THE EFFECTIVENESS OF JOBS-HOUSING BALANCE AS A STRATEGY FOR REDUCING TRAFFIC CONGESTION: A STUDY OF METROPOLITAN BANGKOK

A Dissertation

by

SONCHAI LOBYAEM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2006

Major Subject: Urban and Regional Science

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August 2006

Major Subject: Urban and Regional Science

ABSTRACT

The Effectiveness of Jobs-Housing Balance as a Strategy

for Reducing Traffic Congestion: A Study of Metropolitan Bangkok.

(August 2006)

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Co-Chairs of Advisory Committee: Dr. George O. Rogers
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Bangkok is widely known for its severe traffic congestion. The Thai government advocates the concept of jobs and housing balance (JHB) as a strategy for reducing traffic congestion in Metropolitan Bangkok. The basic idea is to decentralize the jobs to the neighboring provinces so that the commuters would live closer to their workplaces and thereby alleviate traffic congestion.

The main purpose of this research is to examine empirically the effectiveness of JHB in reducing the severity of traffic congestion in the Bangkok Metropolitan Region. For this purpose, three data sets derived from the Bangkok Metropolitan Region Extended City Model (BMR-ECM) were obtained from the Office of the Commission for the Management of Land Traffic and the National Statistical Office of Thailand. Travel time index (TTI) was developed to measure congestion. In addition to JHB, a number of land use variables were included in the analysis. They are population density, school density, and job accessibility index. Multiple regression models of TTI as functions of JHB and other variables were estimated at two geographic scales: subsector and traffic analysis zone (TAZ).

The study finds JHB is significant in influencing congestion levels in the Bangkok Metropolitan Region. Other influential factors include the population density, school density, and job accessibility. All of these factors are found to be statistically significant in explaining the variation of traffic congestion at the traffic analysis zone level, but not at the subsector level, however.

DEDICATION

This dissertation is dedicated to my late beloved father, Payong Lobyaem, who kept encouraging and supporting me in the pursuit of this doctoral degree. Without his great love and understanding, I would not have come this far. In addition, I would like to thank my mother, Vanida Lobyaem, who nourished me and gave me unconditional love. There are not enough words in this world to describe how much you both mean to me. I love you both.

ACKNOWLEDGEMENTS

First, I wish to acknowledge the time and helpful guidance given by all my advisory committee members including Dr. George O. Rogers, Dr. Ming Zhang, Dr. Byoung-Suk Kweon, Dr. Daniel Z. Sui, and, last but not least, Dr. Timothy Lomax.

Dr. Zhang has played an important role in inspiring and mentoring me since my start at Texas A&M University as a new Ph.D. student in the Urban and Regional Science program. I appreciate your counseling and understanding of my personal goals in the pursuit of this doctoral degree. For Dr. Rogers, thank you for taking the reins of the committee that were left in need of direction with Dr. Zhang's departure. I appreciate the help you provided me with the dissertation process and for listening patiently as I expounded on the virtues of my research. Thanks Dr. Kweon for helping me with the research design and statistical analyses. Dr. Sui gave me a great number of valuable comments and suggestions for my research. I am grateful for Dr. Lomax's sincerity and guidance throughout my dissertation work.

For the data support, I want to thank my colleagues who worked with me at the Office of Transport and Traffic Policy and Planning (OTP), previously known as the Office of the Commission for the Management of Land Traffic (OCMLT), the Ministry of Transport, Thailand. I know I may not have listed all of the people who gave me assistance with this research work, so I apologize for my omission. You all are remembered and greatly appreciated.

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CHAPTER I

INTRODUCTION

Bangkok is widely known for its severe traffic congestion. The Thai government advocates the concept of jobs and housing balance as a strategy for reducing traffic congestion in Metropolitan Bangkok. The basic idea is to decentralize the jobs to the neighboring provinces so that the commuters would live closer to their workplaces and thereby alleviate traffic congestion. The main purpose of this research is to examine empirically the effectiveness of jobs and housing balance in reducing the severity of traffic congestion in the Bangkok Metropolitan Region.

Background

Bangkok, the capital of Thailand (see Figure 1), produces over 30 percent of the country's economic output and its population accounts for about 20 percent of the nation's population (Office of the Commission for Management of Land Traffic [OCMLT], 2001). A third of national economic activity and half of economic growth occur in Bangkok. The Bangkok Metropolitan Region consists of the Bangkok Metropolitan Administration (BMA) and five neighboring provinces including Nonthaburi, Pathumthani, Nakhon Pathom, Samut Prakan, and Samut

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This dissertation follows the style of *Journal of the American Planning Association*.

Sakorn (see Figures 2 to 3). The next largest city in Thailand is Chiang Mai (located in the northern part of Thailand) with an estimated population of 409,000 people accounting for only five percent of Bangkok's population[1] (National Statistical Office (NSO), 2000). Nearly 75 percent of Thailand's urban dwellers live in the Bangkok Metropolitan Region. About half of this growth is accounted by the migration from rural and other urban areas due to employment opportunities.

Figure 1. Thailand Location (Source: www.google.com, retrieved April 30, 2004)

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[1] The area of Bangkok alone is 1,568.7 square kilometers with the population density of 4,051 persons/square kilometers, which rates as the most populated city in the nation (NSO, 2000).

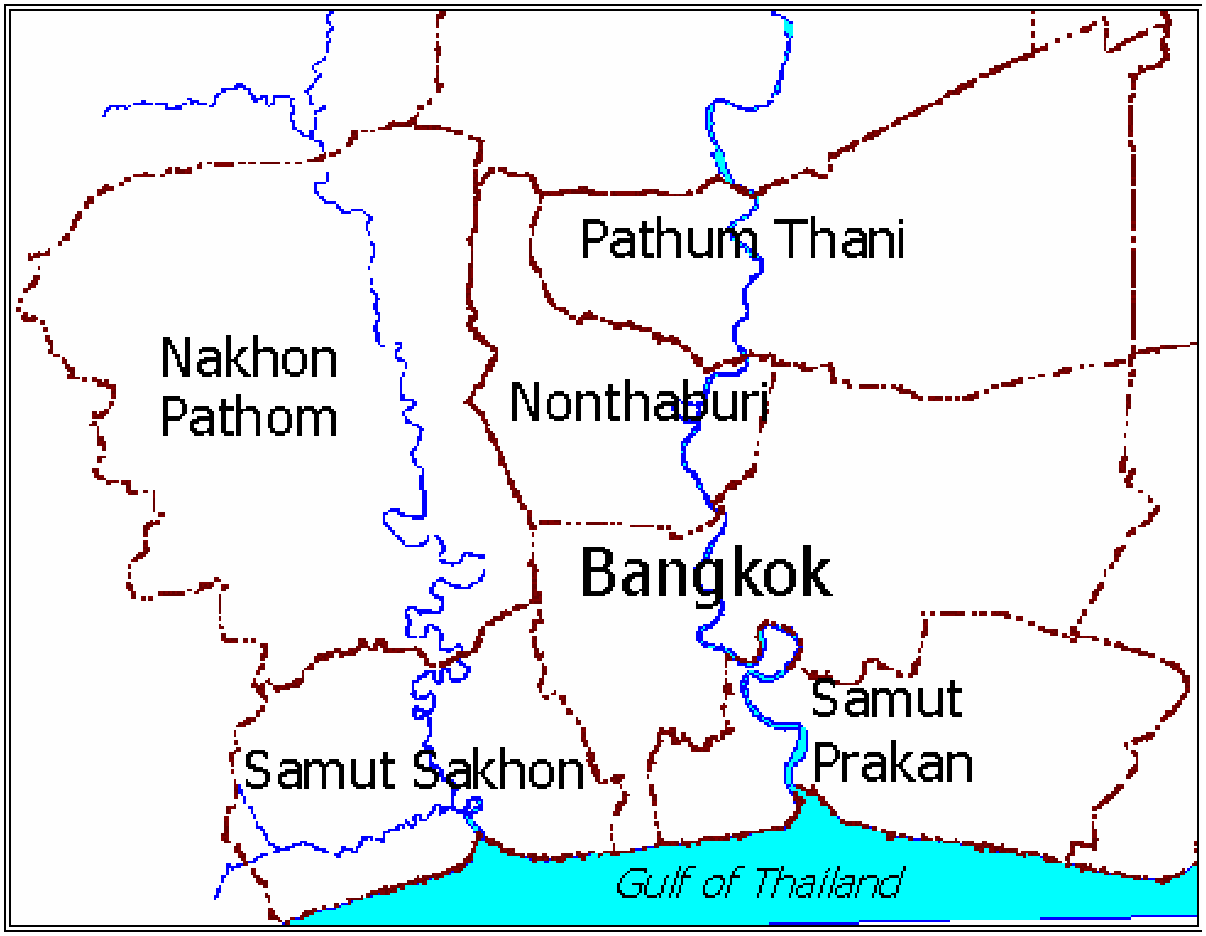

Figure 2. Bangkok Metropolitan Region (Source: www.google.com, retrieved April 30, 2004)

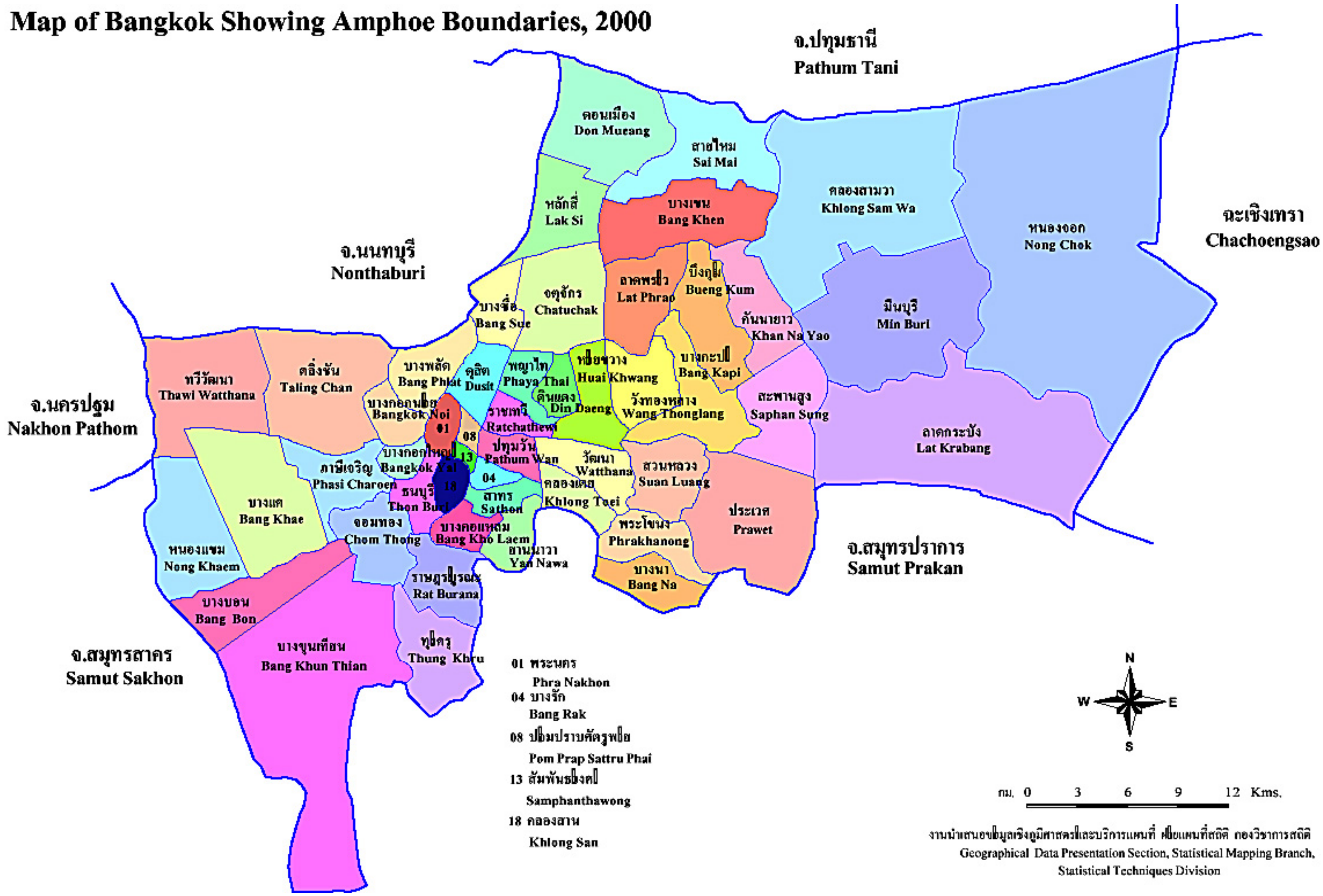

Figure 3. Bangkok Municipal Districts (Source: NSO, 2000)

Traffic Condition

A study on Bangkok's traffic congestion by OCMLT (1998b) reports that the direct cost of congestion alone, which does not include the accidental and environmental costs, is Baht 163 billion (about US$ 6.52 billion) each year to which the commuters' time loss value of Baht 116 billion (about US$ 4.64 billion) is the most attributed. During the morning peak period (6:00 am-9:00 am), commuter's average travel time for each trip ranges from 18 minutes for walk trips to 64 minutes for the public transportation mode (mainly bus), and commuters involving mode transfers expect a lot longer (see Figure 4). Moreover, car-mode commuters travel in the morning peak period for almost an hour per trip.

The variation between the peak and off-peak traffic volumes is minimal. In other words, the congestion condition spreads throughout the day, and this trend seems to continue unless no major improvement is implemented. Figure 5 shows the traffic volumes (vehicles per hour) of automobile mode along with other transportation modes that were observed at the sampled intersections for the day. Obviously, the automobile volume (located at the top of the graph) is quite high during both the morning peak period (6:00 am to 9:00 am) and the evening peak period (4:00 pm to 6:00 pm).

Based on all trip purposes, the largest portion of the daily trips is home-based work trips contributing 42 percent, while home-based education (school) trips and home-based other account for 22 percent each. The least is non-home-based trips contributing only 14 percent (see Figure 6).

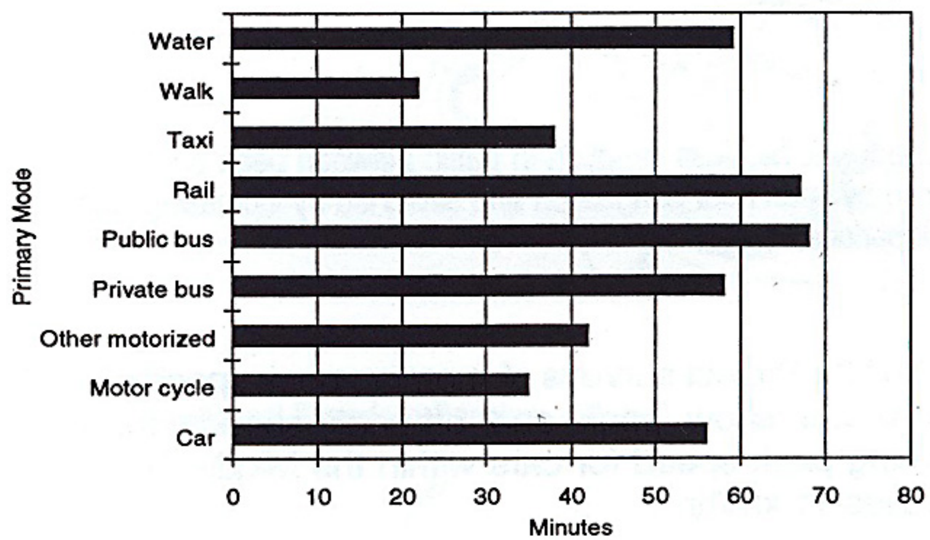

Figure 4. Average Morning Peak Commute Time in BMR (Source: OCMLT, 1998b)

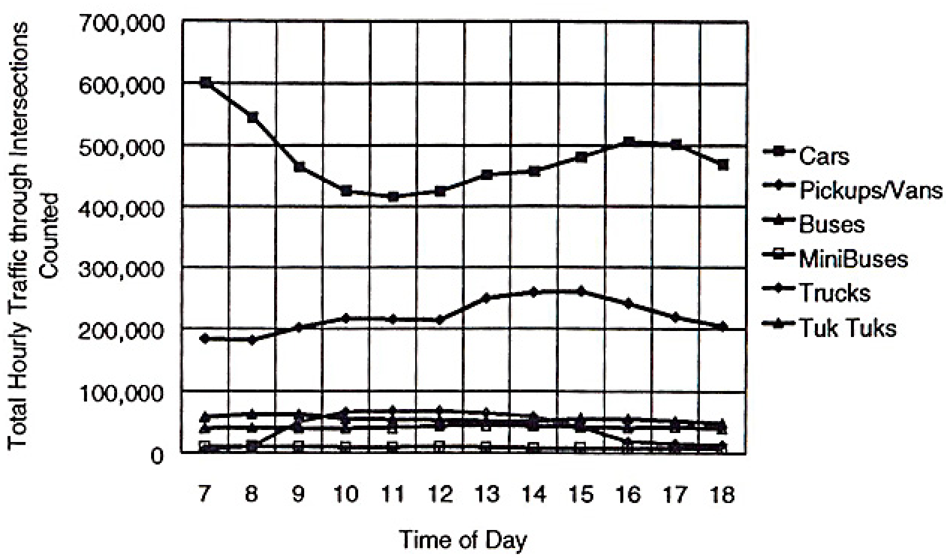

Figure 5. Hourly Traffic Volume by Vehicle Types (Source: OCMLT, 1998b)

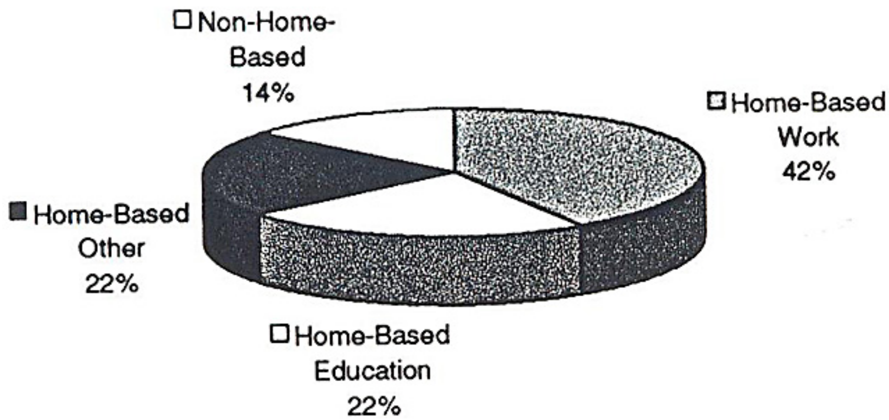

Figure 6. Proportion of Daily Trips by Purposes (Source: OCMLT, 1998b)

The negative impacts of the congestion include excessive delays, enormous fuel wastage, and numerous harmful environmental impacts such as noise and air pollution. These impacts harm the economy by reducing productivity and by increasing the need for imported fuel, with consequent foreign import requirements. Foreign investment and tourism in Thailand are discouraged by the difficulty of traveling around town. There are also severe social, health, and quality of life effects on the 11.4 million Bangkok's residents (OCMLT, 2001).

The study by OCMLT (2001) reports that, during peak hours in the central business districts, the speed averages nearly 10 kilometers per hour (less than 6.25 miles per hour), as the outside traffic congestion is almost as bad. Because of the lack of alternative transportation beside roads combined with the urban sprawl, now traffic congestion spreads over a radius of 20 kilometers from the central business districts. Moreover, traffic congestion exists in many parts of Bangkok for up to 16 hours per day.

In 1994 and 1998, the Thai Cabinet authorized two vital mass transit master plans for the Bangkok Metropolitan Region (BMR) proposed by OCMLT in 1994 and 1998 respectively. The first master plan laid out the framework for establishing the mass transit system in BMR, and the other plan introduces building the feeder system for the mass transit system (OCMLT, 2001). Unfortunately, during early 1997 and late 1999, there was an economic crisis happening to the Southeast Asian countries causing a great delay to the economic growth of this particular region. OCMLT was then assigned by the Thai Cabinet to update those two plans. In 2000, the master plan entitled as the Urban Rail Transportation Master Plan for Bangkok and Surrounding Areas (URMAP) was completed as a revision to the previous master plans. One year later, the URMAP was approved by the Cabinet as a regional master plan. As a result, any subsequent urban development and transportation-related investment are obligated to comply with this master plan and its suggested strategy.

Causes of Traffic Congestion

Given the findings from the previous studies, the major causes of traffic congestion in the Bangkok Metropolitan Region are summarized as the following:

inefficiency and inadequacy of public transportation, imbalance between supply and demand of private transportation, inappropriate fund allocation for public infrastructure, and lack of institutional coordination. Each of these causes is discussed in further details below.

Inefficiency and Inadequacy of Public Transportation

Despite the largest share of public mode, buses have the declining productivity due to its recurring debts (Kenworthy, 1995; Kubota, 1996; OCMLT 1998b, 2001; Poboon, Kenworthy, Newman, & Barter, 1995). Their fares are low for political reasons, even though the operating revenue does not recover the total expenditures. In addition, buses are often found stuck in the traffic due to congested roads. Since the inauguration of the green line or the Bangkok Mass Transit System (BTS) in 1999, the service coverage is inadequate for the Bangkok Metropolitan Region's travelers because of its limited length which is almost entirely within the center of the region.

Imbalance between Supply and Demand of Private Transportation

With the existing level of private vehicle use (mainly cars and pick-ups) in Bangkok, land devoted to the roads is much lower than in most cities of developed countries. Figure 7 shows eleven percent of Bangkok's urban areas are allocated for road space as compared to 25 percent in the developed countries on average (Kenworthy, 1995; Kenworthy & Laube 1999). This shortage causes the mismatch between supply and demand of road infrastructure. Regarding the existing road classification, the lack of the collector roads is part of the congestion causes (BMA, 1996; Bhattacharjee, Haider, Tanaboriboon, & Sinha, 1997; Suraswadee, 1999). Much traffic volume dumping onto the limited arterials causes the traffic to overwhelm the road capacity.

Numbers of land parcels are inaccessible by almost any mode of transportation. These areas are defined as *super blocks* (BMA, 1996; Suraswadee, 1999). The steady increases of the vehicle ownership and free or low-fee parking spaces compound the congestion problem (NSO, 2000; OCMLT, 1998a, 1998b, 2000, 2001).

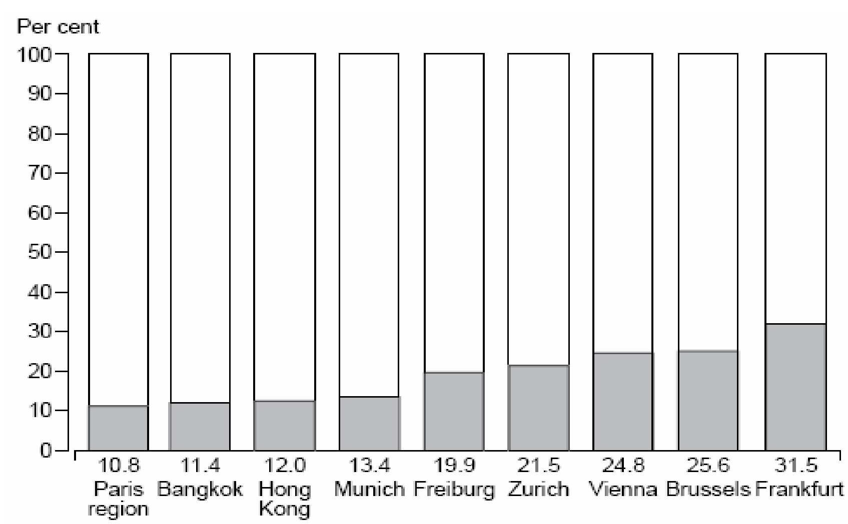

Figure 7. Urbanized Area Covered by Road (Source: Kenworthy, 1995)

Inappropriate Fund Allocation for Public Infrastructure

The Thai government has favors toward building more roads for automobile use rather than improving the existing public transportation (OCMLT, 1998b, 1999b). According to the government investment on infrastructure in both periods of 1987 to 1991 and 1992 to 1996, there appeared to be much more investment in building roads than in public transportation improvement (see Tables 1 to 2 and Figures 8 to 9).

Despite the investment shortage, the study reveals that one of the most popular travel modes people choose for their daily commutes is public transportation (see Figure 10).

Table 1. Infrastructure Investment 1987-1991

Infrastructure	**Planned**		**Actual**	
	Million (Baht)	***Percent***	***Million (Baht)***	***Percent***
Public roads and bridges	20,157.00	70.00	35,868.00	96.00
Public transportation	8,480.00	29.00	441.00	1.00
Others	225.00	1.00	919.00	3.00
Total	*28,862.00*	*100.00*	*37,228.00*	*100.00*

Note. Baht 25 approximately equals US$ 1 at Y 1991 price.

Source: OCMLT, 1994

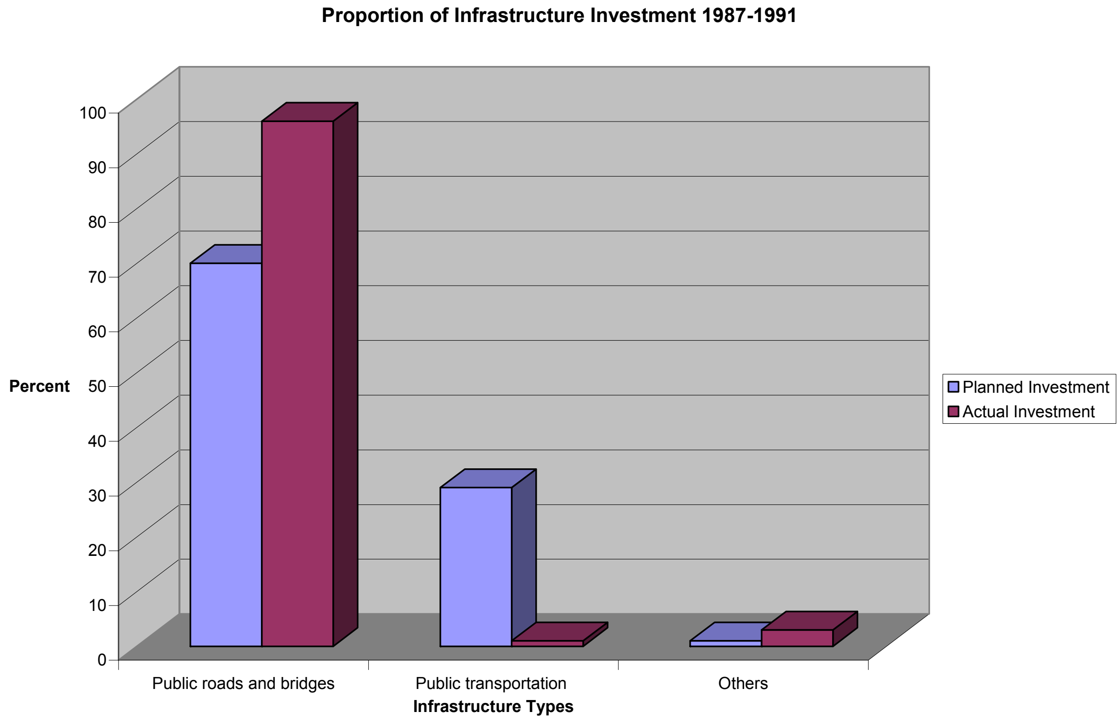

Figure 8. Proportion of Infrastructure Investment (1987-1991)

Table 2. Infrastructure Investment 1992-1996

Infrastructure	**Planned**		**Actual**	
	Million (Baht)	***Percent***	***Million (Baht)***	***Percent***
Public roads, bridges	174,829.00	52.00	131,274.00	62.00
Public transportation	141,623.00	42.00	73,216.00	35.00
Others	18,729.00	6.00	6,048.00	3.00
Total	*335,181.00*	*100.00*	*210,538.00*	*100.00*

Note. Baht 25 approximately equals US$ 1 at 1996 price.

Source: the Office of the National Research Committee Board, 1998

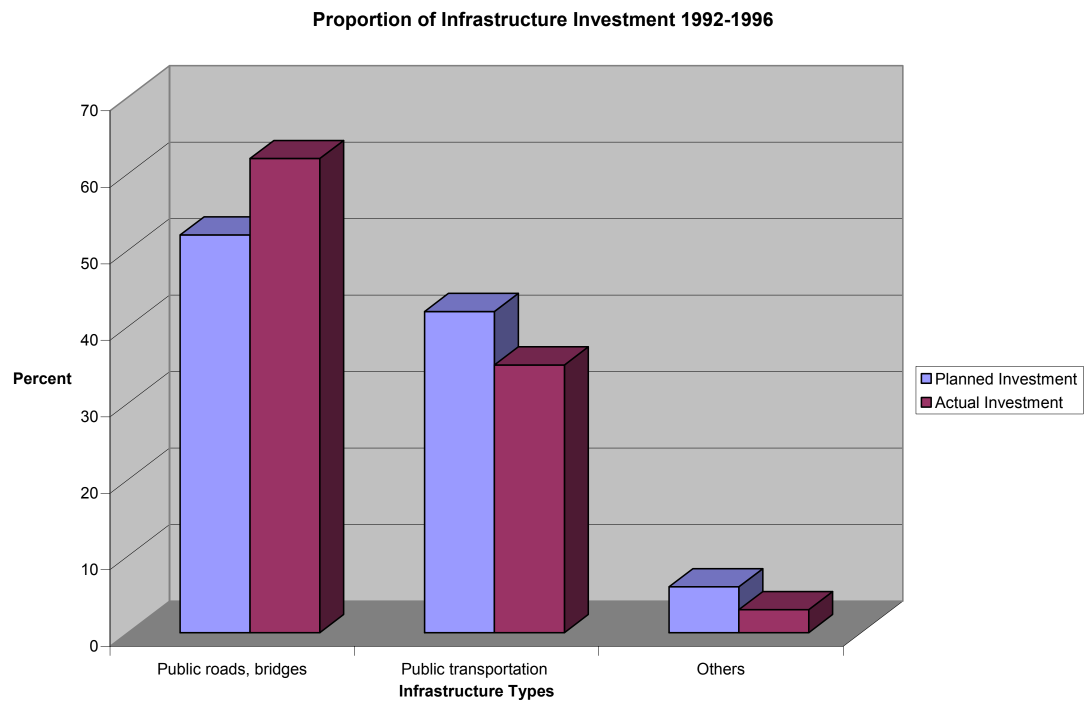

Figure 9. Proportion of Infrastructure Investment (1992-1996)

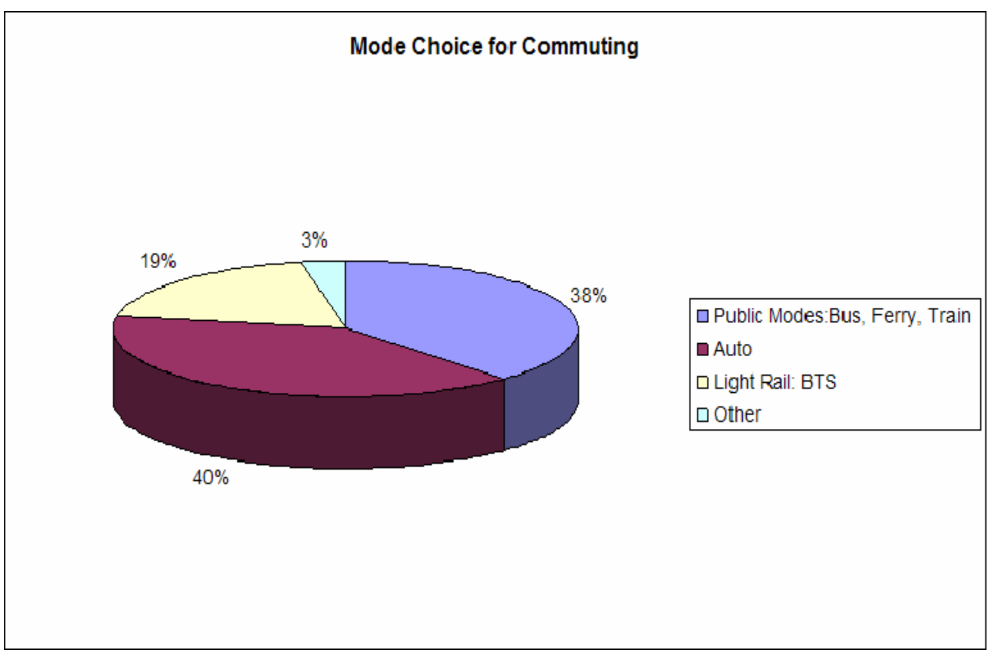

Figure 10. Modal Proportion for Commuting (Source: OCMLT, 2001)

Lack of Institutional Coordination

Thailand's authorities involved in the transportation planning and implementation are not well integrated and instead overlapped for some (OCMLT 1998b, 1999b; Poboon, Kenworthy, Newman & Barter, 1995). The coordination among parties involved is rare; therefore, the congestion in the Bangkok Metropolitan Region is a chronic national problem. Without the authoritative coordination, any plan or measure meant to tackle with the congestion problem is unlikely to prevail.

Jobs and Housing Balance as a Responding Strategy

The Thai government initiated a land use related strategy to cope with the traffic congestion problem. The strategy focuses on two areas that include redistributing employment and residence within the region and encouraging people to use public transportation rather than private transportation (Kubota, 1996; Massachusetts Institute of Technology (MIT), 1996; OCMLT, 1998, 2001). For the first area, balancing jobs and housing is encouraged for the employment decentralization. The MIT's study titled as *The Bangkok Plan*, a cooperative work carried out by MIT and the Bangkok Metropolitan Administration (BMA), suggests creating a number of balanced satellite towns (or sub-centers) in a proximity of 50 to

75 kilometers (31.25-46.88 miles) from the Bangkok capital and then decentralizing the economic and other metropolitan functions from the capital to these sub-centers (see Figure 11). The expectation is to ease the traffic and population concentration in Bangkok. Through the implementation of the jobs and housing balance concept, commuters can live closer to their employment locations and thereby have no needs for long commutes. In the balanced areas, there will be less inbound and outbound commuting flows, which are believed to be a major cause of traffic congestion (OCMLT, 2001).

According to the plan, the covered areas of 4,000 squared kilometers include Bangkok and other five adjacent provinces, which are expected to serve as *buffer* that will render the discouragement to those living in the sub-centers or outside to come into Bangkok for either jobs or other activity participation. The plan aims to decrease numbers of trips from approximately 14 million daily trips coming into the capital down to 4 million (MIT, 1996). Regarding the authoritative involvement, the participating parties are composed of the central government agencies as facilitators, local agencies as supervisors, and private sectors as joint developers and/or investors. The local government will be in charge of town planning and be provided with the fiscal support from the national tax base, while assistance in implementing the Bangkok Plan is expected to come from specialized organizations such as MIT, Japan International Cooperation Agency (JICA), and Thai environmental and roadwork task forces.

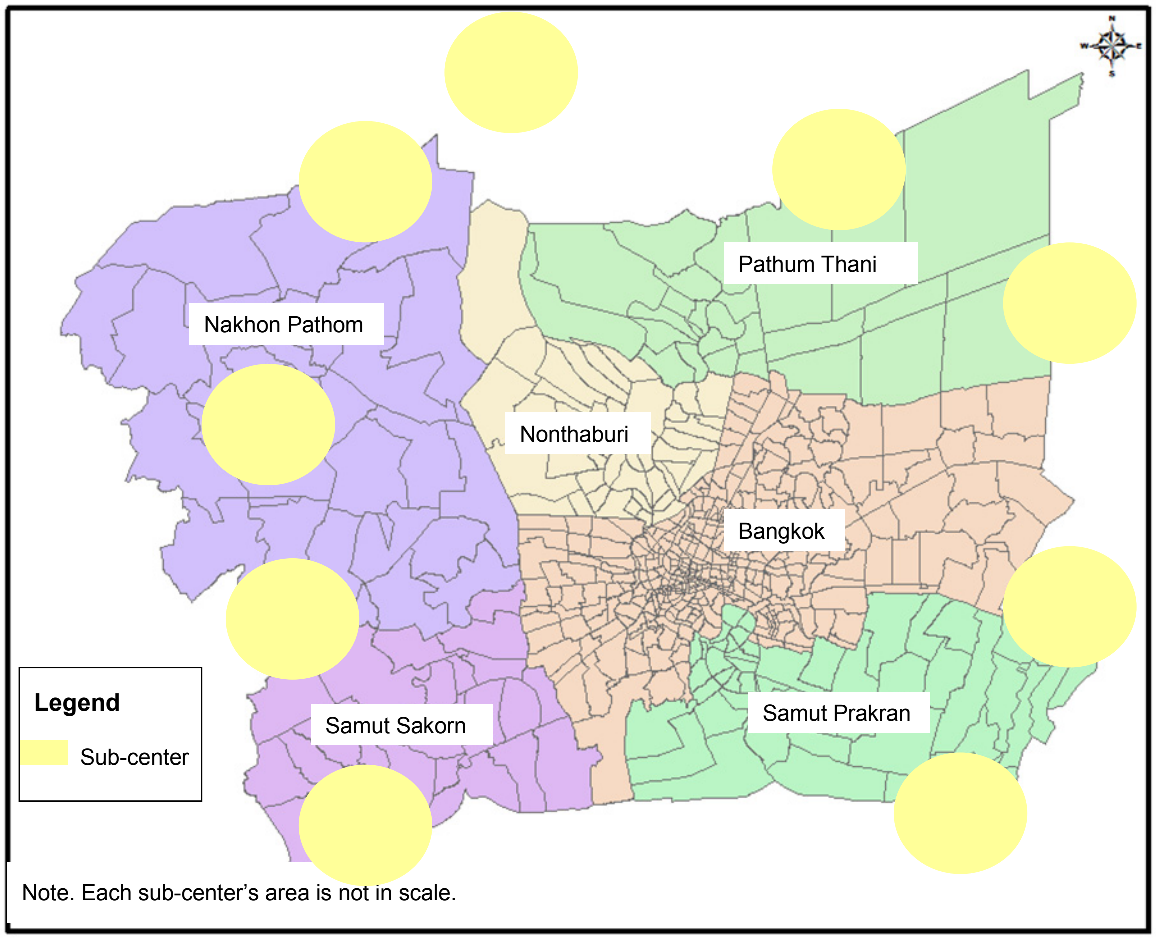

Figure 11. Proposed Balanced Sub-Centers (Source: OCMLT, 2001)

Problem Statement

The centralization of employment opportunity within Metropolitan Bangkok seems to be a major cause of traffic problem. These employment establishments attract great numbers of commuters from the surrounding areas or provinces (Bhattacharjee, Haider, Tanaboriboon, & Sinha, 1997; NSO, 2000; OCLMT, 2000, 2001). The most chaotic period of the weekday is the morning peak period (starting from 6:30 am to 9:00 am) since all of these commuters want to use the same road network, which is limited in capacity, to get to their workplaces and transport their children to schools.

In the morning peak, all work-based trips as well as school-based trips is made and results in an influx of cars on the streets (OCMLT, 1998b; Bhattacharjee, Haider, Tanaboriboon, & Sinha, 1997). Children have to sleep less and get up early due to the traffic jam. Furthermore, most popular schools are located in the dense areas of Bangkok such as central business districts (CBDs), and high traffic congestion occurs around these school clusters. Figures 12 to 14 show the distribution of the student seat density (as a proxy for the school density) of year 1995, year 2001, and year 2003.

During the morning peak period in the central business districts, speeds average nearly 10 kilometers per hour (less than 6.25 miles per hour), as the outside traffic congestion is almost as bad (OCMLT, 2001). Because of the lack of alternatives to road transportation in conjunction with the urban sprawl, traffic congestion at times extends over a radius of 20 kilometers from the central business districts. Moreover, traffic congestion exists in many parts of Bangkok for up to 16 hours per day. The negative impacts of traffic congestion include excessive delays, enormous fuel wastage, and numerous harmful environmental impacts such as noise and air pollution for the locality and the nation as a whole.

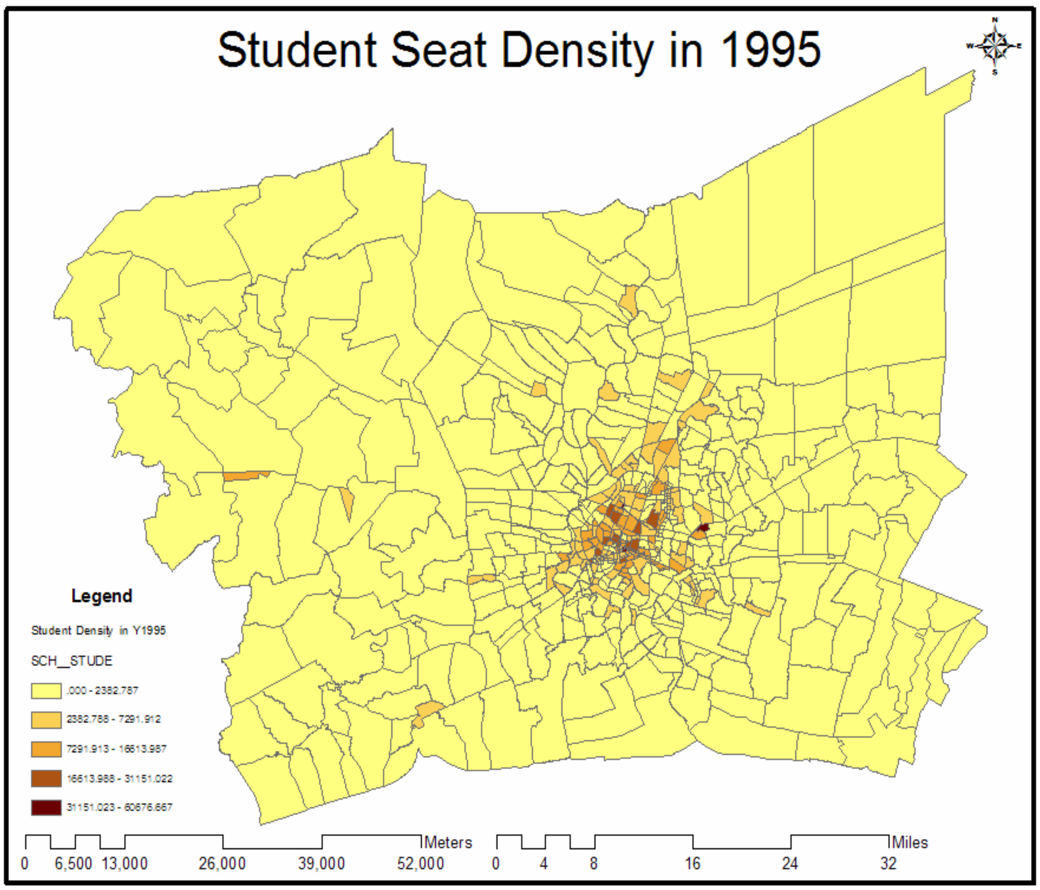

Figure 12. Student Seat Density 1995

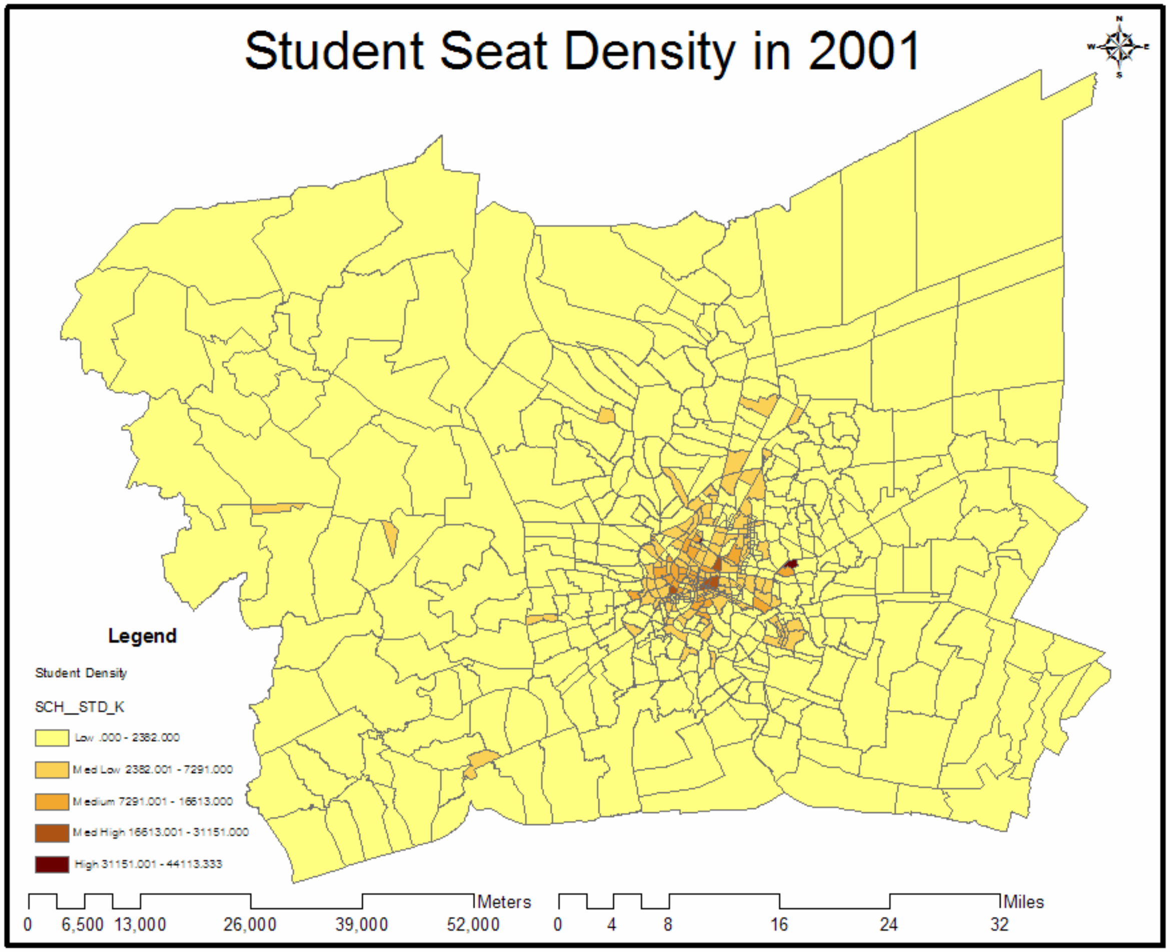

Figure 13. Student Seat Density 2001

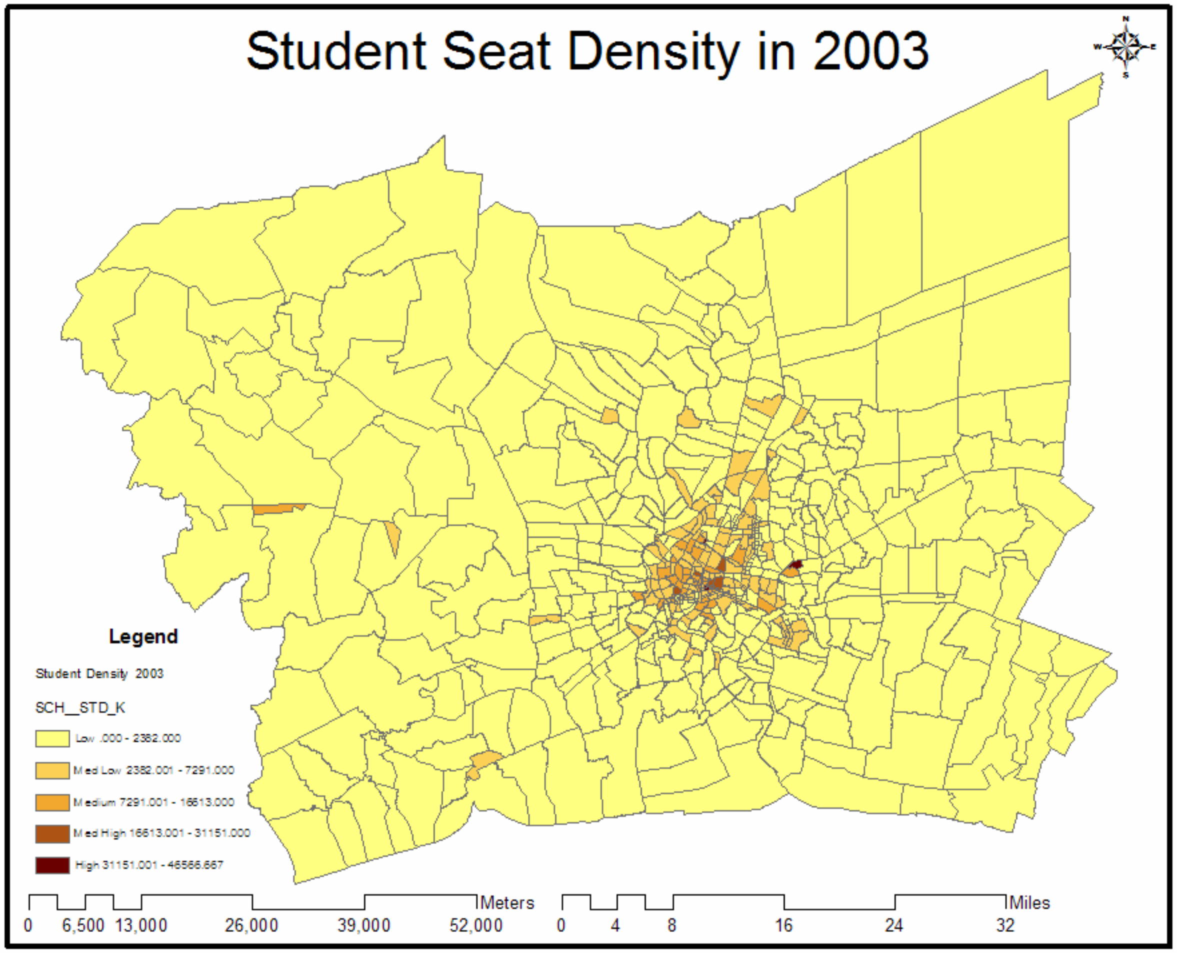

Figure 14. Student Seat Density 2003

In 2000, the Urban Rail Transportation Master Plan for Bangkok and surrounding areas (URMAP) was completed and later approved by the Cabinet as a regional master plan in 2001. Accordingly, any succeeding national urban development and transportation investment is strongly recommended to comply with this plan and its suggested strategies. To alleviate traffic congestion in the Bangkok Metropolitan Region, one strategy advocated by the URMAP is to achieve a better jobs and housing balance for new urban development. The idea is inspired by the Bangkok Metropolitan Development Plan proposed by the Massachusetts Institute of Technology (MIT, 1996). The plan recommends establishing Bangkok's neighboring provinces as new satellite-towns (or sub-centers) utilizing the jobs and housing balance strategy to cope with the growing congestion problem (see Figures 15 to 16). A highlighted approach is to decentralize employment centers to surrounding areas of Bangkok expecting that commuters will live closer to their workplaces; thus there will be less inbound and outbound traffic, which appeared to be a major cause of congestion (OCMLT, 2001).

In general, the measure of jobs and housing balance is the ratio of the number of jobs to the amount of housing available within the employment area. According to the empirical studies, the ratio value of the balanced condition ranges 0.75 to 1.5, the ratio value of the job-rich condition exceeds 1.5, and the ratio value of the job-poor (or housing-rich) condition is less than 0.75. Figures 17 to 19 indicate the increase of job-rich areas in the Bangkok Metropolitan Region from year 1995 to year 2003. From the figures, the job-rich areas are represented in the darkest color, while the lighter colors represent the balanced areas and the job-poor areas respectively.

Regarding traffic volume, the desired line maps shown in Figures 20 to 22 illustrate high trip volume occurs each day between the Bangkok province (the center of the region) and the neighboring provinces. As the measurement unit is daily person-trips, these three figures show the increase of the daily trips made in the region in three years (year 1995, year 2001, and year 2003 respectively).

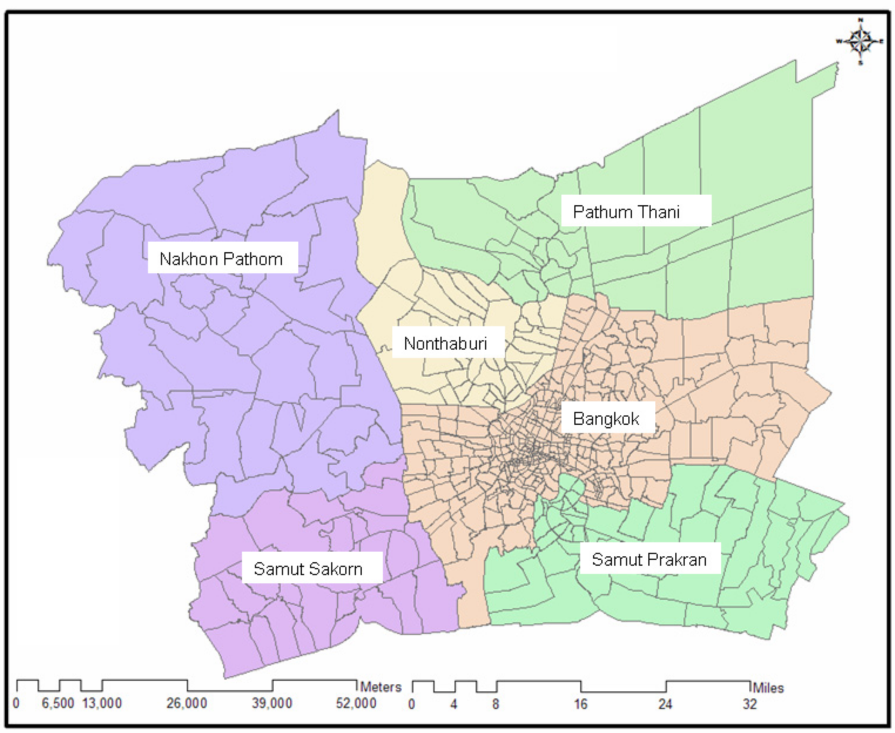

Figure 15. Bangkok Metropolitan Region

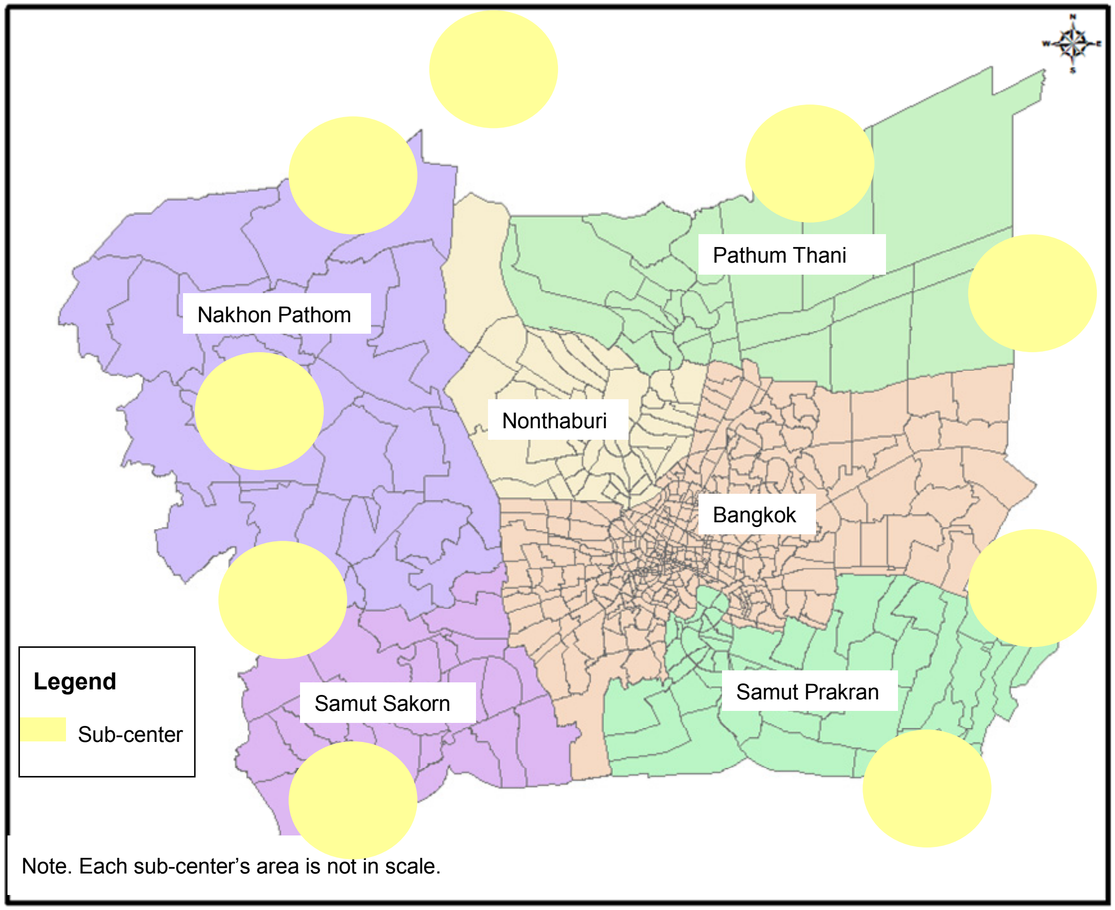

Figure 16. Bangkok's New Balanced Sub-Centers (Source: OCMLT, 2001)

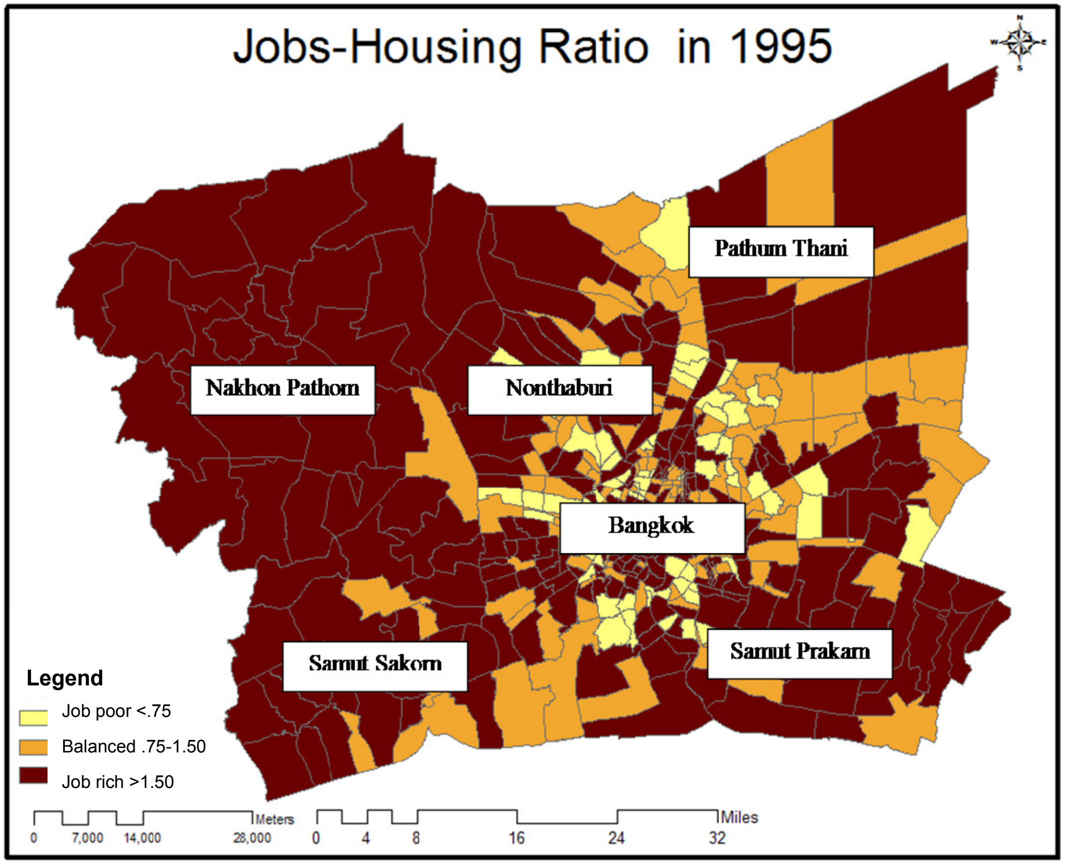

Figure 17. Jobs-Housing Ratio in 1995

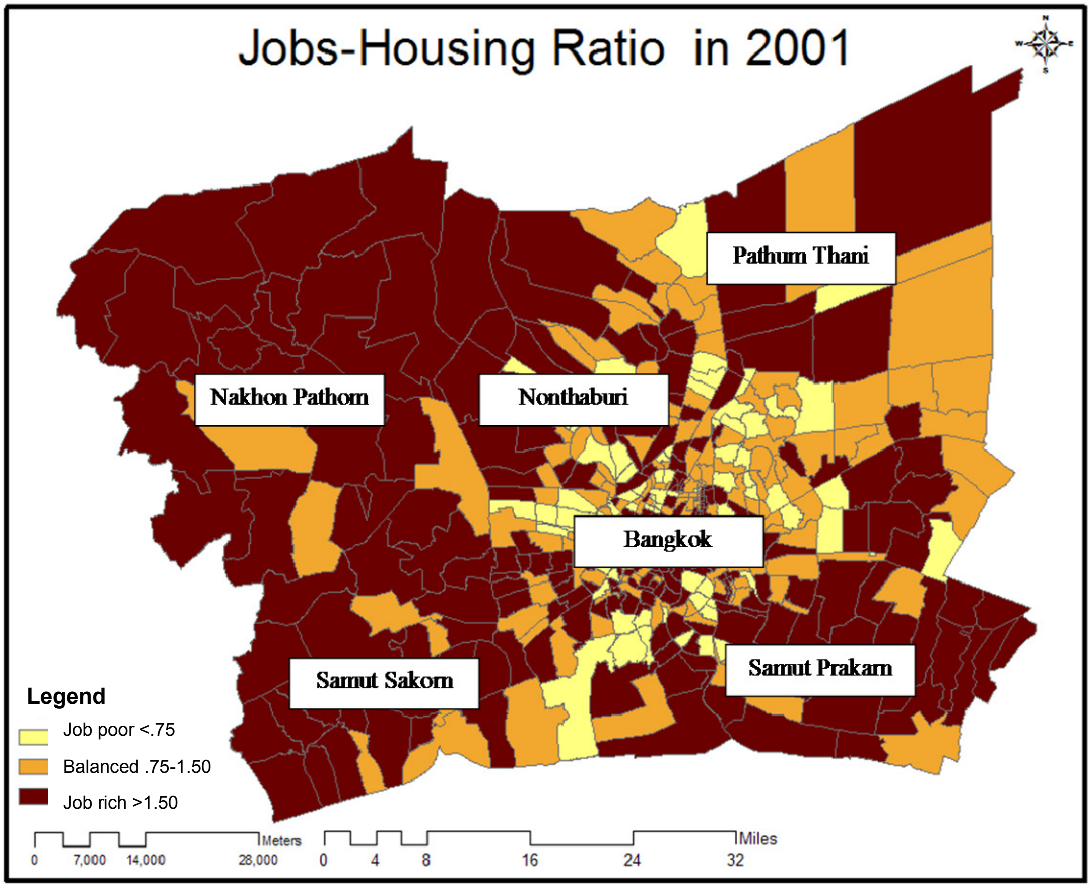

Figure 18. Jobs-Housing Ratio in 2001

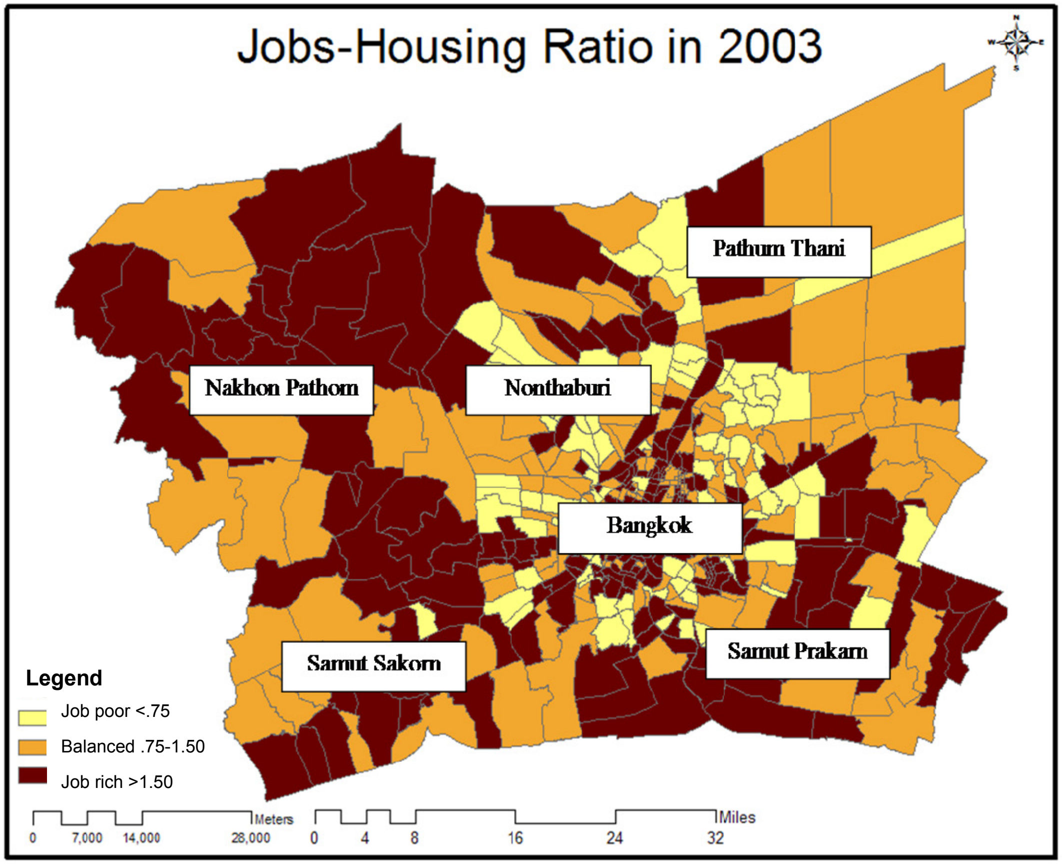

Figure 19. Jobs-Housing Ratio in 2003

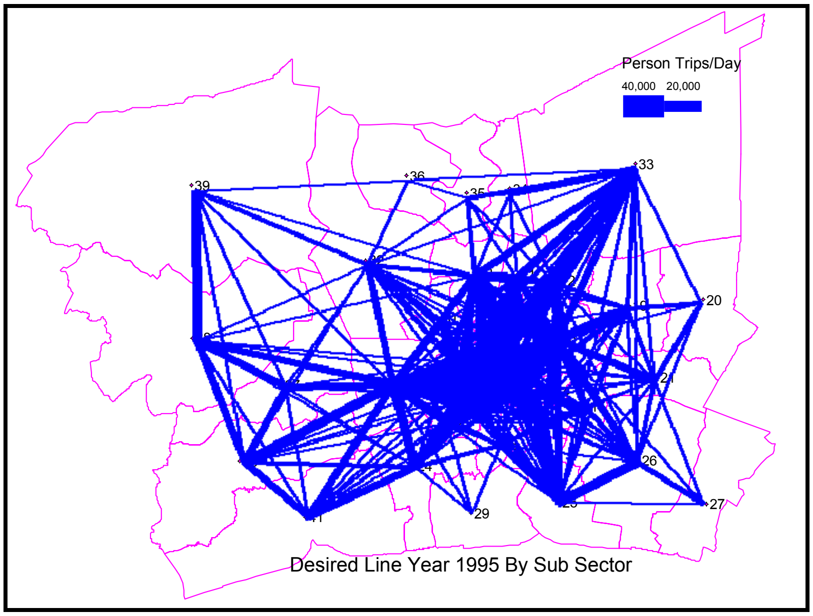

Figure 20. Desired Line in 1995

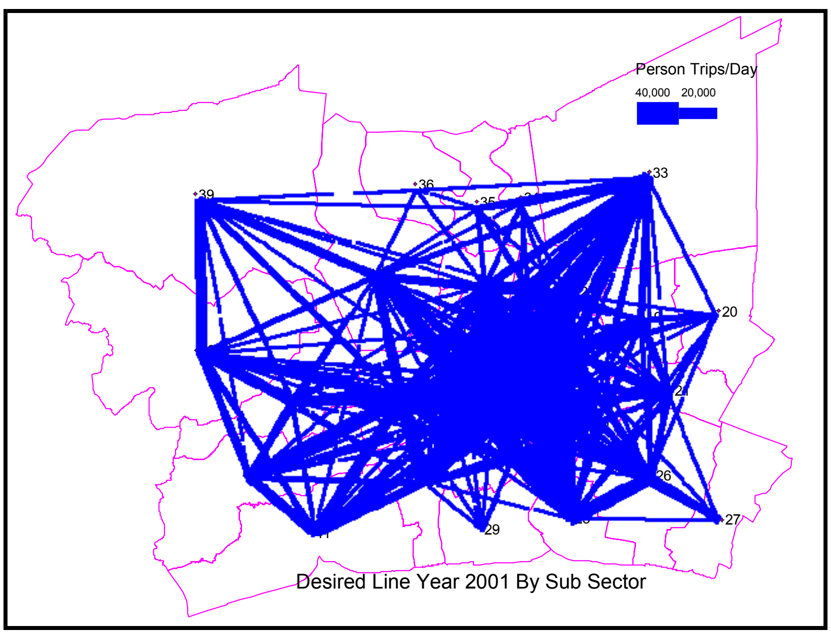

Figure 21. Desired Line in 2001

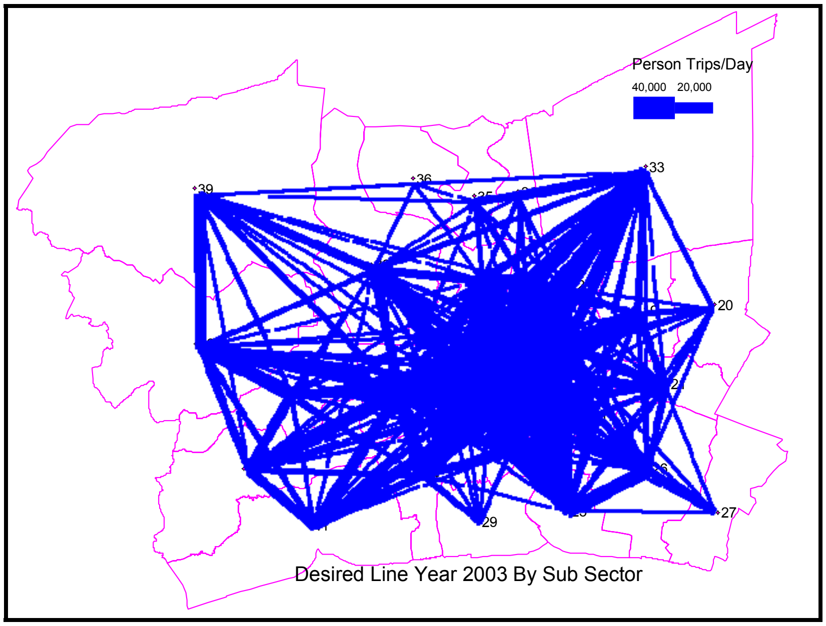

Figure 22. Desired Line in 2003

Research Objectives

The objectives of this research are outlined as the following:

First, to examine the degree to which jobs and housing balance influences traffic congestion in the Bangkok Metropolitan Region,

Second, to assess the relative influence of specific factors related to the land use, and

Third, to determine an appropriate geographic scale for implementing the jobs-housing balance strategy

Significance of Research

The research assesses the effectiveness of jobs and housing balance strategy for reducing traffic congestion in the Bangkok Metropolitan Region. Officially since 2000 Thai government has encouraged an integration of a jobs-housing balance concept as a vital strategy on any new transportation-related development meant to cope with traffic congestion in the associated areas. However, for years, the effectiveness of this jobs-housing balance strategy for coping with traffic congestion has been debated. In addition, there is a shortage of empirical studies on this topic, especially for the context of the Bangkok area.

This research not only explores the effectiveness of jobs and housing balance as a strategy for reducing traffic congestion in a quantitative term, but also reviews other relative influences of specific land use factors. Those factors are population density, school density, and job accessibility. Finally, based on the research findings, the policy implication will be provided for the Thai authorities involved in the areas of transportation and urban planning.

Organization of the Dissertation

This research dissertation is organized into six chapters. Chapter I provides the introduction to Bangkok and its traffic congestion problem along with the responding strategy to cope with the problem. This chapter also presents the research objectives and significance of the study. Chapter II elaborates the concept of jobs and housing balance as well as the related issues according. Chapter III provides the theoretical framework along with the research hypotheses.

Chapter IV describes the methodology designed for conducting this research. Chapter V discusses the regression analysis of the research and results. Lastly, Chapter VI provides the conclusion derived from the research findings. The limitation of the research and the implication for future research are also provided in this chapter.

CHAPTER II

JOBS-HOUSING BALANCE CONCEPT

Jobs and housing balance refers to the parity between a number of jobs and the amount of housing within a geographic area (Cervero, 1989a, 1989b). Other related terms with similar definitions include smart growth control, urbanism, neo-traditional neighborhood design, cluster development (VCTC, 2004). Theoretically, if there is a harmony between jobs and housing that are financially accessible to the employees in a community, then certain environmental impacts such as traffic congestion may be reduced. Harmony occurs when the number of jobs and the amount of housing available to people holding these jobs are in balance. This implies that workers will have the required working skills for the jobs and that the employment compensation allows them to have access to the existing housing in the community. In quantitative terms, the jobs and housing ratio represents the ratio of the number of jobs to the number of housing units in each area. However, this balance measure does not specifically address the issue of matching housing prices with job salaries. The concept of a balanced community has solid roots in the early years of American planning. The theory is explored by the Southern California Association of Governments (SCAG, 2001). One portion of their transportation demand management (TDM) plan focuses on balancing the numbers of jobs and housing. The plan points out that unbalanced areas lack the positive side of growth.

The value of the balance ratio empirically ranges from 0.75 to 1.5 compared to the theoretical value of 1 (see, for instance, Cervero, 1989a; ARC, 2002). The following two figures (Figure 23 and Figure 24) describe the definition of the balanced concept in relation to the home-based work trips. Figure 23 explains a theoretical case when outgoing trips of the zone (or area) are equal to the incoming trips from other zones (external zones). Those trips cancel out each other resulting in an optimized use of a road network. Figure 24 shows the other case when the majority of the trips are circulated within the zone or internalized. According to the *self-contained* concept, all the transportation-related activities, such as the commuting, are contained within the zone.

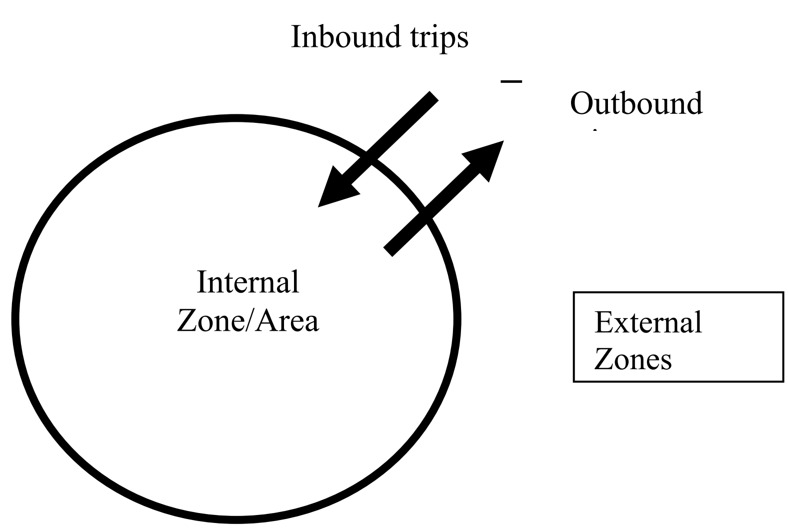

Figure 23. Balanced Condition

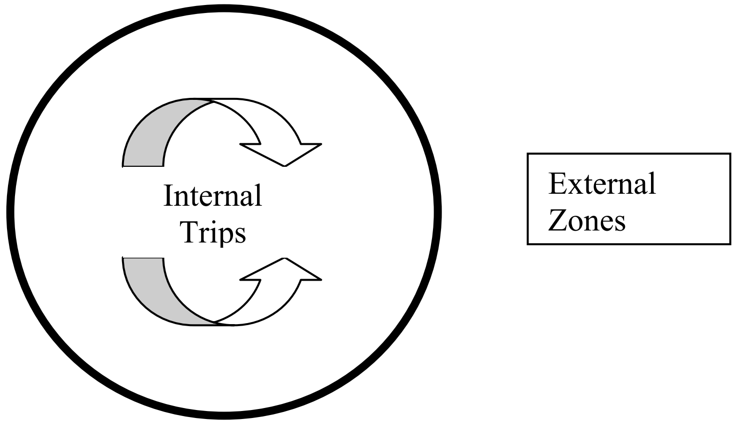

Figure 24. Self-Contained Condition

The next section will point out the most mentioned benefits of implementing the concept of jobs and housing balance as well as the challenging issues.

Jobs and Housing Balance's Benefits

The idea of a jobs and housing balance as a goal to address increased traffic congestion has been promoted for the past three decades (Cervero, 1989b). These policies also reflect more general concerns about developing and maintaining communities with an adequate variety of employment opportunities, a sustainable tax base, and housing mix affordable to a wide range of income levels. These concerns can be understood as a reaction to the high volume of growth many communities are facing. In general, there are four advantageous aspects possibly obtained from the implementation of jobs and housing balance policies that are as the following: reducing traffic congestion and commute time, improving air quality, optimizing economic and fiscal benefits, and improving quality of life. Each of these aspects will be discussed in more details below.

Reducing Traffic Congestion and Commute Time

Numbers of studies (Downs, 1992, 2004; Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard Stein-Hudson Associates, Inc., & Zupan, 1996) find that an opportunity to live close to the workplace afforded by providing housing close to jobs translates to lower congestion and commute times by eliminating the necessity for long-distance commutes. It also provides increased opportunities to use transit, bike, or walk to work instead of driving. Certainly, placing housing in close proximity to employment is no guarantee that those who live in the housing will work at the nearby jobs, or vice versa. This would be particularly true for two income households who split the difference between the locations of their two employment destinations in choosing where to live (Giuliano, 1995; Levine, 1992). It does, however, eliminate barriers for those who wish to live close to work, and reduces needs for long-distance commuting and traffic congestion those people contributing to the road systems especially at peak hours. Frank and Pivo (1994) find travel distances and times tend to be shorter for the commuting in balanced areas.

Florida's study uses the 1990 census data to compute the proportion of work trips which remained within more than 500 cities and town in Florida (ARC, 2002). The study reports that the share of internal or within-community commutes significantly increased when there is a greater balance between the numbers of local jobs and the numbers of working residents. A study of Chicago suburbs by Cervero (1989b) demonstrates that the jobs and housing mismatch leads to longer commutes.

Improving Air Quality

As the need for driving long distances is reduced by providing housing in balance with jobs, so are the resultant emissions associated with driving. The literature on the relationship between auto travel and air pollution is extensive. Most relevant is research done for the Southern California Association of Government's (SCAG) 1989 Regional Growth Management Plan.

While regional agencies originally took the lead in many of the jobs and housing programs because their role in regulating air quality, the use of regional governments as the primary agent for affecting jobs and housing balance has been disappointing. Supporters of balancing jobs and housing agree that balance is a regional issue. However, imbalance is often a result of local land use policy and therefore requires an action of local governments to make those changes necessary to bring about balance. In addition, regional governments generally do not have regulatory powers necessary to adequately address the issue.

Optimizing Economic and Fiscal Benefits

Since a successful implementation of jobs-housing balance strategies result in less need for long-distance commuting and its associated congestion, fewer public resources are required for traffic congestion mitigation of the regional transportation. Ewing and Cervero (2001) explain reduced hours spent in long-distance travel by commuters translate to lower fuel costs and other automobile-related expenses, lower costs to employers in terms of reduced employee tardiness and higher productivity, and eventually lower business trip costs. Furthermore, because the balance between jobs and housing often refers to the more compact urban form with less urban sprawl, costs to local government of providing new facilities and services to new development are less because those facilities and services can be provided more efficiently.

However, another aspect of an economic-benefit argument rests upon a value of commercial growth to the city, in the form of jobs and tax revenues. Employment growth is an essential element of a healthy community. The more complicated questions include types, quantities, and locations of the employment growth. Due to the varying values of different types of development, in the senses of both tax revenue and municipal costs, communities may benefit from encouraging and/or discouraging certain uses. For instance, zoning areas for more commercial uses may be a greater fiscal benefit to cities than more residential uses.

Improving Quality of Life

This occurrence requires the combination of all merits of jobs and housing balance aforementioned. The balance between jobs and housing benefits the local residents (who should to live and work in the balanced area) in reducing their stress from commuting and thereby allowing them to gain more leisure time to spend with their families (SCAG, 2001; VCTC, 2004). For example, the families are affected when members are under the stress and strain caused by the long commutes. When both parents have to go to work, longer commutes take away their time from caring their children or loved ones. This may result in a higher cost of child care expenses and so on. When living within the community they work in, the opportunity for more socialization increases because of the time savings and increased sense of belonging to the community. Balancing numbers of jobs and housing implies the diversity, compactness, and travel convenience in a geographic sense, therefore the urban life can then be effectively promoted.

Challenging Issues

As the benefits are listed above, the challenging issues for the jobs and housing balance implementation can be grouped into three aspects: geographic scale, jobs and housing balance measure, and traffic congestion mitigation. Regarding the spatial scale issue, whether jobs and housing balance control is effective at a local scale. Second, the more complicated consideration is needed beyond the ratio of jobs to housing. Lastly, if only balancing numbers of jobs and housing can effectively reduce traffic congestion. Each of these issues will be elaborated in the following sub-section.

Geographic Scale

Regions are balanced by its definition, as they are identified as economically self-contained units (Giuliano, 1995; Levine, 1998). Balancing jobs and housing in sub-regional areas were a challenge that most communities addressing this issue face. While regional agencies often take leads in prescribing policies, an act of implementation generally falls to counties and cities (Song, & Knaap, 2004). Since traffic mostly moves between jurisdictions, and commute sheds are rarely contained within one jurisdiction, implementing policies on a strictly local level has been challenged indeed.

Some critics argue that balancing exercised on an individual community may be useless. For instance, Giuliano (1991) argues that balance normally occurs on its own through the market force, thus imbalance is more a result of incorrectly defining the study area both spatially and temporally.

Matching Jobs and Housing within a Community

Balance involves more than matching numbers of housing units and numbers of jobs. The adjustment must be made for local conditions, such as household sizes, percentage of resident workers, and other demographic factors (Downs, 2004). Balancing *appropriate housing* opportunities with *appropriate jobs* complicates the issue, necessitating the consideration of more difficult matters such as housing prices and wage rates (Sultana, 2000).

Traffic Congestion

Of particular interest is the effect of balance in reducing traffic volume and congestion when this is a common drive of jobs and housing balance policies (Giuliano & Small, 1993). An imposing question is whether jobs and housing balance will ever be an effective tool for addressing the congestion issue. There are several reasons for having such a question. First, the residential choice may become difficult when there are two household wage earners working in different locations. Second, the high job-turnover rate reduces the ability to locate with the reference to one's workplace. Finally, other factors including the access to other amenities, housing prices, qualities of schools and neighborhoods impact the relocation decision as well. Many suggest jobs and housing balance needs to be used in combination with other measures, such as the transportation demand management programs (TDM programs) to be an effective means of traffic congestion mitigation.

Summary

Despite ongoing arguments on the implementation of the jobs and housing balance concept, numbers of available quantitative findings show balanced areas are associated with lowered average commute trip (home-based work trips) lengths by seven to 30 percent, comparing to where jobs and housing are out of balance. For instance, in greater Seattle, the commute trip lengths in Census tracts with the jobs to housing ratio ranging 0.7 to 1.3 are approximately 30 percent shorter than in less well balanced tracts (Frank & Pivo, 1994). Although trip length differentials found in San Francisco Bay Area are not significant (Ewing, 1997; NTI, 2000), middle-of-the road jobs and housing balance as a strategy for land development and redevelopment seems to offer a substantial traffic volume reduction potential (Cervero, 1991; Pivo, Hess, & Thatte, 1995; Ewing, 1996; Nowlan & Stewart, 1991).

Cervero (1996b, p. 508) sums it up well when he commented “for every study showing that jobs and housing balance does not matter, there are at least as many that show it does.” In the context of the Bangkok Metropolitan Region, the impact of jobs and housing balance is worth for further examination, as traffic congestion and the long commutes are believed to negatively affect the economic growth of the associated areas and the quality of life of the involved parties through the wasted resources, increased pollution, and deprived sleeps.

CHAPTER III

THEORETICAL FRAMEWORK AND HYPOTHESES

This chapter will elaborate on the theory, concept, and empirical finding serving as the framework for establishing the research hypotheses.

Points of View on Traffic Congestion

Regarding the point of view of traffic congestion, a number of scholars present slightly different views about it. Some point out successful cities are places where economic transactions are promoted and social interactions occur, and that traffic congestion occurs where lots of people pursue these ends simultaneously in limited space (Downs, 2004; Taylor, 2002). It is also noted that traffic congestion is not necessarily all bad, since it can be a sign that a community has a healthy growing economy and refrains from over-investing in transportation infrastructure such as roads (Cervero, 1998a). Unpopular places rarely experience traffic congestion, and the declining cities actually experience a certain reduction in traffic congestion (Taylor, 2002).

That being said, Bangkok (Thailand's Capital) is no exception. Bangkok produces over 30 percent of the country's economic output and its population accounts for about 20 percent of the nation's population (OCMLT, 2001). A third of national economic activity and half of economic growth occur in Bangkok. In addition, Bangkok and its five neighboring provinces combined is Thailand's most dominant region in terms of economic power and the tax revenues generated. The Bangkok Metropolitan Region consists of Bangkok and five adjacent provinces, namely Nonthaburi, Pathumthani, Nakhon Pathom, Samut Prakan, and Samut Sakorn. The next largest city in Thailand is Chiang Mai (located in the northern part of Thailand) with an estimated population of 409,000 people accounting for only five percent of Bangkok's population[1] (NSO, 2000). Nearly 75 percent of Thailand's urban dwellers live in the Bangkok Metropolitan Region. About half of it is accounted by the migration from rural and other urban areas due to the employment opportunities.

Influence of Jobs and Housing Balance

According to numbers of studies, the imbalance between numbers of jobs and available housing is believed to be a major cause of traffic congestion especially in the peak period (OCMLT, 2001, Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard Stein-Hudson Associates, Inc., & Zupan, 1996). To tackle Bangkok's traffic congestion, the Thai government advocates a prominent land use strategy aiming at balancing numbers of jobs and available housing to reduce an

[1] The area of Bangkok alone is 1,568.7 square kilometers with the population density of 4,051 persons/square kilometers, which rates as the most populated city in the nation (NSO, 2000).

influx of commuting trips into the central business districts (CBDs) of the Bangkok Metropolitan Region. The basic idea is to decentralize the economic and other metropolitan functions including employment establishments, population density, and school density from the capital to satellite sub-centers or new towns (Kubota, 1996; MIT, 1996; OCMLT, 1998, 2001). This strategy is based on the jobs and housing balance theory and was originally introduced in the Bangkok Plan, a study jointly conducted by MIT and the Bangkok Metropolitan Administration. The study proposes establishing eleven balanced sub-centers in the proximity of 50 to 75 kilometers (31.25 to 46.88 miles) from the Bangkok province.

The expectation is to offer choices for Metropolitan Bangkok's commuters to live closer to their workplaces in the proposed sub-centers, and as a result the commuting trips as well as traffic congestion induced to Bangkok's CBDs will be lowered (see Figure 25). Figuratively, the plan aims to decrease numbers of trips from between 13 and 14 million daily trips coming into the capital down to between 3 and 4 million. As a rough estimate, the amount of the reduced daily trips is over 70 percent of the current trips made into the capital each day. Accordingly, these new sub-centers are built based on the *self-containment concept* introduced in the jobs and housing balance theory. By having an appropriate number of jobs for residents, the concept claims more commuting trips will likely to be contained within the area and fewer will go out to other areas.

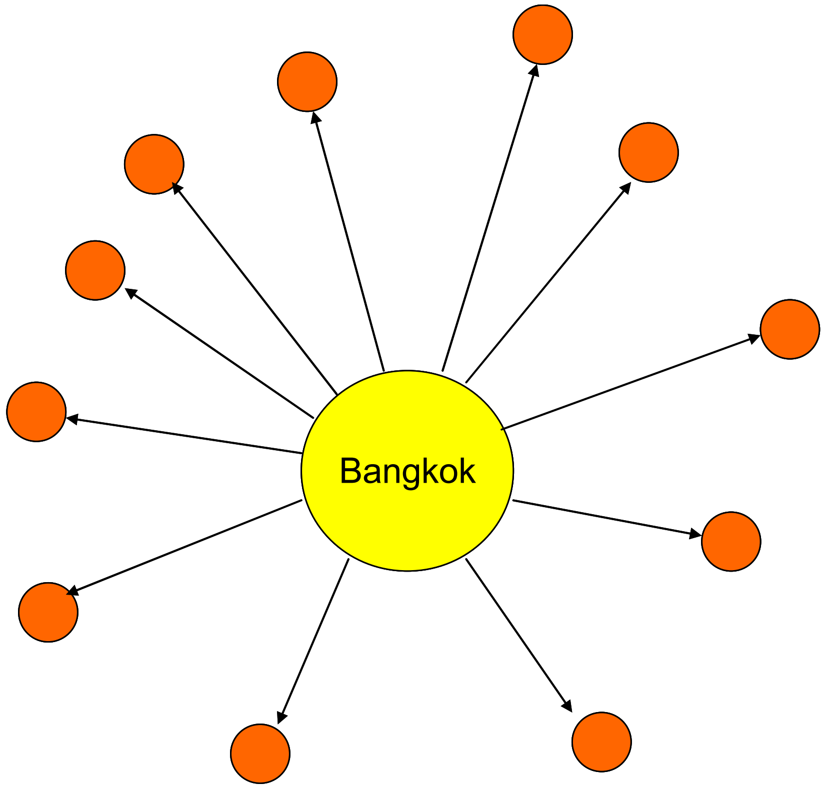

Figure 25. Balanced Sub-Center Concept

Influence of Other Factors

In addition to the influence of jobs and housing balance, previous studies show other factors related to the land use contribute to the change of traffic congestion and traveling as well (Cervero & Kockelman, 1997; Crane, 1996; Frank, & Pivo, 1994; Giuliano & Small, 1993). Based on the research interest, the factors considered include population density, school density, and job accessibility. Each of these factors is discussed with more details below.

Population Density

A number of related studies find the dense areas are associated with traffic congestion (Bertini, 2005; Lomax & Turner, 2003; Schrank & Lomax, 2003). Based on the knowledge of the causes of traffic congestion, the positive population growth contributes to the traffic increase (Downs, 1992, 2004; Pisarski, 1987, 1996).

School Density

The area having higher school density generates more traffic volume than the area having less school density. Thai studies (OCMLT, 1998b, 1999b, 2001; NSO, 2000) reveal that, regardless of school locations, a large percentage of Thai parents preferred having their children attend schools with good reputation. Apparently, those big-named schools are clustered in a certain places, mostly in the Bangkok area. Due to the lack of the safety standard for school buses, in rush hours, most Thai parents choose to drive their children to these schools before going to their workplaces. Resulting from this type of travel behavior, the public roads in the morning peak period (from 6:30 a.m. to 9:00 a.m.) become very congested especially within and around school sites.

Job Accessibility

Previous findings indicate that travel time is comparatively lower in an area with good job accessibility than in an area with poor job accessibility since commuters can move in and out of a road network faster, and as a result the network's traffic load is reduced in a shorter period of time (see, for example, Bertini, 2005; Bhat, Govindarajan, & Pulugurta, 1998).

Figure 26 illustrates the influential connection between the land use factors and traffic congestion.

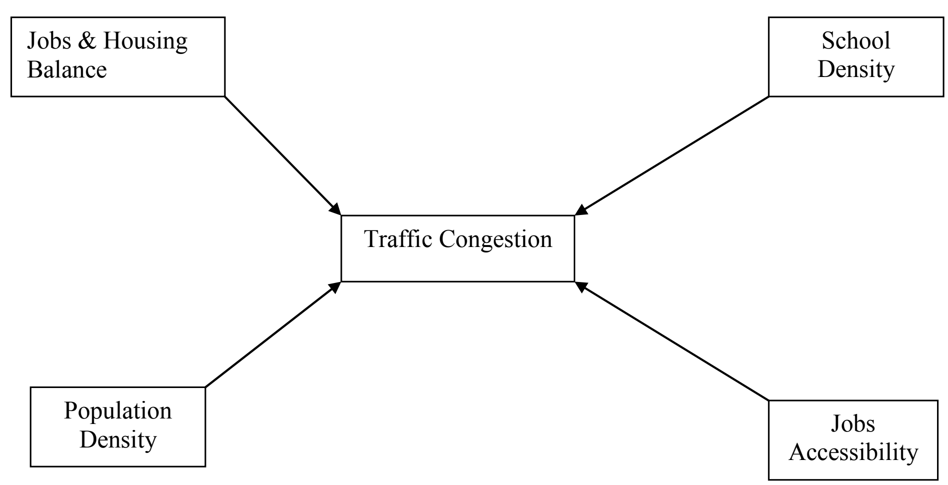

Figure 26. Influential Connection

The subsequent section will describe the research hypotheses that are based on the theory, concept, and empirical finding aforementioned.

Research Hypotheses

This section specifies a set of research hypotheses focusing on the relationship between specific land use factors (namely, jobs and housing balance, population density, school density, and job accessibility) and traffic congestion. There are four hypotheses as the following:

First, jobs and housing balance is negatively associated with traffic congestion. As the balance between numbers of jobs and available housing in the area increases, traffic congestion in the area decreases.

Second, the population density is positively associated with traffic congestion. As population density increases, traffic congestion increases.

Third, the school density is positively associated with traffic congestion. As school density increases, traffic congestion increases.

Fourth, the job accessibility is negatively associated with traffic congestion. The area having higher job accessibility has less traffic congestion than the area having lower job accessibility.

Table 3 represents the hypothetical relationship between the land use factors and traffic congestion.

Table 3. Summary of Hypothetical Relationship

	Land Use			
Mobility	**Jobs and Housing Balance**	**Population Density**	**School Density**	**Job Accessibility**
Traffic Congestion	-	+	+	-

Note. The plus sign (+) represents the positive relationship, while the minus sign (-) represents the negative relationship.

The measurements of the land use factors and traffic congestion will be presented with more details in the following chapter, the methodology.

CHAPTER IV

METHODOLOGY

This chapter will present an overview of the research design, sources of collected data, key procedures taken to carry out the analyses, definitions and measures of the dependent and independent variables, and lastly specifications of the models.

Overview

This research examines the relationship between two constructs: one is the land use aspect, and the other is traffic congestion (see Table 4). For the measurement purpose, the land use includes the following four variables: jobs and housing balance, population density, school density, and job accessibility. Traffic congestion has the travel time index as the variable. The travel time index focuses on the home-based work trips in both peak period and off-peak period. The dependent variable and independent variables used in the analyses will be elaborated in the variable-definition section.

Responding to the research objective, two geographic scales (units of analysis) are used to examine the effectiveness of the jobs and housing balance impact on traffic congestion. One unit is denoted as the subsector level composed of forty-one subsectors, and the other unit is denoted as the traffic analysis zone level comprising five-hundred-five traffic analysis zones (TAZs). These units of analysis are available from the Thai transportation planning models (OCMLT, 1998a, 2001; OTP, 2004).

Table 4. Research Constructs

Land Use	Traffic Congestion
Jobs and Housing Balance	Travel Time Index
Population Density	
School Density	
Job Accessibility	

Data Sources

Most of research data are available from the Bangkok Metropolitan Region Extended City Model (BMR-ECM) database and the National Statistical Office of Thailand (NSO). The BMR-ECM model is widely used by numbers of Thai agencies as a strategic planning model in transportation or related fields. The data categories includes both socio-economic aspect (namely, population, household, employment, income, and school enrolment) and transportation aspect (namely, road arterials, collectors, expressways, and public transportation system). With the total coverage areas of 7,760 squared kilometers (1,917,537.76 acres), this four-step based BMR-

ECM model encompasses Bangkok and five adjacent provinces - Nakhon Pathom, Pathumthani, Samut Sakhon, Samut Pakran, and Nonthaburi (see Figure 27).

The coverage areas are structured into three geographic scales in order: a largest coverage area is referred as *sector,* composed of fourteen sectors for the whole BMR. A second largest is referred as *subsector,* comprising forty-one subsectors (see Figure 28). A smallest coverage area is referred to as *traffic analysis zone (TAZ),* including five-hundred-twenty TAZs (see Figure 29). Five-hundred-five TAZs are internal (located within Metropolitan Bangkok) zones, and fifteen TAZs are external, which are located outside the metropolitan area. In addition, some socio-economic and demographic were obtained from the National Statistical Office of Thailand.

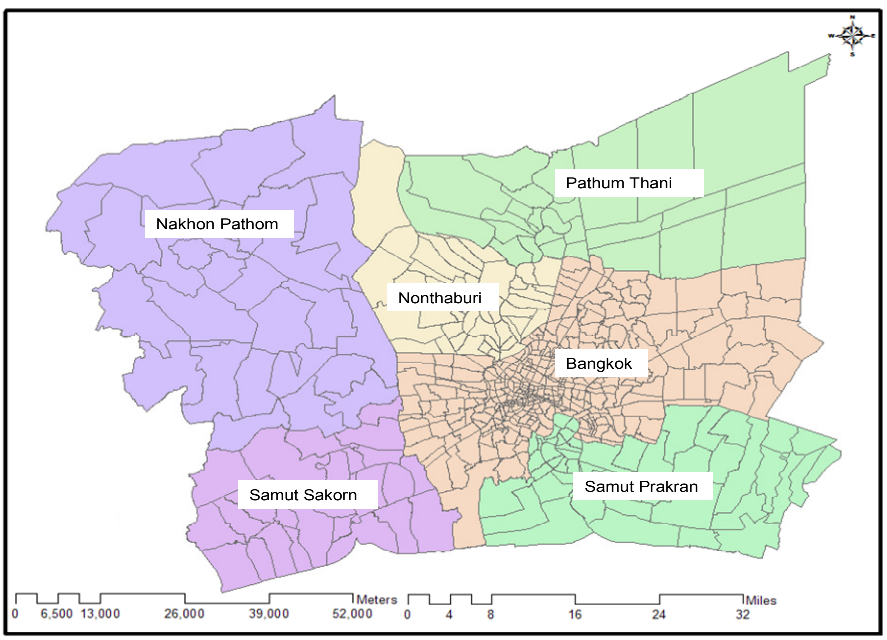

Figure 27. Covered Provinces in the BMR-ECM Model

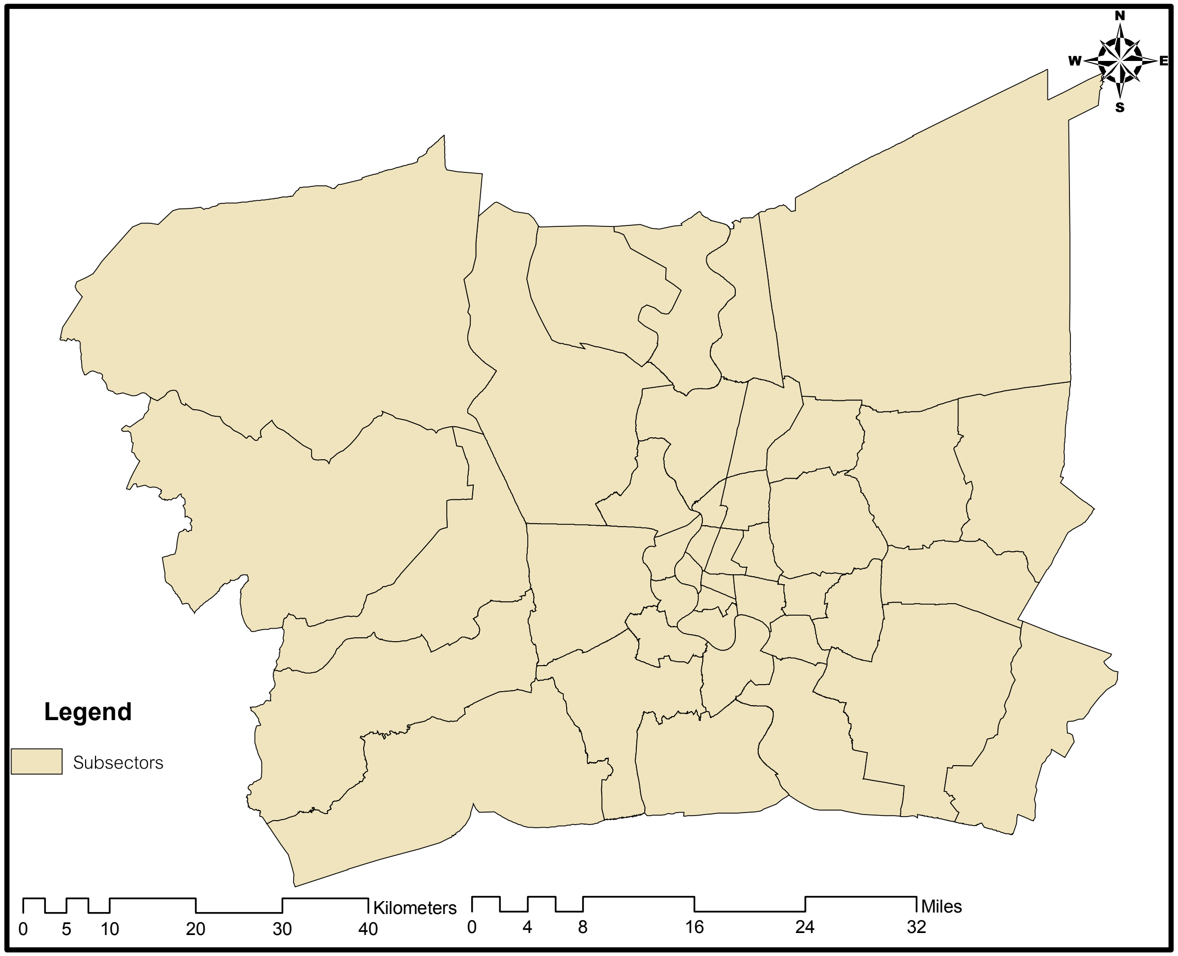

Figure 28. Subsectors

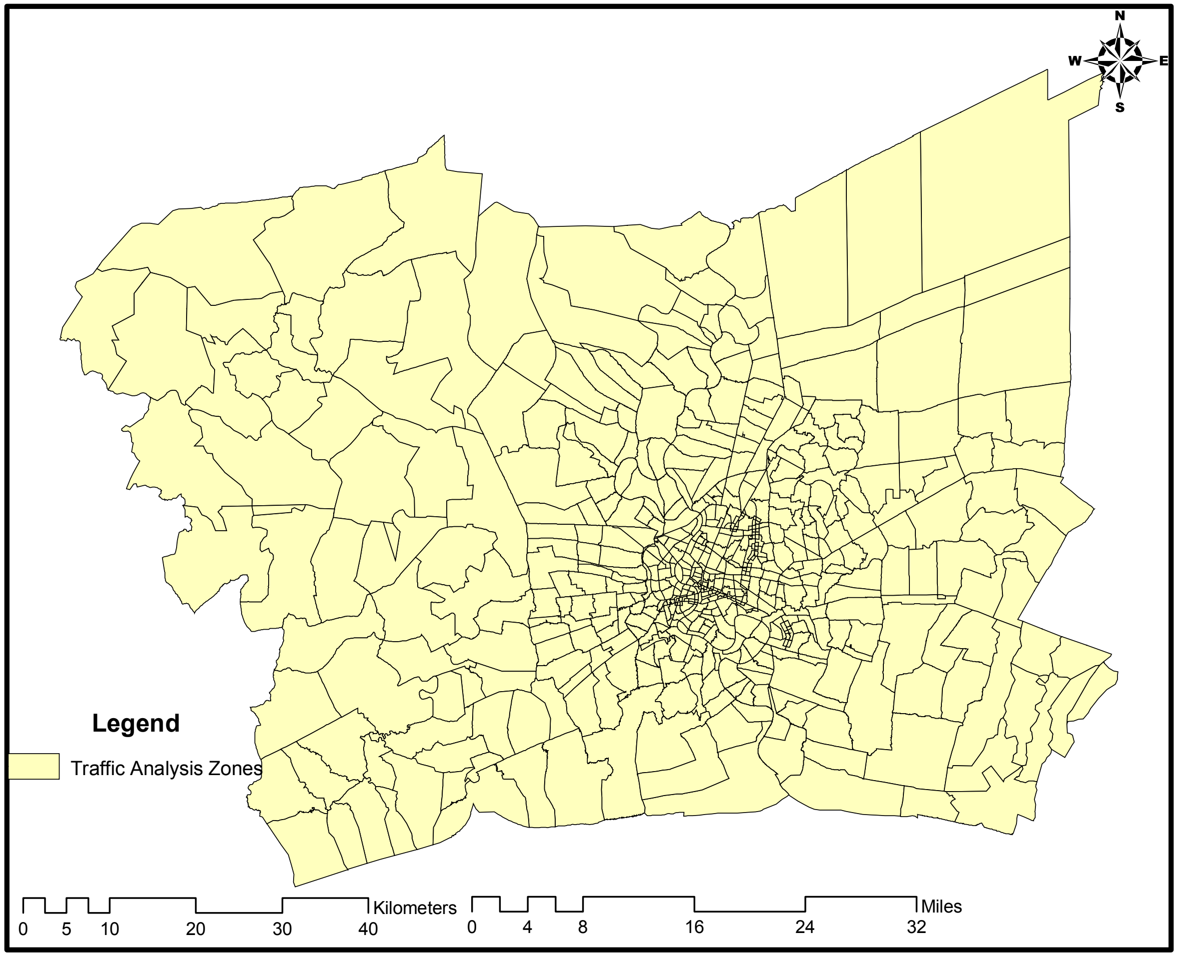

Figure 29. Traffic Analysis Zones

Procedures

First, three data sets representing year 1995, 2001, and 2003 are derived from the BMR-ECM database. Each data set is aggregated within two different geographic scales that include subsectors and traffic analysis zones respectively. Each aggregate includes traffic data, namely vehicle-hours[1] and vehicle-kilometers on expressways and arterials, focusing on the morning peak period (6:30 A.M. to 9:00 A.M.), which seemed to be a crisis period according to Thai official studies (BMA, 1996; OCMTL, 1998a, 2000, 2001),

Second, the independent variables are the land use factors (of year 1995, year 2001, and year 2003) including numbers of jobs, housing units, population, and student seats (as a proxy for schools). The details of these variables are given in a variable definition section, and

Finally, with the application of the SPSS statistical software package, the multiple regression modeling is then conducted upon three yearly data sets (year 1995, year 2001, and year 2003).

Variable Definitions

Two linear regression models are used to examine the relationship between

[1] Vehicle herein refers to a private car equivalent unit (PCU). The conversion includes all private transportation modes such as automobiles and pick-up trucks.

the dependent variable and a specific set of independent variables. The dependent variable is the travel time index (TTI). The independent variables include jobs and housing balance, population density, school density, and job accessibility index. Table 5 describes the definitions of all variables and their acronyms used in the analyses.

Table 5. Variable Definition

Dependent Variable	**Traffic Congestion**	**Acronyms**	**Units**
	Travel Time Index	TTI	None
Independent Variables	**Land Use**	**Acronyms**	**Unit**
	Jobs and Housing Balance	JHB	None
	Population Density	D	Persons per Squared Kilometers
	School Density	Sch	Seats per Squared Kilometers
	Job Accessibility Index	Ai	None

The following section will discuss the measures of specific variables, namely, the travel time index (TTI), jobs and housing balance (JHB), and job accessibility index (Ai).

Variable Measures

Some variables of this research are measured in straightforward manners (namely, population density and school density), while other variables require specific measures to be consistent with the theoretical implication. These variables include the travel time index, jobs and housing balance, and job accessibility index.

Travel Time Index

Among well regarded congestion measures introduced by Texas Transportation Institution, the Travel Time Index (TTI) is used to measure an amount of additional time needed to make a trip during a typical peak travel period compared to traveling at free-flow speeds (Schrank & Lomax, 2003). The travel time index includes both recurring and incident conditions. The TTI formula in simplified version is shown in Equation 1, while the same formula in detailed version is shown in Equation 2.

$$\text{Travel Time Index} = \text{Peak-Period Travel Time} / \text{Free-Flow Travel Time} \tag{1}$$

$$\text{Travel Time Index} = \frac{\left(\dfrac{\text{Freeway Travel Rate}}{\text{Freeway Free-flow Rate}} \times \text{Freeway Peak Period VMT}\right) + \left(\dfrac{\text{Principal Arterial Street Travel Rate}}{\text{Principal Arterial Street Free-flow Rate}} \times \text{Principal Arterial Street Peak Period VMT}\right)}{\left(\text{Freeway Peak Period VMT} + \text{Principal Arterial Street Peak Period VMT}\right)} \tag{2}$$

Jobs and Housing Balance

According the research hypotheses, this independent variable is for measuring the effect of jobs and housing balance on traffic congestion, regardless of job-rich or job-poor conditions. The variable of jobs and housing balance is normalized on the scale of zero (0) to one (1) according to the preset conditions. First, it is helpful to know the terms used for the measure. The raw jobs and housing ratio (JHRraw) is defined as the ratio of the number of job to the number of housing units in an area. Second, the region-wide jobs and housing ratio (JHRregion) is defined as the ratio of the sum of job number to the sum of housing number within the region. Finally, jobs and housing balance (JHB) is defined as either the ratio of the JHRraw to the JHRregion or the JHRregion to the JHRraw depending on two conditions as shown in Equation 3 and Equation 4 below.

If JHRraw > Region-wide JHR (JHRregion), then JHB = JHRregion/JHRraw (3)

If JHRraw ≤ Region-wide JHR (JHRregion), then JHIB = JHRraw/ JHRregion (4)

In theory, when the area becomes balanced, the ratio of jobs to housing is equal to one; however, the ratio varies with the geographic scales. Empirical studies find the numbers of jobs and the amount of housing is likely to be in balance at the regional scale (Cervero 1996b; Ewing & Cervero, 2001; Giuliano, 1995). The main idea of this measure is to compare the areal jobs and housing ratio with the region-wide jobs and housing ratio. Based on this measure of jobs and housing balance, the value of JHB ranges from zero (0) to one (1).

Job Accessibility Index

The job accessibility is a way to characterize the ease of reaching the employment activities. That ease is determined by a combination of the transportation system, which determines the physical connections between activities, and land use patterns, which determine the locations and intensity of activities. The formula used for measuring the job accessibility score for each area is specified as shown in Equation 5. To obtain the job accessibility index for each area, the derived score will then be divided by the average score in the region.

$$A_i \text{ score} = \sum_j O_j f(C_{ij}) \quad (5)$$

Where

O_j = number of jobs in zone j
C_{ij} = travel time from zone i to zone j
$f(C_{ij})$ = impedance function

$$f(C_{ij}) = \alpha * C^{\beta}_{ij} * e^{\gamma * C_{ij}}$$

Where

α, β, γ = model coefficients given by the model; for home-based work trips
C_{ij} = travel time from zone i to zone j
e = base of the natural logarithm

This job accessibility measure indicates two possible implications. First, as the job opportunity (the number of jobs) around the interest site (Ai) increases, the index value increases. Second, the index value increases as the commute travel time decreases.

Table 6 shows the descriptive statistics of all variables aforementioned (at the TAZ level) in year 1995, year 2001, and year 2003 respectively. The TTI's means range from 1.26 to 1.56, which implies congested condition, as they are quite stable with a small decrease in year 2001. The JHB's means are 0.5 on average, implying the imbalance (out-of-balance). Table 7 exhibits the result from the Pearson correlation study of variables (at the TAZ level). The study reveals there is no extreme correlation among all the independent variables. All statistics shown in the table are significant at five percent significance level.

Table 6. Descriptive Statistics of Variables

	Minimum	Maximum	Mean	Std. Deviation
TTI95	0.101	9.637	1.559	1.019
JHB95	0.045	1.000	0.572	0.252
D95	83.808	146,307.990	12,268.947	19,057.624
Sch95	0.000	60,676.667	2,767.044	5,981.062
Ai95	0.024	4.923	1.000	1.015
TTI01	0.393	4.565	1.256	0.386
JHB01	0.057	0.995	0.569	0.251
D01	84.591	141,514.175	12,028.370	18,563.659
Sch01	0.000	44,113.333	2,301.177	4,243.765
Ai01	0.014	7.927	1.000	1.258
TTI03	0.679	4.935	1.353	0.524
JHB03	0.029	0.997	0.548	0.262
D03	51.424	53,824.632	7,952.909	9,358.376
Sch03	0.000	46,566.667	2,429.082	4,479.738
Ai03	0.009	8.445	1.000	1.298

Note. TTI: Travel Time Index; JHB: Job and Housing balance; D: Population Density; Sch: School Density; and Ai: Job Accessibility Index

Table 7. Correlation Study of Variables

		JHB95	D95	Sch95	Ai95
JHB95	Pearson Correlation	1	-0.079	-0.086	-0.145
	Sig. (2-tailed)		*0.048*	*0.044*	*0.001*
D95	Pearson Correlation	-0.079	1	0.494	0.660
	Sig. (2-tailed)	*0.078*		*0.000*	*0.000*
Sch95	Pearson Correlation	-0.086	0.494	1	0.529
	Sig. (2-tailed)	*0.044*	*0.000*		*0.000*
Ai95	Pearson Correlation	-0.145	0.660	0.529	1
	Sig. (2-tailed)	*0.001*	*0.000*	*0.000*	
		JHB01	***D01***	***Sch01***	***Ai01***
JHB01	Pearson Correlation	1	-0.082	-0.113	-0.129
	Sig. (2-tailed)		*0.046*	*0.011*	*0.004*
D01	Pearson Correlation	-0.082	1	0.598	0.465
	Sig. (2-tailed)	*0.046*		*0.000*	*0.000*
Sch01	Pearson Correlation	-0.113	0.598	1	0.415
	Sig. (2-tailed)	*0.011*	*0.000*		*0.000*
Ai01	Pearson Correlation	-0.129	0.465	0.415	1
	Sig. (2-tailed)	*0.004*	*0.000*	*0.000*	
		JHB03	***D03***	***Sch03***	***Ai03***
JHB03	Pearson Correlation	1	0.020	-0.053	-0.11
	Sig. (2-tailed)		*0.050*	*0.034*	*0.014*
D03	Pearson Correlation	0.020	1	0.609	0.452
	Sig. (2-tailed)	*0.050*		*0.000*	*0.000*
Sch03	Pearson Correlation	-0.053	0.609	1	0.408
	Sig. (2-tailed)	*0.034*	*0.000*		*0.000*
Ai03	Pearson Correlation	-0.11	0.452	0.408	1
	Sig. (2-tailed)	*0.014*	*0.000*	*0.000*	

Model Specifications

Based on the research hypotheses, the regression is specified into two models: one is the reduced model, and the other is the full model. In terms of the reduced model is designed to examine the relationship between jobs and housing balance and the travel time index in quantitative sense. While the full model is to explore the relationship between a set of land use factors and the travel time index. The land use variables are composed of jobs and housing balance, population density, school density, and job accessibility index. All models are applied to both subsector analysis and zonal analysis. Table 8 and Equation 6 exhibit the specification of the reduced model, as Table 9 and Equation 7 show the specification of the full model.

Table 8. Model 1 – The Reduced Model

	MODEL 1
Dependent Variable	Travel Time index (TTI)
Independent Variable	Jobs and Housing Balance (JHB)

$$TTI = \beta_0 + \beta_1 \, JHB \qquad (6)$$

Table 9. Model 2 – The Full Model

	MODEL 2
Dependent Variable	Travel Time index (TTI)
Independent Variables	Jobs and Housing Balance (JHB)
	Population Density (D) School Density (Sch) Job Accessibility Index (Ai)

$$TTI = \beta_0 + \beta_1 \, JHB + \beta_2 \, D + \beta_3 \, Sch + \beta_4 \, A_i \qquad (7)$$

Validity and Reliability

The designed measurement of the research should be reliable and valid because of their content validity, meaning the measurement adequately measure or represent the content of the property that the investigator wishes to measure (Sommer, R. & Sommer, B. 2002; Dillman, 2000). The measurement tools including the BMR-ECM model and reliable software applications (SPSS and ArcGIS) have been widely used and well regarded up to the present time. The BMR-ECM model was established by the Office of the Commission for the Management of Land Traffic (OCMLT), a transportation planning authority of Thailand, and the software applications used are professional software globally recognized in the transportation planning and the related fields. In addition, all three data sets of year 1995, year 2001, and year 2003 used in this research were collected along with the national census of the National Statistical Office of Thailand (NSO).

CHAPTER V

REGRESSION ANALYSIS

The regression is designed to be carried out in two separate model specifications. The first model, reduced model, is meant to specifically test the effect of jobs and housing balance on traffic congestion. The other model, full model, is designed for examine the additive powers of all four land use factors in predicting the variation of traffic congestion. The four factors include jobs and housing balance, population density, school density, and job accessibility.

One of the research questions is to explore which unit of analysis (geographic of scale) is appropriate for the implementation of jobs-and-housing balance led policy for reducing traffic congestion in the Bangkok Metropolitan Region. Given both availability and consistency of the data, two units of analysis are examined. The results indicate the jobs and housing balance is a significant variable for predicting the variation in traffic congestion at the traffic analysis zone (TAZ) level, while this is not the case at the subsector level.

The following section will elaborate on the analytical findings for both the subsector level and traffic analysis zone level. In addition, the examination of the linear regression assumptions will be presented.

Analysis at the Subsector Level

Table 10 summarizes the statistical results of the regression analysis for the available data of year 1995, year 2001, and year 2003, including both the reduced and full models at the subsector level. None of the models indicates the jobs and housing balance as a statistically significant variable in explaining the variation of the travel time index.

For the full models, population density is the only significant variable in predicting the variation of the travel time index. The coefficient values of the density ranges from 2.21 x 10^{-5} to 5.18 x $10.^{-5}$ The T-Statistics vary from 4.615 to 9.993. On average, 62 percent of the variation in the travel time index is explained by the full models.

Table 10. Summary of All Three-Year Regressions (Subsector Level)

Year	1995		2001		2003	
Model No.	1	2	1	2	1	2
Constant		1.345		1.194		1.329
JHB						
D		2.37E-05 (4.615)		2.21E-05 (9.993)		5.18E-05 (9.248)
SCH						
AC						
R^2		0.407		0.748		0.719
Adjusted R^2		0.375		0.735		0.704

Note. All variables shown are significant at 95% confidence level. T-Statistics are in brackets.

Variable Definitions
Dependent Variable: TTI within subsector
JHIB: Jobs-Housing Imbalance within subsector
D: Population Density within subsector
SCH: School Density within subsector
AC: Accessibility Index within subsector

Analysis at the TAZ Level

The jobs and housing balance variable appears to be significant in explaining the variation of the travel time index in the reduced model for year 1995, year 2001, and year 2003. Table 11 summarizes the statistical results of the regression analysis for the data of year 1995, year 2001, and year 2003, including both the reduced and full models at the traffic analysis zone level. Based on the full models, the study shows the balance is significant in predicting the travel time index in year 1995 and year 2003. For year 2001, the balance is not a significant predictor, while population density, school density, and the job accessibility index do matter in predicting the variation of the travel time index. This occurrence is probably a result of random variation of data for this particular year (2001). More yearly data sets for further analyses will be helpful to confirm this randomness.

In full models, other independent variables include population density, school density, and the job accessibility index. Based on the analysis, population density is significant in explaining the variation of the travel time index for year 2001 and year 2003. School density is a significant predictor in year 1995 and year 2001. The job accessibility index is also significant in explaining the variation of the travel time index in year 1995 and year 2001. The full models explain 15 percent of the variation in the travel time index on average, while the reduced models explain approximately two percent on average.

Table 11. Summary of All Three-Year Regressions (TAZ Level)

Year	1995		2001		2003	
Model No.	**1**	**2**	**1**	**2**	**1**	**2**
Constant	1.898	1.524	1.341	1.176	1.490	1.329
JHB	-0.593 (-3.327)	-0.418 (-2.449)	-0.150 (-2.192)		-0.250 (-2.826)	-0.265 (-3.242)
D				5.03E-06 (4.533)		2.12E-05 (9.267)
SCH		3.06E-05 (3.652)		1.05E-05 (2.212)		
AC		0.193 (3.884)		0.038 (2.636)		
R^2	0.022	0.126	0.009	0.167	0.016	0.159
Adjusted R^2	0.020	0.120	0.007	0.161	0.014	0.156

Note. All variables shown are significant at 95% confidence level. T-Statistics are in brackets.

Variable Definitions
Dependent Variable: TTI within TAZ
JHIB: Jobs-Housing Imbalance within TAZ
D: Population Density within TAZ
SCH: School Density within TAZ
AC: Accessibility Index within TAZ

The implication, based on the regression findings, is that as the area approaches the balance (jobs and housing balance increases), traffic congestion declines (travel time index decreases). Second, as population density increases, traffic congestion is also increased. Likewise, as school density is increased, traffic congestion is increased. Finally, as job accessibility increases, traffic congestion increases.

In comparison with other independent variables for the effect on traffic congestion, the jobs and housing balance has the highest magnitude based on its coefficient's size. The largest coefficient's size of jobs and housing balance is 0.418 with the T-Statistic of 2.449 (all are in absolute values).

Examination of Linear Regression Assumptions

Figures 30 to 32 show the linear relationship between the travel time index and jobs and housing balance from the reduced models of year 1995, year 2001, and year 2003. The balance variable is negatively correlated with the traffic congestion. As the balance variable increases, the travel time index decreases.

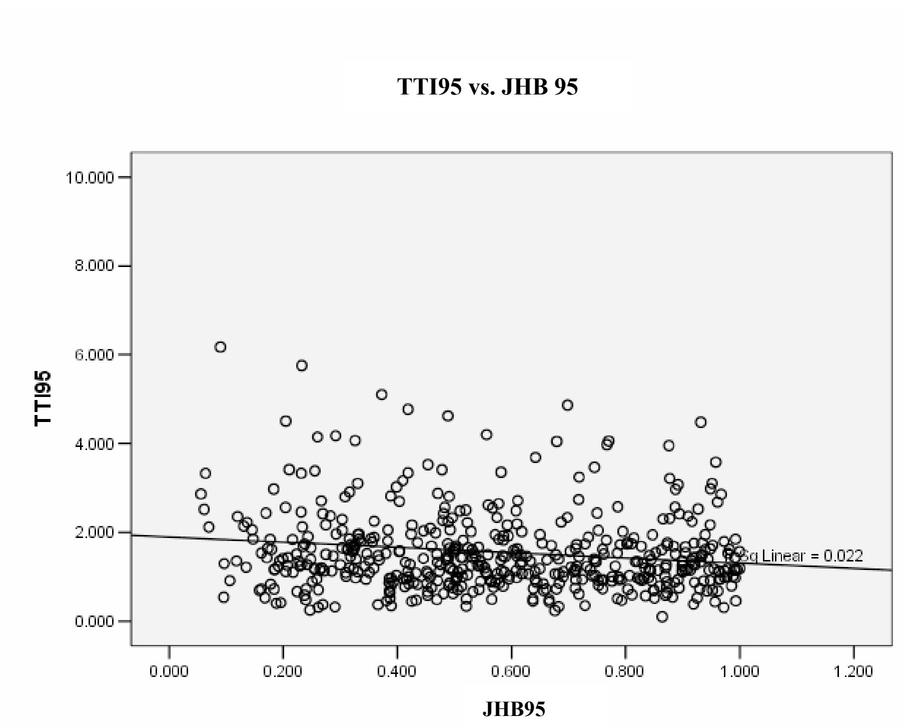

Figure 30. TTI vs. Jobs-Housing Balance (1995)

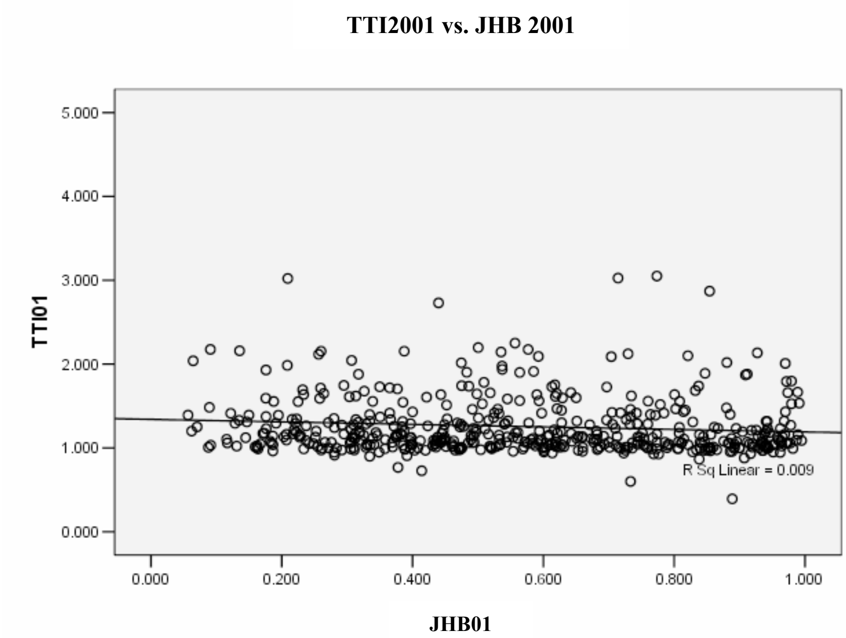

Figure 31. TTI vs. Jobs-Housing Balance (2001)

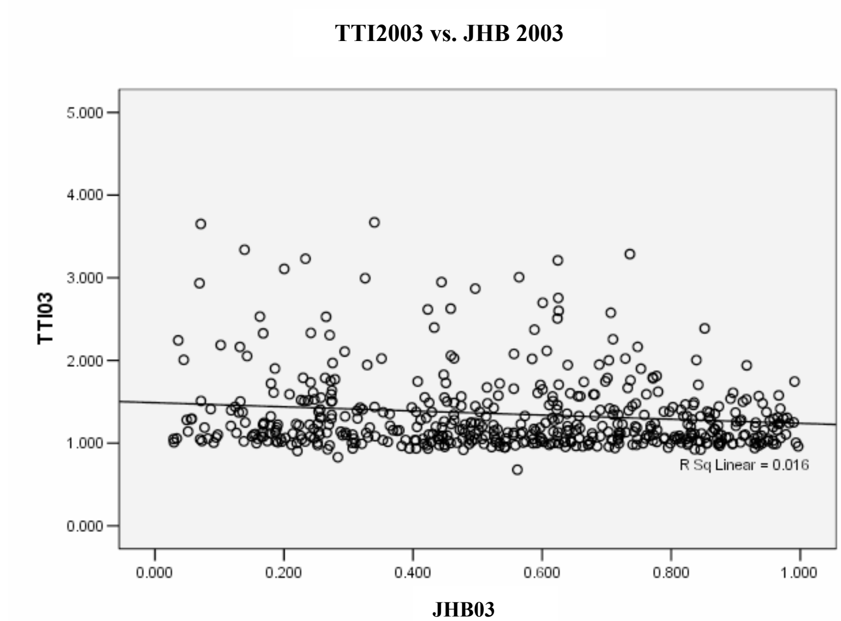

Figure 32. TTI vs. Jobs-Housing Balance (2003)

Regarding the heteroscedasticity, figures 33 to 35 illustrate the standardized residual plotted against the predicted travel time index from the full models of year 1995, year 2001, and year 2003. The results show there is no apparent pattern of inconstant variance for the error terms and their dependence, indicating that the linear-relationship assumptions are not violated. In addition, the transformation of the dependent variable (TTI) was made for checking the heteroscedasticity of the error terms, but there is no significant improvement in the residual plots, and the transformation can make the interpretation more difficult.

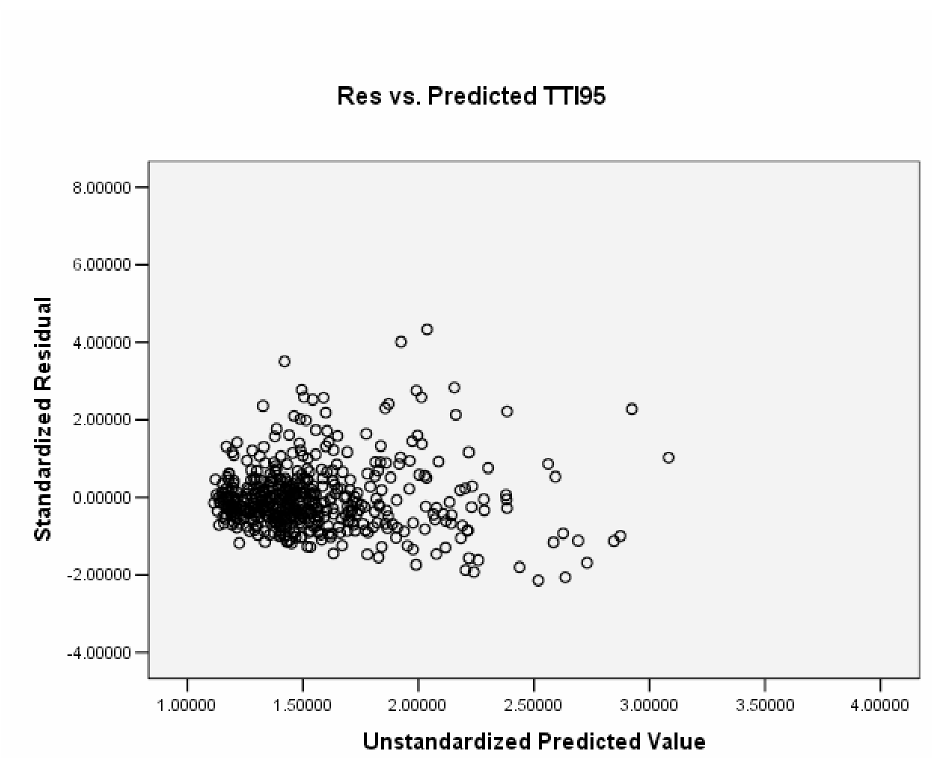

Figure 33. Residual Plot for Year-1995 Regression

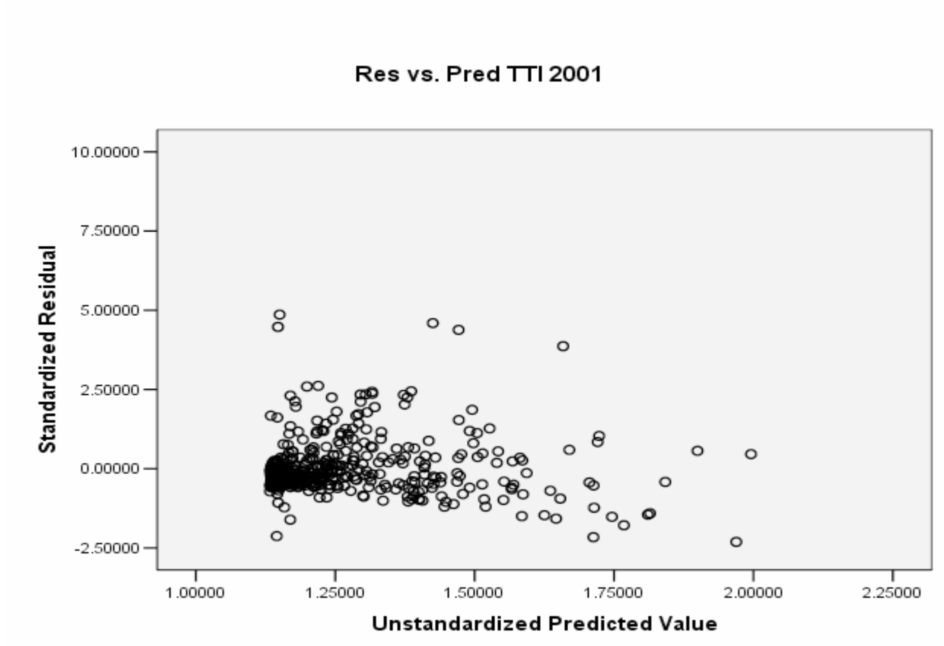

Figure 34. Residual Plot for Year-2001 Regression

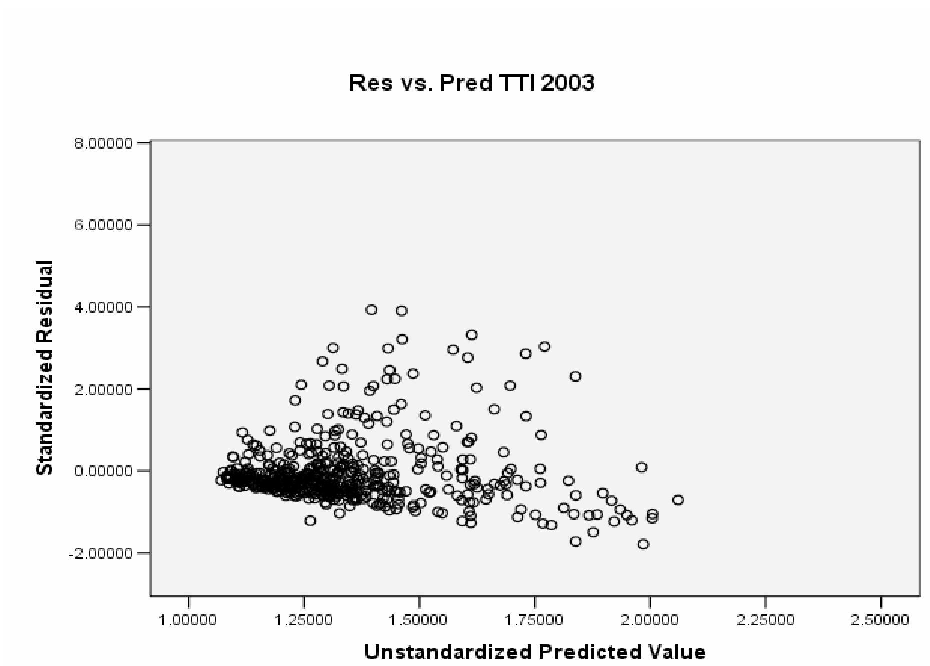

Figure 35. Residual Plot for Year-2003 Regression

The next chapter, conclusion, will conclude the research findings and discuss the policy implication for the Thai government and authorities involved. In the end, the research limitation as well as the implication for future research will be described.

CHAPTER VI

CONCLUSION

Bangkok is widely known for its severe traffic congestion. The centralization of the employment opportunity is conceivably a major cause of the morning-peak traffic congestion and long commute according to a number of previous studies. Studies also reveal that, during morning-peak hours in Metropolitan Bangkok, travel speeds average nearly 10 kilometers per hour (less than 6.25 miles per hour). Beside the inadequacy of road capacity, the lack of alternatives to road transportation in conjunction with urban sprawl cause traffic congestion at times extends over a radius of 25 kilometers from the central business districts (CBDs). Traffic congestion is severe in many parts of Bangkok for up to 16 hours per day.

In 2000, the Urban Rail Transportation Master Plan for Bangkok and surrounding areas (URMAP) was completed and later approved by the Cabinet as a regional master plan in 2001. Accordingly, any subsequent national urban development and transportation investment is obligated to comply with the plan and its suggested strategies. To alleviate the Bangkok Metropolitan Region's traffic congestion, one strategy advocated by the URMAP is to achieve a better jobs and housing balance for new urban development. The strategy is suggested in the Bangkok Plan, a study proposed by Massachusetts Institute of Technology and the Bangkok Metropolitan Administration (MIT, 1996). The expectation is to bring Bangkokian commuters to live closer to their workplaces implying there will be less inbound and outbound commuting flows, which is believed to be the major cause of traffic congestion in peak hours (OCMLT, 2001).

Impacts of the Land Use on Traffic Congestion

Regarding the hypothetical analyses, the study finds jobs and housing balance is significant in predicting the variation of traffic congestion in Metropolitan Bangkok. Other influential factors related to the land use include population density, school density, and job accessibility. As the area approaches the balance between the number of jobs and available housing, traffic congestion declines. Second, as population density increases, traffic congestion is also increased. Likewise, as school density increases, traffic congestion increases. Finally, as the area's job accessibility increases, traffic congestion increases. Although, the last finding is opposite from the fourth hypothesis, this can be well explained through the triple convergence principle mentioned by Downs (1992, 2004).

According to the triple convergence principle, once an area's traffic condition is improved, it can attract more new trips into the area. For instance, many drivers who previously used alternative routes during peak hours switch to the improved roads. Drivers who previously traveled just before or after peak hours start to travel during peak hours. Moreover, commuters who used public transportation during peak hours change to drive their cars since it becomes faster.

Regarding the effectiveness of the congestion mitigation strategy, jobs and housing balance statistically have the highest impact on the traffic congestion reduction because of its largest coefficient size and its significant T-Statistic compared to other land use factors, while the population density is the second most influential factor. As far as the spatial unit is concerned, the study reveals that the traffic analysis zone level is appropriate for implementing the land use based strategy. The land use factors including the jobs and housing balance, population density, school density, and job accessibility are found to be statistically significant at the traffic analysis zone level, not at the subsector level, nonetheless.

Policy Implication

As Thailand's governing system is democratic, yet mostly centralized to the central government or the Cabinet. Most policies related to the improvement of traffic condition have been made by the government (BMA, 1996; MIT, 1996; OCLMT, 1998b). Therefore, the traffic improvement strategy involving any land use change is possible for Thailand's case. This section highlights the potential for the interest land use factors to influence traffic congestion in the Bangkok Metropolitan Region. The potential is related to the following: job location, population density, school location, and job accessibility.

Job Location

An over-concentration of employment sites in Metropolitan Bangkok is known to be an essential cause of traffic congestion in the region since it generates both intra-zonal trips and extra-zonal trips to the zone (MIT, 1996; OCMLT, 2001). When Bangkok's employment centers are decentralized or re-distributed to its vicinities or elsewhere, theoretically the average commute distance can be reduced by a certain amount. As a result, the traffic volume and congestion on the streets will be reduced as well.

Population Density

Reducing population density of Bangkok is one of the suggested strategies for coping with traffic congestion. As the population growth is positively correlated with the job growth especially in the urban areas (Levine, 1992, 1998; Levinson & Kumar, 1996), the re-distribution of jobs and population can be carried out in combination for the purpose of traffic reduction. The relevant measures for achieving this include the city planning or town zoning, municipal ordinance, and enacted urban growth control. To some extent the implementation of these measures may require the coordination among the local agencies in the affected areas.

School Location

The implication here is that dispersing these big-named schools located in the CBDs to other areas outside Bangkok may help reduce traffic concentration in the area to some extent. Building additional qualified schools in other areas may help distribute some traffic volume to the new school sites. In addition, the alternative transportation mode for school trips, such as school buses, and its safety standard should be taken more seriously by the Thai government. To the extent that bus safety is underlying the lack of the bus usage, improved safety may improve traffic flow in the associated areas. When all these measures, including the decentralization of the qualified schools and the improvement of public transportation, are implemented, the amount of home-based school traffic is likely to decrease.

Job Accessibility

Once travel time (for home-based work trips) from residence to workplace is improved or reduced, traffic congestion level will be lowered. The finding suggests higher road capacity and more road networks are in needs for alleviating the current traffic congestion. Furthermore, the government should continue supporting the investment and use of public transportation, namely mass transit and buses, as public alternative modes for traveling. As a precaution, improving the accessibility to jobs for one area may induce more trips from other areas according to the triple convergence principle.

The following section will describe the limitation of this research as well as the implication for future research.

Limitation and Implication for Future Research

Being place specific as the Bangkok Metropolitan Region, the generalization of the findings would be subject to the adjustment when used elsewhere. Another limitation is limited choices and observation quantity of the independent variables available from the existing BMR-ECM project database and the national statistics; for instance, only the household income data is available. The land use variables were not available from the transportation database at the time of data collection. When more data such as median income, median housing and renting price, as well as land use become available, more robust modeling can be conducted. The median income along with housing and renting prices, if known, may result in finding a way to match available housing with the potential residents as far as the jobs and housing balance concept is concerned.

At the time of data collection, most transportation databases focused on private transportation, particularly automobile. For less than five years, part of Bangkok's mass transit network, proposed by the Office of the Commission for the

Management of Land Traffic, has been in service. In the near future, when transit-related information is well integrated into the existing transportation databases, the potential research is to study the impact of jobs and housing balance on the transit patronage and the change of Bangkokians' commuting pattern after the mass transit was inaugurated.

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