776$

The computed *F*-value is smaller than the value of *F*-criticle. We now fail to reject the null hypothesis at 5-percent level. In other words, it shows the insignificant reduction in RSS when NEF35, NEF30, and buf5 dummies variables are excluded from the model. Since these dummies have no significant effect on the property prices, we would drop them from the model. Note that N35af, N30af, and buf5af are still included in the model.

4.8 Multicollinearity

The problem of multicollinearity can be detected when there is high correlation between explanatory variables. As can be seen in Table 4.7, the highest correlation factors found are 0.622 and 0.554 occurred in pair-wise of lot size – floor area and lot size – single-family detached house, respectively. As mentioned earlier in section 4.9.3, it will lead to the imprecise estimate of coefficients if the problem occurred in our data set. However, the problem does not lead to biasness but it would lead to high standard error or low *t*-statistic. In our hypothesis in Table 4.8, it can be seen that standard error and *t*-statistic of the two variables with high correlation do not raise the concerns on the multicollinearity problem because both have high *t*-statistic and low standard error value.

4.9 Test for Heteroscedasticity

As mentioned in section 3.5.1, we have two methods to test for a problem of heteroscedasticity. Those methods include using the graphical illustration and statistical tests and will be discussed in this section.

4.9.1 Graphical Method

An informal method that can be used to test for heteroscedasticity is to plot the graph using OLS residuals on the Y-axis and the fitted values of ln(Price) on the X-axis. Figure 4.10 provides the scatter points of squared residuals against the fitted values. From the figure, we see that some scatters especially for large value of predicted dependent variable seem to be far away from the rest of residuals. This sign shows that the variances of residuals might not be constant along with the fitted values. However, we still can not be certain whether problem of heteroscedasticity occurs or not. To verify this, we use the formal method under White's General Heteroscedasticity test as discussed in the next section.

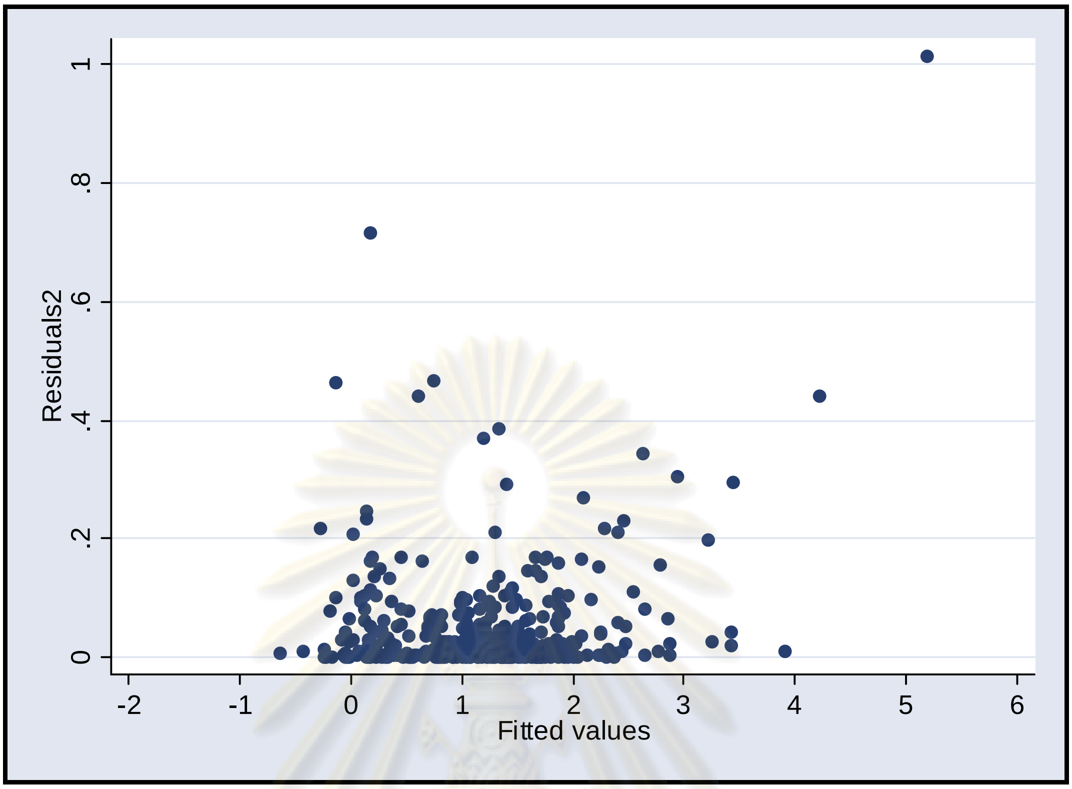


Figure 4.10 Scatter points of squared residuals and fitted values

4.9.2 White's Test

Among several statistical tests that can be used, White's General Heteroscedasticity test is chosen to test for heteroscedasticity in the data this study. The purpose in this section is whether there is heteroscedasticity in the data. Therefore, we follow the four steps mentioned in section 3.5.1.

Step 1. Given the data, the residuals $\hat{\varepsilon}_i$ from equation (18) referring to the base model results shown in Table 4.8.

Step 2. Since the base model consists of several regressors, the auxiliary regression is run using $\hat{\varepsilon}_i^2$ as dependent variable against all the regressors, their squared terms, and their cross products. The auxiliary regression is written:

$$\begin{aligned}\hat{\varepsilon}_i^2 = {} & \psi_1 + \mathrm{fa}_i\psi_2 + \mathrm{lotsize}_i\psi_3 + \mathrm{stories}_i\psi_4 \ldots + \\ & + \mathrm{fa}_i^2\psi_{26} + \mathrm{lotsize}_i^2\psi_{27} + \mathrm{stories}_i^2\psi_{28} + \ldots + \\ & + \mathrm{fa}_i\mathrm{lotsize}_i\psi_{50} + \mathrm{fa}_i\mathrm{stories}_i\psi_{51} + \ldots + v_i\end{aligned}$$

There are 150 regressors in the auxiliary regression. We would run this regression in STATA software. Then regression results are show in Table 4.13

Table 4.13 Estimate results of auxiliary regression

	SS	df	MS		
				Number of obs=	384
	SS	df	MS	F(150, 233)=	2.83
Model	2.293952	150	0.015293	Prob > F=	0.0000
Residual	1.260636	233	0.005410	R-squared=	**0.6453**
Total	3.554588	383	0.009281	Adj R-squared=	0.4170
Dependent variable = $\hat{\varepsilon}_i^2$				Root MSE =	0.07356

Step 3. With the belief that the product of sample size n and R^2 from auxiliary regression asymptotically follows the chi-square distribution with (k-1) degrees of freedom $n \times R^2 \sim \chi^2_{df}$, the hypotheses can be stated as follow:

H_0 : Homoscedastic variance of disturbance

H_1 : Heteroscedastic variance of disturbance

We have n = 384 observations

k = 151 parameters

and R^2= 0.6453

Now we can compute $n \times R^2 = 384 \times 0.6453 = 247.7952$ whereas the critical value of chi-square with (k−1) = 150 degrees of freedom at 5-percent level is $\chi^2_{critical,150,95\%} = 179.5806$.

Step 4. In this step, we do the comparison of computed $n \times R^2 \sim \chi^2_{148}$ and the critical value. The computed value of chi-square from White's General Heteroscedasticity test is somewhat higher than the critical value of chi-square. So we reject the null hypothesis. In conclusion, the problem of heteroscedasticity is clearly present in our regression model. Therefore, the correction for this type of issue is required.

4.9.3 Correction for Heteroscedasticity

As mentioned earlier in section 3.5.1.2, the problem due to heteroscedasticity can be solved by two different approaches: when σ_i^2 is known and σ_i^2 is unknown. In general, the values of σ_i^2 is unknown. So the White's Robust Standard Errors method is used in this study. The formula for robust standard errors is rewritten as $\mathrm{var}(\hat{\beta}_j) = \frac{\sum \hat{w}_{ji}^2 \hat{\varepsilon}_i^2}{(\sum \hat{w}_{ji}^2)^2}$. This remedial method can be done easily using STATA program. The estimated results after correction for problem of heteroscedasticity are provided in Table 4.14.

4.10 Estimation Results and Discussion

Of all, the OLS estimation results shown in Table 4.14 is finally considered as the best preferred model since it has passed several test procedures as well as correction for econometric issues such as multicollinearity and heteroscedasticity.

4.10.1 Goodness of Fit

The OLS estimation results of the best hedonic regression model with robust standard errors are provided in Table 4.14. The specification of variables listed in Table 4.14 is considered the best model because it is obtained after several inclusions and exclusions of variables, comparing the goodness of fit of the data, and performing several statistical tests as well as correcting for the statistical issues. As can be seen, the value of R^2 indicates that all the included explanatory variables can explain about 92 percent of the variation in property sale prices. Comparing to the previous studies, it can be said that the estimated model fits the data very well. Most of the coefficient estimates are highly significant with expected sign and magnitude.

Table 4.14 Hedonic price regression results with robust standard errors

					Number of obs =	384
Regression with robust standard errors					F(21, 362) =	179.72
					Prob > F =	0.0000
					R-squared =	0.9242
Dependent variable = ln (Sale Price)					Root MSE =	0.23399
	Coef.	Robust Std. Err.	t	P > | t |	[95% confident interval]	
Structural variables						
fa	0.003901	0.000265	14.70	0.0000	0.003379	0.004423
lotsize	0.002503	0.001012	2.47	0.0140	0.000513	0.004494
stories	0.280906	0.041550	6.76	0.0000	0.199197	0.362615
SFD	0.721465	0.060602	11.90	0.0000	0.602288	0.840641
DPX	0.468530	0.048113	9.74	0.0000	0.373915	0.563145
LH	0.210422	0.046589	4.52	0.0000	0.118804	0.302040
PS	-0.199168	0.047074	-4.23	0.0000	-0.291740	-0.106596
NO	0.275287	0.103128	2.67	0.0080	0.072483	0.478091
SA	0.330106	0.094148	3.51	0.0010	0.144961	0.515250
Location variables						
ap_dist	-9.71E-03	2.75E-03	-3.53	0.0000	-1.51E-02	-4.30E-03
bts	-1.80E-02	1.73E-03	-10.45	0.0000	-2.14E-02	-1.46E-02
exp	-2.62E-03	1.58E-03	-1.65	0.0990	-5.73E-03	4.93E-04
Temporal variables						
Y03	0.124577	0.071757	1.74	0.0830	-0.016537	0.265691
Y04	0.132714	0.064214	2.07	0.0390	0.006434	0.258994
Y05	0.168101	0.063657	2.64	0.0090	0.042917	0.293285
Y06	0.221716	0.068040	3.26	0.0010	0.087914	0.355519
Y07	0.146817	0.065345	2.25	0.0250	0.018313	0.275320
Y08	0.294978	0.065753	4.49	0.0000	0.165672	0.424284
Environmental variables						
N35af	-0.258967	0.044841	-5.78	0.0000	-0.347148	-0.170785
N30af	-0.095308	0.082034	-1.16	0.2460	-0.256630	0.066014
buf5af	-0.042532	0.049954	-0.85	0.3950	-0.140768	0.055705
_cons	-0.316336	0.131187	-2.41	0.0160	-0.574320	-0.058352

4.10.2 Effects of Property Characteristics

Using robust standard errors does not necessarily lead to improvement in *t*-statistics (Gujarati and Porter (2009)), and therefore it is necessary to examine the statistics again after reestimation of standard errors. As can be seen in Table 4.14, the coefficient estimates of structural characteristics are all significant at 5-percent level with the robust standard errors with the correct signs. The coefficient of floor area, lot size and number of stories are positive, and the magnitudes of these coefficients suggest that a marginal increase in the values of these variables would increase in the property price by 0.39, 0.25, and 28.09 percent, respectively. That is: an addition of one square meter in floor area will lead to 18,890 Baht in residential property price; an increase of one square wa (4 square meters) in lot size will lead to 12,109 Baht in price; and one more story increases will lead to about 1.36 million Baht increase in property price with all computed values based on the average price.

4.10.3 Effects of Property Types

As for the effects of property types, a single-family detached house has a sale price about 25.29 percent higher than that of a duplex unit, and both, on average, sell for more than a townhouse by 72.15 and 46.85 percent, respectively, all else being held constant. Based on average price, this can be interpreted that the townhouse sells for about 3.5 million Baht less than single-family and about 2.27 million Baht less than duplex unit, *ceteris paribus*. As mentioned earlier, people are more likely to purchase the single-family detached and duplex houses rather than townhouse. The reason behind this is probably due to the construction location where land is abundant and with convenient access to the transportation facilities as well as business district. Since the results showed significant effect of different types of residential property, it is important that these type of dummies should be included in the model as verified by Chow test.

4.10.4 Effects of Branding

The brand names of the reputable developers are generally believed to command a significant amount of price premium. This is reflected by the result, for example, the properties constructed by Land & House (LH), Noble Home (NH), and Sansari (SA) would sell for at least 21 percent or greater price premium compared to other less well-known developers. This is not surprising because these three developers are large and well-known real estate companies. Additionally, most people are likely to buy the houses these real estate companies with the belief of good quality of work and construction. In contrast, the coefficient estimate of properties developed by Preuksa (PS) is negative and significant. The result shows that there is a significant discount in prices of the property developed by Preuksa real estate with a percentage of about 20 percent. This discount is probably due to the decline of the company's reputation for having poor quality of construction work.

4.10.5 Effects of Year dummy Variables

Other results are generally as expected. The coefficients of year dummies are all significant at 5-percent level except for 2003 which is significant at 10-percent level, and they show a generally increasing trend of property prices compared to the base year of 2002. The magnitude of year dummy variables can be computed into the property prices with respect to the average sale price, as presented in Figure 4.11. As can be seen, the price of property sold in 2003 is about 600,000 Baht higher than a similar property sold in 2002, computed based on the average price. However, the coefficient estimates of year dummies show a growing trend of residential property prices near Suvarnabhumi airport, except for a decline in 2007. The fall in price could probably be attributed by the ambiguity about the status of the nation's economy. In September 2006, the event of the coup d'état in Thailand might also influence on this drop in price. In the same period, another probable reason is that the problem of noise impact primarily started to be considered by buyers of the properties located nearby the airport. Nevertheless, the increasing trend resumed in 2008 after the reinstatement of democratically elected government in December 2007.

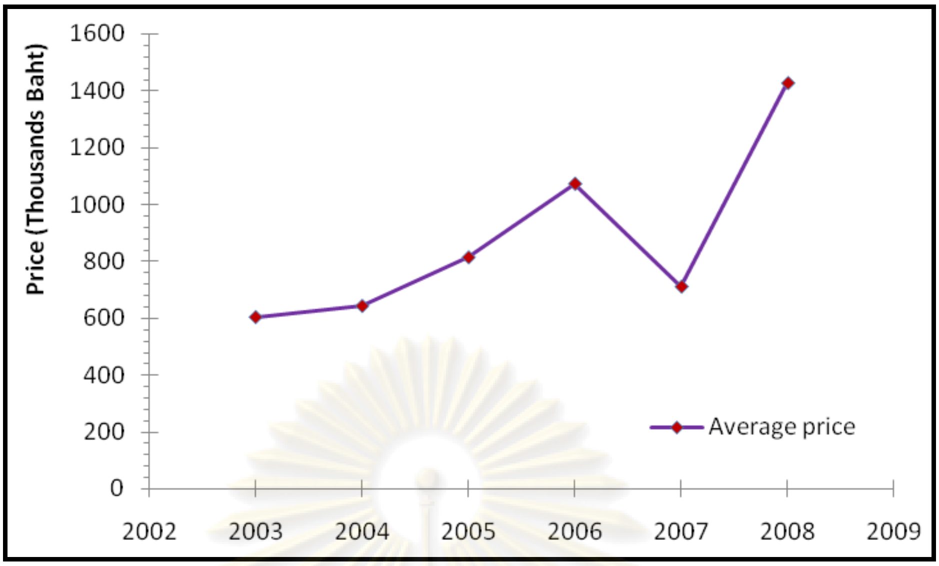


Figure 4.11 Variation in average-based-computed sale prices over years

4.10.6 Effects of Location Characteristics

It is also shown in the Table 4.14 that the coefficients for location variables are highly significant, except for the coefficient of distance from each property to the nearest expressway ramps which is significant at 10-percent level. As can be expected, the negative coefficients of location variables suggest that there is a beneficial effect of being closer to the transportation facilities. The negative coefficient of distance from each property to the nearest BTS station is higher than the coefficients estimates for access to the airport entrance and the nearest expressway. This implies that every one kilometer further from the nearest transit station sells for 1.8 percent less. Besides, there is also reduction in property price of 0.97 and 0.26 percent for every one additional kilometer from the airport entrance and the nearest expressway ramp, respectively.

4.10.7 Effects of the Airport Noise

Finally, the estimated coefficients for noise dummy variables in the hedonic model are negative suggesting noise discount for residential properties located inside the noise contour zone. As can be seen in Table 4.14, however, only the coefficient of N35af is highly statistically significant. The magnitude of the coefficient implies that the residential properties located between the NEF 35 and NEF 40 noise contour lines were sold at 25.9 percent discount compared to similar residential properties located elsewhere. This can be translated into a substantial 1.25 million Baht discount due to the airport noise, when computed based on the average price. Although the other two noise dummy variables are not significant at 10-percent level, the coefficient estimates imply the noise discount of 9.53 percent for properties located inside the noise contour lines of NEF 30 and NEF 35, and noise discount 4.25 percent for those properties located in the 500 meters buffer zone outside NEF 30 noise contour line. It should be noted that the noise discount described above refer only to those properties sold after the airport operation began and the amount of decline in prices is accorded with the level of noise impact. For the omitted noise variables (NEF35, NEF30, and buf5), we also run another regression including all noise variables with robust standard errors, but there is still no statistical significant effect of these three variables on the property price.

These results indicate that the airport noise had an impact on property values in the vicinity of the airport. The empirical estimates indicate a noise discount of 25.9 percent or computed as monetary discount about 1.25 million Baht for property located inside the NEF between 35 and 40. But, it does not appear that there was an impact of the airport noise on property values in the low noise zone. These estimate results are significantly higher than those derived from previous hedonic price studies. In comparison with other studies, Miseszkowki and Saper (1978) estimated hedonic price regression using 509 individual properties located near the Toronto Airport from 1969 to 1973 and found that the noise discount might be as high as 15 percent for house located in noise contour line NEF 35 and above. This noise discount could be translated to 0.87 percent per dB for NDI. Uyeno et al. (1993) using 645 detached house units in the vicinity of Vancouver Airport in the period from 1978 to 1988 found that the noise discount for house located in NEF between 35 and 40 is 14.72 percent.

Up to a certain level, noise assumed to be a normal fact of life. The levels of annoyance based on NEF values were mentioned by Nelson (1980) that the level of NEF between 15 and 20 is suitable for residential area with little annoyance, NEF between 25 and 40 for some to much annoyance, and for above NEF 40 is for considerable annoyance. To reduce such a level of noise annoyance, several policies and programs have been proposed on the impact airport noise impact on housing prices (Cohen and Choughlin (2008)). The first approach is that the local government authorities help the affected property owners to take defensive actions against the airport noise through installing sound-proofing or relocating. The second possibility is that the airport authorities should impose the tax on aircrafts based on the amount of noise they produce. The third option is that the local government should take control over the noise level and flight paths. Besides, Feitelson et al. (1996) claimed that noise insulation which is the most popular type of compensation program does not fully compensate for the airport noise impact. The airport authorities should not rely only on the decline of property values estimated from hedonic approach, but they should try to differentiate between affected parties who would like to relocate and those who would like to stay in place and face with the impact of airport noise, that is the use of Contingent Valuation method.

CHAPTER V
CONCLUSION AND FUTURE STUDY

5.1 Conclusion

The objective of this study is to assess the discount in residential property values that is caused by the impact of the airport noise. To achieve the objective, the hedonic price regression model was estimated to quantify the noise discount using new residential property sale prices that were in the vicinity of Suvarnabhumi airport transacted between 2002 and 2008. As the analysis results reveal, there is no impact of the airport noise on property prices transacted before the airport operation began in 2006. Based on the insignificance of noise dummy variables NEF30 and NEF35, we can interpret that the buyers of new properties in the areas did not anticipate the upcoming noise effects. The hedonic model estimation shows a substantial impact of the airport noise on property prices transacted after 2006. The outcomes indicate that there is a reduction in price of about 25.9 percent if the new property is sold after the opening of airport in 2006 and located between the NEF 35 and NEF 40 noise contour lines compared with a similar property located elsewhere, all else being held constant. In addition, the noise discount would be 9.53 percent for properties located between NEF 30 and NEF 35 noise contour lines and were transacted after 2006. These two noise discounts can be translated to noise depreciation index (NDI) of 3.27 percent per dB. In this study, the value of NDI found is in the high range of those reported by Praag and Baarsma (2005). The high noise discount should not come as a surprise, as in this study, the data provided by the AREA is unreliable because the data was self-reported by sellers who often underreport transaction prices. In addition, there were already many complaints about the airport noise generating form Suvarnabhumi airport in the year when the airport operation begun. The reactions from the protestors like KMIL and other affected homeowners might also encourage the decline in prices of properties located near the airport. However, we expect that the value of NDI might decrease if the test for autocorrelation and other spatial effects are performed to strengthen the model properties.

The results in this study provide a scientific piece of evidence that homeowners living closer to the airport not only acquire the benefit of easy access but also experience the decline in their residential property values, due to the impact of the aircraft noise at the airport. This evidence also serves as a basis on which the determination of what the appropriate amount of compensation for decline in property prices due to the airport noise should be. As can be observed, the number of properties constructed after the airport construction started in 2002 continued to grow because there was no efficient land use regulation and control for the areas affected by Suvarnabhumi airport noise. Since the opening of the airport, numerous homes affected by severe noise were compensated by the AoT following by strident protests, and eventually the huge amount of budget needed to be allocated by the Thai government for such compensation. In Thailand and other developing countries, there is little concerns about the environmental impacts such as large construction of infrastructure projects, Suvarnabhumi airport serves as a good example. So this experience should be noted by the Thai government as well as the responsible authorities.

Finally, we hope that the value of NDI computed in this research would help the AoT in formulating an apposite policy in compensating the homeowners affected by the airport noise. Besides, the responsible authorities should also propose a rule to control for limits of noise annoyance level emitted by the aircraft, control over the land use regulation; so that the problem of the airport noise would decrease and also save the significant amount of public funds in the future, especially when the ultimate development plan of airport expansion takes place.

5.2 Future study

Although the present study is quite advanced compared to similar studies conducted on the topic using hedonic approach in Thailand, this study can be improved by several ways:

1) Include more control variables such as number of garage, number of bathroom and bedroom, age of the property, the presence of installed sound-proofing and other socio-economic variables. These important control variables might improve the explanatory power of hedonic price models.
2) Since the current study analyzes only the new sale price data, inclusion of the resale prices in the model could increase the completeness of the evidence.
3) Test and correction for spatial autocorrelation should be incorporated in the analysis in order to compare the preciseness of the estimates.

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APPENDIX

Tables of Full OLS Results

Table A.1 Full OLS estimation results without year dummies

	SS	df	MS		
				Number of obs =	384
				F(18, 365) =	228.72
Model	240.04543	18	13.335857	Prob > F =	0.0000
Residual	**21.282051**	365	0.0583070	R-squared =	0.9186
Total	261.32748	383	0.6823172	Adj R-squared =	0.9145
Dependent variable = ln (Sale Price)				Root MSE =	0.24147

	Coef.	Std. Err.	t	P > | t |	[95% confident	interval]
Structural variables						
fa	0.003708	0.000213	17.40	0.0000	0.003289	0.004127
lotsize	0.002800	0.000434	6.45	0.0000	0.001947	0.003654
stories	0.303227	0.033669	9.01	0.0000	0.237017	0.369437
SFD	0.724658	0.037110	19.53	0.0000	0.651681	0.797634
DPX	0.475862	0.044219	10.76	0.0000	0.388907	0.562817
LH	0.184006	0.050965	3.61	0.0000	0.083785	0.284227
PS	-0.184011	0.060269	-3.05	0.0020	-0.302529	-0.065493
NO	0.270794	0.104378	2.59	0.0100	0.065537	0.476051
SA	0.300376	0.112965	2.66	0.0080	0.078231	0.522520
Location Variables						
ap_dist	-1.06E-02	2.69E-03	-3.93	0.0000	-1.59E-02	-5.28E-03
bts	-1.82E-02	1.78E-03	-10.24	0.0000	-2.17E-02	-1.47E-02
exp	-1.21E-03	1.89E-03	-0.64	0.5230	-4.93E-03	2.51E-03
Environmental variables						
NEF35	-0.062140	0.144967	-0.43	0.6680	-0.347214	0.222936
NEF30	-0.000585	0.173749	-0.00	0.9970	-0.342261	0.341090
buf5	-0.029500	0.102433	-0.29	0.7740	-0.230934	0.171933
N35af	-0.140453	0.222414	-0.63	0.5280	-0.577827	0.296920
N30af	-0.074105	0.214018	-0.35	0.7290	-0.494968	0.346757
buf5af	0.043477	0.138012	0.32	0.7530	-0.227922	0.314877
_cons	-0.177580	0.101534	-1.75	0.0810	-0.377246	0.022085

Table A.2 Full OLS estimation results without developer types

					Number of obs =	384
	SS	df	MS		F(20, 363) =	196.04
Model	239.1827	20	11.959134		Prob > F =	0.0000
Residual	**22.14479**	363	0.0610049		R-squared =	0.9153
Total	261.3275	383	0.6823172		Adj R-squared =	0.9106
Dependent variable = ln (Sale Price)					Root MSE =	0.24699
	Coef.	Std. Err.	t	P > | t |	[95% confident interval]	
Structural variables						
fa	0.003816	0.000224	17.03	0.0000	0.003375	0.004256
lotsize	0.002888	0.000443	6.53	0.0000	0.002018	0.003759
stories	0.303135	0.034359	8.82	0.0000	0.235567	0.370702
SFD	0.749996	0.038148	19.66	0.0000	0.674977	0.825015
DPX	0.460305	0.045757	10.06	0.0000	0.370324	0.550286
Location variables						
ap_dist	-8.42E-03	2.76E-03	-3.06	0.0020	-1.38E-02	-3.00E-03
bts	-1.88E-02	1.79E-03	-10.48	0.0000	-2.23E-02	-1.53E-02
exp	-3.45E-03	1.95E-03	-1.77	0.0780	-7.29E-03	3.89E-04
Temporal variables						
Y03	0.085021	0.074467	1.14	0.2540	-0.061419	0.231462
Y04	0.119508	0.070532	1.69	0.0910	-0.019195	0.258210
Y05	0.116714	0.071365	1.64	0.1030	-0.023628	0.257055
Y06	0.177548	0.073611	2.41	0.0160	0.032790	0.322307
Y07	0.077251	0.072783	1.06	0.2890	-0.065878	0.220380
Y08	0.238214	0.073729	3.23	0.0010	0.093226	0.383203
Environmental variables						
NEF35	-0.090492	0.150364	-0.60	0.5480	-0.386186	0.205202
NEF30	-0.027657	0.179288	-0.15	0.8770	-0.380231	0.324917
buf5	0.033620	0.105695	0.32	0.7510	-0.174232	0.241472
N35af	-0.164349	0.231739	-0.71	0.4790	-0.620070	0.291371
N30af	0.079051	0.219058	0.36	0.7180	-0.351731	0.509833
buf5af	-0.108088	0.144655	-0.75	0.4550	-0.392555	0.176379
_cons	-0.324315	0.119599	-2.71	0.0070	-0.559508	-0.089122

Table A.3 Full OLS estimation results without property types

					Number of obs =	384
	SS	df	MS		F(22, 361) =	86.87
Model	219.80715	22	9.9912344		Prob > F =	0.0000
Residual	**41.520325**	361	0.1150147		R-squared =	0.8411
Total	261.32748	383	0.6823172		Adj R-squared =	0.8314
Dependent variable = ln (Sale Price)					Root MSE =	0.33914
	Coef.	Std. Err.	t	P > | t |	[95% confident interval]	
Structural variables						
fa	0.004831	0.000302	15.99	0.0000	0.004237	0.005425
lotsize	0.004588	0.000604	7.60	0.0000	0.003401	0.005775
stories	0.027085	0.044290	0.61	0.5410	-0.060013	0.114183
LH	0.307559	0.072553	4.24	0.0000	0.164879	0.450239
PS	-0.320394	0.086606	-3.70	0.0000	-0.490709	-0.150079
NO	0.197260	0.147194	1.34	0.1810	-0.092206	0.486726
SA	0.404403	0.161527	2.50	0.0130	0.086750	0.722055
Location variables						
ap_dist	-2.16E-02	3.70E-03	-5.83	0.0000	-2.89E-02	-1.43E-02
bts	-1.50E-02	2.49E-03	-6.00	0.0000	-1.99E-02	-1.01E-02
exp	2.39E-04	2.69E-03	0.09	0.9290	-5.05E-03	5.53E-03
Temporal variables						
Y03	0.277385	0.102653	2.70	0.0070	0.075513	0.479257
Y04	0.189704	0.097544	1.94	0.0530	-0.002122	0.381530
Y05	0.318977	0.099146	3.22	0.0010	0.124001	0.513954
Y06	0.311606	0.102098	3.05	0.0020	0.110824	0.512389
Y07	0.216593	0.101232	2.14	0.0330	0.017515	0.415670
Y08	0.371731	0.102167	3.64	0.0000	0.170815	0.572648
Environmental variables						
NEF35	0.024309	0.206632	0.12	0.9060	-0.382045	0.430663
NEF30	0.106525	0.246924	0.43	0.6660	-0.379065	0.592115
buf5	-0.097604	0.146345	-0.67	0.5050	-0.385400	0.190192
N35af	-0.222122	0.317010	-0.70	0.4840	-0.845541	0.401296
N30af	-0.193624	0.304343	-0.64	0.5250	-0.792132	0.404883
buf5af	-0.010403	0.199928	-0.05	0.9590	-0.403574	0.382768
_cons	0.396742	0.156805	2.53	0.0120	0.088376	0.705108

Table A.4 Full OLS estimation results without NEF35, NEF30, and buf5

	SS	df	MS			
					Number of obs =	384
	SS	df	MS		F(21, 362) =	210.04
Model	241.5068	21	11.500321		Prob > F =	0.0000
Residual	19.82073	362	0.0547534		R-squared =	0.9242
Total	261.3275	383	0.6823172		Adj R-squared =	0.9198
Dependent variable = ln (Sale Price)					Root MSE =	0.2340
	Coef.	Std. Err.	t	P > | t |	[95% confident interval]	
Structural variables						
fa	0.003901	0.000212	18.36	0.0000	0.003483	0.004319
lotsize	0.002503	0.000426	5.88	0.0000	0.001666	0.003341
stories	0.280906	0.033110	8.48	0.0000	0.215794	0.346017
SFD	0.721465	0.036545	19.74	0.0000	0.649598	0.793331
DPX	0.468530	0.043408	10.79	0.0000	0.383167	0.553893
LH	0.210422	0.049811	4.22	0.0000	0.112467	0.308377
PS	-0.199168	0.060101	-3.31	0.0010	-0.317359	-0.080976
NO	0.275287	0.101660	2.71	0.0070	0.075368	0.475206
SA	0.330106	0.111372	2.96	0.0030	0.111089	0.549122
Location variables						
ap_dist	-9.71E-03	2.59E-03	-3.76	0.0000	-1.48E-02	-4.63E-03
bts	-1.80E-02	1.70E-03	-10.64	0.0000	-2.14E-02	-1.47E-02
exp	-2.62E-03	1.84E-03	-1.42	0.1560	-6.24E-03	1.00E-03
Temporal variables						
Y03	0.124577	0.071203	1.75	0.0810	-0.015445	0.264599
Y04	0.132714	0.066926	1.98	0.0480	0.001100	0.264327
Y05	0.168101	0.068399	2.46	0.0140	0.033591	0.302610
Y06	0.221716	0.070542	3.14	0.0020	0.082993	0.360440
Y07	0.146817	0.070283	2.09	0.0370	0.008603	0.285030
Y08	0.294978	0.070614	4.18	0.0000	0.156112	0.433843
Environmental variables						
N35af	-0.258967	0.170567	-1.52	0.1300	-0.594393	0.076459
N30af	-0.095308	0.124795	-0.76	0.4460	-0.340723	0.150107
buf5af	-0.042532	0.095190	-0.45	0.6550	-0.229727	0.144664
_cons	-0.316336	0.113960	-2.78	0.0060	-0.540442	-0.092230

BIBLIOGRAPHY

Veng Kheang PHUN was born in 1983 in Kompong Cham Province, Cambodia. In 1986, he moved to live in Prey Veng Province where he started primary school until he finished his high school degree in year 2002. At the same year, he came to Phnom Penh, the capital city of Cambodia, and then he passed the entrance exam to pursue his bachelor degree at Institute of Technology of Cambodia (ITC), where studied in the Department of Civil Engineering. After graduating from ITC in 2007, he was awarded AUN/SEED-Net JICA Scholarship which enabled him to pursue his Master Degree in Civil Engineering (Transportation Engineering) at Chulalongkorn University, Thailand. Upon graduation, Veng Kheang has planned to further his PhD in Transportation Engineering with the research interest of transportation planning before returning to work in Cambodia.